GOLD STANDARD METHODOLOGY

REDUCING METHANE EMISSIONS FROM ENTERIC FERMENTATION IN DAIRY COWS THROUGH APPLICATION OF FEED SUPPLEMENTS

Gold Standard®

SDG: 13 – Climate Action

Version: **0.9.1** (for Road Testing)

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The Gold Standard has approved this new greenhouse gas (GHGs) methodology that reduces emissions from enteric fermentation through the use of methane inhibiting feed supplements. This methodology is globally applicable and available for project development, in a road-testing phase. Experiences and learnings gained through this phase will be incorporated into the next iteration of the methodology.

The Gold Standard invites the submission of eligible activities for road-testing this methodology. Projects with robust dairy farm management practices already in place are best suited for this initial testing phase. Other relevant projects are encouraged but are requested to discuss the project and its feasibility in developing and implementing a monitoring plan in line with the methodology requirements.

The eligible projects that complete the Gold Standard for the Global Goals certification during the road-testing period will be eligible for the issuance of GS-VERs. Other interested stakeholders are also invited to send feedback during this phase.

Due to the unique nature of the methodology, Gold Standard Verification and Validation Bodies (VVBs) also need to meet some additional eligibility requirements in order to certify these projects: These include:

- *VVB shall have Gold Standard accreditation for the activity type (Agriculture/CDM Scope – 15)*
- *VVB auditing team shall have at least one team member with 5 years of working/research experience of direct and/or modelling approaches for GHG accounting in the dairy sector. If the VVB engages an external expert to meet the above requirement, the VVB shall take prior approval from Gold Standard by submitting the credentials of the selected expert.*
- *The subject matter expert shall be included in the team visit to the project site*

1. DEFINITIONS

For the purposes of this methodology the following definitions based on Gold Standard for the Global Goals apply:

Baseline	The baseline is the estimated emissions from dairy cow management in the baseline scenario.
Baseline scenario	The baseline scenario in this methodology is the pre-project dairy cow management, feeding practices and manure management that would occur in the absence of the proposed project (business-as-usual).
Gold Standard Verified Emissions Reduction (GS-VER)	A Gold Standard issued Verified Emissions Reduction is a single unit (one tonne) of CO_2 equivalent reduction captured as a carbon credit for use as a commodity within the voluntary carbon market.
Crediting period	The crediting period is the time span in which SDG Impacts can be accounted for and are subject to monitoring.
Digestible energy in feed (DE)	Digestible energy in feed is a measure for the actual amount of energy from a feed that can be available for use by the animal. DE is measured in MJ/kg dry matter.
Dry matter intake (DMI)	Dry matter intake is the amount (kg) of feed consumed by an animal, excluding its water content.
Enteric fermentation	Enteric fermentation is a digestive process by which organic matter is broken down by microorganisms into simple molecules for absorption into the bloodstream of an animal.
Fat and protein corrected milk	Quantity of milk, normalized to a common energy basis. Calculation of fat and protein corrected milk (FPCM), also called Energy Corrected Milk (ECM) may differ by geography and market segments.
Feed supplement	In this methodology, a feed supplement is a product added to the animal feed for purposes of reductions of methane emissions from enteric fermentation. This may include application of organic or non-organic products to inhibit the methanogenesis.
Methane (CH_4)	Methane is greenhouse gas with a global warming potential (GWP) of 25.[1]
Methanogenesis	Methanogenesis is the formation of methane in the rumen of livestock by microorganisms known as methanogens.

1 According to current Gold Standard rules, the latest GWP accepted by Gold Standard shall be applied.

Neutral Detergent Fiber (NDF):	NDF is the most common measure of fiber used for animal feed analysis. It comprises most of the structural components in plant cells (namely hemicellulose, cellulose, and lignin). In this methodology, NDF is quantified as percentage of DMI[2].
Nitrous oxide (N_2O)	Nitrous oxide is a greenhouse gas with a global warming potential (GWP) of 298.[2]
Project	The project is the activity or action being implemented for which Gold Standard Certification is sought. A project may include project activities implemented in more than one dairy farm.
Project activity/ies	Project activities are those activities that are required to plan, implement and manage a project over its lifetime, with the objective of producing land-based products and additional, certifiable ecosystem services. In this methodology, project activities include the application of feed supplements for dairy cows to reduce methane (CH_4) emissions from enteric fermentation.
Project area	The project area is a spatial area or areas submitted for certification with clearly defined boundaries managed to a set of explicit long term management objectives. A project area can contain several dairy farms.
Project region	The project region is the spatial area where people and environment are influenced by the project activities. A project region can be expanded over time. All project areas are located within the project region.
Project scenario	The project scenario is defined as the scenario that will exist once the project is implemented and operational.
Ration	Ration is the daily feed portion prepared from various feeds according to various animals' requirements. It is based on feeding standards and information about the composition and nutritive value of feeds.
Monitoring period	Monitoring period is the time period between two points in time for which a reduction in GHG emissions is calculated, e.g., the time between project performance certifications.

[2] In some regions, NDF may be provided in other units, e.g. as g/kg DMI. In such cases, NDF must be scaled to %.

2. REFERENCES

This methodology refers to and makes use of elements from the latest approved versions of the following methodologies, methodological tools, guidelines, and key sources:

Gold Standard Requirements:

- Gold Standard for the Global Goals Land-use & Forests Activity Requirements version 1 July 2017
- Gold Standard for the Global Goals GHG Emissions Reduction & Sequestration Product Requirements version 1 July 2017
- Gold Standard for the Global Goals Principles & Requirements, version 1 July 2017
- Gold Standard for the Global Goals Safeguarding Principles & Requirements version 1 July 2017
- Gold Standard for the Global Goals Stakeholder Consultation & Engagement Procedure, Requirements & Guidelines version 1 July 2017

Gold Standard Methodologies and Templates:

- Gold Standard for the Global Goals AGR Additionality (AGR Projects) Template
- Gold Standard for the Global Goals Monitoring Report Template
- Gold Standard for the Global Goals Principles & Requirements Annual Report Template
- Gold Standard Agriculture Smallholder Dairy Methodology 2016
- Gold Standard Agriculture Methodology for Increasing Soil Carbon Through Improved Tillage Practices 2015

Other documents and publications:

- Alberta Protocol: Quantification protocol for emission reductions from dairy cattle version 1 January 2010
- FAO Livestock solutions for climate change 2017
- IPCC 2006 Good Practice Guidelines Volume 4 Chapter 10 Emissions from Livestock and Manure Management
- IPCC 2006 Good Practice Guidelines Volume 4 Chapter 11 N_2O Emissions from Managed Soils, and CO_2 Emissions from Lime and Urea Application
- VCS VM0017: Adoption of Sustainable Agricultural Land Management, v1.0
- Niu et al. 2018: Prediction of enteric methane production, yield and intensity in dairy cattle using an intercontinental database; Global Change Biology 2018; 1-22; doi: 10.1111/gcb.14094 (open access article)

3. SUMMARY

Cows release methane (CH_4) as a result of the digestion of feed materials in the rumen. Fermentation in the rumen - one of the four stomach chambers of ruminant livestock - generates hydrogen as a result of the feed degradation by microorganisms. The animals must remove the produced hydrogen. One of the ways to reduce hydrogen in the rumen is the production of methane which is released by respiration and eructation into the atmosphere. These emissions are called enteric emissions.

The aim of this methodology is to quantify reduction of methane (CH_4) emissions from enteric fermentation for dairy cows as well as impacts on emissions from manure handling. The methodology focuses on application of feed supplements to directly inhibit methanogenesis, which is the formation of methane in the rumen of livestock by microbes.

The methodology provides two approaches for quantification of emissions from enteric fermentation for baseline and project scenario quantification. This accounts for the fact that not all relevant measurements and parameters may be available to projects. Approach 1 requires on-site measurements to directly document pre-project and project emission levels. Approach 2 applies regression models or IPCC Tier 2 equations integrating data from peer-reviewed publications to quantify emissions for baseline and project scenarios. Project proponents need to document that the coefficients applied are conservative and applicable to the project site and management practice.

A recent publication based on intercontinental data from numerous research studies on methane emission from enteric fermentation shows that a number of parameters can be used in regression models to quantify relevant emissions (Niu et al. 2018). The publication summarizes recent results that represent a considerable improvement from default parameters used in IPCC 2006 guidelines (in revision at time of this methodology's publication). To accommodate the improvements, this methodology allows application of regression models under Approach 2 introduced above and includes a new table for selection of methane conversion factors based on key parameters of the best-fit intercontinental model outlined in Niu et al (2018).

Similarly, new models may be used in the calculation of emissions from manure management if proof of validity (e.g., publication in peer-reviewed scientific papers) and applicability is provided.

4. APPLICABILITY

The project shall meet all requirements listed below for this methodology to be applicable. In addition, it must meet all Gold Standard for the Global Goals Land-use & Forests Activity Requirements and Gold Standard for the Global Goals Principles & Requirements including associated documents.

This methodology is applicable under the following conditions:

- Projects are eligible in all countries;
- The project activity reduces methane (CH_4) emissions from enteric fermentation through application of feed supplements for dairy cows. This may include application of organic or non-organic products to inhibit the methanogenesis. The methodology shall not be applied if manure management is the only project measure to reduce emissions;
- The feed supplement applied shall have proven efficacy of emissions reductions in in-vivo application with dairy cattle published in peer-reviewed scientific literature;
- All feed supplements applied under the project activity must be officially registered for use with dairy cows in the project country and must be granted authorization by the respective country authority. This may involve publication in an official register[3]. In countries where specific regulations on feed supplements are not in place, a product may be applied if its application is documented as non-harmful in peer-reviewed publications and it has been officially registered in at least one other country with stringent regulations for feed supplements.
- Application of feed supplement shall not exceed maximum dosages according to the relevant product registration.
- All farm owners participating in the project must be trained on potential animal and human health risks related to the application of the feed supplement. Respective safety and mitigation mechanisms must be established with all project participants.
- The methodology is only applicable to dairy farms that have been producing milk at least three years prior to the start of the project activities. Reliable and verifiable data on the amount of milk produced per animal stratum per year shall be available for a minimum of three years;
- No reduction in milk yield which is caused by the project activity shall be allowed. Project activities in the project area shall deliver a milk yield at least equivalent to the baseline yield at same or lower energy input levels. Reductions in milk yield due to non-project related factors, e.g., fluctuations in herd structure, drought effects or reaction to reduced demand, are exempt from this applicability condition;
- The project activity is not mandated by any law or regulation;
- The project activity shall not lead to a decrease of aboveground woody biomass or soil carbon stocks in the project area;
- The methodology is not applicable to off-farm management practices, including milk transportation, processing and distribution;
- Animal welfare and livestock management requirements set out in the Gold Standard for the Global Goals Safeguarding Principles & Requirements shall be met in all project areas. Unless stated otherwise in

[3] E.g., in the case of the European Union: Authorized feed additives are listed in the European Union’s register of feed additives by the European Commission.

current Principles and Requirements, the welfare of animals shall be ensured by:

a) Provision of sufficient drinking water, **AND**
b) Access to daylight, **AND**
c) The prohibition of cattle trainers[4], **AND**
d) No hindrance in their sensory perception and performing their basic needs, **AND**
e) No mistreatment[5]
f) Injured or sick animals shall be treated and isolated, if necessary, for recovery
g) Excessive or inadequate use of veterinary medicines shall be avoided; thus, all medications shall be administered strictly according to label and package instructions or according to instructions from a trained veterinarian
h) Synthetic growth promoters including hormones shall not be used
i) Animals shall be exposed to the least stress possible during transportation and slaughtering
j) Appropriate space per animal and stocking rates per land unit should be set according to their developmental and physical needs

5. PROJECT BOUNDARIES

5.1 Spatial boundary

The spatial boundary encompasses the project activities that are under the project proponent's control and those directly influenced by the project which result in GHG emission reductions (compare Figure 5-01).

Feed production is excluded as upstream production or other agricultural inputs are not impacted by the implementation of the project and as such the baseline and project conditions will be functionally equivalent. Changes through adding a feed supplement will not require or motivate a change in feed production.

Supplement production and transport is included as this is not part of the baseline and the supplement is the driver for the project emisson reductions.

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4 A cattle trainer is a metal holder or wire that is fixed slightly above the back of the tethered cattle, which gives an electric shock to the animal if it bends its back during urinating or defecating. The electric shock forces the animal to step backwards and to urinate or defecate in the manure trench instead of in its own laying bed.

5 Mistreatment is the use of sharp objects, misusing irritating substances, including potash for branding and moving animals in a pain-inflicting way.

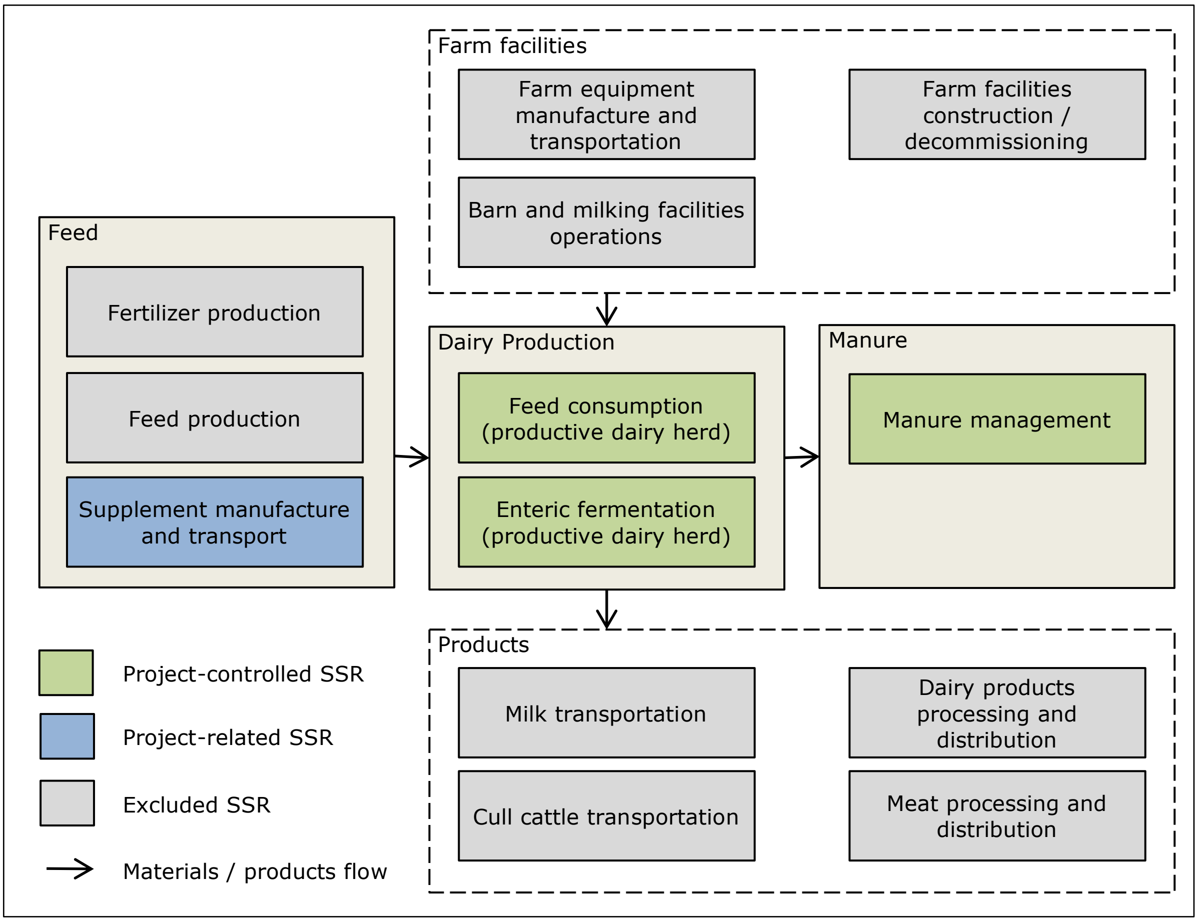

Figure 5-01: Spatial boundary

5.2 Temporal boundary

According to the Gold Standard for the Global Goals Land-use & Forests Activity Requirements, the duration of the crediting period is determined on methodology level. For activities applying this methodology, the project crediting period shall be 5 years and may be renewed once.

In accordance with the Gold Standard for the Global Goals Principles & Requirements and the Gold Standard for the Global Goals Land-use & Forests Activity Requirements, the project proponent shall undergo a performance review within two years of project implementation or certification, whichever is later, and at least every five years after that.

5.3 Greenhouse Gases

The greenhouse gases included or excluded from the project boundary are shown in Table 5-01.

Table 5-01: GHGs included or excluded from the project boundary

Source		Gas	Included	Justification / Explanation
Baseline	Enteric fermentation	CO_2	No	Not relevant in enteric fermentation[6]
		CH_4	Yes	Emitted in enteric fermentation
		N_2O	No	Not emitted in enteric fermentation
	Manure management	CO_2	No	CO_2 emissions in manure handling are biogenic
		CH_4	Yes	Emitted in manure handling
		N_2O	Yes	Emitted in manure handling
	Supplement manufacture	CO_2	Yes	May be emitted in production process
		CH_4	Yes	May be emitted from combustion of fossil fuels
		N_2O	No	Not expected in production process
Project	Enteric fermentation	CO_2	No	Not relevant in enteric fermentation
		CH_4	Yes	Emitted in enteric fermentation
		N_2O	No	Not emitted in enteric fermentation
	Manure management	CO_2	No	CO_2 emissions in manure handling are biogenic
		CH_4	Yes	Emitted in manure handling
		N_2O	Yes	Emitted in manure handling
	Supplement manufacture	CO_2	Yes	May be emitted in production process
		CH_4	Yes	May be emitted from combustion of fossil fuels
		N_2O	No	Not expected in production process

6. EMISSIONS REDUCTION CALCULATION APPROACHES

[6] Some publications indicate that feed supplements may increase CO_2 and H_2 emissions. However, these emissions are currently excluded due to the absence of detailed quantification models and as CO_2 emissions and indirect effects of H_2 are considered insignificant compared to CH_4 reductions.

The methane emissions reduction from enteric fermentation is calculated as the net changes in GHGs emission as summarised below. Consequently, the CO_2 equivalent to the reduction of emissions from enteric fermentation minus potential emissions leakage effects is considered the greenhouse gas benefit attributable to the project activity.

$$ER_{t-0} = [\Delta E_{t-0} - LK_{t-0}] \quad (1)$$

Where:

ER_{t-0}	= Emissions reduction for the monitoring period [tCO_2e]
ΔE_{t-0}	= Emissions reduction from dairy cows in the monitoring period [tCO_2e]
LK_{t-0}	= Leakage emissions due to project activity in the monitoring period [tCO_2e]

The reduction of emissions for the monitoring period ΔE_{t-0} is calculated as the difference between average emission levels in the baseline scenario and the annual emissions in the current monitoring period (Equation 2).

$$\Delta E_{t-0} = \sum_y \left[\left(E_y - E_0\right) \times M_y\right] \times (1 - UD) \quad (2)$$

Where:

ΔE_{t-0}	= Emissions reduction from dairy cows in the monitoring period [tCO_2e]
E_0	= Emissions per kg of Fat and Protein Corrected Milk in the baseline scenario [tCO_2e (kg FPCM)$^{-1}$]
E_y	= Emissions per kg of Fat and Protein Corrected Milk in year y in the monitoring period [tCO_2e (kg FPCM)$^{-1}$]
M_y	= The total milk production in year y in the monitoring period, expressed as Fat and Protein Corrected Milk [kg FPCM]
y	= Year in the monitoring period [1..n; n≤5]
UD	= Uncertainty deduction [dimensionless] (compare section 9 Uncertainty)

6.1 Approaches for baseline and project scenario quantification

To account for the fact that not all relevant measurements and parameters may be available to projects, this methodology provides two approaches to baseline and project scenario quantification for accounting of emissions from enteric fermentation:

Approach 1 requires on-site measurements to directly document pre-project and project emission levels.

Approach 2 applies Tier 2 (or higher) parameters or information from peer reviewed research data / models to quantify emissions for baseline and project scenarios. The project proponent needs to document that the parameters and coefficients applied are conservative and applicable to the project area and management practice.

The same approach must be used for baseline and project scenario quantification. Generally, the project proponent shall apply the most specific approach possible with the data available, giving preference to local data sources and models. A decision tree to determine an eligible approach is supplied in Figure 6-01 below. Further requirements for each approach and its application are given below.

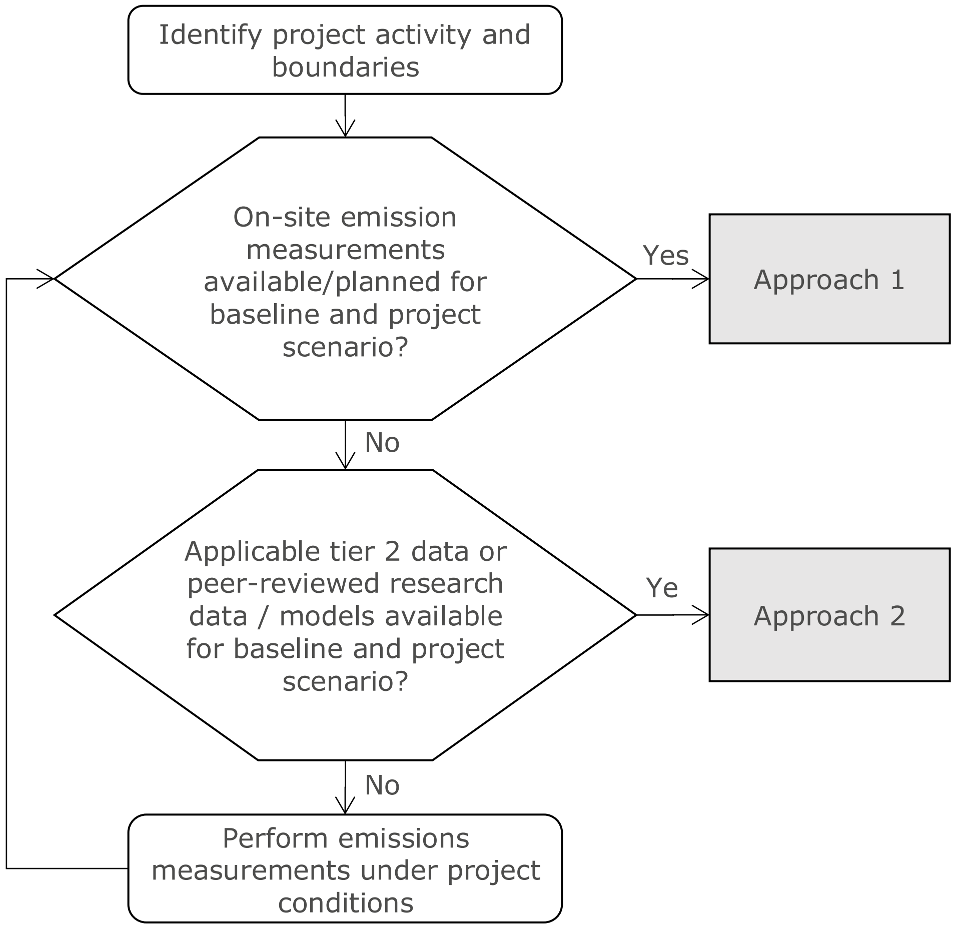

Figure 6-01: Decision tree for identification of appropriate emissions reduction calculation approach for enteric fermentation.

6.1.1 Herd stratification

For emissions calculations for baseline and project scenarios, as described in the following sections, the productive herd must be split into strata to limit variance in accounting parameters. Common stratum parameters are animal age and productivity (e.g. early/late lactation, dry cows, heifers, calves, bulls) as well as feed and feeding system. Generally, emissions accounting shall include the entire productive herd including animals currently not producing milk.

However, under the following conditions, certain animal groups (strata) may be excluded from emissions accounting:

- The total emissions for the animal group can be considered negligible, i.e. contribute less than 5% to total herd emissions. This may be calculated applying IPCC default emission factors from published sources (e.g. IPCC 2006 or respective research papers)

OR

- The animal group is not given the feed supplement, ***AND***
- No change in feeding and management is done for the animal group as consequence to project activity, ***AND***
- The animal group is physically separated from the herd in scope for the project. All relevant processes, especially feeding and manure management, are clearly distinguished from the rest of the herd.

Evidence of the above shall be provided to the Validation/Verification Body at time of registration and performance reviews. No benefit accounting shall be done for any part of the herd that is excluded from detailed emissions accounting.

7. BASELINE SCENARIO

Under this methodology the relevant baseline scenario is the continuation of the pre-project livestock management and feeding practices, i.e. a business as usual (BAU) practice. BAU practice is determined as the average activity and emissions quantification over at least 3 continuous years ending no more than 2 years prior to the start of project activities.

For the baseline scenario, emissions are calculated as the sum of average annual emissions over 3 baseline years from enteric fermentation and manure management according to Equation 3:

$$E_0 = \left(E_{F,0} + E_{M,0}\right)/M_0 \qquad (3)$$

Where:

E_0 = Emissions per kg of Fat and Protein Corrected Milk in the baseline scenario [tCO_2e (kg FPCM)$^{-1}$]

$E_{F,0}$ = Average annual emissions from enteric fermentation in the baseline scenario [tCO_2e]

$E_{M,0}$ = Average annual emissions from manure management in the baseline scenario [tCO_2e]

M_0 = Average annual milk production in the baseline scenario, expressed as Fat and Protein Corrected Milk (kg FPCM)

7.1 Emissions from enteric fermentation

Methane emissions from enteric fermentation for the baseline scenario *$E_{F,0}$* are calculated using Equations 4 or 5 below.

Approach 1:

The most specific approach to quantify emission reduction is measurement of methane emissions for a sample group of cows in a project environment. As methane measurement techniques are evolving and may not be suitable for all management systems and environments, this methodology allows measurement approaches that meet the following conditions:

1) The measurement technology is scientifically tested, and results are documented in peer-reviewed publications.
2) The applicability of the system under project conditions is confirmed and documented.
3) The measurement error of the system under the project conditions is known or the statistical sample is large enough to estimate this error. A respective uncertainty deduction shall be applied in the calculation of emission reductions (compare Equation 2 above).

If all of these conditions are met, annual emissions for baseline scenario shall be estimated according to Equation 4:

$$E_{F,0} = \sum_G N_{G,0} \times EF_{G,0} \times 365 \times GWP_{CH4}/1000 \quad (4)$$

Where:

$E_{F,0}$ = Average annual emissions from enteric fermentation in the baseline scenario [tCO_2e]

$N_{G,0}$ = Number of animals in animal stratum G in baseline scenario (annual average) [heads]

$EF_{G,0}$ = Methane emission factors from enteric fermentation per animal in animal stratum G in the baseline scenario [kg CH_4 $head^{-1}$ day^{-1}]

365 = Number of days per year

GWP_{CH4} = Global warming potential of methane [tCO_2e tCH_4^{-1}]

1000 = kg per metric tonne [kg t^{-1}]

Baseline emission factor $EF_{G,0}$ shall be measured either in the baseline with a sample for each stratum of animals subsequently included in the project, or alternatively after start of the project activity in a control stratum not included in the project scenario (i.e., remaining under pre-project BAU management). As required for the baseline scenario quantification, documentation of baseline emissions shall be performed for at least 3 years for both approaches.

Approach 2:

In the absence of direct emissions measurements, a baseline emission factor $E_{F,0}$ is calculated. Recent research (summarized in Niu et al. 2018) has shown strong impact of feed composition, especially fiber content, on these emissions. This methodology thus does not allow general application of tier 1 default emission and conversion factors in IPCC 2006 as these factors are not differentiating between feeding systems and management practices. Instead, calculations shall be done using data from locally applicable research that has been published in peer-reviewed scientific journals or through national or subnational authorities for GHG accounting. Uncertainty of parameters and models shall be considered and quantified according to section 9 Uncertainty.

$\mathbf{E_{F,0}}$ shall be calculated either directly applying published emission models (e.g., regression models) or following the approach in Equation 5, based on animal numbers, energy intake through feed and project-related conversion factors for methane emissions.

$$\mathrm{E_{F,0}} = \sum_{\mathrm{G}}(\mathrm{GE_{G,0}} \times \mathrm{Ym_{G,0}} \times \mathrm{N_{G,0}} \times 365 \, / \, \mathrm{EC_{CH4}}) \times \mathrm{GWP_{CH4}}/1000 \qquad (5)$$

Where:

$E_{F,0}$	=	Average annual emissions from enteric fermentation in the baseline scenario [tCO_2e]
$GE_{G,0}$	=	Gross energy intake per animal in animal stratum G, based on measured dry matter intake under baseline conditions [MJ head^{-1} day^{-1}]
$Ym_{G,0}$	=	Fraction of gross energy in feed converted to methane for animal stratum G under baseline conditions [dimensionless]
$N_{G,0}$	=	Number of animals in animal stratum G in baseline scenario (annual average) [heads]
365	=	Number of days per year
EC_{CH4}	=	Energy content of methane [MJ (kg methane)$^{-1}$]
	=	55.65
GWP_{CH4}	=	Global warming potential of methane [tCO_2e tCH_4^{-1}]
1000	=	kg per metric tonne [kg t^{-1}]

Gross energy intake $\mathbf{GE_{G,0}}$ is calculated from measurements of dry matter intake, DMI, on a daily basis using Equation 6. The DMI value shall be determined as the sum of all ration ingredients.

$$GE_{G,0} = DMI_{G,0} \times EC_{DM} \qquad (6)$$

Where:

$GE_{G,0}$	=	Gross energy intake per animal in animal stratum G, based on measured dry matter intake [MJ head^{-1} day^{-1}]

$DMI_{G,0}$ = Dry matter intake per animal in animal stratum G, [kg head-1 day-1]

EC_{DM} = Average energy content of dry matter [MJ kg^{-1}]
= 18.45

The **methane conversion factor $Ym_{G,0}$** is determined for each animal stratum. It shall be selected to best meet project conditions, especially feed composition, and its applicability documented by the project proponent. Acceptable proofs of applicability include peer-reviewed scientific publications based on data collected under comparable conditions as well as documentation published by national or subnational authorities for GHG accounting. Data from direct measurements under project conditions may also be used if measurement methodology, setup, full results and analysis are provided for review for registration and performance audits. Internationally applicable conversion factors may only be applied conservatively, taking into account the respective errors. Note that the high uncertainty common to global models will likely lead to uncertainty deductions according to section 9 of this methodology. Table 7-01 provides a matrix of conversion factors in dependence of DMI and NDF, calculated with intercontinental regression models by Niu et al. 2018.

Table 7-01: Methane conversion factors Y_m for enteric fermentation, by dry matter intake (DMI) and fiber fraction (NDF) (calculated applying intercontinental regression model no. 3 published in Niu et al. 2018)

		DMI [kg]									
		5	10	15	20	25	30	35	40	45	50
NDF [%]	5	0.067	0.055	0.050	0.048	0.046	0.046	0.045	0.044	0.044	0.044
	10	0.075	0.058	0.053	0.050	0.048	0.047	0.046	0.045	0.045	0.044
	15	0.082	0.062	0.055	0.052	0.049	0.048	0.047	0.046	0.046	0.045
	20	0.089	0.066	0.057	0.053	0.051	0.049	0.048	0.047	0.047	0.046
	25	0.096	0.069	0.060	0.055	0.052	0.050	0.049	0.048	0.047	0.047
	30	0.104	0.073	0.062	0.057	0.054	0.052	0.050	0.049	0.048	0.047
	35	0.111	0.077	0.065	0.059	0.055	0.053	0.051	0.050	0.049	0.048
	40	0.118	0.080	0.067	0.061	0.057	0.054	0.052	0.051	0.050	0.049
	45	0.125	0.084	0.070	0.063	0.058	0.055	0.053	0.052	0.051	0.050
	50	0.133	0.088	0.072	0.064	0.060	0.057	0.054	0.053	0.051	0.050
	55	0.140	0.091	0.075	0.066	0.061	0.058	0.055	0.054	0.052	0.051
	60	0.147	0.095	0.077	0.068	0.063	0.059	0.056	0.055	0.053	0.052
	65	0.154	0.099	0.079	0.070	0.064	0.060	0.057	0.055	0.054	0.053
	70	0.161	0.102	0.082	0.072	0.066	0.061	0.059	0.056	0.055	0.053
	75	0.169	0.106	0.084	0.074	0.067	0.063	0.060	0.057	0.055	0.054
	80	0.176	0.110	0.087	0.075	0.068	0.064	0.061	0.058	0.056	0.055

Y_m table calculated using the following equation based on intercontinental regression model no. 3 by Niu et al. 2018:

Y_m = [33.2 + 13.6 * DMI + 2.43 * NDF] * 0.05565 / (DMI * 18.7)

Where:

Ym = methane conversion rate [dimensionless]

33.2, 13.6, 2.43 = regression coefficients according to Niu et al. 2018, Table 2, Eq. 3

DMI = Dry matter intake [kg/cow/day]

NDF = fraction of neutral detergent fiber in DMI [%]

0.5565 = energy in methane [MJ/gram]

18.7 = gross energy (GE) in DMI [MJ/kg], according to Niu et al. 2018, Table 1

Niu et al. 2018 lists a RSME (root mean square error in % of emissions) of 17.1% for Eq. 3.

7.2 Emissions from manure management

Emissions from manure management for the baseline scenario $E_{M,0}$ are calculated using Equation 7:

$$E_{M,0} = E_{MCH4,0} + E_{MN2O,0} \quad (7)$$

Where:

$E_{M,0}$ = Average annual emissions from manure management in the baseline scenario [tCO_2e]

$E_{MCH4,0}$ = Average annual methane emissions from manure management in the baseline scenario [tCO_2e]

$E_{MN2O,0}$ = Average annual nitrous oxide emissions from manure management in the baseline scenario [tCO_2e]

Methane emissions from manure management $E_{MCH4,0}$ shall be calculated applying Equation 8. Emissions are quantified based on the quantity of volatile solids excreted by the animal stratum and the storage technique for the manure.

$$E_{MCH4,0} = \sum_{S,G} VS_{G,0} \times N_{G,0} \times 365 \times B_o \times CF_{CH4} \times MCF_S \times MS_{S,G,0} \times GWP_{CH4}/1000 \quad (8)$$

Where:

$E_{MCH4,0}$ = Annual methane emissions from manure management in the baseline scenario [tCO_2e]

$VS_{G,0}$ = Daily volatile solid excreted per animal in animal stratum G in baseline scenario [kg dry matter $head^{-1}$ day^{-1}]

$N_{G,0}$ = Number of animals in animal stratum G in baseline scenario (annual average) [heads]

365 = Number of days per year

B_o = Maximum methane producing capacity from dairy manure [m3 kg^{-1} of VS]
= 0.24 or dairy cows in developed countries, or 0.13 in developing countries (IPCC 2006)

CF_{CH4} = Conversion factor of m3 methane to kg methane [kg methane (m^3 methane)$^{-1}$]
= 0.67

MCF_S = Methane conversion factor for manure management system S [dimensionless]

$MS_{S,G,0}$ = Fraction of animal stratum G's manure handled using manure management system S under baseline conditions[dimensionless]

GWP_{CH4} = Global warming potential of methane [tCO_2e tCH_4^{-1}]

1000 = kg per metric tonne [kg t^{-1}]

Daily volatile solids excreted per animal in animal stratum VS_G under baseline conditions in above Equation 8 are calculated using Equation 9 below. Alternatively, VS_G may be calculated through the application of more recent models published in peer-reviewed scientific journals with proven applicability under project conditions. The same calculation approach must be applied for baseline and project scenario.

$$VS_{G,0} = GE_{G,0} \times \left(\left(1 - DE_{G,0}\right) + UE\right) \times (1 - ASH)/EC_{DM} \qquad (9)$$

Where:

$VS_{G,0}$ = Daily volatile solid excreted per animal in animal stratum G in baseline scenario [kg dry matter $head^{-1}$ day^{-1}]

$GE_{G,0}$ = Gross energy intake per animal in animal stratum G based on measured dry matter intake under baseline conditions [MJ $head^{-1}$ day^{-1}]

$DE_{G,0}$ = Digestible energy in feed for animal stratum G under baseline conditions, as fraction of GE [dimensionless]

UE = Urinary energy expressed as fraction of $GE_{G,0}$ [dimensionless]
= 0.04 for dairy cows with less than 85% grain in diet (see section 13 for alternative value)

ASH = Ash content of manure as a fraction of the dry matter feed intake [dimensionless]
= 0.08 for cattle

EC_{DM} = Average energy content of dry matter [MJ kg^{-1}]
= 18.45

Digestible energy in feed DE_0 shall be documented for each feed type applied in baseline scenario.[7]

Fraction of manure $MS_{S,G,0}$ handled in manure management system S per animal stratum G shall be monitored and documented for the baseline activity.

Methane conversion factors MCF_S shall be determined for each manure management system S applied in the baseline activity. Where available, nationally or sub-nationally determined, peer-reviewed emission factors shall be applied. In the absence of such factors, data from other applicable sources (e.g., comparable practices from another country) can be applied if applicability is documented. If no localized emission factors are available, emission factors shown in Table 7-02 shall be applied. As these factors are based on IPCC defaults, an uncertainty value of ±20% shall be assumed for these parameters[8].

[7] If fraction of metabolizable energy (ME) is available instead of digestible energy, term (1-ME) may be used instead of ((1-DE)+UE) in equation 9.

[8] IPCC 2006 Guidelines for National Greenhouse Gas Inventories, Volume 4: Agriculture, Forestry and Other Land Use, Chapter 10, Section 10.4.4 cites uncertainty ranges of ±20% for tier 2 data provided.

Table 7-02: Methane conversion factors MCF_S for manure management systems by average annual temperature (Source: IPCC 2006 Guidelines for National Greenhouse Gas Inventories, Volume 4, Chapter 10, Table 10.17)

Manure management system*	CH_4 conversion factors (MCF) for manure management systems by average annual temperature																		
	Cool					Temperate											Warm		
	≤10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	≥28
Pasture / Range / Paddock	0.01					0.015											0.02		
Daily spread	0.001					0.005											0.01		
Solid storage	0.02					0.04											0.05		
Dry lot	0.01					0.015											0.02		
Liquid / slurry (with crust cover)	0.10	0.11	0.13	0.14	0.15	0.17	0.18	0.2	0.22	0.24	0.26	0.29	0.31	0.34	0.37	0.41	0.44	0.48	0.50
Liquid / slurry (without crust cover)	0.17	0.19	0.20	0.22	0.25	0.27	0.29	0.32	0.35	0.39	0.42	0.46	0.50	0.55	0.60	0.65	0.71	0.78	0.80
Uncovered anaerobic lagoon	0.66	0.68	0.7	0.71	0.73	0.74	0.75	0.76	0.77	0.77	0.78	0.78	0.78	0.79	0.79	0.79	0.79	0.80	0.80
Pit storage below animal confinements < 1 month	0.03					0.03											0.3		
Pit storage below animal confinements > 1 month	0.17	0.19	0.2	0.22	0.25	0.27	0.29	0.32	0.35	0.39	0.42	0.46	0.5	0.55	0.6	0.65	0.71	0.78	0.8
Anaerobic digester	0 - 1 (see IPCC 2006 Table 10.17 for specific calculations)																		
Burned for fuel or as waste	0.1					0.1											0.1		
Deep bedding < 1 month	0.03					0.03											0.3		
Deep bedding > 1month	0.17	0.19	0.2	0.22	0.25	0.27	0.29	0.32	0.35	0.39	0.42	0.46	0.5	0.55	0.6	0.65	0.71	0.78	0.8
Composting (in-vessel or pile)	0.005					0.005											0.005		
Composting (intensive windrow)	0.005					0.01											0.015		
Composting (passive windrow)	0.005					0.01											0.015		
Aerobic treatment	0.0					0.0											0.0		

* For definitions, see IPCC 2006 Table 10.18

Data source: IPCC 2006 Table 10.17

Nitrous oxide emissions from manure management $E_{MN2O,0}$ shall be calculated applying Equation 10. Alternatively, emissions from manure management may be calculated through the application of more recent models published in peer-reviewed scientific journals with proven applicability under project conditions. The same calculation approach must be applied for baseline and project scenario.

Quantification of emissions from manure storage includes direct N_2O emissions as well as indirect emissions from volatilization of NH_3 and NO_x. Emissions from spreading of manure and subsequent emissions from soil are not accounted for under this methodology.

The assessment of the protein content of the diet and the intake of feed is provided by the farmer/nutritionist formulating the rations for the dairy cows, and this professional will attest to the accuracy of the monitoring procedures used.

$$E_{MN2O,0} = \sum_G \left(FeedN_{G,0} - MilkN_{G,0} - LWgainN_{G,0} \right) \times N_{G,0} \times 365 \times E_{N2O,G,0} \times GWP_{N2O}/1000 \quad (10)$$

Where:

$E_{MN2O,0}$ = Average annual nitrous oxide emissions from manure management in the baseline scenario [tCO_2e]

$FeedN_{G,0}$ = Feed N intake per animal in animal stratum G in the baseline scenario [kg N head^{-1} day^{-1}]
= $DMI_{G,0} * CP_{G,0} * fN_{FP}$

Where:

$DMI_{G,0}$ = Dry matter intake per animal in animal stratum G in the baseline scenario [kg head^{-1} day^{-1}]

$CP_{G,0}$ = Crude protein in diet per animal in animal stratum G in the baseline scenario [fraction of DMI]

fN_{FP} = Fraction N in feed protein
= 0.16

$MilkN_{G,0}$ = N retained in milk N per animal in animal stratum G [kg N head^{-1} day^{-1}]
= $Milk_{G,0}$ * Milk $protein_{G,0}$ * fN_{MP}

Where:

$Milk_{G,0}$ = daily milk production per animal in animal stratum in the baseline scenario [kg head^{-1} day^{-1}]

Milk $protein_{G,0}$ = protein content of milk per animal in animal stratum G in the baseline scenario [fraction on weight basis]

fN_{MP} = fraction N in milk protein
= 0.157

$LWgainN_{G,0}$ = N retained in live weight gain per animal in animal stratum G in the baseline scenario [kg N $head^{-1}$ day^{-1}]
= $LWgain_{G,0} * fN_{WG}$

Where:

$LWgain_{G,0}$ = daily live weight gain per animal in animal stratum G in the baseline scenario [kg $head^{-1}$ day^{-1}]

fN_{WG} = fraction N in live weight gain
= 0.027

365 = Number of days per year

$N_{G,0}$ = Number of animals in animal stratum G in the baseline scenario (annual average) [heads]

$E_{N2O,G,0}$ = N_2O emitted per kg of N excreted per animal in animal stratum G in the baseline scenario [g N_2O (kg excreted $N)^{-1}$]
= $MS_{S,G,0} * E_{N2O,S}$

Where:

$MS_{S,G,0}$ = Fraction of animal stratum G's manure handled using manure management system S under baseline conditions [dimensionless]

$E_{N2O,S}$ = N_2O emitted per kg of N excreted in a specific manure management system [g N_2O (kg excreted $N)^{-1}$]

GWP_{N2O} = Global warming potential of nitrous oxide [tCO_2e tN_2O^{-1}]

1000 = kg per metric tonne [kg t^{-1}]

The fraction of nitrous oxide emitted per kg of N excreted $E_{N2O,S}$ shall be determined for each manure management system S applied in the baseline scenario. Where available, nationally or sub-nationally determined, peer-reviewed emission factors shall be applied. In the absence of such factors, data from other applicable sources (e.g., comparable practices from another country) can be applied if applicability is documented. If no localized emission factors are available, the emission factors shown in Table 7-03 (column "Total") shall be applied. As these factors are based on IPCC defaults with high uncertainty[9], an uncertainty value of ±50% shall be assumed for these parameters. Generally, factors from the latest IPCC Guidelines shall be applied.

[9] IPCC 2006 Guidelines for National Greenhouse Gas Inventories, Volume 4: Agriculture, Forestry and Other Land Use, Chapter 10, Section 10.5.5 cites uncertainty ranges of ±50% for data provided.

Table 7-03: Nitrous oxide emissions $E_{N20,S}$ from manure management system S (calculated based on: IPCC 2006 Guidelines for National Greenhouse Gas Inventories, Vol. 4, Chapter 10, Table 10.21 and Table 10.22)

Manure management system S	N_2O emissions from manure management system (g N_2O per kg N excreted)		
	Direct*	Indirect**	Total
Daily spread	0.0	1.1	1.1
Solid storage	7.9	4.7	12.6
Dry lot	31.4	3.1	34.5
Liquid / slurry (with crust cover)	7.9	6.3	14.2
Liquid / slurry (without crust cover)	0.0	6.3	6.3
Uncovered anaerobic lagoon	0.0	5.5	5.5
Pit storage below animal confinements	3.1	4.4	7.5
Anaerobic digester	0.0	-	0.0
Burned for fuel or as waste	0.0	-	0.0
Deep bedding (no mixing)	15.7	-	15.7
Deep bedding (active mixing)	110.0	-	110.0
Composting (in-vessel or pile)	9.4	-	9.4
Composting (intensive windrow)	157.1	-	157.1
Composting (passive windrow)	15.7	-	15.7
Aerobic treatment (natural aeration)	15.7	-	15.7
Aerobic treatment (forced aeration)	7.9	-	7.9

* calculated from IPCC 2006 Table 10.21

** calculated from IPCC 2006 Table 10.22

8. PROJECT SCENARIO

For the project scenario, annual emissions are calculated for each year in the monitoring period as the sum of emissions from enteric fermentation, supplement production and manure storage according to Equation 11:

$$E_y = \left(E_{F,y} + E_{SP,y} + E_{M,y}\right)/M_y \tag{11}$$

Where:

E_y = Emissions per kg of Fat and Protein Corrected Milk in year y of the monitoring period [tCO_2e (kg FPCM)$^{-1}$]

$E_{F,y}$ = Emissions from enteric fermentation in year y of the monitoring period [tCO_2e]

$E_{SP,y}$ = Emissions from supplement production and transport in year y of the monitoring period [tCO_2e]

$E_{M,y}$ = Emissions from manure management in year y of the monitoring period [tCO_2e]

M_y = Milk production in year y of the monitoring period, expressed as Fat and Protein Corrected Milk (kg FPCM).

8.1 Emissions from enteric fermentation

Methane emissions from enteric fermentation for the project scenario $E_{F,y}$ are calculated using Equations 12 or 13 below.

Approach 1:

The most specific approach to quantify emission reduction is measurement of methane emissions for a sample group of cows in a project environment. As methane measurement techniques are evolving and may not be suitable for all management systems and environments, this methodology allows measurement approaches that meet the following conditions:

1) The measurement technology is scientifically tested, and results are documented in peer-reviewed publications.
2) The applicability of the system under project conditions is confirmed and documented.
3) The measurement error of the system under the project conditions is known or the statistical sample is large enough to estimate this error. A respective uncertainty deduction shall be applied in the calculation of emission reductions (compare Equation 2).

If all of these conditions are met, annual emissions for the project scenario shall be estimated according to Equation 12:

$$E_{F,y} = \sum_G N_{G,y} \times EF_{G,y} \times 365 \times GWP_{CH4}/1000 \qquad (12)$$

Where:

$E_{F,y}$ = Annual emissions from enteric fermentation in year y of the monitoring period [tCO_2e]

$N_{G,y}$ = Number of animals in animal stratum G in year y of the monitoring period [heads]

$EF_{G,y}$ = Methane emission factors from enteric fermentation per animal in animal stratum G in year y of the monitoring period [kg CH_4 $head^{-1}$ day^{-1}]

365 = Number of days per year

GWP_{CH4} = Global warming potential of methane [tCO_2e tCH_4^{-1}]

1000 = kg per metric tonne [kg t^{-1}]

Project emission factor $EF_{G,y}$ shall be measured during the entire monitoring period with a sample for each stratum of animals.

Approach 2:

In the absence of emissions measurements, project emissions $E_{F,y}$ for each year in the monitoring period shall be calculated. Recent research (summarized in Niu et al. 2018) has shown strong impact of feed composition, especially fiber content, on these emissions. This methodology thus does not allow general application of tier 1 default emission and conversion factors in IPCC 2006 as these factors are not differentiating between feeding systems and management practices. Instead, calculations shall be done using data from locally applicable research that has been published in peer-reviewed scientific journals or through national or subnational authorities for GHG accounting. Uncertainty of parameters and models shall be considered and quantified according to section 9 Uncertainty.

$E_{F,y}$ shall be calculated either directly applying published emission models (e.g., regression models) with an impact factor for the feed supplement matching the regression parameters, or by following the approach in Equation 13, based on animal numbers, energy intake through feed and project-related conversion factors for methane emissions.

$$E_{F,y} = \sum_G GE_{G,y} \times Ym_{G,y} \times RYm_{G,y} \times N_{G,y} \times 365/EC_{CH4} \times GWP_{CH4}/1000 \qquad (13)$$

Where:

$E_{F,y}$	=	Emissions from enteric fermentation in year y of the monitoring period [tCO_2e]
$GE_{G,y}$	=	Daily gross energy intake per animal in animal stratum G, based on measured dry matter intake in year y of the monitoring period [MJ $head^{-1}$ day^{-1}]
$Ym_{G,y}$	=	Fraction of gross energy in feed converted to methane per animal in animal stratum G in year y of the monitoring period [dimensionless]
$RYm_{G,y}$	=	Supplement impact coefficient reducing the fraction of gross energy in feed converted to methane, per animal in animal stratum G in year y of the monitoring period [dimensionless]
$N_{G,y}$	=	Number of animals in animal stratum G in year y of the monitoring period [heads]
365	=	Number of days per year
EC_{CH4}	=	Energy content of methane [MJ (kg methane)$^{-1}$] = 55.65
GWP_{CH4}	=	Global warming potential of methane [tCO_2e tCH_4^{-1}]
1000	=	kg per metric tonne [kg t^{-1}]

Gross energy intake $GE_{G,y}$ is calculated from measurements of dry matter intake DMI on a daily basis using Equation 14. The DMI value shall be determined as the sum of all ration ingredients.

$$GE_{G,y} = \frac{DMI_{G,y}}{EC_{DM}} \quad (14)$$

Where:

$GE_{G,y}$ = Gross energy intake per animal in animal stratum G, based on measured dry matter intake in year y of the monitoring period [MJ head^{-1} day^{-1}]

$DMI_{G,y}$ = Dry matter intake per animal in animal stratum G in year y of the monitoring period [kg head^{-1} day^{-1}]

EC_{DM} = Average energy content of dry matter [MJ kg^{-1}] = 18.45

The methane conversion factor $Ym_{G,y}$ is determined for each animal stratum G. It shall be selected to best meet project conditions, especially feed composition, and its applicability documented by the project proponent. Acceptable proofs of applicability include peer-reviewed publications based on data collected under comparable conditions as well as documentation published by national or subnational authorities for GHG accounting. Data from direct measurements under project conditions may also be used if measurement methodology, setup, full results and analysis are provided for review for registration and performance audits. Internationally applicable conversion factors may only be applied conservatively, taking into account the respective errors. Note that the high uncertainty common to global models will likely lead to uncertainty deductions according to section 9 of this methodology. Table 7-01 in section 7 provides a matrix of conversion factors in dependence of DMI and NDF, calculated with intercontinental regression models by Niu et al. 2018.

The supplement impact coefficient $RYm_{G,y}$ shall be determined from data provided by the supplier of the feed supplement, based on peer-reviewed data. The data shall describe the efficacy of each specific supplement's emissions reductions in in-vivo application and define applicability of the data, especially dependencies on feed composition and product application, animal type, environmental and management conditions as well as any other factors that could impact the supplements performance with regard to emission reductions.

8.2 Emissions from feed supplement production

Emissions from production and transport of feed supplements applied to reduce emissions from enteric fermentation $E_{SP,y}$ for each year in the monitoring period are calculated based on amount applied and the respective emission factor (Equation 15).

$$E_{SP,y} = \sum_G \left(S_{G,y} \times N_{G,y}\right) \times \left(EF_{SP,y} + EF_{ST,y}\right) \quad (15)$$

Where:

$E_{SP,y}$ = Emissions from supplement production in year y of the monitoring period [tCO_2e]

$S_{G,y}$ = Amount of supplement applied per animal in animals stratum G in year y of the monitoring period [kg head^{-1}]

$N_{G,y}$ = Number of animals in animal stratum G in year y of the monitoring period [heads]

$EF_{SP,y}$ = Emission factor for supplement production in year y of the monitoring period [$tCO_2e\ kg^{-1}$]

$EF_{ST,y}$ = Emission factor for supplement transport in year y of the monitoring period [$tCO_2e\ kg^{-1}$]

Emission factor EF_{SP} shall be provided by the supplier of the feed supplement, following accepted methodologies, e.g., LCA data according to ISO 14040 and 14044. Suppliers should also report the standard error of the mean to allow quantification of uncertainty.

Emission factor EF_{ST} shall be calculated taking into account means of transport and average distance from the production site to the farms. Calculation should be done with an appropriate tool such as the GHG protocol transport emissions calculator[10].

8.3 Emissions from manure management

Emissions from manure management $E_{M,y}$ for each year in the monitoring period are calculated using Equation 16:

$$E_{M,y} = E_{MCH4,y} + E_{MN2O,y} \quad (16)$$

Where:

$E_{M,y}$ = Emissions from manure management in year y of the monitoring period [tCO_2e]

$E_{MCH4,y}$ = Methane emissions from manure management in year y of the monitoring period [tCO_2e]

$E_{MN2O,y}$ = Nitrous oxide emissions from manure management in year y of the monitoring period [tCO_2e]

Methane emissions from manure management $E_{MCH4,y}$ shall be calculated applying Equation 17. Emissions are quantified based on the quantity of volatile solids excreted by the dairy herd and the storage technique for the manure.

$$E_{MCH4,y} = \sum_{S,G} VS_{G,y} \times N_{G,y} \times 365 \times B_o \times CF_{CH4} \times MCF_S \times MS_{S,G,y} \times GWP_{CH4}/1000 \quad (17)$$

Where:

$E_{MCH4,y}$ = Methane emissions from manure management in year y of the monitoring period [tCO_2e^1]

[10] https://ghgprotocol.org/sites/default/files/Transport_Tool_v2_6.xlsx

$VS_{G,y}$ = Daily volatile solid excreted per animal in animal stratum G in year y of the monitoring period [kg dry matter head^{-1} day^{-1}]

$N_{G,y}$ = Number of animals in animal stratum G in year y of the monitoring period [heads]

365 = Number of days per year

B_o = Maximum methane producing capacity from dairy manure [m3 kg^{-1} of VS]
= 0.24 or dairy cows in developed countries, or 0.13 in developing countries (IPCC 2006)

CF_{CH4} = conversion factor of m3 methane to kg methane [kg methane (m^3 methane)$^{-1}$]
= 0.67

MCF_S = Methane conversion factor for manure management system S [dimensionless]

$MS_{S,G,y}$ = Fraction of animal stratum G's manure handled using manure management system S in year y of the monitoring period [dimensionless]

GWP_{CH4} = Global warming potential of methane [tCO_2e tCH_4^{-1}]

1000 = kg per metric tonne [kg t^{-1}]

Daily volatile solids $VS_{G,y}$ excreted per animal in animal stratum G for each year of the monitoring period are calculated using Equation 18 below. Alternatively, VS_G may be calculated through the application of more recent models published in peer-reviewed scientific journals with proven applicability under project conditions. The same calculation approach must be applied for baseline and project scenario.

$$VS_{G,y} = GE_{G,y} \times \left(\left(1 - DE_{G,y}\right) + UE\right) \times (1 - ASH)/EC_{DM} \qquad (18)$$

Where:

$VS_{G,y}$ = Daily volatile solid excreted per animal in animal stratum G in year y of the monitoring period [kg dry matter head^{-1} day^{-1}]

$GE_{G,y}$ = Gross energy intake per animal in animal stratum G in year y of the monitoring period, based on measured dry matter intake [MJ head^{-1} day^{-1}]

$DE_{G,y}$ = Digestible energy in feed for animal stratum G in year y of the monitoring period, as fraction of GE [dimensionless]

UE = Urinary energy expressed as fraction of GE [dimensionless]
= 0.04 for dairy cows with less than 85% grain in diet (IPCC 2006)

ASH = Ash content of manure as a fraction of the dry matter feed intake [dimensionless]
= 0.08 for cattle (IPCC 2006)

EC_{DM} = Average energy content of dry matter [MJ kg^{-1}] = 18.45

Digestible energy in feed DE_y shall be documented for specific feed applied in the project scenario. [11]

Fraction of manure $MS_{S,G}$ handled using each manure management S system per animal stratum G shall be monitored and documented in the project scenario.

Methane conversion factors for manure management systems MCF_S shall be determined for each manure management system S applied in the project activity. Where available, nationally or sub-nationally determined peer-reviewed emission factors shall be applied. In the absence of such factors, data from other applicable sources (e.g., comparable practices from another country) can be applied if applicability is documented. If no localized emissions factors are available, emission factors shown in Table 7-02 in section 7 Baseline Scenario shall be applied. As these factors are based on IPCC defaults, an uncertainty value of ±20% shall be assumed for these parameters[12].

Nitrous oxide emissions from manure management $E_{MN2O,y}$ shall be calculated applying Equation 19. Alternatively, emissions from manure management may be calculated through the application of more recent models published in peer-reviewed scientific journals with proven applicability under project conditions. The same calculation approach must be applied for baseline and project scenario. Quantification of emissions from manure storage includes direct N_2O emissions as well as indirect emissions from volatilization of NH_3 and NO_x. Emissions from spreading of manure and subsequent emissions from soil are not accounted for under this methodology.

The assessment of the protein content of the diet and the intake of feed is provided by the farmer/nutritionist formulating the rations for the dairy cows, and this professional will attest to the accuracy of the monitoring procedures used.

$$E_{MN2O,y} = \sum_G \left(FeedN_{G,y} - MilkN_{G,y} - LWgainN_{G,y} \right) \times N_{G,y} \times 365 \times E_{N2O,G,y} \times GWP_{N2O}/1000 \quad (19)$$

Where:

$E_{MN2O,y}$ = Nitrous oxide emissions from manure management in year y of the monitoring period [tCO_2e]

G = Animal stratum

$FeedN_{G,y}$ = Feed N intake per animal in animal stratum G in year y of the monitoring period [kg N $head^{-1}$ day^{-1}]
= $DMI_{G,y} * CP_{G,y} * fN_{FP}$

Where:

$DMI_{G,y}$ = Dry matter intake per animal in animal stratum G in year y of the monitoring period [kg $head^{-1}$ day^{-1}]

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[11] If fraction of metabolizable energy (ME) is available instead of digestible energy, term (1-ME) may be used instead of ((1-DE)+UE) in equation 18.

[12] IPCC 2006 Guidelines for National Greenhouse Gas Inventories, Volume 4: Agriculture, Forestry and Other Land Use, Section 10.4.4 cites uncertainty ranges of ±20% for tier 2 data provided.

$CP_{G,y}$ = Crude protein in diet per animal in animal stratum G in year y of the monitoring period [fraction of DMI]

fN_{FP} = Fraction N in feed protein
= 0.16

$MilkN_{G,y}$ = N retained in milk N per animal in animal stratum G [kg N head^{-1} day^{-1}]
= $Milk_{G,y}$ * Milk $protein_{G,y}$ * fN_{MP}

Where:

$Milk_{G,y}$ = daily milk production per animal in animal stratum G in year y of the monitoring period [kg head^{-1} day^{-1}]

Milk $protein_{G,y}$ = protein content of milk per animal in animal stratum G in year y of the monitoring period [fraction on weight basis]

fN_{MP} = fraction N in milk protein
= 0.157

$LWgainN_{G,y}$ = N retained in live weight gain per animal in animal stratum G in year y of the monitoring period [kg N head^{-1} day^{-1}]
= $LWgain_{G,y}$ * fN_{WG}

Where:

$LWgain_{G,y}$ = daily live weight gain per animal in animal stratum G in year y of the monitoring period [kg head^{-1} day^{-1}]

fN_{WG} = fraction N in live weight gain
= 0.027

365 = Number of days per year

$N_{G,y}$ = Number of animals in animal stratum G in year y of the monitoring period [heads]

$E_{N2O,G,y}$ = N_2O emitted per kg of N excreted per animal in animal stratum G in year y of the monitoring period [g N_2O (kg excreted N)$^{-1}$]
= $MS_{S,G,y}$ * $E_{N2O,S}$

Where:

$MS_{S,G,y}$ = Fraction of excreted N handled by manure management system S per animal in animal stratum G in year y of the monitoring period [dimensionless]

$E_{N2O,S}$ = N_2O emitted per kg of N excreted in a specific manure management system [g N_2O (kg excreted N)$^{-1}$]

GWP_{N2O}	=	Global warming potential of nitrous oxide [$tCO_2e\ tN_2O^{-1}$]
1000	=	kg per metric tonne [$kg\ t^{-1}$]

The fraction of nitrous oxide emitted per kg of N excreted $E_{N2O,S}$ shall be determined for each manure management system S applied in the project scenario. Where available, nationally or sub-nationally determined, peer-reviewed emission factors shall be applied. In the absence of such factors, data from other applicable sources (e.g., comparable practices from another country) can be applied if applicability is documented. If no localized emission factors are available, the emission factors shown in Table 7-03 in section 7 Baseline Scenario shall be applied. As these factors are based on IPCC defaults with high uncertainty[13], an uncertainty value of ±50% shall be assumed for these parameters. Generally, factors from the latest IPCC Guidelines shall be applied.

9. UNCERTAINTY

The project proponent shall use a precision of 20% of the mean at the 90% confidence level as the criteria for reliability of sampling efforts. This target precision shall be achieved by selecting appropriate parameters, sampling and measurement techniques in accordance with Annex A "Uncertainty of LUF Parameters" of the Gold Standard for the Global Goals Land-use & Forests Activity Requirements.

Overall uncertainty for calculation of emissions reduction is performed as follows[14]:

Step 1: Calculate upper and lower confidence limits for all input parameters
Calculate the mean $\bar{X}_p$, and standard deviation σ_p, for each parameter and coefficient used in emissions calculations. The standard error of the mean is then given by

$$SE_p = \frac{\sigma_p}{\sqrt{n_p}} \tag{20}$$

Where:

SE_p	= Standard error in the mean of parameter p
σ_p	= Standard deviation of the parameter p
n_p	= Number of samples used to calculate the mean and standard deviation of parameter p

If SE_p (mean standard error) is available directly from the parameter source (e.g., literature, metadata) it may be used directly in the following calculations (without the use of Equation 20).

[13] IPCC 2006 Guidelines for National Greenhouse Gas Inventories, Volume 4: Agriculture, Forestry and Other Land Use, Section 10.5.5 cites uncertainty ranges of ±50% for data provided.
[14] This chapter on uncertainty is adapted from VCS VM0017 and registered "Gold Standard Agriculture Methodology for Increasing Soil Carbon Through Improved Tillage Practices".

Assuming that values of the parameter are normally distributed about the mean, values for the upper and lower confidence intervals for the parameters are given by

$$\mathrm{Lower_p} = \overline{\mathrm{X}}_\mathrm{p} - \mathrm{t_{np}} \times \mathrm{SE_p} \qquad (21)$$

$$\mathrm{Upper_p} = \overline{\mathrm{X}}_\mathrm{p} + \mathrm{t_{np}} \times \mathrm{SE_p}$$

Where:

$Lower_p$ = Value at the lower end of the 90% confidence interval for parameter p

$Upper_p$ = Value at the upper end of the 90% confidence interval for parameter p

$\overline{X}_p$ = Mean value for parameter p

SE_p = Standard error in the mean of parameter p

t_{np} = t-value for the cumulative normal distribution at 90% confidence interval for the number of samples n_p for parameter p (apply Table 9-1 below). If no information is available on n_p a conservative value of 1.675 (n=3) shall be used.

Step 2: Calculate reduction of emissions from dairy cows in the monitoring period (ΔE_{t-0}) with the lower and upper confidence interval values of the input parameters

Apply the Lower and Upper parameter values in the models for ΔE_{t-0}, specifically equations for E_t and E_0, to achieve a lower and upper value for ΔE_{t-0}

$$Lower_{\Delta Et-0} = Model_{\Delta Et-0}\{Lower_p\} \qquad (22)$$

$$Upper_{\Delta Et-0} = Model_{\Delta Et-0}\{Upper_p\}$$

Where:

$Lower_{\Delta Et-0}$ = Lower value of emissions change at a 90% confidence interval

$Upper_{\Delta Et-0}$ = Upper value of emissions change at a 90% confidence interval

$Model_E$ = Calculation models for ΔEt-0 including models for E_t, E_0 and below

$Lower_p$ = Values at the lower end of the 90% confidence interval for all parameters p

$Upper_p$ = Values at the upper end of the 90% confidence interval for all parameters p

Table 9-1: t-values (t_{np}) applicable in equation (21). Select appropriate t_{np} value depending on the number of samples (n_p) measured for parameter p.

n_p	t_{np}	n_p	t_{np}	n_p	t_{np}	n_p	t_{np}	n_p	t_{np}	n_p	t_{np}	n_p	t_{np}
		31	1.6973	61	1.6706	91	1.6620	121	1.6577	151	1.6551	181	1.6534
		32	1.6955	62	1.6702	92	1.6618	122	1.6575	152	1.6550	182	1.6533
3	2.9200	33	1.6939	63	1.6698	93	1.6616	123	1.6574	153	1.6549	183	1.6533
4	2.3534	34	1.6924	64	1.6694	94	1.6614	124	1.6573	154	1.6549	184	1.6532
5	2.1319	35	1.6909	65	1.6690	95	1.6612	125	1.6572	155	1.6548	185	1.6532
6	2.0150	36	1.6896	66	1.6686	96	1.6610	126	1.6571	156	1.6547	186	1.6531
7	1.9432	37	1.6883	67	1.6683	97	1.6609	127	1.6570	157	1.6547	187	1.6531
8	1.8946	38	1.6871	68	1.6679	98	1.6607	128	1.6570	158	1.6546	188	1.6531
9	1.8595	39	1.6859	69	1.6676	99	1.6606	129	1.6568	159	1.6546	189	1.6530
10	1.8331	40	1.6849	70	1.6673	100	1.6604	130	1.6568	160	1.6545	190	1.6529
11	1.8124	41	1.6839	71	1.6669	101	1.6602	131	1.6567	161	1.6544	191	1.6529
12	1.7959	42	1.6829	72	1.6666	102	1.6601	132	1.6566	162	1.6544	192	1.6529
13	1.7823	43	1.6820	73	1.6663	103	1.6599	133	1.6565	163	1.6543	193	1.6528
14	1.7709	44	1.6811	74	1.6660	104	1.6598	134	1.6564	164	1.6543	194	1.6528
15	1.7613	45	1.6802	75	1.6657	105	1.6596	135	1.6563	165	1.6542	195	1.6528
16	1.7530	46	1.6794	76	1.6654	106	1.6595	136	1.6562	166	1.6542	196	1.6527
17	1.7459	47	1.6787	77	1.6652	107	1.6593	137	1.6561	167	1.6541	197	1.6527
18	1.7396	48	1.6779	78	1.6649	108	1.6592	138	1.6561	168	1.6540	198	1.6526
19	1.7341	49	1.6772	79	1.6646	109	1.6591	139	1.6560	169	1.6540	199	1.6526
20	1.7291	50	1.6766	80	1.6644	110	1.6589	140	1.6559	170	1.6539	≥200	1.6525
21	1.7247	51	1.6759	81	1.6641	111	1.6588	141	1.6558	171	1.6539		
22	1.7207	52	1.6753	82	1.6639	112	1.6587	142	1.6557	172	1.6538		
23	1.7172	53	1.6747	83	1.6636	113	1.6586	143	1.6557	173	1.6537		
24	1.7139	54	1.6741	84	1.6634	114	1.6585	144	1.6556	174	1.6537		
25	1.7109	55	1.6736	85	1.6632	115	1.6583	145	1.6555	175	1.6537		
26	1.7081	56	1.6730	86	1.6630	116	1.6582	146	1.6554	176	1.6536		
27	1.7056	57	1.6725	87	1.6628	117	1.6581	147	1.6554	177	1.6536		
28	1.7033	58	1.6720	88	1.6626	118	1.6580	148	1.6553	178	1.6535		
29	1.7011	59	1.6715	89	1.6623	119	1.6579	149	1.6552	179	1.6535		
30	1.6991	60	1.6711	90	1.6622	120	1.6578	150	1.6551	180	1.6534		

Step 3: Calculate the uncertainty in the model output

The uncertainty in the output model is given by

$$UNC = \frac{|Upper_{\Delta Et-0} - Lower_{\Delta Et-o}|}{2 \times \Delta E_{t-0}} \tag{23}$$

Where:

UNC = Model output uncertainty [%]

$Lower_{\Delta Et-0}$ = Lower value of emissions change at a 90% confidence interval [tCO_2e]

$Upper_{\Delta Et-0}$ = Upper value of emissions change at a 90% confidence interval [tCO_2e]

ΔE_{t-0} = Change in emissions [tCO_2e]

Step 4: Adjust the estimate of emissions change (ΔE_{t-0}) based on the uncertainty in the model output

If the overall uncertainty of the emission change model is less than or equal to 20% of the calculated emissions change value then the project proponent may use the estimated value without any deduction for uncertainty, i.e., UD = 0 in Equation 2.

If the uncertainty of emission models is greater than 20% of the mean value, then the project proponent shall use the estimated emission reduction subject to an uncertainty deduction (UD) in Equation 2, calculated as

$$\mathrm{UD} = \mathrm{UNC} - 20\% \tag{24}$$

Where:

UD = Uncertainty deduction [%]

UNC = Model output uncertainty (>20%) [%]

10. LEAKAGE

Leakage is defined as an increase in GHG emissions outside the project area as a result of project activities. In the context of this methodology, leakage could occur in relation to shift of milk production to other lands to compensate for yield reductions.

As the project area is being actively maintained for commodity production during the project crediting period, yield-related leakage risks are relatively small. Milk producers are commonly risk averse and are unlikely to intentionally suffer reduced yields. Moreover, under the Gold Standard for the Global Goals, projects must not lead to a decrease in agricultural productivity, thus all projects must be set up to maintain or increase yield. Accordingly, this methodology's applicability conditions do not allow yield reduction.

For project calculations, LK_{t-0} is thus considered equal 0.

11. ADDITIONALITY

All Gold Standard certified projects seeking carbon credit issuance need to demonstrate that they would not have been implemented without the benefits of carbon certification. Specific rules and guidelines on how to assess additionality can be found in the Additionality section of Gold Standard for the Global Goals Land-use & Forests Activity Requirements and the Gold Standard for the Global Goals AGR Additionality (AGR projects) Template.

12. SUSTAINABLE DEVELOPMENT GOALS

The primary SDG targeted by this methodology is SDG 13, through GHG emissions reduction from enteric fermentation. Contributions to further specific SDGs is not defined in this methodology as it is specified at the project level.

13. MONITORING

13.1 Monitoring frequency and performance reviews

The project proponent shall submit a monitoring report at project registration and at each performance review according to the Gold Standard for the Global Goals Principles & Requirements Monitoring Report document, the Gold Standard for the Global Goals Monitoring Report Template and the information listed in below monitoring tables.

In addition, the project proponent shall submit an annual report containing at least the information listed in The Gold Standard for the Global Goals Principles & Requirements Annual Report document, the Gold Standard for the Global Goals Principles & Requirements Annual Report Template and those labelled as annually in below monitoring tables.

In addition to the parameters listed below, the project proponent shall collect and document evidence that the methodology's applicability conditions are met at all times. In addition, the project proponent shall:

- Electronically archive all data collected as part of monitoring for a period lasting until 2 years after the end of the last crediting period; and
- Ensure that measuring equipment is certified to national or international standards and calibrated according to the national standards and reference points or international standards and recalibrated at appropriate intervals according to manufacturer specifications

13.2 Data and Parameters collected for baseline calculation and when project areas (farms) are being added and at renewable of crediting period if required

Data/Parameter	$CP_{G,0}$
Data unit	dimensionless
Description	Crude protein in diet, quantified as a fraction of DMI, per animal in animal stratum G
Source of data	Nutritionist and/or feed supplier (feed description)
Values applied	
Measurement methods and procedures	Calculation of annual average per animal group, based on feed description over baseline period
Monitoring frequency	Annually
QA/QC procedures	Data and source(s) to be audited at validation
Additional comment	If no data is available for pasture feed, locally applicable, published research may be used. Evidence of applicability has to be proven by the project proponent and verified by the by the Gold Standard Validation/Verification Body.

Data/Parameter	$DE_{G,0}$
Data unit	dimensionless
Description	Digestible energy in feed for animal stratum G, quantified as fraction of GE
Source of data	Nutritionist and/or feed supplier (feed description), based on applicable research
Values applied	
Measurement methods and procedures	Calculation approach for DE should follow common practice for the project area (i.e., approaches may differ between nations/regions). Once an approach is chosen for a project activity, it must be retained for the entire project duration (baseline and project).
Monitoring frequency	Annually
QA/QC procedures	Data and source(s) to be audited at validation
Additional comment	If no data is available for pasture feed, locally applicable, published research may be used. Evidence of applicability has to be proven by the project proponent and verified by the Gold Standard Validation/Verification Body.

Data/Parameter	$DMI_{G,0}$
Data unit	kg $head^{-1}$ day^{-1}
Description	Dry matter intake for animal group G

Source of data	Feeding records (farm reports)
Values applied	
Measurement methods and procedures	For pasture-fed animals, DMI may be modelled based on locally applicable research (e.g., based on pasture productivity and stocking density).
Monitoring frequency	Annually
QA/QC procedures	Data and source(s) to be audited at validation
Additional comment	

Data/Parameter	$EF_{G,0}$
Data unit	kg CH_4 head^{-1} day^{-1}
Description	Methane emission factors from enteric fermentation per animal in animal group G
Source of data	Approach 1: Measured for each animal group (study reports). Approach2: $EF_{G,0}$ is calculated using Equation 5.
Values applied	
Measurement methods and procedures	Methane emissions from enteric fermentation are measured on-farm for a representative sample of animals for each animal stratum. Measurement techniques must meet the following conditions: 1) The measurement technology is scientifically tested, and results are documented in peer-reviewed publications. 2) The applicability of the system under project conditions is confirmed and documented. The measurement error of the system under the project conditions is known or the statistical sample is large enough to estimate this error.
Monitoring frequency	Annually
QA/QC procedures	Data and source(s) to be audited at validation
Additional comment	

Data/Parameter	$E_{N2O,S}$
Data unit	g N_2O (kg N excreted)$^{-1}$
Description	Nitrous oxide emitted per kg N excreted in manure management system S
Source of data	Data shall be used from the following sources (ordered by priority):

	1) Nationally or sub-nationally determined, peer-reviewed emission factors 2) Data from other applicable sources (e.g. comparable practices from another country), if applicability is documented Emission factors shown in Table 7-03 shall be applied.
Values applied	
Measurement methods and procedures	
Monitoring frequency	Once
QA/QC procedures	Data and source(s) to be audited at validation
Additional comment	Respective errors of the mean shall be documented and applied for uncertainty assessment.

Data/Parameter	$LWgain_{G.0}$
Data unit	kg head^{-1} day^{-1}
Description	Daily live weight gain per animal in animal stratum G
Source of data	Farm reports
Values applied	
Measurement methods and procedures	Daily weight gain may be measured with adequate measurement techniques or modeled based on average entry weight, target weight and growth duration in animal stratum G. In both cases an estimate of error of the mean shall be established.
Monitoring frequency	Annually (average per animal stratum)
QA/QC procedures	Data and source(s) to be audited at validation
Additional comment	May not be available for all farms. Sample must be large enough to calculate representative average for animal stratum G.

Data/Parameter	M_0
Data unit	kg FPCM yr^{-1}
Description	Average annual milk production in the baseline scenario, expressed as Fat and Protein Corrected Milk
Source of data	Milking records (farm reports)
Values applied	
Measurement methods and procedures	Local common practice for calculation of FPCM (or ECM) shall be applied.

	If no common approach is available, FPCM shall be calculated according to IFCN: $$M_0 = \sum_G \left[Milk_{G,0} \times 365 \times \left(\begin{array}{c} 0.383 \times Milk\ fat_{G,0} \\ + 0.242 \times Milk\ protein_{G,0} \\ +0.7832 \end{array} \right) \Big/ 3.1138 \right]$$ Where: M_0 = average annual milk production in baseline [kg FPCM] $Milk_{G,0}$ = daily milk production for animal stratum G in baseline [kg day^{-1}] 365 = days in year $Milk\ fat_{G,0}$ = fat content of milk for animal stratum G in baseline [Fraction on weight basis] $Milk\ protein_{G,0}$ = protein content of milk for animal stratum G in baseline [Fraction on weight basis] (formula source: IFCN, http://ifcndairy.org/about-ifcn-neu/ifcn-dairy-research-center-method/)
Monitoring frequency	Annually
QA/QC procedures	Data and source(s) to be audited at validation
Additional comment	

Data/Parameter	MCF_S
Data unit	dimensionless
Description	Methane conversion factor for manure management system S
Source of data	Data shall be used from the following sources (ordered by priority): 1) Nationally or sub-nationally determined, peer-reviewed emission factors 2) Data from other applicable sources (e.g. comparable practices from another country), if applicability is documented Emission factors shown in Table 7-02 shall be applied.
Values applied	

Measurement methods and procedures	
Monitoring frequency	Once
QA/QC procedures	Data and source(s) to be audited at validation
Additional comment	Respective errors of the mean shall be documented and applied for uncertainty assessment.

Data/Parameter	$Milk_{G,0}$
Data unit	kg head^{-1} day^{-1}
Description	Daily milk production for animal stratum G
Source of data	Milking records (farm reports)
Values applied	
Measurement methods and procedures	Milk production shall be reported by all farms participating in the project. Daily production may be calculated from average values (maximum one year). Analysis shall report error or the mean for each animal stratum G.
Monitoring frequency	Annually (average per animal stratum)
QA/QC procedures	Data and source(s) to be audited at validation
Additional comment	

Data/Parameter	$Milk\ fat_{G,0}$
Data unit	dimensionless
Description	Fat content of milk for animal stratum G (fraction on weight basis)
Source of data	Milking records (farm reports)
Values applied	
Measurement methods and procedures	
Monitoring frequency	Annually (average per animal stratum)
QA/QC procedures	Data and source(s) to be audited at validation
Additional comment	May not be available for all farms. Sample must be large enough to calculate representative average for animal stratum G.

Data/Parameter	$Milk\ protein_{G,0}$
Data unit	dimensionless

Description	Protein content of milk for animal stratum G (fraction on weight basis)
Source of data	Milking records (farm reports)
Values applied	
Measurement methods and procedures	
Monitoring frequency	Annually (average per animal stratum)
QA/QC procedures	Data and source(s) to be audited at validation
Additional comment	May not be available for all farms. Sample must be large enough to calculate representative average for animal stratum G.

Data/Parameter	$MS_{S,G,0}$
Data unit	dimensionless
Description	Fraction of animal stratum G's manure handled using manure management system S
Source of data	Manure records (farm reports) according to applicable legislation and practices. If records are not available or cannot be verified, e.g., from submission records to authorities, additional evidence (e.g. imagery, storage facility documentation) and conservative expert judgement may be provided.
Values applied	
Measurement methods and procedures	For baseline quantification, fraction of manure shall be based on annual quantities and variance over the 3 baseline years.
Monitoring frequency	Annually (average per animal stratum)
QA/QC procedures	Data and source(s) to be audited at validation
Additional comment	May not be available for all farms. Sample must be large enough to calculate representative average for animal stratum G. If expert judgement is used for estimation, conservativeness of estimate shall be reviewed and confirmed by the Validation/Verification Body.

Data/Parameter	$N_{G,0}$
Data unit	heads
Description	Number of animals in animal stratum G
Source of data	Farm reports
Values applied	

Measurement methods and procedures	Each farm report shall list all animals of the productive herd individually, including tag numbers and their allocation to an animal stratum. If animals are removed (e.g., sold or deceased), added or moved between strata during an annual reporting period, this shall be clearly documented and allocated pro-rata to the respective stratum. After consolidation, annual average number of animals and variance shall be calculated for each animal stratum G.
Monitoring frequency	Annually
QA/QC procedures	Data and source(s) to be audited at validation
Additional comment	

Data/Parameter	$Ym_{G,0}$
Data unit	dimensionless
Description	Fraction of gross energy in feed converted to methane for animal stratum G
Source of data	This factor shall be selected to best meet project conditions, especially the feed composition for each animal stratum G, and its applicability must be documented by the project proponent. Acceptable proofs of applicability include: 1) Peer-reviewed scientific publications based on data collected under comparable conditions Data from direct measurements under project conditions if measurement methodology, setup, full results and analysis are provided for review for registration and performance audits.
Values applied	
Measurement methods and procedures	
Monitoring frequency	Annually (average per animal stratum)
QA/QC procedures	Data and source(s) to be audited at validation
Additional comment	Respective errors of the mean shall be documented and applied for uncertainty assessment.

13.2 Data and Parameters monitored

The parameters in this section are required for quantification of emission reductions, but values used do not need to be derived from monitored data. Parameters resulting from calculations are not included in these tables.

Data/Parameter	ASH
Data unit	dimensionless
Description	Ash content of manure as a fraction of the dry matter feed intake
Source of data	IPCC 2006 Guidelines for National Greenhouse Gas Inventories, Volume 4: Agriculture, Forestry and Other Land Use, Chapter 10, p 10.42
Value applied	0.08 (IPCC default for cattle)
Measurement methods and procedures	
Additional comment	Country-specific values may be used if available

Data/Parameter	B_0
Data unit	m^3 (kg of volatile solids)$^{-1}$
Description	Maximum methane producing capacity from dairy manure
Source of data	IPCC 2006 Guidelines for National Greenhouse Gas Inventories, Volume 4: Agriculture, Forestry and Other Land Use, Chapter 10, p 10.77, Table 10A-4
Value applied	0.24 for dairy cows in developed countries (IPCC default) or 0.13 for dairy cows in developing countries (IPCC default)
Measurement methods and procedures	
Additional comment	Country-specific values may be used if available

Data/Parameter	CF_{CH4}
Data unit	kg methane (m^3 methane)$^{-1}$
Description	Conversion factor of m^3 methane to kg methane

Source of data	IPCC 2006 Guidelines for National Greenhouse Gas Inventories, Volume 4: Agriculture, Forestry and Other Land Use, Chapter 10, p 10.42
Value applied	0.67 (IPCC default)
Measurement methods and procedures	
Additional comment	

Data/Parameter	EC_{CH4}
Data unit	MJ (kg methane)$^{-1}$
Description	Energy content of methane
Source of data	IPCC 2006 Guidelines for National Greenhouse Gas Inventories, Volume 4: Agriculture, Forestry and Other Land Use, Chapter 10, p 10.31
Value applied	55.65 (IPCC default)
Measurement methods and procedures	
Additional comment	

Data/Parameter	EC_{DM}
Data unit	MJ (kg dry matter)$^{-1}$
Description	Average energy content of dry matter
Source of data	IPCC 2006 Guidelines for National Greenhouse Gas Inventories, Volume 4: Agriculture, Forestry and Other Land Use, Chapter 10, p. 10.21
Value applied	18.45 (IPCC default)
Measurement methods and procedures	
Additional comment	If feed-specific information is available specific energy contents may be used. Applicability and transparent calculations shall be documented by project proponent.

Data/Parameter	EF_{SP}
Data unit	tCO_2e kg^{-1}
Description	Emission factor for supplement production
Source of data	Product supplier (product information for supplements used)

Value applied	Project-specific coefficient
Measurement methods and procedures	The supplier of the feed supplement shall report emissions from production of the supplied product following accepted methodologies, e.g., LCA data according to ISO 14040 and 14044. Suppliers should also report the standard error of the mean to allow quantification of uncertainty.
Additional comment	

Data/Parameter	fN_{FP}
Data unit	dimensionless
Description	Fraction N in feed protein
Source of data	IPCC 2006 Guidelines for National Greenhouse Gas Inventories, Volume 4: Agriculture, Forestry and Other Land Use, Chapter 10, p. 10.58, Eq. 10.32
Value applied	0.16 (equivalent to 1/6.25 factor for milk N in IPCC Equation 10.32 above)
Measurement methods and procedures	
Additional comment	

Data/Parameter	fN_{MP}
Data unit	dimensionless
Description	Fraction N in milk protein
Source of data	IPCC 2006 Guidelines for National Greenhouse Gas Inventories, Volume 4: Agriculture, Forestry and Other Land Use, Chapter 10, p. 10.60, Eq. 10.33
Value applied	0.157 (equivalent to 1/6.38 factor for milk N in IPCC Equation 10.33 above)
Measurement methods and procedures	
Additional comment	

Data/Parameter	fN_{WG}
Data unit	dimensionless
Description	Fraction N in live weight gain
Source of data	Alberta Protocol: Quantification protocol for emission reductions from dairy cattle, Version 1 January 2010, p. 26

Value applied	0.027
Measurement methods and procedures	
Additional comment	This value can be replaced with national, sub-national or project specific data or calculation, as available. The respective term on N in live weight gain in Equation 10.33 in IPCC 2006 Guidelines for National Greenhouse Gas Inventories, Volume 4: Agriculture, Forestry and Other Land Use, Chapter 10, p. 10.60 may be applied for this calculation.

Data/Parameter	GWP_{CH4}
Data unit	dimensionless
Description	Global warming potential of methane
Source of data	According to Gold Standard rules, projects shall apply GWP values as listed in IPCC Fourth Assessment Report (2007). Working Group I: The Physical Science Basis. Chapter 10: Global Warming Potentials and Other Metrics for Comparing Different Emissions; Table 2.14
Value applied	25
Measurement methods and procedures	
Additional comment	Latest GWP values as approved by Gold Standard shall be applied.

Data/Parameter	GWP_{N2O}
Data unit	dimensionless
Description	Global warming potential of nitrous oxide
Source of data	According to Gold Standard rules, projects shall apply GWP values as listed in IPCC Fourth Assessment Report (2007). Working Group I: The Physical Science Basis. Chapter 10: Global Warming Potentials and Other Metrics for Comparing Different Emissions; Table 2.14
Value applied	298
Measurement methods and procedures	
Additional comment	Latest GWP values as approved by Gold Standard shall be applied.

Data/Parameter	UE
Data unit	dimensionless
Description	Urinary energy expressed as fraction of GE
Source of data	IPCC 2006 Guidelines for National Greenhouse Gas Inventories, Volume 4: Agriculture, Forestry and Other Land Use, Chapter 10, p. 10.42
Value applied	0.04 (IPCC default for dairy cows with less than 85% grain in diet)
Measurement methods and procedures	
Additional comment	Value shall be reduced to 0.02 for ruminants fed with 85% or more grain in the diet.