METHODOLOGY

METHODOLOGY FOR REDUCING METHANE EMISSIONS FROM ENTERIC FERMENTATION IN BEEF CATTLE THROUGH APPLICATION OF FEED SUPPLEMENTS

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SUMMARY

Cows release methane (CH_4) as a result of the digestion of feed materials in the rumen, one of the four stomach chambers of ruminant livestock. Fermentation in the rumen generates hydrogen as a result of the feed degradation by microorganisms present in the rumen. 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.

This methodology quantifies the reduction of methane emissions from enteric fermentation in beef cattle, as well as impacts on emissions during manure handling. It focuses on the application of feed supplements to reduce enteric methane production in the rumen of livestock. The methodology provides two approaches for quantification of emissions from enteric fermentation. Approach 1 requires on-site measurements whereas Approach 2 applies regression models or IPCC Tier 2 equations integrating data from peer-reviewed publications. New models may also be used if proof of validity and applicability is provided.

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1| Definition

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

a. **Annual pasture:** An area of land put down to grass, clover, herbs, etc., for a single season or limited number of years. It is typically used for forage and replaced on a regular basis (including tillage and/or re-seeding).

b. **Baseline:** The baseline is the estimated emissions from beef cattle management in the baseline scenario.

c. **Baseline scenario:** The baseline scenario in this methodology is the pre-project beef cattle management, feeding practices and manure management that would occur in the absence of the proposed project (business-as-usual).

d. **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 commonly measured in MJ/kg dry matter. Note: in this methodology, DE is quantified as a fraction of gross energy (GE) in feed.

e. **Dry matter intake (DMI):** The amount (kg) of feed consumed by an animal, excluding its water content.

f. **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.

g. **Feed supplement:** In this methodology, a feed supplement is a product added to the animal feed for purposes of reducing methane emissions from enteric fermentation. This may include application of organic or non-organic products to reduce enteric methane production.

h. **Feed type:** In this methodology, feed type indicates a feedstuff with specific components and from a specific source to associate nutritional information as well as respective emissions from production and transport.

i. **Gross Energy (GE):** Gross energy content in feed matter (MJ/kg dry matter)

j. **Methanogenesis:** Formation of methane in the rumen of livestock by microorganisms known as methanogens.

k. **Natural grassland:** Area in which the vegetation is naturally dominated by a nearly continuous cover of grasses. Grasslands occur in environments conducive to the growth of this plant cover but not to that of taller plants, particularly trees and shrubs. The factors preventing establishment of such taller, woody vegetation are varied, ranging from seasonal dryness (e.g. African savannah, American prairies) to flooding (e.g. South American Pantanal). (modified from Britannica)

l. **Pasture:** Pasture refers to land covered by grasses, legumes and/or other herbage used or suitable for the grazing of animals.

m. **Perennial pasture:** An area that is laid down to grass for a period of multiple years, often decades and has not been ploughed for other crops during that time. It is typically used for grazing or occasional cutting.

n. **Project:** The activity or action being implemented for which Gold Standard Certification is sought. A project may include project activities implemented in more than one cattle ranch or feed yard operation.
o. **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 cattle to reduce methane (CH4) emissions from enteric fermentation.
p. **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 cattle ranches or feed yard operations.
q. **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.
r. **Project scenario:** The Project Scenario is defined as the scenario that will exist once the Project is implemented and operational.
s. **Ration:** The daily feed portion prepared from various feedstuffs according to various animals' requirements. It is based on feeding standards and information about the composition and nutritive value of feedstuffs.

Key Abbreviations:

BAU: Business as usual
DMI: Dry matter intake
EF: Emission factor
FAO: Food and Agriculture Organization of the United Nations
GHG: Greenhouse gas
GIS: Geographic information system
GWP: Global warming potential
IPCC: Intergovernmental Panel on Climate Change
PMR: Partially mixed ration
RMSPE: Root mean square prediction error
SDG: Sustainable Development Goals
SE: Standard error
TMR: Totally mixed ration
UD: Uncertainty deduction

2| Scope, Applicability, and entry into force

2.1 | Scope

2.1.1 | The aim of this methodology is to quantify reduction of methane (CH_4) emissions from enteric fermentation from beef cattle as well as impacts on emissions from manure handling. The methodology focuses on application of feed supplements to reduce enteric methane production in the rumen of livestock.

2.1.2 | The methodology provides two approaches for quantification of emissions from enteric fermentation for baseline and project scenario quantification. This accommodates 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 whereas 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 developers need to document that the coefficients applied are conservative and applicable to the project site and management practice.

2.1.3 | Recent publications based on intercontinental data from numerous research studies on methane emission from enteric fermentation show that a number of parameters can be used in regression models to quantify said emissions (Niu et al. 2018, Van Lingen et al. 2019). The publications consolidate results from recent research and have contributed to the updated quantification parameters used in the 2019 Refinement to the IPCC 2006 Guidelines for National Greenhouse Gas Inventories. This methodology allows direct application of regression models under Approach 2 as introduced above and includes a table for selection of methane conversion factors based on key parameters of the best-fit intercontinental model outlined in Van Lingen et al. (2019).

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

2.1.5 | Primary SDG targeted by this methodology is SDG 13, through reduction of emissions from enteric fermentation. Contribution to further specific Sustainable Development Goals (SDGs) is not defined in this methodology as it is specified on project level.

2.2 | Applicability

2.2.1 | The project shall meet all requirements listed below for this methodology to be applicable. In addition, it needs to meet all [Land-use & Forests Activity Requirements] and [Principles & Requirements] including associated documents.

2.2.2 | This methodology is applicable under the following conditions:

a. Projects are eligible in all countries.

b. The project activity reduces methane (CH_4) emissions from enteric fermentation through application of feed supplements for beef cattle. This may include application of organic or non-organic products to reduce enteric methane production. The methodology shall not be applied if changes in other carbon pools or emission sources (e.g. from feed production and transport, animal transport, pasture or manure management) are the only project impacts on greenhouse gas emissions (GHG) or removals.

c. The methodology shall not be applied for calculation of benefits not directly related to the application of the feed supplement. Specifically, no non-related benefits from increase in carbon pools (GHG sequestration in biomass or soil organic carbon) or from emission reductions for feed production and transport, animal transport, pasture or manure management shall be accounted under this methodology. If such effects are expected, a respective dedicated Gold Standard approved methodology shall be applied instead.

d. The feed supplement applied shall have consistently proven efficacy of emissions reductions in in-vivo application with beef cattle published in peer-reviewed scientific literature. The data shall quantify the specific supplement's emissions reductions and define applicability of the data, especially dependencies on diet and product application, animal type, age and weight, environmental and management conditions as well as any other factors that could impact the supplements performance with regard to emission reductions.

e. The use of live microorganisms, hormones and synthetic growth promoters as the active supplement to reduce GHG emissions is not allowed under this methodology.

f. All feed supplements applied under the project activity must be officially registered for use with beef cattle in the project country and provide evidence for such authorization by the respective country authority. This may involve publication in an official register[1]. 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.

g. Application of feed supplement shall not exceed maximum dosages according to the relevant product registration and follow all additional requirements listed by the manufacturer to ensure efficacy, e.g. transport and storage conditions and duration, as well as processing requirements (e.g. temperature limits). Documentation of all such requirements shall be provided along with the project documentation.

h. The methodology is only applicable to farms that have been producing beef at least three years prior to the start of the project activities. Reliable and verifiable data on the average increase of animal live weight per stratum per year shall be available for a minimum of three years.

i. No reduction in meat yield which is caused by the project activity shall be allowed. Project activities in the project area shall deliver a meat yield at least equivalent to the baseline yield at same or lower energy input levels. Reductions in meat yield due to non project-related factors, e.g. fluctuations in herd structure, market demand (evidence to be provided), drought

[1] 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.

effects or reaction to reduced demand, are exempt from this applicability condition.

j. The project activity is not mandated by any law or regulation.

k. The project activity shall not lead to an expansion of pasture area.

l. The project activity shall not lead to a permanent decrease of aboveground woody biomass. If woody biomass is removed in non-forest areas (e.g. from tree patches on pasture), projects shall ensure that removed volume does not exceed total annual tree growth on the field and that regeneration is ensured, either through planting or protection of natural regrowth immediately (within 1 year of biomass removal). The project activity shall not lead to any decrease of soil carbon stocks from the baseline situation in the project area (e.g. due to increase in tillage activities or intensity).

m. The project activity shall not include pastures, feed sources and/or cattle sourced from lands that have been converted from forests, woodlands or perennial grasslands within 10 years prior to project start or thereafter. Cattle grazing on perennial grassland (or sourcing of such cattle for project activity) is permitted as long as the land is not converted to annual pasture or feed production. Where off-farm feedstuff (including concentrates) with "deforestation-free" certification or from a known source area without deforestation is not available, exceptions may be granted at verification, though projects are encouraged to prioritize products from low-deforestation risk areas.

n. The methodology is not applicable to off-farm management practices, e.g. meat processing and distribution.

2.3 | Safeguards

2.3.1 | Animal health, welfare and livestock management requirements set out in the Safeguarding Principles & Requirements shall be met in all project areas in addition to any national and regional animal care guidelines.

2.3.2 | 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.

2.4 | Entry into force

2.4.1 | The date of entry into force of this methodology is 18 July 2023.

3| Baseline Methodology

3.1 | Project Boundary

3.1.1 | **Spatial boundary**

a. The spatial boundary encompasses the project activities that are under the project developer's control and those directly influenced by the project which result in GHG emission reductions.

b. Feed production and pasture management are included as these activities may be impacted by the implementation of the project. The same is true for cattle transportation, e.g. if cattle are transported over longer distances due to the project activities (e.g. between rearing phases). Projects shall delineate boundaries for all on-farm areas to be used for feed production or grazing (including areas including such uses in rotation). If any new areas are added for feed production or grazing during the project, they shall be documented, including proof of adherence to all eligibility criteria and safeguards under this methodology.

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

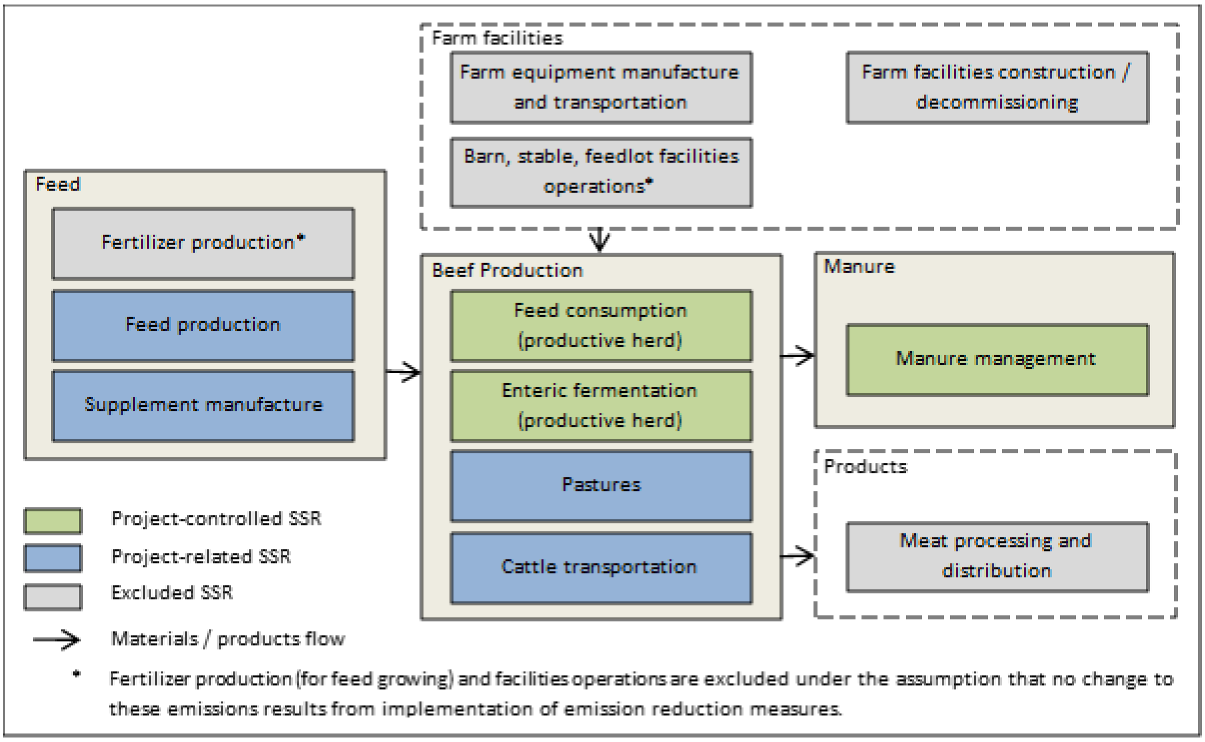

Figure 1 : Spatial project boundary (SSR = greenhouse gas sources, sinks and reservoirs)

3.1.2 | **Temporal boundary**

a. According to the 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.

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

3.2 | Emissions sources included in the project boundary

3.2.1 | The greenhouse gases included or excluded from the project boundary are shown in Table 1 below.

3.2.2 | If evidence of sustainable and unchanged pasture or management is provided at project level, respective emission sources may be omitted or declared “de minimis” if emissions change is non-significant (i.e. sum of omitted sources is less than 5% of total emissions reductions).

Table 1 : Emissions sources included in or excluded from the project boundary

Scenario	Source	Gas	Included	Justification/Explanation
Baseline scenario	Enteric fermentation	CO_2	No	This gas is not relevant in enteric fermentation[3]
		CH_4	Yes	Emitted in enteric fermentation
		N_2O	No	Not emitted in enteric fermentation
	Manure and pasture management	CO_2	No	CO2 emissions in manure handling are biogenic
		CH_4	Yes	Emitted in manure handling
		N_2O	Yes	Emitted in manure handling and pasture management (e.g. fertilizer application)
Project scenario	Enteric fermentation	CO_2	No	This gas is not relevant in enteric fermentation
		CH_4	Yes	Emitted in enteric fermentation
		N_2O	No	Not emitted in enteric fermentation
	Manure and pasture 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 and pasture management (e.g. fertilizer application)
	Supplement manufacture	CO2	Yes	May be emitted in production process
		CH4	Yes	May be emitted from combustion of fossil fuels
		N2O	Yes	May be emitted in production process, depending on supplement applied

3.3 | Demonstration of additionality

3.3.1 | All GS projects 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 Land-use & Forests Activity Requirements and the AGR Additionality (AGR projects) Template.

3.3.2 | The regulatory surplus shall be demonstrated by all the projects, irrespective of scale. The project shall demonstrate that proposed activity is neither directly mandated by law nor otherwise triggered by legal requirements (e.g., legally binding agreements, covenants, consent decrees, or contracts (with government agencies or private parties). If such legal requirements are identified, then crediting for the activity shall only be allowed until the date the legal requirements would take effect.

3.4 | Baseline scenario determination

3.4.1 | 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.

3.5 | Selection and justification of the baseline scenario

3.5.1 | Approaches for baseline and project scenario quantification: To accommodate 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:

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

b. ***Approach 2:*** 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 developer needs to document that the parameters and coefficients applied are conservative and applicable to the project area and management practice.

3.5.2 | The same approach must be used for baseline and project scenario quantification. Generally, the project developer 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 2 below. Further requirements for each approach and its application are given below.

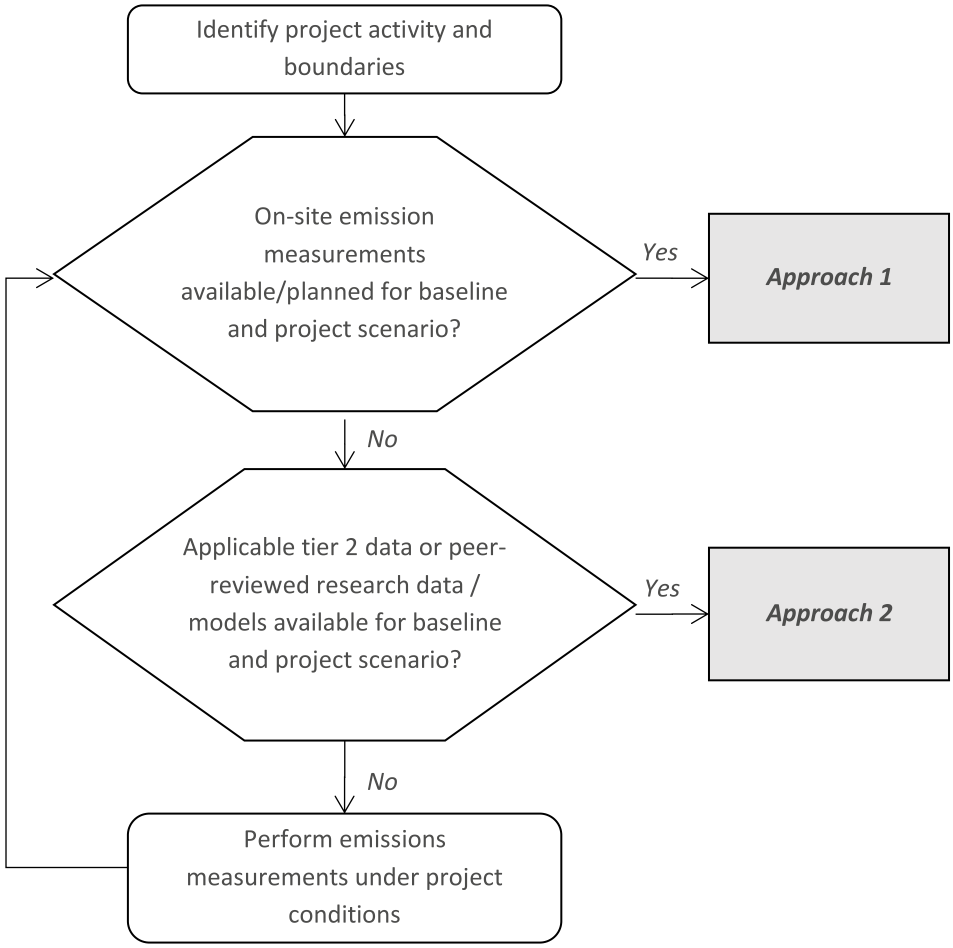

Figure 2: Decision tree for identification of appropriate calculation approach for enteric fermentation.

3.5.3 | The assessment of applicability for models, parameters and/or data sources shall include at minimum that the following characteristics of the scientific source correspond to the project activities (under the baseline and project scenario conditions):

a. animal age and weight range
b. feeding system (e.g. TMR, PMR, grazing)
c. management system (e.g. feedlot, stabled, pasture-based)
d. supplement type and quantity per animal
e. feed composition, including all feed parameters relevant in the selected model (e.g. forage content if applying conversion factors listed in Table 02, and digestible energy and crude protein content for quantification of manure emissions according to equations 8 and 9)
f. manure management system (for manure emissions),

g. climatic conditions (especially for grazing animals and manure emissions)

3.5.4 | If a scientific source specifies further criteria (e.g. breeds, environmental conditions, seasonal impacts etc.) impacting the applied models, parameters or data sources, match of these criteria to project conditions shall also be documented.

3.5.5 | **Conservativeness of parameters applied for benefits quantification** shall be shown in that values applied are specific to project activities (as listed for applicability above) and therefore fully correspond to expected impact level under project conditions. For parameters or data with high variance in the scientific source (e.g. global IPCC default values), project owners shall provide evidence that application of chosen parameter values are conservative in benefits quantification, i.e. that emission reductions from the project activities are rather underestimated. Choice of conservative parameter will depend on its impact on emission calculations:

a. If benefits calculation for baseline and project scenario are done with separate emission factors, i.e. multiplying activity data with an emission factor, both activity data and emission factors should be rather underestimated for baseline calculations (resulting in “low emissions”), and overestimated for project calculations (resulting in “high emissions”), resulting in a conservatively low reduction from project activities.

b. If a project applies a parameter-based quantification, conservative parameters selection shall lead to the same effect, i.e. underestimation of project emission reduction. If, for example, emission reductions are quantified as a fraction of a baseline emission factor (as is done with impact coefficient RYm reducing CH_4 conversion in equation 16 of this methodology), conservativeness can be ensured by applying low baseline emission levels as well as a low reduction fraction for project activity impact.

3.5.6 | Notably, the inverse of above guidance shall be applied for conservative estimation of project activity emissions (i.e. increases against the baseline, such as increased emissions from manure), for which project activity impact shall rather be overestimated.

3.5.7 | **Herd stratification:** For emissions calculations for baseline and project scenarios, as described in the paragraph , the herd must be split into strata to limit variance in accounting parameters. Common stratum parameters are animal age and weight, management approach (e.g. pasture-based cow-calf operations, semi-confined backgrounding, or finishing in feedlots), as well as diet and feeding system. Generally, emissions accounting shall include the entire herd.

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

a. 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 2006/2019[2] or respective research papers) ***OR***

b. 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 separated from the rest of the herd.

3.5.9 | Evidence of the above shall be provided to the VVB at time of design and performance reviews. No benefit accounting shall be done for any part of the herd that is excluded from monitoring and specific emissions accounting.

3.6 | Baseline Emissions

3.6.1 | For the baseline scenario, average annual emissions over 3 baseline years are calculated as the sum of emissions from enteric fermentation, feed production, manure storage, pasture management and transport according to Equation 1:

$$E_0 = \sum_G \left[\left(E_{F,G,0} + E_{FP,G,0} + E_{M,G,0} + E_{P,G,0} + E_{T,G,0}\right) / \left(N_{G,0} \times Days_{G,0} \times AWI_{G,0}\right)\right] \quad \text{Equation 1}$$

Where:

E_0	=	Emissions per kg of animal weight increase in the baseline scenario [tCO_2e (kg AWI)-1]
$E_{F,G,0}$	=	Average annual emissions from enteric fermentation in animal stratum G in the baseline scenario [tCO_2e]
$E_{FP,G,0}$	=	Average annual emissions from feed production for animal stratum G in the baseline scenario [tCO_2e]

[2] IPCC 2006/2019: Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories

$E_{M,G,0}$	=	Average annual emissions from manure management in animal stratum G in the baseline scenario [tCO_2e]
$E_{P,G,0}$	=	Average annual emissions from pasture management in animal stratum G in the baseline scenario [tCO_2e]
$E_{T,G,0}$	=	Average annual emissions from transport in animal stratum G in the baseline scenario [tCO_2e]
$N_{G,0}$	=	Number of animals in animal stratum G per year in baseline scenario (average over baseline years) [head]
$Days_{G,0}$	=	Average duration an animal spends in animal stratum G in the baseline scenario (average over baseline years) [day]
$AWI_{G,0}$	=	Average daily animal weight increase per head in animal stratum G in the baseline scenario [kg head^{-1} day^{-1}].

3.6.2 | **Emissions from enteric fermentation: Methane emissions from enteric fermentation for the baseline scenario** $\boldsymbol{E_{F,G,0}}$ are calculated using Equations 2 or 3 below.

a. ***Approach 1:***

The most specific approach to quantify emission reduction is measurement of methane emissions for a sample group of cattle 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 2:

$$E_{F,G,0} = N_{G,0} \times EF_{G,0} \times Days_{G,0} \times GWP_{CH4}/1000 \quad \text{Equation 2}$$

Where:

$E_{F,G,0}$	= Average annual emissions from enteric fermentation in animal stratum G in the baseline scenario [tCO_2e]
$N_{G,0}$	= Number of animals in animal stratum G per year in the baseline scenario (average over baseline years) [head]
$EF_{G,0}$	= Methane emission factors from enteric fermentation per animal in animal stratum G in the baseline scenario [kg CH_4 head^{-1} day^{-1}]
$Days_{G,0}$	= Average duration an animal spends in animal stratum G in the baseline scenario (average over baseline years) [day]
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 business-as-usual management). As required for the baseline scenario quantification, documentation of baseline emissions shall be performed for at least 3 years for both approaches.

3.6.3 | ***Approach 2:*** In the absence of direct emissions measurements, baseline emissions $E_{F,G,0}$ are calculated. Research (summarized in Van Lingen et al. 2019) has shown strong impact of diet, e.g. digestibility and fiber content, on these emissions. This methodology thus does not allow general application of tier 1 default emission factors in IPCC 2006/2019 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 Uncertainty.

3.6.4 | $E_{F,G,0}$ shall be calculated either directly applying published emission models (e.g. regression models) or following the approach in Equation 3 based on animal numbers, energy intake through feed, and project-related conversion factors for methane emissions.

$$E_{F,G,0} = \left(GE_{G,0} \times Ym_{G,0} \times N_{G,0} \times Days_{G,0} / EC_{CH4}\right) \times GWP_{CH4} / 1000$$

Equation 3

Where:

$E_{F,G,0}$ = Average annual emissions from enteric fermentation in animal stratum G in the baseline scenario [tCO2e]

$GE_{G,0}$ = 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 per year in the baseline scenario (average over baseline years) [head]

$Days_{G,0}$ = Average duration an animal spends in animal stratum G in the baseline scenario (average over baseline years) [day]

EC_{CH4} = Energy content of methane [MJ (kg methane)-1] = 55.65

GWP_{CH4} = Global warming potential of methane [tCO2e tCH4-1]

1000 = kg per metric tonne [kg t-1]

3.6.5 | **Gross energy intake $GE_{G,0}$** 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 diet ingredients (pasture feed, rations, supplements).

$$GE_{G,0} = \mathrm{DMI}_{G,0} \times \mathrm{EC}_{DM,G,0}$$

Equation 4

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}]

$EC_{DM,G,0}$= Average gross energy content of dry matter in feed for animal stratum G the baseline scenario. [MJ kg^{-1}]

3.6.6 | The **methane conversion factor $Ym_{G,0}$** is determined for each animal stratum. It shall be selected to best meet project conditions, especially diet and animal weight, and its applicability documented by the project developer. 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. Assessment of applicability for Ym values shall include all factors used for quantification of Ym in the publications. Ym shall also consider variation in feed for animal group G, using weighted average composition in the baseline period. 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, such as IPCC Tier 2 factors (IPCC 2019[3], Table 10.12), may only be used conservatively, taking into account the respective errors. Note that high uncertainty may lead to uncertainty deductions .Table 2 provides a matrix of conversion factors in dependence of DMI, forage content and animal weight, calculated with an intercontinental regression model by Van Lingen et al. 2019. When using Ym values from Table 02, a relative standard error of 0.85%[4] for Ym (SE_P=0.0085*Ym) shall be used in uncertainty calculations

Table 2: Methane conversion factors Ym for enteric fermentation, by forage content (For), dry matter intake (DMI) and animal body weight (BW) (calculated applying regression model no. 6 published in Van Lingen et al. 2019)

BW (kg)	DMI (kg)	For (%)																			
		5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100
200	5	0.028	0.031	0.035	0.038	0.042	0.045	0.048	0.052	0.055	0.058	0.062	0.065	0.069	0.072	0.075	0.079	0.082	0.085	0.089	0.092

[3] IPCC 2006/2019: Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories

[4] Calculated as SE(%)=RMSPE(%)/√(n)=26.9%/√(991), applying RMSPE and n for Van Lingen Eq. 6 (all data).

300	5	0.033	0.037	0.040	0.044	0.047	0.050	0.054	0.057	0.060	0.064	0.067	0.071	0.074	0.077	0.081	0.084	0.087	0.091	0.094	0.098
300	10	0.032	0.034	0.036	0.037	0.039	0.041	0.042	0.044	0.046	0.047	0.049	0.051	0.052	0.054	0.056	0.058	0.059	0.061	0.063	0.064
400	5	0.039	0.042	0.045	0.049	0.052	0.056	0.059	0.062	0.066	0.069	0.073	0.076	0.079	0.083	0.086	0.089	0.093	0.096	0.100	0.103
400	10	0.035	0.037	0.038	0.040	0.042	0.043	0.045	0.047	0.048	0.050	0.052	0.053	0.055	0.057	0.059	0.060	0.062	0.064	0.065	0.067
400	15	0.034	0.035	0.036	0.037	0.038	0.039	0.040	0.042	0.043	0.044	0.045	0.046	0.047	0.048	0.049	0.051	0.052	0.053	0.054	0.055
500	5	0.044	0.047	0.051	0.054	0.058	0.061	0.064	0.068	0.071	0.074	0.078	0.081	0.085	0.088	0.091	0.095	0.098	0.101	0.105	0.108
500	10	0.038	0.039	0.041	0.043	0.044	0.046	0.048	0.049	0.051	0.053	0.054	0.056	0.058	0.060	0.061	0.063	0.065	0.066	0.068	0.070
500	15	0.035	0.037	0.038	0.039	0.040	0.041	0.042	0.043	0.044	0.046	0.047	0.048	0.049	0.050	0.051	0.052	0.053	0.055	0.056	0.057
500	20	0.034	0.035	0.036	0.037	0.038	0.039	0.039	0.040	0.041	0.042	0.043	0.044	0.044	0.045	0.046	0.047	0.048	0.049	0.050	0.050
600	5	0.049	0.053	0.056	0.060	0.063	0.066	0.070	0.073	0.076	0.080	0.083	0.087	0.090	0.093	0.097	0.100	0.103	0.107	0.110	0.114
600	10	0.040	0.042	0.044	0.045	0.047	0.049	0.050	0.052	0.054	0.055	0.057	0.059	0.061	0.062	0.064	0.066	0.067	0.069	0.071	0.072
600	15	0.037	0.038	0.039	0.041	0.042	0.043	0.044	0.045	0.046	0.047	0.048	0.050	0.051	0.052	0.053	0.054	0.055	0.056	0.057	0.059
600	20	0.036	0.036	0.037	0.038	0.039	0.040	0.041	0.042	0.042	0.043	0.044	0.045	0.046	0.047	0.047	0.048	0.049	0.050	0.051	0.052
600	25	0.035	0.035	0.036	0.037	0.037	0.038	0.039	0.039	0.040	0.041	0.041	0.042	0.043	0.044	0.044	0.045	0.046	0.046	0.047	0.048
700	10	0.043	0.045	0.046	0.048	0.050	0.051	0.053	0.055	0.056	0.058	0.060	0.061	0.063	0.065	0.067	0.068	0.070	0.072	0.073	0.075
700	15	0.039	0.040	0.041	0.042	0.043	0.045	0.046	0.047	0.048	0.049	0.050	0.051	0.052	0.054	0.055	0.056	0.057	0.058	0.059	0.060
700	20	0.037	0.038	0.039	0.040	0.040	0.041	0.042	0.043	0.044	0.045	0.045	0.046	0.047	0.048	0.049	0.050	0.050	0.051	0.052	0.053
700	25	0.036	0.036	0.037	0.038	0.039	0.039	0.040	0.041	0.041	0.042	0.043	0.043	0.044	0.045	0.045	0.046	0.047	0.047	0.048	0.049
700	30	0.035	0.036	0.036	0.037	0.037	0.038	0.038	0.039	0.040	0.040	0.041	0.041	0.042	0.042	0.043	0.043	0.044	0.045	0.045	0.046
800	10	0.046	0.047	0.049	0.051	0.052	0.054	0.056	0.057	0.059	0.061	0.062	0.064	0.066	0.068	0.069	0.071	0.073	0.074	0.076	0.078
800	15	0.041	0.042	0.043	0.044	0.045	0.046	0.047	0.049	0.050	0.051	0.052	0.053	0.054	0.055	0.057	0.058	0.059	0.060	0.061	0.062
800	20	0.038	0.039	0.040	0.041	0.042	0.043	0.043	0.044	0.045	0.046	0.047	0.048	0.048	0.049	0.050	0.051	0.052	0.053	0.054	0.054
800	25	0.037	0.038	0.038	0.039	0.040	0.040	0.041	0.042	0.042	0.043	0.044	0.044	0.045	0.046	0.046	0.047	0.048	0.048	0.049	0.050
800	30	0.036	0.036	0.037	0.038	0.038	0.039	0.039	0.040	0.040	0.041	0.042	0.042	0.043	0.043	0.044	0.044	0.045	0.045	0.046	0.047
800	35	0.035	0.036	0.036	0.037	0.037	0.038	0.038	0.039	0.039	0.040	0.040	0.041	0.041	0.041	0.042	0.042	0.043	0.043	0.044	0.044
900	10	0.048	0.050	0.052	0.053	0.055	0.057	0.058	0.060	0.062	0.063	0.065	0.067	0.069	0.070	0.072	0.074	0.075	0.077	0.079	0.080
900	15	0.043	0.044	0.045	0.046	0.047	0.048	0.049	0.050	0.052	0.053	0.054	0.055	0.056	0.057	0.058	0.059	0.061	0.062	0.063	0.064
900	20	0.040	0.041	0.041	0.042	0.043	0.044	0.045	0.046	0.046	0.047	0.048	0.049	0.050	0.051	0.051	0.052	0.053	0.054	0.055	0.056
900	25	0.038	0.039	0.039	0.040	0.041	0.041	0.042	0.043	0.043	0.044	0.045	0.045	0.046	0.047	0.047	0.048	0.049	0.049	0.050	0.051
900	30	0.037	0.037	0.038	0.038	0.039	0.040	0.040	0.041	0.041	0.042	0.042	0.043	0.044	0.044	0.045	0.045	0.046	0.046	0.047	0.047
900	35	0.036	0.036	0.037	0.037	0.038	0.038	0.039	0.039	0.040	0.040	0.041	0.041	0.042	0.042	0.043	0.043	0.044	0.044	0.045	0.045
900	40	0.035	0.036	0.036	0.037	0.037	0.037	0.038	0.038	0.039	0.039	0.040	0.040	0.040	0.041	0.041	0.042	0.042	0.043	0.043	0.043
1000	15	0.044	0.045	0.047	0.048	0.049	0.050	0.051	0.052	0.053	0.054	0.056	0.057	0.058	0.059	0.060	0.061	0.062	0.063	0.065	0.066
1000	20	0.041	0.042	0.043	0.044	0.044	0.045	0.046	0.047	0.048	0.049	0.049	0.050	0.051	0.052	0.053	0.054	0.055	0.055	0.056	0.057
1000	25	0.039	0.040	0.040	0.041	0.042	0.042	0.043	0.044	0.044	0.045	0.046	0.046	0.047	0.048	0.048	0.049	0.050	0.050	0.051	0.052
1000	30	0.038	0.038	0.039	0.039	0.040	0.040	0.041	0.042	0.042	0.043	0.043	0.044	0.044	0.045	0.046	0.046	0.047	0.047	0.048	0.048
1000	35	0.037	0.037	0.038	0.038	0.039	0.039	0.040	0.040	0.041	0.041	0.042	0.042	0.043	0.043	0.043	0.044	0.044	0.045	0.045	0.046
1000	40	0.036	0.036	0.037	0.037	0.038	0.038	0.039	0.039	0.039	0.040	0.040	0.041	0.041	0.042	0.042	0.042	0.043	0.043	0.044	0.044
1000	45	0.035	0.036	0.036	0.037	0.037	0.037	0.038	0.038	0.038	0.039	0.039	0.040	0.040	0.040	0.041	0.041	0.041	0.042	0.042	0.043

Y_m table calculated using the following equation based on regression model no. 6 by Van Lingen et al. 2019:
Y_m = [-28.3+10.3* DMI + 1.12*For+ 0.0885*BW] * 0.05565 / (DMI * 18.45)
Where: Y_m = methane conversion rate [dimensionless]
DMI= dry matter intake [kg cow^{-1} day^{-1}]
For= fraction of forage feed dry matter in DMI [%]
BW= average animal body weight [kg]
0.05565= energy in methane [MJ gram^{-1}]
18.45= average gross energy (GE) in DMI [MJ kg^{-1}]
Van Lingen et al. 2019 lists a RMSPE (root mean square prediction error in % of emissions) of 26.9% (all data, n=991) for Eq. 6.

3.6.7 | **Emissions from feed production:** Emissions from feed production for the baseline scenario $E_{FP,G,0}$ are calculated based on amount of feed (per feed type) and emissions for production and transport, using Equation 5:

$$E_{FP,G,0} = \sum_{t} \left[\left(F_{t,G,0} \times N_{G,0} \times Days_{G,0} \right) \times \left(EF_{FP,t,0} + EF_{FT,t,G,0} \times Dist_{FT,t,G,0} \right) \right]$$

Equation 5

Where:

EFP,G,0= Average annual emissions from feed production for animal stratum G in the baseline scenario [tCO2e]

Ft,G,0= Average annual amount of feed type t, fed per head in animal stratum G in the baseline scenario [kg head-1 day-1]

NG,0= Number of animals in animal stratum G per year in the baseline scenario (average over baseline years) [head]

DaysG,0= Average duration an animal spends in animal stratum G in the baseline scenario (average over baseline years) [day]

EFFP,t,0= Emission factor for production of feed type t in the baseline scenario [tCO2e kg-1]

EFFT,t,G,0= Emission factor for transport of feed type t for animal stratum G in the baseline scenario [tCO2e km-1 kg-1]

DistFT,t,G,0= Average transport distance for feed type t in animal stratum G in the baseline scenario [km]

3.6.8 | **Amount of feed per feed type $F_{t,G,0}$** per animal stratum G shall be monitored and documented for the baseline activity. Should no detailed information be available on feed type, conservative and documented expert opinion may be used to estimate average amounts for the baseline. For grazing cattle, $F_{t,G,0}$ shall only include feedstuffs and supplements provided in addition to pasture feed ("Emissions from pastures" are covered in separate subsection below).

3.6.9 | **Emission factors for feed production per feed type $EF_{FP,t,0}$** shall be documented for the baseline activity. If no specific emission factors are available for a feed type, default emission factors may be applied (e.g. based on LCA (life cycle assessment) calculator from FAO LEAP global database of GHG emissions related to feed crops[5]).

3.6.10 | **Emission factors for feed transport per feed type $EF_{FT,t,G,0}$** shall be documented for the baseline activity (if not already covered in LCA calculation for $EF_{FP,t,G,0}$). National values specific to the transport means (vehicle type, capacity, etc.) shall be applied. If no national emission factors are available, default emission factors can be applied conservatively (e.g. using tools or emission factors published by the Greenhouse Gas Protocol[6]).

3.6.11 | **Feed transport distance from production to farm ($Dist_{FT,t,G,0}$)** shall be documented based on farm locations for each animal stratum using verifiable distance calculation, e.g GIS/map distances. If animals in the stratum are

[5] Calculator: http://www.fao.org/partnerships/leap/database/ghg-crops/en/, *Note: Standard deviations of results are provided if "Export Data as CSV" function is used to download the data.*
Methodology documentation: http://www.fao.org/3/a-i8275e.pdf (links accessed March 2021)

[6] "Emission Factors from Cross-Sector Tools" (EF list) or "GHG Emissions from Transport or Mobile Sources" (calculation tool, results provided correspond to $EF_{FT,t}$*$Dist_{FT,t}$) published at https://ghgprotocol.org/calculation-tools#cross_sector_tools_id (link accessed March 2021)

located in different farms, average distance weighted by number of animals in the stratum per farm shall be used for calculation. If emission factor for feed production ($EF_{FP,t,0}$) already includes transportation (e.g. to distribution centers), the remaining transport distance to the farms shall be calculated for $Dist_{FT,t,G,0}$. If different transport types (air, sea, ground) are used, respective distances shall be calculated separately and respective emission factors ($EF_{FT,t,0}$) applied.

3.6.12 | As per the applicability conditions of this methodology, no benefits from emission reductions for feed production and transport shall be accounted under this methodology. If such effects are expected, a respective dedicated Gold Standard methodology shall be applied.

3.6.13 | **Emissions from manure management :** Emissions from manure management include manure storage, field application and emissions from on-field excretions for grazing cattle. As supplements reducing methane emissions from enteric fermentation can impact manure composition, project developers are required to assess changes in emissions from manure.

3.6.14 | If on-site direct measurements or scientific evidence from peer-reviewed scientific sources can be presented at project validation that the supplements applied in the project do not impact manure composition and CH_4 and N_2O emissions from manure under project conditions, calculation of these emission sources may be omitted upon review by the VVB.

3.6.15 | If no such evidence is available, emissions from manure for the baseline scenario $E_{M,0}$ shall be calculated using Equation 6:

$$E_{M,0} = E_{MCH4,0} + E_{MN2O,0}$$

Equation 6

$E_{M,0}$ = 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]

3.6.16 | **Methane emissions from manure management *$E_{MCH4,0}$*** shall be calculated applying Equation 7. Emissions are quantified based on the quantity of volatile solids excreted by the animal stratum and the storage technique or direct pasture deposition for the manure.

$$E_{MCH4,0} = \sum_{S,G} VS_{G,0} \times N_{G,0} \times Days_{G,0} \times B_o \times CF_{CH4} \times MCF_S \times MS_{S,G,0} \times GWP_{CH4}/1000$$

Equation 7

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 per year in baseline scenario (average across baseline years) [head]

$Days_{G,0}$ = Average duration an animal spends in animal stratum G in the baseline scenario (average over baseline years) [day]

B_o = Maximum methane producing capacity from cattle manure [m3 kg^{-1} of VS] = 0.19 For North America, 0.18 for Western Europe, 0.17 for Eastern Europa an Oceania, 0.18 for other high-productivity systems or 0.13 for other low-productivity systems (IPCC 2019)[7]

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}]

3.6.17 | **Daily volatile solids $VS_{G,0}$** excreted per animal in animal stratum G under baseline conditions are calculated using Equation 8 below. Alternatively, VS_G may be calculated through the application of improved 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.

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

Equation 8

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]

[7] Uncertainty values of ±15% according to IPCC 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Table 10.16 shall be applied to calculate standard error for B_0 ($SE_P=B_0*0.15$) for uncertainty assessment according to section 9.

UE = Urinary energy expressed as fraction of $GE_{G,0}$ [dimensionless]
= 0.04 for cattle with less than 85% grain in diet, and 0.02 for cattle with more than 85% grain (IPCC 2019)

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

$EC_{DM,G,0}$ = Average gross energy content of dry matter in feed for animal stratum G in the baseline scenario [MJ kg^{-1}]

3.6.18 | **Digestible energy in feed *DE_0*** shall be documented for each feed type applied in baseline scenario.[8]

3.6.19 | **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.

Table 3 : Methane conversion factors MCF_S for manure management systems by average annual temperature (Source: 2019 Refinement to IPCC 2006 Guidelines for National Greenhouse Gas Inventories, Volume 4, Chapter 10, Table 10.17)

Manure management system*		CH4 conversion factors (MCF) for manure management systems by average annual temperature									
		Cool				**Temperate**		**Warm**			
		Cool Temperate Moist	Cool Temperate Dry	Boreal Moist	Boreal Dry	Warm Temperate Moist	Warm Temperate Dry	Tropical Montane	Tropical Wet	Tropical Moist	Tropical Dry
Uncovered anaerobic lagoon		0.60	0.67	0.50	0.49	0.73	0.76	0.76	0.80	0.80	0.80
Liquid / Slurry, and Pit storage below animal confinement	1 Month	0.06	0.08	0.04	0.04	0.13	0.15	0.25	0.38	0.36	0.42
	3 Months	0.12	0.16	0.08	0.08	0.24	0.28	0.43	0.61	0.57	0.62
	4 Months	0.15	0.19	0.09	0.09	0.29	0.32	0.50	0.67	0.64	0.68
	6 Months	0.21	0.26	0.14	0.14	0.37	0.41	0.59	0.76	0.73	0.74
	12 Months	0.31	0.42	0.21	0.20	0.55	0.64	0.73	0.80	0.80	0.80
Cattle and Swine deep bedding (cont.) > 1 month		0.21	0.26	0.14	0.14	0.37	0.41	0.59	0.76	0.73	0.74
Cattle and Swine deep bedding < 1 month		0.0275				0.065		0.18			

[8] 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.

Manure management system*	CH_4 conversion factors (MCF) for manure management systems by average annual temperature									
	Cool				**Temperate**		**Warm**			
	Cool Temperate Moist	Cool Temperate Dry	Boreal Moist	Boreal Dry	Warm Temperate Moist	Warm Temperate Dry	Tropical Montane	Tropical Wet	Tropical Moist	Tropical Dry
Solid storage	0.02				0.04		0.05			
Solid storage - Covered/compacted	0.02				0.04		0.05			
Solid storage - Bulking agent addition	0.005				0.01		0.015			
Solid storage - Additives	0.01				0.02		0.025			
Dry lot	0.01				0.015		0.02			
Daily spread	0.001				0.005		0.01			
Composting - In-vessel	0.005									
Composting - Static pile (forced aeriation)	0.01				0.02		0.025			
Composting – Intensive windrow	0.005				0.01		0.015			
Composting – Passive window (unfrequent turning)	0.01				0.02		0.025			
Pasture / Range / Paddock	0.0047									
Aerobic treatment	0.00									
Burned for fuel	0.10									
Anaerobic digester – Low leakage, High quality gastight storage, Best complete industrial technology	0.01									
Anaerobic digester – Low leakage, High quality industrial technology, Low quality gastight storage	0.0141									
Anaerobic digester – Low leakage, High quality industrial technology, Open storage	0.0355				0.0438		0.0459			
Anaerobic digester – High leakage, Low quality technology, High quality gastight storage technology	0.0959									

Manure management system*	CH4 conversion factors (MCF) for manure management systems by average annual temperature									
	Cool				Temperate		Warm			
	Cool Temperate Moist	Cool Temperate Dry	Boreal Moist	Boreal Dry	Warm Temperate Moist	Warm Temperate Dry	Tropical Montane	Tropical Wet	Tropical Moist	Tropical Dry
Anaerobic digester – High leakage, Low quality technology, Low quality gastight storage technology	0.1085									
Anaerobic digester – High leakage, Low quality technology, Open storage	0.1214				0.1297		0.1317			
* For definitions, see IPCC 2019 Table 10.17							Data source: IPCC 2019 Table 10.17			

3.6.20 | **Methane conversion factors MCF_S** shall be determined for each manure management system S applied in the baseline activity. For cattle which are held on pasture, paddocks or open feedlots without dung collection and storage, respective methane conversion factor MCF_S for direct field deposition shall be used. 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 manure management practices, including type and duration of storage, under matching environmental conditions from another country, peer-reviewed or verified by independent expert) can be applied if applicability is documented. If no localized emission factors are available, emission factors shown in Table 3 shall be applied. As the factors in the table are based on IPCC defaults, an uncertainty value of ±20% shall be assumed for these parameters[9].

3.6.21 | **Nitrous oxide emissions from manure management $E_{MN2O,0}$** shall be calculated applying Equation 8 or, if project- or supplement-specific information and/or data is available, through the application of improved models or emission factors published in peer-reviewed scientific journals with proven applicability under project conditions. The same calculation approach must be applied for baseline and project scenario.

3.6.22 | 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 added for any manure brought out on managed lands.

3.6.23 | The assessment of the protein content of the diet and the intake of feed is provided by the farmer/nutritionist for the feedstuffs and rations for the cattle,

[9] 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.

and this professional will attest to the accuracy of the monitoring procedures used (see also section on Monitoring).

$$E_{MN2O,0} = \sum_{G} (FeedN_{G,0} - LWgainN_{G,0}) \times N_{G,0} \times Days_{G,0} \times E_{N2O,G,0} \times GWP_{N2O}/1000$$

Equation 9

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}] à see equation 10

$LWgainN_{G,0}$ = N retained in live weight gain per animal in animal stratum G in the baseline scenario [kg N head^{-1} day^{-1}] à see equation 11

$N_{G,0}$ = Number of animals in animal stratum G per year in the baseline scenario (average over baseline years) [head]

$Days_{G,0}$ = Average duration an animal spends in animal stratum G in the baseline scenario (average over baseline years) [day]

$E_{N2O,G,0}$ = N_2O emitted per kg of N excreted per animal in animal stratum G in the baseline scenario [kg N_2O (kg excreted N)$^{-1}$] à see equation 12

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

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

$$FeedN_{G,0} = DMI_{G,0} \times CP_{G,0} \times fN_{FP}$$

Equation 10

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

$$LWgainN_{G,0} = AWI_{G,0} \times fN_{WG}$$

Equation 11

Where:

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

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

$$E_{N2O,G,0} = \sum_{S,P} MS_{S,G,0} \times (E_{N2O,S} + E_{N2O,P})$$

Equation 12

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 and stored in a specific manure management system [kg N_2O (kg excreted N)$^{-1}$]

$E_{N2O,P}$ = N_2O emitted per kg of N in manure or excretions deposited on managed lands [kg N_2O (kg deposited N)$^{-1}$]

3.6.24 | **The fraction of nitrous oxide emitted per kg of N excreted from storage $E_{N2O,S}$ and from field deposition $E_{N2O,P}$** 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 manure management practices, including type and duration of storage, under matching environmental conditions from another country) can be applied if applicability is documented. If no localized emission factors are available, the emission factors shown in columns "Total" in Table 4(storage) and Table 5 (field deposition) shall be applied. As the factors in the table are based on IPCC defaults with high uncertainty[10], an uncertainty value of ±50% shall be assumed for these parameters. Generally, factors from the latest IPCC Guidelines shall be applied.

Table 4: Nitrous oxide emissions $E_{N20,S}$ from manure management system S (calculated based on: 2019 Refinement to the 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** (kg N_2O per kg N excreted)		
	Direct[1)]	**Indirect[2)]**	**Total**
Pasture / Range / Paddock	0 (accounted as $E_{N2O,P}$, see Table 7-04)		
Daily spread	0	0.0011	0.0011
Solid storage	0.0157	0.0074	0.0231
Solid storage - Covered/compacted	0.0157	0.0035	0.0192
Solid storage - Bulking agent addition	0.0079	0.0094	0.0173
Solid storage - Additives	0.0079	0.003	0.0109
Dry lot	0.0314	0.0053	0.0367
Liquid / Slurry with natural crust cover	0.0079	0.0047	0.0126
Liquid / Slurry without natural crust cover	0	0.0075	0.0075
Liquid / Slurry with cover	0.0079	0.0016	0.0095
Uncovered anaerobic lagoon	0	0.0055	0.0055
Pit storage below animal confinement	0.0031	0.0039	0.007
Anaerobic digester	0.0009	0.0047	0.0056
Cattle and Swine deep bedding - No mixing	0.0157	0.0045	0.0202
Cattle and Swine deep bedding - Active mixing	0.11	0.0045	0.1145

[10] 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.

Manure management system S	N_2O emissions from manure management system (kg N_2O per kg N excreted)		
	Direct[1)]	Indirect[2)]	Total
Composting - In-vessel	0.0094	0.0094	0.0188
Composting - Static pile (Forced aeration)	0.0157	0.0112	0.0269
Composting – Intensive windrow	0.0079	0.0112	0.0191
Composting – Passive windrow (infrequent turning)	0.0079	0.0101	0.018
Aerobic treatment – natural aeration systems	0.0157	no data[3)]	no data[3)]
Aerobic treatment – forced aeration systems	0.0079	0.0134	0.0213
	[1)] calculated from IPCC 2019 Table 10.21 [2)] calculated from IPCC 2019 Table 10.22 [3)] no data available in IPCC 2019 (use project-specific data or other source)		

Table 5 Nitrous oxide emissions $E_{N20,P}$ from manure deposition on managed lands (calculated based on: 2019 Refinement to the IPCC 2006 Guidelines for National Greenhouse Gas Inventories, Vol. 4, Chapter 11, Tables 11.1 and 11.3)

Manure field deposition type		N_2O emissions from manure management system (kg N_2O per kg N excreted or deposited)		
		Direct[3)]	Indirect[4)]	Total
On-field excretions (grazing cattle)	Wet climates[1)]	0.009	0.009	0.018
	Dry climates[2)]	0.003	0.002	0.005
Manure spreading on managed lands (grassland or cropland)	Wet climates	0.009	0.009	0.018
	Dry climates	0.008	0.002	0.010
No spreading		0	0	0
[1)] Temperate and boreal zones: ratio of annual precipitation/potential evapotranspiration > 1. Tropical zones: annual precipitation > 1000 mm. [2)] Temperate and boreal zones: ratio of annual precipitation/potential evapotranspiration < 1. Tropical zones: annual precipitation < 1000 mm		[3)] calculated from IPCC 2019 Table 11.1 [4)] calculated from IPCC 2019 Table 11.3		

3.6.25 | **Non-manure emissions from pastures:** Emissions from pasture areas used for grazing cattle, including natural grasslands, perennial and annual pastures, as well as pastures in rotation with crops, in the baseline scenario $E_{P,G,0}$ are calculated using Equation 13below. If no change in pasture management leading to an *increase* of GHG emissions is caused by the project activity (i.e. no increase in pasture area for the project herd, no increase in stocking rate, no decrease in biomass stocks, no increase in pasture inputs (fertilizer), no increase in tillage and other soil disturbance or erosion, and no increase in machine use on pasture), this emission source may be omitted from GHG calculations, subject to provision of evidence for practices and inputs in baseline scenario and for each project reporting period.

3.6.26 | Pasture management practices shall be documented for each geo-referenced pasture area ($A_{G,0}$), i.e. tillage, organic inputs, machine use and irrigation, as applicable.

3.6.27 | Documentation of pasture areas shall also include patches of above-ground biomass as identified at project start by visual inspection of high-resolution imagery and documented in a geo-referenced map (as ESRI shapefile or kml/kmz) which shall be submitted together with project documentation. This shall constitute the baseline against which it can be monitored and verified how much woody-biomass is removed, the temporal nature of the removal, and the adequacy of the regeneration measures.

$$E_{P,G,0} = A_{G,0} \times EF_{P,0}$$

Equation 13

Where:

$E_{P,G,0}$ = Average annual emissions from pasture for animal stratum G in the baseline scenario [tCO_2e]

$A_{G,0}$ = Average annual pasture area for animal stratum G in the baseline scenario [ha]

$EF_{P,0}$ = Emission factor for pasture management in the baseline scenario [$tCO_2e\ ha^{-1}$]

3.6.28 | **The emission factor per hectare of pasture in the baseline scenario $EF_{P,G,0}$** shall be determined as an average across all pastures impacted by the project activity. The emission factor must include emissions from change in carbon pools (woody and non-woody plant biomass, soil organic carbon), emissions of CH_4 and N_2O from fertilizer (not including on-farm manure and on-field excretions, as such emissions are covered in section "Emissions manure management" above), as well as emissions from use of machinery. If available, national emission factors should be applied for each of these emission sources. If no national data is available, IPCC Tier 1 or Tier 2 calculations and emission factors[11] may be applied conservatively to estimate $EF_{P,G,0}$, taking into account the respective uncertainties.

3.6.29 | As per the applicability conditions of this methodology, no benefits from increase in carbon pools (GHG sequestration in biomass or soil organic carbon) shall be accounted under this methodology. If such effects are expected, a respective dedicated Gold Standard methodology shall be applied.

3.6.30 | **Emissions from animal transport :** Emissions from animal transport in the baseline scenario $E_{T,G,0}$ are calculated using Equation 14:

[11] IPCC 2006/2019: Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories

$$E_{T,G,0} = N_{T,G,y} \times EF_{T,G,0} \times Dist_{T,G,0} \quad \text{Equation 14}$$

Where:

$E_{T,G,0}$ = Average annual emissions from animal transport in the baseline scenario [tCO_2e]

$N_{T,G,0}$ = Average annual number of transported cattle in animal stratum G in the baseline scenario [head]

$EF_{T,G,0}$ = Emission factor for cattle transport in animal stratum G in the baseline scenario [tCO_2e $head^{-1}$ km^{-1}]

$Dist_{T,G,0}$ = Average transport distance for animal stratum G in the baseline scenario [km]

3.6.31 | **Emission factors for cattle transport per head $EF_{T,G,0}$** shall be documented for each transported animal group for the baseline activity. Emission factor per head of cattle can be estimated from average animal weight at time of transport and common tonne-km (or converted ton-mile) emission factors. National values specific to the transport means (vehicle type, capacity, etc.) shall be applied. If no national emission factors are available, default emission factors can be applied conservatively (e.g. using tools or emission factors published by the Greenhouse Gas Protocol[12]). As per the applicability conditions of this methodology, no benefits from emission reductions for animal transport shall be accounted under this methodology. If such effects are expected, a respective dedicated Gold Standard methodology shall be applied.

3.7 | Project emissions

For the project scenario, **annual emissions** are calculated for each year in the monitoring period as the sum of emissions from enteric fermentation, feed and supplement production, manure storage, pasture management and transport according to Equation 15:

$$E_y = \sum_G \left[\left(E_{F,G,y} + E_{FP,G,y} + E_{SP,G,y} + E_{M,G,y} + E_{P,G,y} + E_{T,G,y} \right) / \left(N_{G,y} \times Days_{G,y} \times AWI_{G,y} \right) \right] \quad \text{Equation 15}$$

Where:

E_y = Emissions per kg of animal weight increase in year y of the monitoring period [tCO_2e $(kg\ AWI)^{-1}$]

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

$E_{FP,G,0}$ = Emissions from feed production for animal stratum G in year y of the monitoring period [tCO_2e]

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

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

[12] "Emission Factors from Cross-Sector Tools" (EF list) or "GHG Emissions from Transport or Mobile Sources" (calculation tool) published at https://ghgprotocol.org/calculation-tools#cross_sector_tools_id (link accessed Nov 2020)

$E_{P,G,y}$ = Emissions from pasture management in animal stratum G in year y of the monitoring period [tCO_2e]

$E_{T,G,y}$ = Emissions from transport in animal stratum G 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 [head]

$Days_{G,y}$ = Average duration an animal spends in animal stratum G in year y of the monitoring period (annual average) [day]

$AWI_{G,y}$ = Average daily weight increase per head in animal stratum G in year y of the monitoring period (kg $head^{-1}$ day^{-1}).

3.7.1 | **Emissions from enteric fermentation :** Methane emissions from enteric fermentation for the project scenario $E_{F,G,y}$ are calculated using Equations 16or 17 below.

3.7.2 | ***Approach 1:***The most specific approach to quantify emission reduction is measurement of methane emissions for a sample group of cattle 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:

3.7.3 | The measurement technology is scientifically tested, and results are documented in peer-reviewed publications. 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. A respective uncertainty deduction shall be applied in the calculation of emission reductions .If all of these conditions are met, annual emissions for the project scenario shall be estimated according to Equation 16:

$$E_{F,G,y} = N_{G,y} \times EF_{G,y} \times Days_{G,y} \times GWP_{CH4}/1000 \quad \text{Equation 16}$$

Where:

$E_{F,G,y}$ = Annual emissions from enteric fermentation in animal stratum G 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 [head]

$EF_{G,y}$ = 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}]

$Days_{G,y}$ = Average duration an animal spends in animal stratum G in year y of the monitoring period (annual average) [day]

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

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

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

3.7.5 | ***Approach 2:*** In the absence of emissions measurements, project emissions $E_{F,G,y}$ for each year in the monitoring period shall be calculated. Recent research (summarized in Van Lingen et al. 2019) has shown strong impact of diet, e.g. fiber content, on these emissions. This methodology thus does not allow general application of tier 1 default emission factors in IPCC 2006/2019 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 Uncertainty.

3.7.6 | If the days on supplement for an individual cattle participating in the project () exceed the duration of supplement application in the scientific source for $E_{F,G,y}$, verification samples shall be measured in the period beyond the scientific basis. Measurements shall meet requirements for Approach 1 (above). Size of a representative sample for each animal group shall be sufficient to statistically assess suitability of calculated emissions $E_{F,G,y}$ in equation 16, respectively identify potential bias. In case of deviation, the project shall apply the more conservative value for impact quantification over the entire monitoring period, assessed for the calculated supplement impact, i.e. $E_{F,G,y}$ - $E_{F,G,0}$. (Bias in emission levels can be accepted if (absolute) emissions change is in line with the calculated results.)

3.7.7 | $E_{F,G,y}$ 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 17 based on animal numbers, energy intake through feed, and project-related conversion factors for methane emissions.

$$E_{F,G,y} = \left(GE_{G,y} \times Ym_{G,y} \times RYm_{G,y} \times N_{G,y} \times Days_{G,y}\right)/EC_{CH4} \times GWP_{CH4}/1000$$

Equation 17

Where:

$E_{F,G,y}$	= Emissions from enteric fermentation in animal stratum G 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 [head]
$Days_{G,y}$	=Average duration an animal spends in animal stratum G in year y of the monitoring period (annual average) [day]
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}]

3.7.8 | **Gross energy intake $GE_{G,y}$** is calculated from measurements of dry matter intake DMI on a daily basis using Equation 18. The DMI value shall be determined as the sum of all diet ingredients (pasture feed, rations, supplements).

$$GE_{G,y} = \mathrm{DMI}_{G,y} \times EC_{DM,G,y}$$

Equation 18

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}]
$EC_{DM,G,y}$	= Average energy content of dry matter in feed for animal stratum G in year y [MJ kg^{-1}]

3.7.9 | The **methane conversion factor $Ym_{G,y}$** is determined for each animal stratum G. It shall be selected to best meet project conditions, especially diet and animal weight, and its applicability documented by the project developer. 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. Assessment of applicability for Ym values shall include all factors used for quantification in the publications. Ym shall also consider variation in feed for animal group G, using weighted average composition in year y. 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, such as IPCC Tier 2 factors (IPCC 2019, Table 20.12), may only be used conservatively, taking into account the respective errors. Note that high uncertainty may lead to uncertainty deductions according to section 9 of this methodology. Table 2 provides a matrix of conversion factors in dependence of DMI, forage content and animal weight, calculated with an intercontinental regression model by Van Lingen et al. 2019. When using Ym values from Table 7-01, a relative standard error of 0.85%[13] for Ym (SE_P=0.0085*Ym) shall be used in for uncertainty calculations

3.7.10 |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 diet and product application, animal type, age and weight,

[13] Calculated as SE(%)=RMSPE(%)/√(n)=26.9%/√(991), applying RMSPE and n for Van Lingen Eq. 6 (all data).

environmental and management conditions as well as any other factors that could impact the supplements performance with regard to emission reductions. This specifically includes potential interactions with other feed supplements, e.g. growth promoting "probiotics" or additives to increase feed efficiency.

3.7.11 | **Emissions from feed production** Emissions from feed production for the project scenario $E_{FP,G,y}$ are calculated based on amount of feed (per feed type) and emissions for production and transport, using Equation 19:

$$E_{FP,G,y} = \sum_t \left[\left(F_{t,G,y} \times N_{G,y} \times Days_{G,y} \right) \times \left(EF_{FP,t,y} + EF_{FT,t,G,y} \times Dist_{FT,t,G,y} \right) \right] \quad \text{Equation 19}$$

Where:

$E_{FP,G,y}$ = Emissions from feed production for animal stratum G in year y of the monitoring period [tCO_2e]

$F_{t,G,y}$ = Amount of feed type t, fed per head in animal stratum G in year y of the monitoring period [kg $head^{-1}$ day^{-1}]

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

$Days_{G,y}$ = Average duration an animal spends in animal stratum G in year y of the monitoring period (annual average) [day]

$EF_{FP,t,y}$ = Emission factor for production of feed type t in year y of the monitoring period [tCO_2e kg^{-1}]

$EF_{FP,t,G,y}$ = Emission factor for transport of feed type t for animal stratum G in year y of the monitoring period [tCO_2e kg^{-1} km^{-1}]

$Dist_{FT,t,G,y}$ = Average transport distance for feed type t in animal stratum G in year y of the monitoring period [km]

3.7.12 | **Amount of feed per feed type $F_{t,G,y}$** per animal stratum G shall be monitored and documented for the project activity. For grazing cattle, $F_{t,G,y}$ shall only include feedstuffs and supplements provided in addition to pasture feed ("Emissions from pastures" are covered in separate subsection below).

3.7.13 | **Emission factors for feed production per feed type $EF_{FP,t,y}$** shall be documented for the project activity. If no specific emission factors are available for a feed type, default emission factors may be applied (e.g. based on LCA calculator from FAO LEAP global database of GHG emissions related to feed crops[14]).

3.7.14 | **Emission factors for feed transport per feed type $EF_{FT,t,G,y}$** shall be documented for the project activity (if not already covered in LCA calculation for $EF_{FP,t,y}$). National values specific to the transport means (vehicle type, capacity, etc.) shall be applied. If no national emission factors are available,

[14] Calculator: http://www.fao.org/partnerships/leap/database/ghg-crops/en/, *Note: Standard deviations of results are provided if "Export Data as CSV" function is used to download the data.*
Methodology documentation: http://www.fao.org/3/a-i8275e.pdf (links accessed March 2021)

default emission factors can be applied conservatively (e.g. using tools or emission factors published by the Greenhouse Gas Protocol[15]).

3.7.15 | **Feed transport distance from production to farm ($Dist_{FT,t,G,y}$)** shall be documented based on farm locations for each animal stratum using verifiable distance calculation, e.g GIS/map distances. If animals in the stratum are located in different farms, average distance weighted by number of animals in the stratum per farm shall be used for calculation. If emission factor for feed production ($EF_{FP,t,y}$) already includes transportation (e.g. to distribution centers), the remaining transport distance to the farms shall be calculated for $Dist_{FT,t,G,0}$. If different transport types (air, sea, ground) are used, respective distances shall be calculated separately and respective emission factors ($EF_{FT,t,y}$) applied.

3.7.16 | As per the applicability conditions of this methodology, no benefits from emission reductions for feed production and transport shall be accounted under this methodology. If such effects are expected, a respective dedicated Gold Standard methodology shall be applied.

3.7.17 | **Emissions from feed supplement production, transport and storage** : Emissions from production, transport, and storage 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 of supplement applied and the respective emission factors (Equation 20).

$$E_{SP,y} = \sum_G \left[\left(S_{G,y} \times N_{G,y} \times Days_{G,y} \right) \times \left(EF_{SP,y} + EF_{ST,G,y} \times Dist_{ST,G,y} + EF_{SS,G,y} \right) \right]$$

Equation 20

Where:

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

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

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

$Days_{G,y}$ = Average duration an animal spends in animal stratum G in year y of the monitoring period (annual average) [day]

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

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

$Dist_{ST,G,y}$ = Average transport distance for supplement in animal stratum G in year y of the monitoring period [km]

[15] "Emission Factors from Cross-Sector Tools" (EF list) or "GHG Emissions from Transport or Mobile Sources" (calculation tool, results provided correspond to $EF_{FT,t}$*$Dist_{FT,t}$) published at https://ghgprotocol.org/calculation-tools#cross_sector_tools_id (link accessed March 2021)

$EF_{SS,G,y}$ = Emission factor for supplement storage for animal stratum G in year y of the monitoring period [$tCO_2e\ kg^{-1}$]

3.7.18 | **Emission factor for supplement production 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.

3.7.19 | **Emission factor for supplement transport 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[16].

3.7.20 | **Feed supplement transport distance from production to farm ($Dist_{ST,G,y}$)** shall be documented based on farm locations for each animal stratum using verifiable distance calculation, e.g GIS/map distances. If animals in the stratum are located in different farms, average distance weighted by number of animals in the stratum per farm shall be used for calculation. If emission factor for supplement production ($EF_{SP,y}$) already includes transportation (e.g. to distribution centers), the remaining transport distance to the farms shall be calculated for $Dist_{ST,G,y}$. If different transport types (air, sea, ground) are used, respective distances shall be calculated separately and respective emission factors ($EF_{ST,G,y}$) applied.

3.7.21 | **Emission factor for supplement storage EF_{SS}** shall be calculated taking into account means of storage for supplements, including all emission sources changing due to the introduction of the supplement under this methodology. This includes, but is not limited to, the use of electricity for refrigeration of cooling or heating of storage space dedicated to the feed supplement applied for GHG reduction. Calculation shall be done based on storage volume allocated to the supplement and the energy used for this volume. If larger (pre-existing) storage facilities are used, the proportional use of energy for the storage volume needed for the supplement shall be calculated. Energy use shall be measured at the storage facility or calculated based on power consumption by the cooling and/or heating aggregates and their running time (considering seasonal differences). Emissions per unit of energy shall be calculated by applying national or subnational emission factors for electricity (grid emission factors for the project area) or fuel (e.g. stationary combustion emission factors for generators) as used. Annual average emissions per kg of supplement shall be calculated and applied in Equation 20

3.7.22 | **Emissions from manure management** Emissions from manure management include manure storage, field application and emissions from on-field excretions for grazing cattle. As supplements reducing CH_4 emissions from

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

enteric fermentation can impact manure composition, project developers are required to assess changes in emissions from manure.

3.7.23 | If on-site direct measurements or scientific evidence from peer-reviewed scientific sources can be presented at project validation that the supplements applied in the project do not impact manure composition and CH_4 and N_2O emissions from manure under project conditions, calculation of these emission sources may be omitted upon review by the VVB.

If no such evidence is available, emissions from manure for each year in the monitoring period $E_{M,y}$ shall be calculated using Equation 21:

$$E_{M,y} = E_{MCH4,y} + E_{MN2O,y}$$

Equation 21

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]

3.7.24 | **Methane emissions from manure management *$E_{MCH4,y}$*** shall be calculated applying **Equation 22.** Emissions are quantified based on the quantity of volatile solids excreted by the animal stratum and the storage technique or direct pasture deposition for the manure.

$$E_{MCH4,y} = \sum_{S,G} VS_{G,y} \times N_{G,y} \times Days_{G,y} \times B_o \times CF_{CH4} \times MCF_S \times MS_{S,G,y} \times GWP_{CH4}/1000$$

Equation 22

Where:

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

$VS_{G,y}$ = 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 [head]

$Days_{G,y}$ = Average duration an animal spends in animal stratum G in year y of the monitoring period (annual average) [day]

B_o = Maximum methane producing capacity from cattle manure [m3 kg^{-1} of VS]
= 0.19 For North America, 0.18 for Western Europe, 0.17 for Eastern Europa an Oceania, 0.18 for other high-productivity systems, or 0.13 for low-productivity systems (IPCC 2019)[17]

[17] Uncertainty values of ±15% according to IPCC 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Table 10.16 shall be applied to calculate standard error for B_0 ($SE_P=B_0*0.15$) for uncertainty assessment according to section 9.

CF_{CH4} = conversion factor of m^3 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}]

3.7.25 | Daily volatile solids $VS_{G,y}$ excreted per animal in animal stratum G for each year of the monitoring period are calculated using Equation 23 below. Alternatively, VS_G may be calculated through the application of improved models published in peer-reviewed scientific journals with proven applicability under project conditions. Conservative default parameters (i.e. high levels of VS) may be applied to calculate potential increase of emissions. Use of supplement-specific data or models for volatile solids is required for calculations of emission reductions due to supplement application. The same calculation approach must be applied for baseline and project scenario.

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

Equation 23

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 cattle with less than 85% grain in diet, and 0.02 for cattle with more than 85% grain in diet (IPCC 2019)

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

$EC_{DM,G,y}$ = Average energy content of dry matter in feed for animal stratum G in year y [MJ kg^{-1}]

3.7.26 | **Digestible energy in feed DE_y** shall be documented for specific feed applied in the project scenario. [18]

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

3.7.28 | **Methane conversion factors for manure management systems MCF_S** shall be determined for each manure management system S applied in the

[18] 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 22.

project activity. For cattle which are held on pasture, paddocks or open feedlots without dung collection and storage, respective methane conversion factor MCF_S for direct field deposition shall be used. 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 manure management practices, including type and duration of storage, under matching environmental conditions from another country, peer-reviewed or verified by independent expert) can be applied if applicability is documented. If no localized emissions factors are available, emission factors shown in Table 3 shall be applied. As the factors in the table are based on IPCC defaults, an uncertainty value of ±20% shall be assumed for these parameters[19].

3.7.29 | **Nitrous oxide emissions from manure management $E_{MN2O,y}$** shall be calculated applying Equation 24or, if project-specific information and/or data is available, through the direct use of project data or application of improved models or emission factors published in peer-reviewed scientific journals with proven applicability under project conditions. Conservative default parameters (i.e. high levels of nitrogen in manure) may be applied to calculate potential *increase* of emissions. Use of supplement-specific data or models for nitrogen in manure is required for calculations of emission *reductions* due to supplement application. The same calculation approach must be applied for baseline and project scenario.

3.7.30 | If the project activity increases non-protein nitrogen (NPN) or nitrates in the diet to reduce emissions, or if a supplement's mode of action indicates a risk of increase of nitrogen content in manure or change in route of excretion, peer-reviewed research or project-specific data shall be provided to either (a)prove that the supplement does not lead to a significant increase in urinary or fecal nitrogen and consequently N emissions, *OR* (b)quantify any significant change in N emissions either as a factor to be added to $E_{MN2O,y}$ resulting from Equation 24, or by applying a supplement-specific model related to project activity to quantify impacts.

3.7.31 | 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 added to any manure brought out on managed lands.

3.7.32 | The assessment of the protein content of the diet and the intake of feed is provided by the farmer/nutritionist for the feedstuffs and rations for the cattle, and this professional will attest to the accuracy of the monitoring procedures used (see also section 13 Monitoring).

[19] 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.

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

Equation 24

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}] à see equation 25

$LWgainN_{G,y}$ = 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}] à see equation 26

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

$Days_{G,y}$ = Average duration an animal spends in animal stratum G in year y of the monitoring period (annual average) [day]

$E_{N2O,G,y}$ = N_2O emitted per kg of N excreted per animal in animal stratum G in year y of the monitoring period [kg N_2O (kg excreted N)$^{-1}$] à see equation 27

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

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

$$FeedN_{G,y} = DMI_{G,y} \times CP_{G,y} \times fN_{FP}$$

Equation 25

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}]

$CP_{G,y}$ = 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

$$LWgainN_{G,y} = AWI_{G,y} \times fN_{WG}$$

Equation 26

Where:

$AWI_{G,y}$ = Average daily animal weight increase per head 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

$$E_{N2O,G,y} = \sum_{S,P} MS_{S,G,y} \times \left(E_{N2O,S} + E_{N2O,P} \right)$$

Equation 27

Where:

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

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

$E_{N2O,P}$ = N_2O emitted per kg of N in manure or excretions deposited on managed lands [kg N_2O (kg deposited N)$^{-1}$]

3.7.33 | **The fraction of nitrous oxide emitted per kg of N excreted from storage $E_{N2O,S}$ and from field deposition $E_{N2O,P}$** 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 manure management practices, including type and duration of storage, under matching environmental conditions from another country) can be applied if applicability is documented. If no localized emission factors are available, the emission factors shown in columns "Total" in Table 04 (storage) and Table 5 (field deposition) in section 7 shall be applied. As the factors in the table are based on IPCC defaults with high uncertainty[20], an uncertainty value of ±50% shall be assumed for these parameters. Generally, factors from the latest IPCC Guidelines shall be applied.

3.7.34 | **Non-manure emissions from pastures:** Emissions from pasture areas used for grazing cattle, including natural grasslands, perennial and annual pastures, as well as pastures in rotation with crops, for each year in the monitoring period $E_{P,G,y}$ are calculated using Equation 24 below. If no change in pasture management leading to an increase of GHG emissions is caused by the project activity (i.e. no increase in pasture area for the project herd,no increase in stocking rate, no decrease in biomass stocks, no increase in pasture inputs (fertilizer), no increase in tillage and other soil disturbance or erosion, and no increase in machine use on pasture),, this emission source may be omitted from GHG calculations, subject to provision of evidence for practices and inputs in baseline scenario and for each project reporting period. Pasture management practices shall be documented for each geo-referenced pasture area ($A_{G,y}$), i.e. tillage, organic inputs, machine use and irrigation, as applicable.

3.7.35 |Documentation of pasture areas shall also include patches of above-ground biomass as identified at project start by visual inspection of high-resolution imagery and documented in a geo-referenced map (as ESRI shapefile or kml/kmz) which shall be submitted at verification. Differences against the baseline shall be reported and regeneration efforts shown.

For all pasture areas, evidence shall be provided at verification that stocking rates and density do not exceed the pasture areas' carrying capacity.

$$E_{P,G,y} = A_{G,y} \times EF_{P,y}$$

[20] 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.

Equation 28

Where:

$E_{P,G,y}$ = Emissions from pasture for animal stratum G in year y of the monitoring period [tCO_2e]

$A_{G,y}$ = Average pasture area for animal stratum G in year y of the monitoring period [ha]

$EF_{P,y}$ = Emission factor for pasture management in year y of the monitoring period [$tCO_2e\ ha^{-1}$]

3.7.36 | The **emission factor per hectare of pasture in the project scenario $EF_{P,G,y}$** shall be determined as an average across all pastures impacted by the project activity. The emission factor must include emissions from change in carbon pools (woody and non-woody plant biomass, soil organic carbon) and organic matter inputs (compost, green manure), emissions of CH_4 and N_2O from fertilizer (not including on-farm manure and on-field excretions, as such emissions are covered in section "Emissions from manure management" above), as well as emissions from use of machinery. If available, national emission factors should be applied for each of these emission sources. If no national data is available, IPCC Tier 1 or Tier 2 calculations and emission factors[21] may be applied conservatively to estimate $EF_{P,G,y}$, taking into account the respective uncertainties.

3.7.37 | As per the applicability conditions of this methodology, no benefits from increase in carbon pools (GHG sequestration in biomass or soil organic carbon) or emission sources not related to the supplement fed to cattle (e.g. change in tillage or fertilizing) shall be accounted under this methodology. If such effects are expected, a respective dedicated Gold Standard methodology shall be applied, and project owners shall ensure that emission reductions from manure and pasture animal excretions due to supplement application (e.g. from reduced N-content) are clearly separated from emission reductions due to activities accounted under other methodologies (e.g. from reduced N quantity applied through precision management). If such separation is not possible, no pasture-based emission reductions shall be accounted for under this methodology.

3.7.38 | **Emissions from animal transport :** Emissions from animal transport for each year in the monitoring period $E_{T,G,y}$ are calculated using Equation 29:

$$E_{T,G,y} = N_{T,G,y} \times EF_{T,G,y} \times Dist_{T,G,y}$$

Equation 29

Where:

$E_{T,G,y}$ = Average annual emissions from animal transport in year y of the monitoring period [tCO_2e]

[21] IPCC 2006/2019: Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories

$N_{T,G,y}$ = Average annual number of transported cattle in animal stratum G in year y of the monitoring period [head]

$EF_{T,G,y}$ = Emission factor for cattle transport in animal stratum G in year y of the monitoring period [tCO_2e $head^{-1}$ km^{-1}]

$Dist_{T,G,y}$= Average transport distance for animal stratum G in year y of the monitoring period [km]

3.7.39 | **Emission factors for cattle transport per head $EF_{T,G,y}$** shall be documented for each transported animal group for the project activity. Emission factor per head of cattle can be estimated from average animal weight at time of transport and common tonne-km (or converted ton-mile) emission factors. National values specific to the transport means (vehicle type, capacity, etc.) shall be applied. If no national emission factors are available, default emission factors can be applied conservatively (e.g. using tools or emission factors published by the Greenhouse Gas Protocol[22]). As per the applicability conditions of this methodology, no benefits from emission reductions for animal transport shall be accounted under this methodology. If such effects are expected, a respective dedicated Gold Standard methodology shall be applied.

3.8 | Leakage emissions

3.8.1 | 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 beef production to other lands to compensate for yield reductions, or impacts of pasture management on annual crop yields in areas where pasture is in rotation with other crops. In such fields, crop yields (CY_t) shall be monitored and reported to ensure that yield does not decline below normal annual fluctuation (compared to average yield in baseline period CY_0) and market changes (relative to project region production levels).

3.8.2 | As the project area is being actively maintained for commodity production during the project crediting period, yield-related leakage risks are relatively small. Cattle ranchers 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 yield. Accordingly, this methodology's applicability conditions do not allow yield reduction.

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

[22] "Emission Factors from Cross-Sector Tools" (EF list) or "GHG Emissions from Transport or Mobile Sources" (calculation tool) published at https://ghgprotocol.org/calculation-tools#cross_sector_tools_id (link accessed Nov 2020)

3.9 | Emission reductions

3.9.1 | The emission reductions are calculated as follows:

$$ER_y = BE_y - PE_y - LE_y$$

Equation 30

Where:

ER_y	=	Emission reductions in year y (t CO_2e/yr)
BE_y	=	Baseline emissions in year y (t CO_2e/yr)
PE_y	=	Project emissions in year y (t CO_2e/yr)
LE_y	=	Leakage emissions in year y (t CO_2e/yr)

3.9.2 | **Calculation of GS-VERs:** Greenhouse gas benefits from activities to reduce methane emissions from enteric fermentation are calculated as the net changes in GHG emissions as depicted 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.

$$CO_2Certificates_{t-0} = [\Delta E_{t-0} - LK_{t-0}]$$

Equation 31

Where:

GS-Certificates$_{t-0}$ = Gold Standard emission reductions to be issued for the monitoring period [tCO_2e]

ΔE_{t-0} = Reduction of emissions from cattle in the monitoring period [tCO_2e]

LK_{t-0} = Leakage of emissions due to project activity in the monitoring period [tCO_2e]

3.9.3 | The reduction of emissions for the monitoring period ΔEt-0 is calculated as the difference between average emission levels in the baseline scenario and the annual emissions in the current monitoring period, normalized by animal weight gain.

$$\Delta E_{t-0} = \sum_y \left[\left(E_0 - E_y\right) \times AWI_{total,y}\right] \times (1 - UD)$$

Equation 32

Where:

ΔE_{t-0} = Reduction of emissions from cattle in the monitoring period [tCO_2e]

E_0 = Emissions per kg of total animal weight increase in the baseline scenario [tCO_2e (kg AWI)$^{-1}$]

E_y = Emissions per kg of total animal weight increase in year y in the monitoring period [tCO_2e (kg AWI)$^{-1}$]

$AWI_{total,y}$ = Total animal weight increase across the herd in year y in the monitoring period [kg].

y = Year in the monitoring period [1..n; n≤5]

UD = Uncertainty deduction [dimensionless]

3.9.4 | **Uncertainty :** The project developer 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 :

3.9.5 | **Step 1: Calculate upper and lower confidence limits for all input parameters** :Calculate the mean X¯_p, and standard deviation ☐p, for each parameter and coefficient used in emissions calculations. The standard error of the mean is then given by

$$\mathbf{SE_p} = \frac{\boldsymbol{\sigma}_\mathbf{p}}{\sqrt{\mathbf{n_p}}}$$

Equation 33

Where:

SE_p = Standard error in the mean of parameter p

s_p = Standard deviation of the parameter p

n_p = Number of samples used to calculate the mean and standard deviation of parameter p

3.9.6 | If SEp (mean standard error) is available directly from the parameter source (e.g. literature, metadata) it shall be used directly in the following calculations (without the use of Equation 33).

3.9.7 | If no information on SD or SE is known for a parameter, SE of 50% of the parameter value shall be assumed. For the calculations of the upper and lower confidence intervals, a t-value of 3 shall be applied. Exception to this rule are accepted default values considered constant (e.g. physical conversion rates, Global Warming Potentials).

3.9.8 | 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

$$\mathrm{Lower_p} = \overline{\mathrm{X}}_\mathrm{p} - \mathrm{t}_{np} \times \mathrm{SE_p}$$

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

Equation 34

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). If no information is available on n_p a conservative value of 1.675 (n=3) shall be used.

3.9.9 | Step 2: Calculate reduction of emissions from cattle in the monitoring period (ΔEt-0) with the lower and upper confidence interval values of the input parameters :Apply the Lower and Upper parameter values in the models for ΔEt-0, specifically equations for Et and E0, to achieve a lower and upper value for ΔEt-0

$$\mathrm{Lower}_{\Delta \mathrm{Et-0}} = \mathrm{Model}_{\Delta \mathrm{Et-0}}\{\mathrm{Lower}_{\mathrm{p}}\}$$

$$\mathrm{Upper}_{\Delta \mathrm{Et-0}} = \mathrm{Model}_{\Delta \mathrm{Et-0}}\{\mathrm{Upper}_{\mathrm{p}}\}$$

Equation 35

Where:

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

$\mathrm{Upper}_{\Delta Et\text{-}0}$ = 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 6 : t-values (t_{np}) applicable in Equation 35. 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		

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}
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		

3.9.10 | Step 3: Calculate the uncertainty in the model output: The uncertainty in the output model is given by

$$\mathrm{UNC} = \frac{|\mathrm{Upper}_{\Delta Et-0} - \mathrm{Lower}_{\Delta Et-0}|}{2 \times \Delta E_{t-0}}$$

Equation 36

Where:

UNC = Model output uncertainty [%]

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

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

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

3.9.11 | **Step 4: Adjust the estimate of emissions change (ΔEt-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 developer may use the estimated value without any deduction for uncertainty, i.e. *UD* = 0 If the uncertainty of emission models is greater than 20% of the mean value, then the project developer shall use the estimated emission reduction subject to an uncertainty deduction (*UD*) in Equation 32, calculated as

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

Equation 37

UD = Uncertainty deduction [%]

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

3.10 | Changes required for methodology implementation in 2nd and 3rd crediting periods

3.10.1 | When the project developers apply for crediting period renewal, the baseline scenario and emission factor shall be reassessed, in addition to other relevant methodological parameters as per the latest version of the methodology available at the time submission of renewal of crediting period.

3.11 | General requirements for data and information sources

3.11.1 | The project developer 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 and the Gold Standard for the Global Goals Monitoring Report Template and the information listed in below monitoring tables.

3.11.2 | In addition, the project developer 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.

3.11.3 | In addition to the parameters listed below, the project developer shall collect and document evidence that the methodology's applicability conditions are met at all times. In addition, the project developer shall: (a)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 (b)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.

3.12 | Data and parameters not monitored

3.12.1 | 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.

Parameter ID	**BEEF.1**
Data/parameter	B_0
Unit	m^3 CH_4 (kg of volatile solids)$^{-1}$
Description	Maximum methane producing capacity from manure
Source of data	2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 4: Agriculture, Forestry and Other Land Use, Chapter 10, Table 10.16
Value(s) applied	Values for non-dairy cattle: 0.19 for North America 0.18 for Western Europe 0.17 for Eastern Europe and Oceania 0.18 for other regions (high productivity systems) 0.13 for other regions (low productivity systems) Uncertainty of ±15% according to IPCC 2019, Table 10.16 shall be applied to calculate standard error for B_0 ($SE_P=B_0*0.15$) for uncertainty assessment according to section 9.
Measurement procedures	
Additional comments	Country-specific values may be used if available

Parameter ID	**BEEF.2**
Data/parameter	CF_{CH4}
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(s) applied	0.67 (IPCC default)
Measurement procedures	
Additional comments	

Parameter ID	**BEEF.3**
Data/parameter	EC_{CH4}
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(s) applied	55.65 (IPCC default)
Measurement procedures	
Additional comments	EC_{CH4} on a mass basis (MJ/kg) is considered constant, thus no SD must be considered in uncertainty assessment.

Parameter ID	**BEEF.4**
Data/parameter:	EF_{SP}
Unit	tCO_{2e} kg^{-1}
Description	Emission factor for supplement production
Source of data	Product supplier (product information for supplements used)
Value(s) applied	Project-specific coefficient
Measurement 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, and indicating quality assurance for quantification and author of LCA.Suppliers should also report the standard error of the mean to allow quantification of uncertainty. Project developers shall contact the product producer to request the latest version of the product LCA (to account in changes in production process).
Additional comments	The latest version of the product's LCA report shall be assessed by an LCA expert who shall be part of the VVBs team at project validation

Parameter ID	**BEEF.5**
Data/parameter	fN_{FP}
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(s) applied	0.16 (equivalent to 1/6.25 factor for N intake in IPCC Equation 10.32 above)
Measurement procedures	
Additional comments	

Parameter ID	**BEEF.6**
Data/parameter	fN_{WG}
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(s) applied	0.027
Measurement procedures	
Additional comments	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.

Parameter ID	**BEEF.7**
Data/parameter	GWP_{CH4}
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 Fifth Assessment Report (2014).
Value(s) applied	28
Measurement procedures	
Additional comments	Latest GWP values as approved by Gold Standard shall be applied.

Parameter ID	**BEEF.8**

Data/parameter:	GWP_{N2O}
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 Fifth Assessment Report (2014).
Value(s) applied	265
Measurement procedures	
Additional comments	Latest GWP values as approved by Gold Standard shall be applied.

Parameter ID	**BEEF.9**
Data/parameter:	MCF_S
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 3) Emission factors shown in Table 7-02 shall be applied.
Value(s) applied	
Measurement procedures	
Monitoring frequency	Once (at project start)
QA/QC procedures	Data and source(s) to be audited at verification
Additional comments	Respective errors of the mean shall be documented and applied for uncertainty assessment.

Parameter ID	**BEEF.10**
Data/parameter:	UE
Unit	dimensionless
Description	Urinary energy expressed as fraction of gross energy (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(s) applied	0.04 for cattle with less than 85% grain in diet 0.02 for cattle with 85% or more grain in the diet
Measurement procedures	
Additional comments	

4| Monitoring methodology

4.1 | Data and parameters monitored

Parameter ID	BEEF.11
Data/Parameter:	$A_{G,y}$
Data unit:	ha
Description:	Average annual pasture area for animal stratum G in year y
Source of data:	Farm reports (geo-referenced data)
Monitoring frequency:	Annually
QA/QC procedures:	Areas shall be documented annually and geo-referenced data provided. Intra-annual changes shall be documented (with geodata) and average annual area calculated over time. Data and source(s) to be audited at verification
Any comment:	Documentation of pasture areas shall include 1)indication of each parcels carrying capacity and average stocking rate for the monitoring period. 2)description of management practices on the parcels including tillage events and organic inputs (amount and frequency). 3)an assessment of tree cover to monitor potential loss of woody biomass (see parameter $EF_{P,y}$ for quantification). Acceptable evidence for tree cover and patches of woody biomass are validated field inventories of woody biomass or aerial imagery with documentation in a geo-referenced format (e.g. shapefile or kml/kmz) or public third-party data on tree cover change (e.g. globalforestwatch.org Tree Cover Change Map). For guidance, refer to Gold Standard LUF Activity Requirements, Annex C. Note: temporary loss of trees (e.g. harvest and regrowth) may be permitted if evidence for sustainable management is provided, including evidence for restocking of trees (e.g.

	replanting or protection of natural regeneration) immediately following removal of biomass (i.e. within one year).

Parameter ID	**BEEF.12**
Data/parameter:	ASH $_{G,y}$
Data Unit	dimensionless
Description	Ash content of manure as a fraction of the dry matter feed intake for animal stratum G in year y
Source of data	Appropriate sources shall be selected depending on whether the project claims emission reductions from manure management: For project emissions (no reductions in manure emissions): IPCC default for cattle of 0.08 may be applied. (Source: IPCC 2006 Guidelines for National Greenhouse Gas Inventories, Volume 4: Agriculture, Forestry and Other Land Use, Chapter 10, p 10.42) For emission reductions (i.e reduction of manure emissions due to feed supplement): Project-specific ash content shall be determined using either periodic measurement of ash content for each diet or respective scientific data (e.g. from feed databases). Ash content shall be selected conservatively, i.e. rather underestimating emission reductions against baseline.
Monitoring frequency	Annually
QA/QC procedures	Data and source(s) to be audited at verification
Any comments	

Parameter ID	**BEEF.13**
Data/parameter:	**$AWI_{G,y}$**
Data Unit	kg head^{-1} day^{-1}
Description	Average annual animal weight increase per head in animal stratum G in year y
Source of data	Farm reports
Monitoring frequency	Annually (average per animal stratum)

QA/QC procedures	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. Data and source(s) to be audited at validation
Additional comments	May not be available for all farms. Sample must be large enough to calculate representative average for animal stratum G.

Parameter ID	**BEEF.14**
Data/parameter:	$\mathbf{AWI_{total,y}}$
Data Unit	kg
Description	Total animal weight increase across the herd in year y in the monitoring period.
Source of data	Farm reports
Monitoring frequency	Annually
QA/QC procedures	Sum of absolute weight gain $AWI_{G,y}$ across all animals in the heard in year y.
Additional comments	

Parameter ID	**BEEF.15**
Data/parameter:	$\mathbf{CP_{G,y}}$
Data Unit	dimensionless
Description	Crude protein in diet, quantified as a fraction of DMI, per animal in animal stratum G in year y
Source of data	Farm records and nutritionist and/or feed supplier (feed description, feed composition/nutrition tables)
Monitoring frequency	Annually

QA/QC procedures	Records shall be kept for every diet/ration per animal group G. Calculation of annual average per animal stratum, based on feed description over baseline period. CP shall be quantified for each feed type separately and annual average calculated (by volume of each feed type). If information on uncertainty of CP estimate is not available for a feed type, a default error of 50% shall be assumed Data and source(s) to be audited at verification
Additional comments	If no data is available for pasture feed, locally applicable, published research may be used. Evidence of applicability has to be provided by the project developer and verified by the Gold Standard Validation/Verification Body.

Parameter ID	**BEEF.16**
Data/parameter:	$\mathbf{CY_y}$
Data Unit	kg
Description	Crop yield on pasture areas in rotation with other crops in year y
Source of data	Farm records
Monitoring frequency	Annually
QA/QC procedures	Evidence shall be provided for crop yields (e.g. sales receipts per crop). Data and source(s) to be audited at verification
Additional comments	Due to variation of yield (and potentially crops) in rotation, differences in crop yield (and respective leakage effects) shall be considered across multiple years, covering at least one full rotation period, and relative to the project regions production levels.

Parameter ID	**BEEF.17**
Data/parameter:	$\mathbf{Days_{G,y}}$

Data Unit	day
Description	Average duration an animal spends in animal stratum G in year y
Source of data	Farm records
Monitoring frequency	Annually
QA/QC procedures	Based on herd list (see details described for $N_{G,y}$ in this section) average number of days an animals spends in each stratum in year y is calculated.Variance of $Days_{G,y}$ shall also be calculated. Data and source(s) to be audited at verification
Additional comments	If variance is too high due to fluctuations in herd composition and stratum allocation, re-stratification (split of strata with high variation) on duration spent in strata may be necessary to achieved required accuracy.

Parameter ID	**BEEF.18**
Data/parameter:	$\mathbf{DE_{G,y}}$
Data Unit	dimensionless
Description	Digestible energy in feed for animal stratum G in year y, quantified as fraction of gross energy (GE)
Source of data	Nutritionist and/or feed supplier (feed description), based on applicable research
Monitoring frequency	Annually

QA/QC procedures	Quantification approach for DE should follow practice common for the project country, e.g. applying feed composition/nutrition tables (approaches may differ between nations/regions) . Up-to-date applicable tables from reliable sources (specific feed supplier or peer-reviewed research) shall be used [23]. Once an approach and source is chosen for a project activity, it must be retained for the entire project duration (baseline and project). If diet is changed with an annual period, weighted average for DE across the annual amount per feed type shall be used in calculations. Documentation for DE shall include indication of mean standard error (or standard deviation). If no MSE or SD information is available, default error of 50% shall be assumed. Data and source(s) to be audited at verification
Additional comments	If no data is available for pasture feed, locally applicable, published research (peer reviewed or verified by an independent expert) may be used. Evidence of applicability has to be provided by the project developer and verified by the Gold Standard Validation/Verification Body.

Parameter ID	**BEEF.19**
Data/parameter:	$\mathbf{DMI_{G,y}}$
Data Unit	kg head^{-1} day^{-1}
Description	Dry matter intake for animal stratum G in year y
Source of data	Feeding records (farm reports)
Monitoring frequency	Monthly (aggregated as annual average)

[23] For US, NASEM 2016 values may be applied, visit https://www.nap.edu/catalog/19014/nutrient-requirements-of-beef-cattle-eighth-revised-edition (accessed April 2021)

QA/QC procedures	Records shall be kept for every diet/ration per animal group G. Feed intake shall be quantified per feed type at farm level, using detailed farm records quantifying the difference between feed offered and the feed leftover on daily, weekly or even biweekly basis or by recording the amount of feed purchase (including all feed ingredients in diet) and the leftover of each ingredient within a given period time. For grazing animals, DMI for the portion of forage consumed on pasture may be modelled based on locally applicable research . Evidence for applicability shall confirm project condition match at least for climatic conditions, season (if applicable), pasture vegetation type and key animal characteristics (e.g. body weight, age, growth rate, as relevant for the model). Depending on the data or model applied, additional factors may have to be considered. Data and source(s) to be audited at verification
Additional comments	Collection of local data for grazing cattle is encouraged to reduce uncertainty (e.g. by monitoring cattle movements and/or feed intake by technical means such as gyrosensor collars, pressure sensor halters, etc.).

Parameter ID	**BEEF.20**
Data/parameter:	$\mathbf{Dist_{FT,t,G,y}}$
Data Unit	km
Description	Average transport distance for feed type t in animal stratum G in year y
Source of data	Calculated based on one or a combination of the following information: 1) Data from supplier (note: if transport from source to feed processor or distributor is included in feed LCA emissions (EF_{FP}), it should be omitted here) 2) Farm records (feed source) and actual transport distance based on supplier information or map systems (e.g. Google maps) 3) Estimates based on common market sources for the feed type (if exact source is unknown)

Monitoring frequency	Annually
QA/QC procedures	Data and source(s) to be audited at verification
Additional comments	

Parameter ID	**BEEF.21**
Data/parameter:	$\mathbf{Dist_{ST,G,y}}$
Data Unit	km
Description	Average transport distance for supplement in animal stratum G in year y
Source of data	Calculated based on one or a combination of the following information: 1) Data from supplier (note: if transport from manufacturer to distributor is included in supplement production emissions (EF_{SP}), it should be omitted here) 2) Farm records (supplement source) and actual transport distance based on supplier information or map systems (e.g. Google maps)
Monitoring frequency	Annually
QA/QC procedures	Data and source(s) to be audited at verification
Additional comments	

Parameter ID	**BEEF.22**
Data/parameter:	$\mathbf{Dist_{T,G,y}}$
Data Unit	km
Description	Average transport distance for cattle in animal stratum G in year y
Source of data	Calculated from farm records (cattle source and destination) and actual transport distance based on supplier information or map systems (e.g. Google maps)

Monitoring frequency	Annually
QA/QC procedures	Data and source(s) to be audited at verification
Additional comments	

Parameter ID	**BEEF.23**
Data/parameter:	$\mathbf{E_{N2O,S}}$
Data Unit	kg 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 3) Emission factors shown in Table 7-03
Monitoring frequency	Annually
QA/QC procedures	Data and source(s) to be audited at verification
Additional comments	Respective errors of the mean shall be documented and applied for uncertainty assessment.

Parameter ID	**BEEF.24**
Data/parameter:	$\mathbf{E_{N2O,P}}$
Data Unit	kg N_2O (kg N excreted)$^{-1}$
Description	Nitrous oxide emitted per kg N in manure or excretions deposited on managed lands

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 3) Emission factors shown in Table 7-03
Monitoring frequency	Annually
QA/QC procedures	Data and source(s) to be audited at verification
Additional comments	Respective errors of the mean shall be documented and applied for uncertainty assessment.

Parameter ID	**BEEF.25**
Data/parameter:	$\mathbf{EC_{DM,G,y}}$
Data Unit	MJ (kg dry matter)$^{-1}$
Description	Average gross energy content of dry matter in feed for animal stratum G in year y

Source of data	If feed-specific information is available, specific energy contents and respective standard deviation shall be used, e.g. converted from: Gross energy (kcal) | Tables of composition and nutritional values of feed materials INRA CIRAD AFZ (feedtables.com/content/gross-energy-kcal) If no feed-specific information is available, the conservative IPCC[1)] default values of 18.45 MJ (kg dry matter)$^{-1}$ may be applied for forage and grain-based diets (not including processed or concentrated grains, oilseeds, soy, rice). As this default value is conservative (i.e. at the lower end of energy content for most forage and grain-based diets), a SD of 5% can be assumed[2)] [1)] 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 4: Agriculture, Forestry and Other Land Use, Chapter 10, p. 10.29 [2)] SD estimate based on respective feed types listed in INRA feed tables (see link above)
Monitoring frequency	Annually
QA/QC procedures	Applicability and transparent calculations shall be documented by project developer. Data and source(s) to be audited at verification
Additional comments	

Parameter ID	**BEEF.26**
Data/parameter:	$\mathbf{EF_{FP,t,y}}$
Data Unit	tCO_2e (kg)$^{-1}$
Description	Emission factor for production of feed type t in year y

Source of data	Calculated based on one or a combination of the following information: 1) Data from supplier (feed LCA emissions per kg of feed type t) 2) Default emission factors for feed type and production (e.g. based on LCA data from FAO Global database of GHG emissions related to feed crops: http://www.fao.org/3/a-i8275e.pdf)
Monitoring frequency	Annually
QA/QC procedures	Data and source(s) to be audited at verification
Additional comments	

Parameter ID	**BEEF.27**
Data/parameter:	$\mathbf{EF_{FT,t,y}}$
Data Unit	$tCO_2e\ (kg*km)^{-1}$
Description	Emission factor for transport of feed type t in year y
Source of data	Calculated based on one or a combination of the following information: 1) National emission factors specific to the transport means (vehicle type, fuel, transport capacity, etc.) 2) Default emission factors for transport type (e.g. tools or emission factors published by the Greenhouse Gas Protocol: https://ghgprotocol.org/calculation-tools#cross_sector_tools_id) Emission factors from most local source shall be applied. Uncertainty of factor applied shall be determined based on parameter source (e.g. scientific source for emission factor used in tools listed above) or, if not available, conservatively assumed to be 50%.
Monitoring frequency	Annually
QA/QC procedures	Data and source(s) to be audited at verification
Additional comments	

Parameter ID	**BEEF.28**
Data/parameter:	$\mathbf{EF_{G,y}}$
Data Unit	kg CH_4 $head^{-1}$ day^{-1}
Description	Methane emission factors from enteric fermentation per animal in animal stratum G in year y
Source of data	Approach 1: Measured for each animal stratum (farm reports). Approach 2: $EF_{G,0}$ is calculated using Equation 5.
Monitoring frequency	Annually
QA/QC procedures	Under approach 1, methane emissions from enteric fermentation are measured on-farm for a representative sample of animals for each animal stratum. Measurement techniques must meet all of 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. Parameters and source(s) to be audited at verification
Additional comments	

Parameter ID	**BEEF.29**
Data/parameter	$\mathbf{EF_{P,y}}$
Data Unit	$tCO_2e\ (ha)^{-1}$
Description	Emission factor for pasture management in year y
Source of data	Calculated based on one or a combination of the following information: 1) Project-specific data (e.g on biomass stocks and changes), based on inventories or estimations from on-field observations or remote sensing data (e.g. satellite imagery). 2) National emission factors for CO2 emissions from change in carbon pools (biomass, soil organic carbon), emissions of CH4 and N2O from fertilizer, animal dung and urine, as well as emissions from use of machinery. 3) If no national data is available, IPCC Tier 1 or Tier 2 calculations and emission factors may be applied conservatively If pasture management includes temporary removal of biomass (on non-forest pasture only), projects shall include in their PDDs what approach will be used to ensure tree regeneration (planting, protection of natural regrowth), and describe respective activities and area status in annual monitoring reports.
Monitoring frequency	Annually
QA/QC procedures	Emission factor and calculations shall take into account potential impacts of feed supplement on N_2O emissions, based on peer-reviewed scientific research. Data and source(s) to be audited at verification
Additional comments	

Parameter ID	**BEEF.30**
Data/parameter:	$\mathbf{EF_{ST,G,y}}$
Data Unit	$tCO_2e\ (kg*km)^{-1}$
Description	Emission factor for supplement transport for animal stratum G in year y
Source of data	Calculated based on one or a combination of the following information: 1) National emission factors specific to the transport means (vehicle type, fuel, transport capacity, etc.) 2) Default emission factors for transport type (e.g. tools or emission factors published by the Greenhouse Gas Protocol: https://ghgprotocol.org/calculation-tools#cross_sector_tools_id) Emission factors from most local source shall be applied.Uncertainty of factor applied shall be determined based on parameter source (e.g. scientific source for emission factor used in tools listed above) or, if not available, conservatively assumed to be 50%.
Monitoring frequency	Annually
QA/QC procedures	Data and source(s) to be audited at verification
Additional comments	

Parameter ID	**BEEF.31**
Data/parameter	$\mathbf{EF_{SS,G,y}}$
Data Unit	$tCO_2e\ (kg)^{-1}$
Description	Emission factor for supplement storage for animal stratum G in year y

Source of data	Calculated based on one or a combination of the following information: 1) Electricity consumption by cooling and heating systems measured on-site or calculated from power consumption (wattage) and running time 2) Grid emission factors for electricity in the project area (national sources) 3) Fuel consumption and emission factors for stationary combustion (for generators) using national emission factor 4) Other applicable sources for emission factors (e.g. tools or emission factors published by the Greenhouse Gas Protocol: https://ghgprotocol.org/calculation-tools#cross_sector_tools_id) Uncertainty of factor applied shall be determined based on parameter source (e.g. scientific source for emission factor used in tools listed above) or, if not available, conservatively assumed to be 50%.
Monitoring frequency	Annually
QA/QC procedures	Data and source(s) to be audited at verification
Additional comments	

Parameter ID	**BEEF.32**
Data/parameter	$\mathbf{EF_{T,G,y}}$
Data Unit	tCO_2e (head * km)$^{-1}$
Description	Emission factor for cattle transport in animal stratum G in year y
Source of data	Calculated based on average animal weight (at time of transport) and tonne-km emission factor from one of the following sources: 1) National emission factors specific to the transport means (vehicle type, fuel, transport capacity, etc.) 2) Default emission factors for transport type (e.g. tools or emission factors published by the Greenhouse Gas Protocol: https://ghgprotocol.org/calculation-tools#cross_sector_tools_id)
Monitoring frequency	Annually
QA/QC procedures	Data and source(s) to be audited at verification
Additional comments	

Parameter ID	**BEEF.33**
Data/parameter	$\mathbf{F_{t,G,y}}$
Data Unit	kg
Description	Annual amount of feed type t, fed per head in animal stratum G in year y
Source of data	Data shall be used from the following sources (ordered by priority): 1) Farm record (average feed consumption per head per feed type) 2) Data from other applicable sources (e.g. comparable practices from another ranch with similar practices and in the same region), if applicability is documented
Monitoring frequency	Annually

QA/QC procedures	Data and source(s) to be audited at verification
Additional comments	

Parameter ID	**BEEF.34**
Data/parameter:	$\mathbf{MS_{S,G,y}}$
Data Unit	dimensionless
Description	Fraction of animal stratum G's manure handled using manure management system S in year y
Source of data	Manure records (farm reports) according to applicable legislation and practices. Records shall be maintained at farm level, including supporting evidence as applicable (e.g. imagery, records of energy use / machine hours, receipts for changes in equipment etc.)
Monitoring frequency	Annually (average per animal stratum)
QA/QC procedures	Quantities of manure shall be recorded on an annual or monthly basis for each animal stratum G on farm level and related to the number of animals in the respective stratum on the farm. Fractions and variance shall be calculated as annual average for each year in the monitoring period.Data and source(s) to be audited at verification
Additional comments	May not be available for all farms. Sample must be large enough to calculate representative average for animal stratum G. Evidence supporting the records shall be reviewed and confirmed by the Validation/Verification Body.

Parameter ID	**BEEF.35**
Data/parameter:	$\mathbf{N_{G,y}}$
Data Unit	head
Description	Number of animals in animal stratum G in year y
Source of data	Farm records
Monitoring frequency	Annually

QA/QC 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. Changes of individuals between strata shall be recorded at daily or weekly resolution, documenting the date of each individual's change into a new stratum. Documentation shall include a list (spreadsheet or database) of all animals and their stratum allocation, including key information on changes (e.g. date when an individual was added to and removed from the animal stratum, reason for change, animal weight at change of stratum). After consolidation, total number of animals for year y shall be calculated for each animal stratum G. Data and source(s) to be audited at verification
Additional comments	List of animals and allocation to strata shall be reviewed by VVB at performance reviews.

Parameter ID	**BEEF.36**
Data/parameter:	$\mathbf{RYm_{G,y}}$
Data Unit	dimensionless
Description	Supplement impact coefficient reducing the fraction of gross energy in feed converted to methane, for animal stratum G in year y
Source of data	Supplement supplier information The supplement impact coefficient shall be determined from data provided by the supplier of the feed supplement, based on peer-reviewed data.
Monitoring frequency	Annually
QA/QC procedures	Data and source(s) to be audited at verification

Additional comments	The data provided by the supplier shall describe the efficacy of each specific supplement's emissions reductions in in-vivo application and define applicability of the data, especially dependencies on diet 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. This is the key factor determining reductions of emissions from enteric fermentation. Project developer shall provide solid documentation that the coefficient chosen matches the project conditions in the respective animal stratum.

Parameter ID	**BEEF.37**
Data/parameter:	$\mathbf{S_{G,y}}$
Data Unit	kg head^{-1} day^{-1}
Description	Daily amount of supplement applied per animal in animal stratum G in year y
Source of data	Farm reports
Monitoring frequency	Annually (average per animal stratum)

QA/QC procedures	The amount administered per animal in each animal stratum shall be recorded and reported by all farms participating in the project. Project documentation shall include how verifiable evidence for supplement intake shall be provided. Provision of supplement and tracing of intake shall be documented in a "standard process" at project level. Quantities provided and rejected (i.e. leftovers) shall be documented for each provision, per stratum and farm. If the supplement is provided as part of a mix, evidence for mix intake shall be provided to correlate, including observations on specific animals, logger data (for mechanical feeders) or physical markers for intake (e.g. snout color markers for critical additive intake). Individual animals deviating from the stratum behavior (e.g. refusing the mix or additive) shall be documented and potentially excluded from the project. For pasture-based animals, controlled feeding mechanisms shall be used (e.g. controlled-release boluses, computer-controlled feeders documenting supplement intake per animal, or hand feeding with respective documentation). Every farm shall further provide original proof of purchase for the total volume of supplement applied. The proof of purchase must be specific to the farm and traceable to the supplement manufacturer. Data and source(s) as well as proofs of purchase to be audited at verification
Additional comments	Reporting amounts of supplement administered at each farm will determine project performance and be an essential part of respective audits. VVBs shall assess the purchased supplement volume against storage at time of audit, standard application process, documentation and evidence of supplement feeding. The VVB shall verify how the procedure and its implementation ensure that safe dosage per animal as prescribed by the supplement manufacturer is not exceeded.

Parameter ID	**BEEF.38**
Data/parameter	$\mathbf{Ym_{G,y}}$
Unit	dimensionless

Description	Fraction of gross energy in feed converted to methane for animal stratum G in year y
Source of data	This factor shall be selected to best meet project conditions, especially the diet for each animal stratum G, and its applicability must be documented by the project developer. Acceptable proofs of applicability include: 1) Peer-reviewed scientific publications based on data collected under comparable conditions. 2) Data from direct measurements under project conditions if measurement methodology, setup, full results and analysis are provided for review for registration and performance audits.
Monitoring frequency	Annually (average per animal stratum)
QA/QC procedures	Data and source(s) to be audited at verification
Additional comments	Respective errors of the mean shall be documented and applied for uncertainty assessment.

4.1.1 | Data and Parameters collected for baseline calculation and when project areas (farms) are being added and at renewal of crediting period if required : The following baseline information on each project area (i.e., ranch) within the project region shall be recorded:

- Unique numerical identifier for each project area (i.e., ranch)
- Name of ranch owner
- Names of site/area manager(s) for reporting period
- Physical address and GPS coordinates of locations

A statement clarifying the ownership of emission reductions.

Parameter ID	**BEEF.39**
Data/parameter	$\mathbf{A_{G,0}}$
Data Unit	ha
Description	Average annual pasture area for animal stratum G in the baseline scenario
Source of data	Farm reports (geo-referenced data)
Measurement procedures	Areas shall be documented annually and geo-referenced data provided. Intra-annual changes shall be documented (with geodata) and average annual area calculated over time.

Monitoring frequency	Annually
QA/QC procedures	Data and source(s) to be audited at validation
Additional comments	Documentation of pasture areas shall also include 1) indication of each parcels carrying capacity and average stocking rate for the baseline period. 2) description of management practices on the parcels including tillage events and organic inputs (amount and frequency). 3) an assessment of tree cover to monitor potential loss of woody biomass. Acceptable evidence for tree cover and patches of woody biomass are validated field inventories of woody biomass or aerial imagery with documentation in a geo-referenced format (e.g. shapefile or kml/kmz) or public third-party data on tree cover change (e.g. globalforestwatch.org Tree Cover Change Map). For guidance, refer to Gold Standard LUF Activity Requirements, Annex C. Note: temporary loss of trees (e.g. harvest and regrowth) may be permitted if evidence for sustainable management is provided, including evidence for restocking of trees (e.g. replanting or protection of natural regeneration) immediately following removal of biomass (i.e. within one year).

Parameter ID	**BEEF.40**
Data/parameter	$\mathbf{ASH_{G,0}}$
Data Unit	dimensionless
Description	Ash content of manure as a fraction of the dry matter feed intake for animal stratum G in the baseline scenario.
Source of data	Appropriate sources shall be selected depending on whether the project claims emission reductions from manure management: For project emissions (no reductions in manure emissions): IPCC default for cattle of 0.08 may be applied. (Source: IPCC 2006 Guidelines for National Greenhouse Gas Inventories, Volume 4: Agriculture, Forestry and Other Land Use, Chapter 10, p 10.42) For emission reductions (i.e reduction of manure emissions due to feed supplement): Project-specific ash content shall be determined from either periodic measurement of ash content for each diet or respective scientific data (e.g. from feed databases). Ash content shall be selected conservatively, i.e. baseline emissions should be rather underestimated by application of a high ash content.
Monitoring frequency	Annually
QA/QC procedures	Data and source(s) to be audited at validation
Additional comments	

Parameter ID	**BEEF.41**
Data/parameter	$\mathbf{AWI_{G,0}}$
Data Unit	kg head^{-1} day^{-1}
Description	Average annual animal weight increase per head in animal in stratum G in the baseline scenario
Source of data	Farm reports

Measurement procedures	Weight gain shall be measured with adequate measurement techniques and average weight calculated for each animal stratum G. For projects with 10 head of cattle or less and no means to weigh the cattle, weight may be 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 comments	

Parameter ID	**BEEF.42**
Data/parameter	$\mathbf{CP_{G,0}}$
Data Unit	dimensionless
Description	Crude protein in diet, quantified as a fraction of DMI, per animal in animal stratum G
Source of data	Farm records and nutritionist and/or feed supplier (feed description, feed composition/nutrition tables)
Measurement procedures	Diet/ration per animal group G shall be assessed based on farm records. Calculation of annual average per animal stratum, based on feed description over baseline period. CP shall be quantified for each feed type separately and average calculated (by volume of each feed type). If information on uncertainty of CP estimate is not available for a feed type, a default error of 50% shall be assumed.
Monitoring frequency	Annually
QA/QC procedures	Data and source(s) to be audited at validation
Additional comments	If no data is available for pasture feed, locally applicable, published research may be used. Evidence of applicability has to be provided by the project developer and verified by the Gold Standard Validation/Verification Body.

Parameter ID	**BEEF.43**
Data/parameter	$\mathbf{CY_0}$
Data Unit	kg
Description	Average annual crop yield on pasture areas in rotation with other crops in the baseline period
Source of data	Farm records
Measurement procedures	Evidence shall be provided for crop yields (e.g. sales receipts per crop)
Monitoring frequency	Annually
QA/QC procedures	Data and source(s) to be audited at validation
Additional comments	Crop production in rotation with pasture varies greatly in frequency and intensity. For baseline quantification, average crop yield across at least one full rotation period (including pasture seasons without crop production).

Parameter ID	**BEEF.44**
Data/parameter	**$Days_{G,0}$**
Data Unit	day
Description	Average duration an animal spends in animal stratum G in the baseline scenario (average over baseline years)
Source of data	Farm records
Measurement procedures	Based on herd list (see details described for $N_{G,0}$ in this section) average number of days an animals spends in each stratum is calculated for each year. Average annual duration is then calculated for the baseline period. Variance of $Days_{G,0}$ shall also be calculated across the baseline period.
Monitoring frequency	Annually
QA/QC procedures	Data and source(s) to be audited at verification
Additional comments	If variance is too high due to fluctuations in herd composition and stratum allocation, re-stratification (split of strata with high variation) on duration spent in strata may be necessary to achieved required accuracy.

Parameter ID	**BEEF.45**
Data/parameter	**$DE_{G,0}$**
Data Unit	dimensionless
Description	Digestible energy in feed for animal stratum G, quantified as fraction of gross energy (GE)
Source of data	Nutritionist and/or feed supplier (feed description), based on applicable research.

Measurement procedures	Quantification approach for DE should follow practice common for the project country, e.g. applying feed composition/nutrition tables (approaches may differ between nations/regions). Up-to-date applicable tables from reliable sources (specific feed supplier or peer-reviewed research) shall be used [24]. Once an approach and source is chosen for a project activity, it must be retained for the entire project duration (baseline and project). If diet is changed within an annual period, weighted average for DE across the annual amount per feed type shall be used in calculations. Documentation for DE shall include indication of mean standard error (or standard deviation). If no MSE or SD information is available, default error of 50% shall be assumed.
Monitoring frequency	Annually
QA/QC procedures	Data and source(s) to be audited at validation
Additional comments	If no data is available for pasture feed, locally applicable, published research (peer reviewed or verified by an independent expert) may be used. Evidence of applicability has to be provided by the project developer and verified by the Gold Standard Validation/Verification Body.

Parameter ID	**BEEF.46**
Data/parameter	$\mathbf{DMI_{G,0}}$
Data Unit	kg head^{-1} day^{-1}
Description	Dry matter intake for animal stratum G
Source of data	Feeding records (farm reports)

[24] For US, NASEM 2016 values may be applied, visit https://www.nap.edu/catalog/19014/nutrient-requirements-of-beef-cattle-eighth-revised-edition (accessed April 2021)

Measurement procedures	Diet/ration per animal group G shall be assessed based on farm records. Feed intake shall be quantified per feed type at farm level, using detailed farm records quantifying the difference between feed offered and the feed leftover on daily, weekly or even biweekly basis or by recording the amount of feed purchase (including all feed ingredients in diet) and the leftover of each ingredient within a given period time. For grazing animals, DMI for the portion of forage consumed on pasture may be modelled based on locally applicable research . Evidence for applicability shall confirm project condition match at least for climatic conditions, season (if applicable), pasture vegetation type and key animal characteristics (e.g. body weight, age, growth rate, as relevant for the model). Depending on the data or model applied, additional factors may have to be considered.
Monitoring frequency	Monthly (aggregated as annual average across the baseline period)
QA/QC procedures	Data and source(s) to be audited at validation
Additional comments	

Parameter ID	**BEEF.47**
Data/parameter	$\mathbf{Dist_{FT,t,G,0}}$
Data Unit	km
Description	Average transport distance for feed type t in animal stratum G in the baseline scenario
Source of data	Calculated based on one or a combination of the following information: 1) Data from supplier (note: if transport from source to feed processor or distributor is included in feed LCA emissions (EF_{FP}), it should be omitted here) 2) Farm records (feed source) and actual transport distance based on supplier information or map systems (e.g. Google maps) 3) Estimates based on common market sources for the feed type (if exact source is unknown)
Monitoring frequency	Once

QA/QC procedures	Data and source(s) to be audited at validation
Additional comments	

Parameter ID	**BEEF.48**
Data/parameter	$\mathbf{Dist_{T,G,0}}$
Data Unit	km
Description	Average transport distance for cattle in animal stratum G in the baseline scenario
Source of data	Calculated from farm records (cattle source and destination) and actual transport distance based on supplier information or map systems (e.g. Google maps)
Monitoring frequency	Once
QA/QC procedures	Data and source(s) to be audited at validation
Additional comments	

Parameter ID	**BEEF.49**
Data/parameter	$\mathbf{E_{N2O,S}}$
Data Unit	kg 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 3) Emission factors shown in Table 7-03
Monitoring frequency	Once

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

Parameter ID	**BEEF.50**
Data/parameter	$\mathbf{E_{N2O,p}}$
Data Unit	kg N_2O (kg N deposited)$^{-1}$
Description	Nitrous oxide emitted per kg N in manure or excretions deposited on managed lands
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 3) Emission factors shown in Table 7-04
Monitoring frequency	Once
QA/QC procedures	Data and source(s) to be audited at validation
Additional comments	Respective errors of the mean shall be documented and applied for uncertainty assessment.

Parameter ID	**BEEF.51**
Data/parameter	$\mathbf{EC_{DM,G,0}}$
Data Unit	MJ (kg dry matter)$^{-1}$
Description	Average gross energy content of dry matter in feed for animal stratum G in the baseline scenario

Source of data	If feed-specific information is available, specific energy contents and respective standard deviation shall be used, e.g. converted from: Gross energy (kcal) | Tables of composition and nutritional values of feed materials INRA CIRAD AFZ (feedtables.com/content/gross-energy-kcal) If no feed-specific information is available, the conservative IPCC[1)] default values of 18.45 MJ (kg dry matter)$^{-1}$ may be applied for forage and grain-based diets (not including processed or concentrated grains, oilseeds, soy, rice). As this default value is conservative (i.e. at the lower end of energy content for most forage and grain-based diets), a SD of 5% can be assumed[2)] [1)] 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 4: Agriculture, Forestry and Other Land Use, Chapter 10, p. 10.29 [2)] SD estimate based on respective feed types listed in INRA feed tables (see link above)
Monitoring frequency	Annually
QA/QC procedures	Applicability and transparent calculations shall be documented by project developer. Data and source(s) to be audited at validation
Additional comments	

Parameter ID	**BEEF.52**
Data/parameter	$\mathbf{EF_{FP,t,0}}$
Data Unit	$tCO_2e\ (kg)^{-1}$
Description	Emission factor for production of feed type t in the baseline scenario
Source of data	Calculated based on one or a combination of the following information: 1) Data from supplier (feed LCA emissions per kg of feed type t) 2) Default emission factors for feed type and production (e.g. based on LCA data from FAO Global database of GHG emissions related to feed crops: http://www.fao.org/3/a-i8275e.pdf)
Monitoring frequency	Once
QA/QC procedures	Data and source(s) to be audited at validation
Additional comments	

Parameter ID	**BEEF.53**
Data/parameter	$\mathbf{EF_{FT,t,0}}$
Data Unit	$tCO_2e\ (kg*km)^{-1}$
Description	Emission factor for transport of feed type t in the baseline scenario

Source of data	Calculated based on one or a combination of the following information: 1) National emission factors specific to the transport means (vehicle type, fuel, transport capacity, etc.) 2) Default emission factors for transport type (e.g. tools or emission factors published by the Greenhouse Gas Protocol: https://ghgprotocol.org/calculation-tools#cross_sector_tools_id) Emission factors from most local source shall be applied. Uncertainty of factor applied shall be determined based on parameter source (e.g. scientific source for emission factor used in tools listed above) or, if not available, conservatively assumed to be 50%.
Monitoring frequency	Once
QA/QC procedures	Data and source(s) to be audited at validation
Additional comments	

Parameter ID	**BEEF.54**
Data/parameter	$\mathbf{EF_{G,0}}$
Data Unit	kg CH_4 $head^{-1}$ day^{-1}
Description	Methane emission factors from enteric fermentation per animal in animal stratum G
Source of data	Approach 1: Measured for each animal stratum (study reports). Approach2: $EF_{G,0}$ is calculated using Equation 5.
Measurement procedures	Under approach 1, 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. 3) 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 (over 3 years)
QA/QC procedures	Data and source(s) to be audited at validation
Additional comments	

Parameter ID	**BEEF.55**
Data/parameter	$\mathbf{EF_{P,0}}$
Data Unit	tCO_2e $(ha)^{-1}$
Description	Emission factor for pasture management in the baseline scenario

Source of data	Calculated based on one or a combination of the following information: 1) Project-specific data (e.g on biomass stocks and changes), based on inventories or estimations from on-field observations or remote sensing data (e.g. satellite imagery). 2) National emission factors for CO2 emissions from change in carbon pools (biomass, soil organic carbon), emissions of CH4 and N20 from fertilizer, animal dung and urine, as well as emissions from use of machinery. 3) If no national data is available, IPCC Tier 1 or Tier 2 calculations and emission factors may be applied conservatively If pasture management includes temporary removal of biomass (on non-forest pasture only), projects shall include in their PDDs what approach will be used to ensure tree regeneration (planting, protection of natural regrowth), and describe respective activities and area status in annual monitoring reports.
Monitoring frequency	Annually
QA/QC procedures	Data and source(s) to be audited at validation
Additional comments	

Parameter ID	**BEEF.56**
Data/parameter	$\mathbf{EF_{T,G,0}}$
Data Unit	tCO_2e (head * km)$^{-1}$
Description	Emission factor for cattle transport in animal stratum G in the baseline scenario

Source of data	Calculated based on average animal weight (at time of transport) and tonne-km emission factor from one of the following sources: 3) National emission factors specific to the transport means (vehicle type, fuel, transport capacity, etc.) 1) Default emission factors for transport type (e.g. tools or emission factors published by the Greenhouse Gas Protocol: https://ghgprotocol.org/calculation-tools#cross_sector_tools_id)
Monitoring frequency	Annually
QA/QC procedures	Data and source(s) to be audited at validation
Additional comments	

Parameter ID	**BEEF.57**
Data/parameter	$\mathbf{F_{t,G,0}}$
Data Unit	kg
Description	Average annual amount of feed type t, fed per head in animal stratum G in the baseline scenario
Source of data	Data shall be used from the following sources (ordered by priority): 1) Farm record (average feed consumption per head per feed type) 2) Data from other applicable sources (e.g. comparable practices from another ranch with similar practices and in the same region), if applicability is documented 3) Conservative and documented expert opinion
Monitoring frequency	Once
QA/QC procedures	Data and source(s) to be audited at validation
Additional comments	

Parameter ID	**BEEF.58**
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 3) Emission factors shown in Table 7-02 shall be applied.
Monitoring frequency	Once
QA/QC procedures	Data and source(s) to be audited at validation
Additional comments	Respective errors of the mean shall be documented and applied for uncertainty assessment.

Parameter ID	**BEEF.59**
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.
Monitoring frequency	Annually (average per animal stratum)

QA/QC procedures	For baseline quantification, fraction of manure shall be based on annual quantities and variance over the 3 baseline years. Data and source(s) to be audited at validation
Additional comments	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.

Parameter ID	**BEEF.60**
Data/parameter	$\mathbf{N_{G,0}}$
Data Unit	head
Description	Number of animals in animal stratum G
Source of data	Farm reports
Measurement 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. Documentation shall include a list (spreadsheet or database) of all animals and their stratum allocation, including key information on changes (e.g. date when an individual was added to and removed from the animal stratum, animal weight at change of 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 comments	List of animals and allocation to strata shall be reviewed by VVB at validation.

Parameter ID	**BEEF.61**

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 developer. Acceptable proofs of applicability include: 1) Peer-reviewed scientific publications based on data collected under comparable conditions. 2) Data from direct measurements under project conditions if measurement methodology, setup, full results and analysis are provided for review for registration and performance audits.
Monitoring frequency	Annually (average per animal stratum)
QA/QC procedures	Data and source(s) to be audited at validation
Additional comments	Respective errors of the mean shall be documented and applied for uncertainty assessment.

4.2 | General requirements for sampling

4.2.1 | Sampling, where applicable, shall be conducted following relevant requirements for sampling in the latest version of the CDM Standard for sampling and surveys for CDM project activities and programme of activities.

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. For Gold Standard rules and requirements, the latest version published by the Gold Standard shall be applied.

Gold Standard Requirements:

- Gold Standard for the Global Goals Land-use & Forests Activity Requirementshttps://globalgoals.goldstandard.org/501-pr-ghg-emissions-reductions-sequestration/
- Gold Standard for the Global Goals Principles & Requirements
- Gold Standard for the Global Goals Safeguarding Principles & Requirements
- Gold Standard for the Global Goals Stakeholder Consultation & Engagement Requirements

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 Annual Report Template
- Gold Standard Agriculture Smallholder Dairy Methodology 2016
- Gold Standard Methodology Reducing Methane Emissions from Enteric Fermentation in Dairy Cows through Application of Feed Supplements 2019

Other documents and publications:

- Alberta Protocol: Quantification protocol for emission reductions from dairy cattle version 1 January 2010
- 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 4 Chapter 10 Emissions from Livestock and Manure Management
- IPCC 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 4 Chapter 10 Emissions from Livestock and Manure
- 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 4 Chapter 11 N2O Emissions from Managed Soils, and CO2 Emissions from Lime and Urea Application
- IPCC 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 4 Chapter 11 Managed Soils, and CO2 Emissions from Lime and Urea Application
- 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)
- Van Lingen et al. 2019: Prediction of enteric methane production, yield and intensity of beef cattle using an intercontinental database; Agriculture, Ecosystems and Environment 2019: Vol. 283; https://doi.org/10.1016/j.agee.2019.106575

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