VCS Methodology

VM0041

METHODOLOGY FOR THE REDUCTION OF ENTERIC METHANE EMISSIONS FROM RUMINANTS THROUGH THE USE OF 100% NATURAL FEED SUPPLEMENT

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Sectoral Scope 15

This methodology was developed by

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1 SOURCES

This methodology was developed based on the requirements and guidelines of the following:

- *VCS Standard, v4.0*
- *VCS Methodology Requirements, v4.0*
- *VCS Guidance: Guidance for Standardized Methods, v3.3*
- *2006 IPCC Guidelines for National GHG Inventories. Volume 4: Agriculture, Forestry and Other Land Use. Chapter 10: Emissions from livestock and manure management*

The following have informed the development of this methodology:

- *VCS module VMD0027: Estimation of domesticated animal populations, v1.0*
- *VCS module VMD0028: Estimation of emissions from domesticated animals, v1.0*
- *"Quantification Protocol" approved by the Alberta Offset System: Quantification protocol for reducing greenhouse gas emissions from fed cattle (version 3.0)*
- *ACR Methodology for Grazing Land and Livestock Management, v1.0*

2 SUMMARY DESCRIPTION OF THE METHODOLOGY

This methodology provides procedures to estimate enteric methane (CH_4) emission reductions generated from the inhibition of methanogenesis due to the introduction of a natural feed supplement into ruminants' diets. This methodology considers only emission reductions from enteric fermentation.

Feed supplements applicable under this methodology reduce CH_4 emissions by directly acting on the population of methanogenic archaea in the rumen. This methodology focuses on application of natural plant-based feed supplements, which along with inhibiting methanogenesis, may also have advantageous effects on rumen bacteria, thereby improving fermentation in the rumen.

Depending on the location where a project is implemented and data availability, this methodology provides three approaches for the quantification of baseline emissions and two approaches for the quantification of project emissions. Specifically, the quantification of baseline emissions may be performed using data from either on-site direct measurements, or by applying one of two different Intergovernmental Panel on Climate Change (IPCC)-approved methods to model emissions using country-specific or peer-reviewed biometric data. The quantification of project emissions may be performed using data from either on-site direct measurements, or by applying an empirically-derived regional emission reduction factor provided by the feed supplement manufacturer.

Table 2: Additionality and Crediting Baseline Methods

Additionality and Crediting Method	
Additionality	Activity method
Crediting Baseline	Project Method

3 DEFINITIONS

In addition to the definitions set out in VCS document *Program Definitions*, the following definitions apply to this methodology:

Animal Group
Animals at each farm grouped based on a homogenous ruminant population characterization such as animal type, weight, production phase (e.g., pregnant or lactating cow) and feed type

Diet
Feed ingredients or mixture of ingredients including water, which is consumed by animals

Dry Matter Intake (DMI)
All nutrients contained in the dry portion of the feed consumed by animals

Emission Reduction Factor
Percent reduction of enteric methane emissions per animal due to project feed supplement

Enteric Methane
Methane emissions from ruminants, due to enteric fermentation, as part of the digestion of feed materials

Enteric Fermentation
A natural part of the digestive process of ruminants where microbes decompose and ferment food present in the digestive tract or rumen. Enteric methane is one by-product of this process and is expelled by the animal through burping.

Feed(s)
Edible material(s) which are consumed by animals and contribute energy and/or nutrients to the animal's diet

Feed Supplement
A feed added to an animal's regular diet to improve the nutritive balance of the total mixed ration (or any other purpose, such as reduction of methane emissions) and intended to be (i)

fed undiluted as a supplement to other feeds; (ii) offered free-choice with other parts of the feed; or (iii) further diluted and mixed to produce a complete feed

Gross Energy
The total caloric energy contained in feed

Livestock Production Operation
An agricultural setting, permanent or semi-permanent facility or non-grazing area, where domesticated animals are kept or raised either indoors or outdoors to provide traction or for livestock commodities purposes1

Methanogenesis
The formation of methane in the rumen by microbes known as methanogens

Neutral Detergent Fiber (NDF)
A measure of total structural components (i.e., lignin, hemicellulose, cellulose, tannins and cutins) within the cells of plants that provides an estimate of fiber constituents of feedstuffs and indicates maturity; the higher the value, the more mature and lower quality the forage

Rumen
The large first compartment of the stomach of a ruminant where fermentation occurs, which allows for the digestion of fiber and other feeds

Ruminant
A mammal that has a different digestive system to monogastric (single stomach) animals. The primary difference is that ruminants' "stomach" consists of four compartments. The ruminants are able to acquire nutrients from plant-based food by fermenting it in the biggest compartment, the rumen, prior to digestion. Ruminating mammals include species like cattle, goat, sheep, deer, giraffes and antelopes.

4 APPLICABILITY CONDITIONS

This methodology applies to project activities which reduce enteric methane (CH_4) emissions through the inhibition of methanogenesis due to the introduction of a natural feed supplement into ruminants' diets.

The methodology is applicable under the following conditions:

1. Livestock producers must feed their animals a natural feed supplement which reduces enteric CH_4 emissions by direct inhibition of methanogens in the rumen.

1 FAO. Shaping the Future of Livestock. Berlin, 18–20 January 2018 http://www.fao.org/3/i8384en/I8384EN.pdf

2. Only ruminant animals shall be included in the project.

3. The project feed supplement must meet the following conditions:

   a. The active ingredients of the feed supplement must be 100% natural plant-based or macroalgae-based and non-GMO. This includes extracted components of plants. The feed manufacturer must provide a non-GMO certificate based on lab analysis.

   b. The feed supplement must have been demonstrated to comply with all feed and food regulations in each national or subnational (including local) jurisdiction in which it is consumed. Where conflict arises between regulations, the most stringent standard must apply.

   c. The feed supplement must have no significant negative health or performance impacts on the animal to which it is fed. Where conflict arises between regulations, the most stringent standard must apply.

   d. The feed supplement must be used as per feeding instructions provided by the manufacturer. The instructions provide critical defining conditions to secure the default level of reduction of the enteric methane emissions, such as the feeding routine and dose of supplement per kg of DMI to the animal.

4. Emission reductions generated by the use of other feed supplements and/or activities (e.g., improving animal productivity or nutritional and management strategies), the objective of which does not lead to the inhibition of methanogenesis, cannot be claimed through this methodology. This is to prevent overestimation of emission reductions achieved.

5. The implementation of project activities must confirm that the herd of ruminants in a given operation is fed the project feed supplement. For this purpose, the project proponent must be able to trace the feed supplement fed to livestock from the producer to on-farm consumption.

6. Evidence must be provided that there will be no increase in the manure emissions due to feed supplementation (e.g., evidence-based literature, peer-reviewed publications, study reports).

7. Baseline emissions included in this methodology are CH_4 production from enteric fermentation and are determined as the average activity over at least three continuous years prior to project implementation. Therefore, the project activities are required to meet the following conditions:

   a. Where project areas involve livestock farms that were operating prior to the start of project activities, reliable data (e.g., gross energy intake and dry matter intake) per animal group must be available for a minimum of two years where using baseline emissions Option 1 and three years where using baseline emissions Option 2. See Section 8.1 below for further details on options for quantifying baseline emissions.

   b. Where project areas involve livestock farms for which no farm records or farming data are available, the project proponent must be able to provide evidence to substantiate the animal group to which each new project area is allocated according to the average group as described in national or regional statistical accounts (i.e., the baseline emissions will be considered as the average activity of where the project is located).

5 PROJECT BOUNDARY

The spatial extent of the project boundary encompasses all geographic locations of supplement production, supplement transport, and project activity locations where natural feed supplement is part of the livestock production operation.

Table 3 below indicates the emission sources and GHGs included in the project boundary and the GHGs to be monitored.

Table 3: GHG Sources Included In or Excluded From the Project Boundary

Source		Gas	Included?	Justification/Explanation
Baseline	Enteric Fermentation	CO_2	No	No changes in biogenic CO_2 emissions are expected due to the project activity.
		CH_4	Yes	CH_4 emissions from enteric fermentation, prior to the project technology implementation, represent the major source of emissions in the baseline scenario.
		N_2O	No	No changes in biogenic N_2O emissions are expected due to the project activity.
Project	Enteric Fermentation	CO_2	No	No changes in biogenic CO_2 emissions are expected due to the project activity.
		CH_4	Yes	CH_4 emissions from enteric fermentation are the major source of emissions in the project scenario.
		N_2O	No	No changes in biogenic N_2O emissions are expected due to the project activity.
	Supplement Production and Transport	CO_2	Yes	CO_2 emitted from supplement transportation and production.
		CH_4	Yes	CH_4 may be emitted from combustion of fossil fuels during the processing.
		N_2O	No	N_2O emissions are not expected during the production process.

As indicated in the table above, the project boundary includes CH_4 emissions from enteric fermentation. The dominant pathway for CH_4 emissions from enteric fermentation is exhalation, and therefore CH_4 emissions need only be monitored via exhalation. The project boundary does not include CH_4 emissions from flatulence, because changes in methanogenesis will not impact the fixed ratio of methane released between exhalation and flatulence due to physiology of the rumen (i.e., a decrease in exhaled methane corresponds to a decrease in methane flatulence). Further, due to rumen physiology, changes in methanogenesis does not impact manure decomposition. For this reason, the project boundary also does not include CH_4 or N_2O emissions from decomposing manure.

Ruminants release methane by exhaling the gas mainly through their mouth and nostrils. Enteric CH_4 is produced mainly in the rumen (90%) and, to a smaller extent (10%), in the large intestine (Muray et al., 1999; Dini et al., 2012). Feed supplements that inhibit rumen methanogenesis cannot influence the ratio of enteric methane emissions in exhaled air compared to methane emissions in extracted feces due to the ruminants' physiology. The specific and direct inhibition of the methanogenesis in the rumen is not demonstrated to cause a major change in the overall rumen fermentation as this process is downstream of these metabolic processes.

Consequently, feed supplements will not impact digestion in a way that would lead to an increase in the CH_4 or N_2O emissions in the manure decomposition. Keuzer et al. (2006) concluded, in fact, that feed additives designed to limit methane emissions reduced methane emissions from both the digestive track and manure decomposition. Another study by Nampoothiri et al. (2015) reports that, in general, dietary manipulations have very little effect on manure N_2O production. Further studies (Aguerre et al, 2011; Aguerre et al, 2012; Hristov et al, 2012) verified that methane reduction achieved by manipulating the rumen fermentation had no change in manure emissions. The emissions from this element are expected to be equal or lower in the project as compared to the baseline scenario. Avoidance of increase in the manure emissions due to feed supplementation is dealt with by the applicability condition 6 of this methodology.

6 BASELINE SCENARIO

At the project start date, the most plausible baseline scenario must be identified as the continuation of livestock operations following business as usual practices (i.e., typical feeding regime without using a natural feed supplement to reduce CH_4 enteric fermentation). There are no plausible alternatives to this baseline scenario.

7 ADDITIONALITY

This methodology uses an activity method for the demonstration of additionality. Project proponents applying this methodology must determine additionality using the procedure below:

Step 1: Regulatory surplus

The project proponent must demonstrate regulatory surplus in accordance with the rules and requirements regarding regulatory surplus set out in the latest version of the *VCS Standard*.

Step 2: Positive list

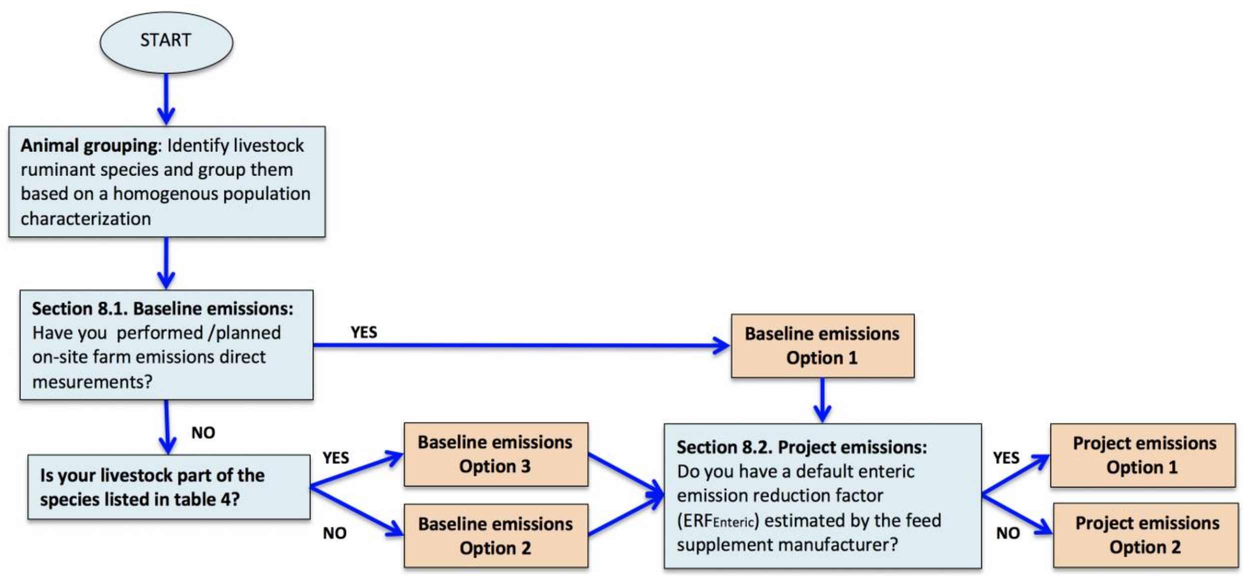
The applicability conditions of this methodology represent the positive list. The project must demonstrate that it meets all of the applicability conditions, and in so doing, it is deemed as complying with the positive list. The positive list was established using the activity penetration option (Option A in the *VCS Methodology Requirements*).

Justification for the activity method is provided in Appendix I.

8 QUANTIFICATION OF GHG EMISSION REDUCTIONS AND REMOVALS

This methodology proposes three approaches for the quantification of baseline emissions and two approaches for the quantification of project emissions, the applicability of each being dependent on data availability. Figure 1 outlines the steps involved in determining baseline and project emissions. The steps are listed below and explained in more detail in the following sections.

Figure 1: Decision Tree for CH_4 Emissions from Enteric Fermentation



8.1 Baseline Emissions

Emissions in the baseline scenario are estimated as the sum of annual emissions from enteric fermentation according to the following equation:

$$BEEnteric_{\mathbf{i}} = \sum_{j=1}^{N} [EFEnteric_{i,j}] \bullet \frac{GWP}{1000} \quad (1)$$

Where:

$BEEnteric_i$	Total baseline CH_4 emissions from livestock enteric fermentation for farm *i* (tCO_2e). Where the project activity includes multiple farms, emissions in the baseline scenario are estimated as the sum of annual emissions from each farm *i*: $\sum_{i=1}^{N}[BEEnteric_{\mathbf{i}}]$
$EFEnteric_{i,j}$	Enteric CH_4 emissions factor for each animal group *j* during the monitoring period (kg CH_4 $group^{-1}$)
GWP	Global Warming Potential of methane (tCO_2/tCH_4)
1000	kg per one metric tonne
i	Identification of livestock farm (1,2,..,N)
j	Animal grouping (1,2,..,N).

This methodology provides three options for determining the enteric emissions factor ($EF_{Enteric j}$). Depending on the availability of relevant project data and measurements, each project proponent must choose the most appropriate of the following options for each animal grouping.

$EF_{Enteric ij}$ Option 1

Option 1 calculates the enteric emission factor for each animal group by performing direct enteric methane measurements to estimate the methane production per animal group per day (enteric emissions production factor - $EFProduction_{i,j}$). The enteric emissions production factor for each animal group measured by the chosen technology must be available at the validation. Therefore, using Option 1, the enteric emission factor for each animal group is calculated as follows:

$$EFEnteric_{\mathbf{i,j}} = EFProduction_{i,j} \bullet N_{i,j} \bullet Days_{i,j} \quad (2)$$

Where:

$EFEnteric_{i,j}$	Enteric CH4 emissions factor for each animal group j during the monitoring period (kg CH4 $group^{-1}$)
$EFProduction_{i,j}$	Average enteric emissions production factor for each animal group during the baseline or monitoring period (on-site direct measurement by chosen technology2) (kg CH4 head-1 day-1)

2 See Appendix II

$Days_{i,j}$	Number of days for each animal in the group j during the monitoring period in farm *i*
$N_{i,j}$	Average number of head in each animal grouping *j* in the farm *i* in the monitoring period (head)
i	Identification of livestock farm (1,2,..,N)
j	Animal grouping (1,2,..,N)

Baseline emission production factor ($EF_{Production}$) may be measured prior to project implementation with a sample for each animal group subsequently included in the project. Alternatively, a control group for each animal group can be used during project implementation, thus allowing baseline monitoring and project monitoring to occur simultaneously. The control group is used as a baseline measure and is identical to all other animals with the exception that it does not receive the feed supplement. $EF_{Production}$ remains fixed for the project crediting period once determined. Please see Appendix II for further details regarding the direct methane measurement technologies and procedures.

Two years of farm-specific data (e.g., gross energy intake and dry matter intake) prior to project implementation must be provided during validation. This data will be used to demonstrate that the Option 1 measured baseline does not represent a biased event as compared to the prior conditions at the farm, and therefore the $EF_{Production}$ reflects the average activity of where the project is located.

$EF_{Enteric_{ij}}$ Option 2

Option 2 provides procedures to calculate the enteric emission factor for each animal group by applying an IPCC Tier 2 method, using the following equation. The emission factor for each animal group is calculated as follows:

$$EF_{Enteric_{\mathbf{i,j}}} = \left[GE_{\mathbf{j}} \bullet Y_{\mathbf{m},\mathbf{j}} \bullet N_{i,j} \bullet Days_{i,j}\right] \bullet EC^{-1} \quad (3)$$

Where:

$EF_{Enteric_{i,j}}$	Enteric CH4 emissions factor for each animal group j during the monitoring period (kg CH4 $group^{-1}$)
GE_j	Average gross energy intake per animal grouping *j* in the farm *i* (MJ $head^{-1}$ day^{-1})
Ym_j	Conversion factor (Ym) indicates the proportion of the animal grouping j gross energy intake (GE) converted to enteric CH_4 energy. Energy of CH_4 as a percentage of GE (dimensionless).

Days — Number of days for each animal in the group j during the monitoring period in farm *i*[3]

$N_{i,j}$ — Average number of head in each animal grouping *j* in the farm *i* in the monitoring period (dimensionless)

EC — Energy content of methane (=55.65 MJ kg^{-1} of CH_4)

i — Identification of livestock farm (1,2,..,N)

j — Animal grouping (1,2,..,N)

Gross energy intake *GE* is calculated by multiplying dry matter intake by the energy density of the feedstuff, using Equation 4:

$$GE_j = [DMI_j \bullet ED] \quad (4)$$

Where

DMI_j — Average dry mass of feed consumed by animal group j in a given day (Kg $head^{-1}$ day^{-1})

ED — Energy Density. Average energy content of dry matter [MJ kg^{-1}] =

- 18.45 MJ kg^{-1} may be used as a default for diets including edible oils with fat contents in the range of 4 to 6%.
- 19.10 MJ kg^{-1} may be used as a default for diets including edible oils with fat contents below 4%.

$EF_{Entericij}$ Option 3

Option 3 is only suitable for animal species listed in Table 4 below, and where the project proponent does not have the required data for Option 2. The enteric emission factor for each animal group, is calculated as follows:

$$EF_{Enteric_{i,j}} = [EF_{i,j} \bullet N_{i,j} \bullet Days_{i,j} \bullet DF_j] \quad (5)$$

Where:

$EF_{Enteric_{i,j}}$ — Enteric CH_4 emissions factor for each animal group *j* during the monitoring period (kg CH_4 $group^{-1}$)

3 Note that the number of days could be less than 365. For example, in the case of young cattle the number of days represents the length of stay in a specific group.

$EF_{i,j}$	Average enteric CH_4 emissions factor for each animal group *j* during the monitoring period (country or regional specific factors, or those provided in Table 4), (kg CH_4 $head^{-1}$ day^{-1})
Days	Number of days for each animal in the group *j* during the monitoring period in farm *i*
$N_{i,j}$	Average number of head in each animal grouping in the farm *i* in the monitoring period; dimensionless
i	Identification of livestock farm (1,2,..,N)
j	Animal grouping (1,2,..,N)

Table 4: Enteric Fermentation Emission Factors for Tier 1 Method 1 (kg CH_4 $head^{-1}$ day^{-1})

Livestock	Emission Factor
Buffalo	0.15
Sheep	0.02[4]
Goats	0.01
Camels	0.13
Deer	0.05
Alpacas	0.02
Other (e.g., Llamas)	To be determined[5]
Note: All estimates are ±30-50% Sources: 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 4, Chapter 10, table 10.10. and background paper by Ulyatt, J. et al.	

8.2 Project Emissions

4 For developing countries the emission factor is 5 kg CH4 $head^{-1}$ yr^{-1}. IPCC is an intergovernmental body of the United Nations therefore we assume countries are classified accordingly.

5 One approach for developing the approximate emission factors is to use the Tier 1 emissions factor for an animal with a similar digestive system and to scale the emissions factor using the ratio of the weights of the animals raised to the 0.75 power. Liveweight values have been included for this purpose. Emission factors should be derived on the basis of characteristics of the livestock and feed of interest and should not be restricted solely to within regional characteristics.

Emissions in the project scenario are estimated as the sum of annual emissions from enteric fermentation, and from the production and transport of the supplement, according to the following equation:

$$PE_{Enteric\ i} = \sum_{j=1}^{N}[\mathrm{EF}_{\mathrm{Enteric}_{ij}}] \bullet [1 - \mathrm{ERF}_{\mathrm{Enteric}_j}] \bullet \frac{GWP}{1000} + \mathrm{EFME}_i \quad (6)$$

Where:

$PE_{Enteric_i}$	Total project enteric CH_4 emissions from livestock enteric fermentation for farm *i,* and the production and transport of the supplement used during the monitoring period (tCO_2e) Where the project activity includes multiple farms, emissions in the project scenario are estimated as the sum of annual emissions from each farm *i*: $\sum_{i=1}^{N}[\mathrm{PE}_{\mathrm{Enteric}_i}]$
$EF_{Enteric_{i,j}}$	Enteric CH_4 emissions factor for each animal group during the monitoring period as determined in Equation 2, 3 or 5 above (kg CH_4 $group^{-1}$)
$ERF_{Enteric_j}$	Enteric CH_4 emissions reduction factor (default or determined percentage value). Supplement's percentage reduction of the enteric CH_4 per animal in an animal group *j* during the monitoring period.
$EFME_i$	Total emissions associated with manufacturing and transport of the feed supplement in the farm *i* during the monitoring period (tCO_2e)
GWP	Global Warming Potential of methane (tCO_2/tCH_4)
1000	kg per one metric tonne
i	Identification of livestock farm (1,2,..,N)
j	Animal grouping (1,2,..,N)

8.2.1 Enteric methane emissions reduction factor

There are two options to calculate the enteric methane emission reduction factor:

$ERF_{Enteric}$ Option 1: Apply the default enteric emission reduction factor (%) estimated by the manufacturer of the feed supplement and calculate the emissions using Equation 6.[6] This option may only be used where the enteric methane emission reduction factor provided by the manufacturer of the feed supplement is supported by peer-reviewed literature or farm-specific emissions data that was determined by following the guidelines specified in Appendix II. This

6 The default factor provided by the manufacturer must meet the requirements for default factors set out in Section 2.5.2 of the *VCS Methodology Requirements v4.0*.

information must be provided for review at validation and at each verification. Additionally, there must be no significant differences between project parameters (e.g., feed regime, animal type, weight, production phase, geographic region, and management practices) and the manufacturer's default enteric emission reduction factor study design. Where there are significant differences between the project parameters and the manufacturer's study design, the project must use Option 2.

$ERF_{Enteric}$ Option 2: Determine the enteric methane emissions reduction factor for each animal group by performing direct enteric methane measurements to estimate the methane production per animal group per day while consuming the feed supplement during the monitoring period. The feed supplement's enteric emission reduction factor will be quantified by comparing actual project performance to enteric emission factors determined when quantifying baseline emissions, using Equation 7.

Enteric emissions reduction factor calculation:

$$\mathrm{ERFEnteric}_{i,j} = \frac{EF_{Enteric\ \boldsymbol{i,j}} - (PE_{\boldsymbol{j}} \bullet N_j * Days)}{EF_{Enteric\ \boldsymbol{i,j}}} \bullet 100 \tag{7}$$

Where:

$ERF_{Enteric_{i,j}}$ = Enteric CH_4 emissions reduction factor for each animal group *j* in farm *i* (default percentage value)

$EF_{Enteric_{i,j}}$ = Enteric CH_4 emissions factor for each animal group *j*, determined using Option 1, 2 or 3 in Section 8.1 above (kg CH_4 $group^{-1}$)

$PE_{i,j}$ = Average enteric emissions production factor for each animal group *j* during the monitoring period in farm *i* (on-site direct measurement by chosen technology[7]) (kg CH_4 $head^{-1}$ day^{-1})

$N_{i,j}$ = Average number of head in each animal grouping *j* in the farm *i* in the monitoring period; dimensionless

$Days_{i,j}$ = Number of days for each animal in the group *j* during the monitoring period in farm *i*

i = Identification of cattle farm (1,2,..,N)

j = Animal grouping (1,2,..,N)

7 See Appendix II, Table 7: Measurement technologies of enteric methane emissions

8.2.2 GHG emissions from feed supplement manufacturing and transport

Emissions from the feed supplement are estimated by including all GHG sources from manufacturing and transport. Accounting for these GHG sources is not required for a project where such emissions are shown to be *de minimis*[8]. Otherwise, these emissions must be estimated as follows:

$$EFME_i = \frac{FM_i \bullet EF_P}{1000} + EF_{T\,i} \quad (8)$$

Where:

$EFME_i$	Total emissions associated with manufacturing and transport of the feed supplement in the farm *i* during the monitoring period (tCO_2e)
FM_i	Amount of feed supplement purchased by the farm *i* during the monitoring period (kg)
EFP	Emission factor for production of feed supplement (kg CO_2e kg^{-1})
EFT	Emissions for transport of feed supplement consumed during monitoring period to the farm *i* (tCO_2e)

Project emissions from the production of the feed supplement at the manufacturer's production facility are calculated as:

$$EF_P = (Q_{elec} \bullet EF_{elec}) + (Q_{ff\,a} \bullet FC_a \bullet EF_a) \quad (9)$$

Where:

Q_{elec}	Quantity of electricity from the grid used per kilogram of feed supplement production MWh kg^{-1}) during the monitoring period. To be determined by the feed supplement manufacturer.
EF_{elec}	Emissions factor for electricity (kg CO_2 MWh^{-1})[9]
Qff_a	Quantity of fossil fuel type *a* used per kilogram of feed supplement production during the monitoring period (volume or kg fuel/kg feed supplement). To be determined by the feed supplement manufacturer.

8 The pool or source may be excluded only if it is determined to be insignificant using appropriate approved tools for significance testing (e.g., the CDM "Tool for Testing Significance of GHG Emissions in A/R CDM Project Activities", available at http://cdm.unfccc.int/EB/031/eb31_repan16.pdf).

9 The latest approved version of CDM tool "Tool to calculate the emission factor for an electricity system" may be used to determine EF_{elec} if country or state/province values are not available.

FC_a Energy content per unit of fuel type *a* combusted (terajoule or TJ/ volume or kg fuel).

EFfuel Emission factor of fuel type *a* (kg CO_2e/ TJ).

a Fossil fuel type

Project emissions from the transport of the feed supplement to the project site are calculated as:

$$EF_T = TEF_i \bullet D_i \bullet FM_i \quad (10)$$

Where:

TEF_i Tonnes per km or miles of CO_2 emitted by transport mode *m* per kg of feed delivering feed supplement consumed during the monitoring period to farm *i* (t CO_2 $kg^{-1} km^{-1}$)

D_i Distance travelled by transport mode *m* delivering feed supplement consumed during the monitoring period to farm *i* (km or miles)

FM_i Amount of feed supplement purchased by the farm *i* during the monitoring period (kg)

8.3 Leakage

In the context of this methodology, leakage could potentially consist of a change in the number of animals in the livestock operation due to livestock performance impacts of introducing the supplement, thereby necessitating changes in livestock populations in non-project operations to fulfill market demand. However, supplements are expected to have an insignificant impact on livestock performance. Additionally, due to the economics of livestock production, it is unlikely that the costs and risks associated with increasing or decreasing the number of animals in the operation is justified from the minimal expected changes in animal performance alone. Therefore, leakage is considered to be zero.

8.4 Net GHG Emission Reductions and Removals

Net GHG emission reductions are calculated as follows:

$$ER_{Enteric\ i} = \sum_{i=1}^{N}[BE_{Enteric\ i} - PE_{Enteric\ i}] \quad (11)$$

Where:

$BE_{Enteric_i}$ Total GHG emission reductions due to project activities during the monitoring period (tCO2e)

$BE_{Enteric_i}$ Total baseline enteric CH_4 emissions from livestock enteric fermentation in the farm *i* during the monitoring period (tCO_2e)

$PE_{Enteric_i}$ Total project enteric CH_4 emissions from livestock enteric fermentation in the farm *i,* and the production and transport of the supplement used during the monitoring period (tCO_2e)

i Identification of farm (1,2,..,N)

9 MONITORING

9.1 Data and Parameters Available at Validation

Data / Parameter	GE_j
Data unit	MJ head^{-1} day^{-1} of dry matter
Description	Average gross energy intake for a specific animal group
Equations	3
Source of data	Records and data from livestock operator or associated partners for three continuous years of historical data prior to the initiation of the project or from national/regional statistical accounts. Records and data during the project implementation also required.
Value applied	N/A
Justification of choice of data or description of measurement methods and procedures applied	Gross energy intake can be calculated by dividing dry matter intake by the energy density of the feedstuff using equation 4 The gross energy (GE) content of the diets is calculated based on the fat level of the diets, therefore the livestock operator or associated partners need to demonstrate the fat content of the diet. Parameter to be updated with any change in the animal's feeding regime.
Purpose of Data	Calculation of baseline emissions
Comments	Calculated based on measured Daily Dry Matter Intake (DMI)

Data / Parameter	DMI_j
Data unit	Kg head^{-1} day^{-1}
Description	Average dry mass of feed consumed by an animal in a given day
Equations	4

Source of data	Records and data from livestock operator or associated partners for three continuous years of historical data prior to the initiation of the project or from national/regional statistical accounts. Records and data during the project implementation also required.
Value applied	N/A
Justification of choice of data or description of measurement methods and procedures applied	Data must be provided by the livestock operator or associated partners for each animal group. The farm records must document the average daily dry matter intake by animal grouping in the project. Parameter to be updated with any changes in the animal's feeding regime.
Purpose of Data	Calculation of baseline emissions
Comments	Required to calculate gross energy intake for equation 3

Data / Parameter	Ym_j
Data unit	Dimensionless
Description	Percentage of feed energy converted to methane for each animal group
Equations	3
Source of data	Country or regional and population specific Ym values should be used when available to better reflect the ruminants' population characteristics. Default values provided in Table 7 or 8 (Appendix III) may be used as an alternative where regional values are not available.
Value applied	N/A
Justification of choice of data or description of measurement methods and procedures applied	National environmental agencies or similar government and research institutions have accurate peer-reviewed studies that provide Ym values. Therefore, these values must be preferred and used where direct applicability can be demonstrated. The IPCC default values for the Ym (Table 7 in Appendix III) are provided for the different animal categories which can be used when no respective values are available from country-specific research. The associated uncertainty estimation of ± 1% of the IPCC Ym values reflects the fact that diets can alter the proportion of feed energy emitted as enteric methane. Table 8 in Appendix III provides Ym values derived from cattle with diets containing various levels of neutral detergent fibers (NDF). The NDF values of the feed used in the project must be available in order to use Table 8. Detailed information can be found in Appendix III.

	The *IPCC Guidelines for National Greenhouse Gas Inventories* is internationally recognized and the data provided in the guidelines is peer reviewed. Parameters from any source (e.g., IPCC or national agencies) must apply the most conservative value of any uncertainty component. Parameters to be updated each crediting period where new data exists.
Purpose of Data	Calculation of baseline emissions
Comments	N/A

Data / Parameter	NDF_j
Data unit	Dimensionless
Description	Forage quality indices (% Neutral detergent fibers)
Equations	None
Source of data	Records and data from livestock operator or associated partners for three continuous years of historical data prior to the initiation of the project or from national/regional statistical accounts. Records and data during the project implementation also required.
Value applied	N/A
Justification of choice of data or description of measurement methods and procedures applied	Data must be provided by the livestock operator or associated partners for each animal group. The assessment of the quality of forages is typically provided by the farmer's nutritionist formulating the rations for the animals. NDF values are used to determine the Ym. Detailed information can be found in appendix III.
Purpose of Data	Calculation of baseline emissions
Comments	N/A

Data / Parameter	ED
Data unit	MJ per kg of dry matter
Description	Energy content of dry matter
Equations	4
Source of data	Default value or farm specific data
Value applied	N/A

Justification of choice of data or description of measurement methods and procedures applied	Farm specific values should be used, when available, otherwise use the typical values provided below: The typical energy density of feedstuff is: - 18.45 MJ kg'$^{-1}$ may be used as a default for diets including edible oils with fat contents in the range of 4 to 6% - 19.10 MJ kg'$^{-1}$ may be used as a default for diets including edible oils with fat contents below 4% Parameters to be updated each crediting period where new data exists.
Purpose of Data	Calculation of baseline emissions
Comments	N/A

Data / Parameter	EC
Data unit	MJ per kg of methane
Description	Energy content of methane
Equations	3
Source of data	Default value taken from IPCC 2006 guidance (Section 10.3.2)
Value applied	55.65
Justification of choice of data or description of measurement methods and procedures applied	This is a standard property of methane. In addition, the *IPCC Guidelines for National Greenhouse Gas Inventories* is internationally recognized and the data provided in the guidelines is peer reviewed. Parameters to be updated each crediting period where new data exists.
Purpose of Data	Calculation of baseline emissions
Comments	N/A

Data / Parameter	$EF_{Enteric\,i,j}$
Data unit	kg CH_4 per animal group
Description	Enteric methane emission factor for each animal group
Equations	1
Source of data	Calculated using equation 2 or 3 or 5
Value applied	N/A
Justification of choice of data or description of	To allow for flexibility for potential projects, this methodology provides different options to calculate baseline emissions.

measurement methods and procedures applied	For option 2 and option 3 the first step in collecting data should be to investigate existing national statistics, national industry sources, research studies and International Environmental Agencies or FAO statistics. National environmental agencies or similar government and research institutions have accurate peer-reviewed data on emission factors or Ym for each animal group. Where no data are available on-site farm measurements can be performed (baseline option 1). The direct enteric methane measurements for ruminants can be conducted using state of the art technologies, well documented in the scientific literature and peer reviewed publications, see examples in table 6 in Appendix II. Parameters from any source (e.g., IPCC, national agencies, or direct measurement) must apply the most conservative value of the uncertainty component. Parameters to be updated each crediting period where new data exists.
Purpose of Data	Calculation of baseline emissions
Comment	Where direct measurements of methane emissions are performed, the project proponent or associated partner must demonstrate experience in methane measurement technologies (i.e., a professional in the area of animal science, livestock health and nutrition who has an M.Sc. or Ph.D. in the relevant discipline).

Data / Parameter	GWP of CH_4
Data unit	tCO_2/tCH_4
Description	Global warming potential of methane
Equations	1,6
Source of data	IPCC defaults
Value applied	N/A
Justification of choice of data or description of measurement methods and procedures applied	The IPCC Guidelines for National Greenhouse Gas Inventories is internationally recognized, and the data provided in the guidelines is peer reviewed. To be updated each crediting period where new data exist or accepted by Verra.
Purpose of Data	Calculation of baseline emissions
Comments	N/A

Data / Parameter:	PE_j
Data unit:	kg CH_4 head^{-1} day^{-1}
Description:	Average project enteric CH_4 emissions calculated by direct measurements using the chosen technology in farm *i* during the monitoring period (kg CH_4 head^{-1} day^{-1})
Equations	7
Source of data:	Measured for each animal group. Data records and study report of farm operations.
Value applied	N/A
Justification of choice of data or description of measurement methods and procedures applied	To quantify the project enteric CH_4 an animal sample for each group is selected to perform the direct measurement. The project proponent needs to describe the required sampling protocols against objectives conditions. Sampling protocols should include sufficient numbers and sampling times to account for diurnal and postprandial variation in CH_4. All CH_4 measurement techniques are subject to experimental variation and random errors therefore it should be taken into account when reporting the final enteric CH_4 emission value. Detailed information can be found in appendix II. Parameter to be updated each crediting period or where the PE value is no longer representative (e.g., due to changes in feed regime, animal type, weight, production phase, geographic region, and management practices) new data must be collected.
Purpose of Data	Determination and calculation of project emissions
Comments	Because this requires direct measurements of methane emissions project proponent or associated partner must demonstrate experience in methane measurement technologies (i.e., a professional in the area of animal science, livestock health and nutrition who has an M.Sc. or Ph.D. in the relevant discipline).

Data / Parameter:	$ERF_{Enteric\ j}$
Data unit:	Percentage (dimensionless)
Description:	Enteric emission reduction factor
Equations	6 or 7
Source of data:	Provided by the feed manufacturer for each animal group or calculated using equation 6. Data records and study report of farm operations.
Value applied	N/A

Justification of choice of data or description of measurement methods and procedures applied	For equation 6 the default percentage value is determined from data provided by the feed supplement manufacturer (Option 1). For equation 7 (option 2) the project proponent must provide evidence to demonstrate the percentage enteric CH_4 reduction for each animal group. The project proponent will need to provide during verification the scientific protocol and the results of the measurements. Parameters from the feed manufacturer must apply the most conservative value of the uncertainty component.
Purpose of Data	Determination and calculation of project emissions
Comments	N/A

Data / Parameter:	$EFProduction_{i,j}$
Data unit:	kg CH_4 head^{-1} day^{-1}
Description:	Average project enteric CH_4 emissions calculated by direct measurements using the chosen technology A in farm *i* during the monitoring period (kg CH_4 head^{-1} day^{-1})
Equations	2
Source of data:	Measured for each animal group. Data records and study report of farm operations
Value applied	N/A
Justification of choice of data or description of measurement methods and procedures applied	To quantify the project enteric CH_4 production per animal samples for each group are selected to perform the direct measurement (option 1). The project proponent needs to describe the required sampling protocols for the relevant project conditions. Sampling protocols should include sufficient numbers and sampling times to account for diurnal and postprandial variation in CH_4. In animal studies the most favoured and most scientific method is the calculation of sample size by power analysis (Charan and Kantharia, 2013). All CH_4 measurement techniques are subject to experimental variation and random errors, therefore it should be taken into account when reporting the final enteric CH_4 emission value. Detailed information on reporting such error can be found in Appendix II. Parameter to be updated each crediting period or where the value is no longer representative (e.g., feed regime, animal type, weight, production phase, geographic region, and management practices).
Purpose of Data	Determination and calculation of baseline emissions
Comments	Because this requires direct measurements of methane emissions project proponent or associated partner must demonstrate experience in methane measurement technologies (i.e, at least one team member

	should be a professional in the area of animal science, livestock health and nutrition who has an M.Sc. or Ph.D. and working/research experience in the relevant discipline)

Data / Parameter:	$EF_{i,j}$
Data unit:	kg CH_4 $head^{-1}$
Description:	Average enteric CH_4 emissions factor for each animal in the group *j* during the monitoring period (country or regional specific factors or table 4), (kg CH_4 $head^{-1}$ day^{-1})
Equations	5
Source of data:	Country or regional and population specific factors should be used when available, to better reflect the ruminants' population characteristics. Default values provided in Table 4 may be used as an alternative where regional values are not available.
Value applied	N/A
Justification of choice of data or description of measurement methods and procedures applied	Country or regional specific EF values should be used, when available, to reflect the ruminant's characteristics. When not available, use the default values provided in Table 4. Parameters from any source (e.g., IPCC or national agencies) must apply the most conservative value of the uncertainty component, (i.e., a 50% reduction must be applied to values taken from Table 4) Parameter to be updated each crediting period where new data exists.
Purpose of Data	Determination and calculation of baseline emissions
Comments	N/A

9.2 Data and Parameters Monitored

Data / Parameter:	N_{ij}
Data unit:	Number of animals (head)
Description:	Average number of head in each animal grouping *j* in the farm *i* consuming a supplement during the monitoring period.
Equations	2, 3, 5 and 7
Source of data:	Data records of livestock operations using the feed supplement. Farm records.
Description of measurement methods and procedures to be applied:	Farm inventory data must be calculated as the average number of animals in each grouping, taking into account animal entry and exit movements from the grouping; this is a weighted average approach using the animal head*days factor; an example is demonstrated in the table below.

	<table><tr><td>Days on feed</td><td>Number of head</td></tr><tr><td>1</td><td>100</td></tr><tr><td>2</td><td>100</td></tr><tr><td>3</td><td>103</td></tr><tr><td>Total=3</td><td>Avg=101</td></tr></table>
Frequency of monitoring/recording:	Single value depending on the number of heads in each animal grouping using the natural feed supplement. Measured by daily or weekly average records.
QA/QC procedures to be applied:	Each farm record must list the number of animals in each group. Management and monitoring system to be established by the project proponent at the start of project. It could include data recording and verification procedures.
Purpose of data:	• Calculation of baseline emissions • Calculation of project emissions • Calculation of emission reduction
Calculation method:	No calculations are needed.
Comments:	Monitoring is established at the feed purchaser level. An appropriate and unique identification system for the purchasers, e.g. Project participant name, tax identification number, number of animals in each group, unique invoice number and date, would avoid double counting of emissions reduction claimed. At the time of reporting, baseline and project emissions shall be calculated based on livestock population, climatic conditions and other factors specific to the project and time period.

Data / Parameter:	Days
Data unit:	Days
Description:	Number of days project activity implemented in the specific animal grouping.
Equations	2, 3, 5, and 7
Source of data:	Data records of livestock operations using project feed supplement
Description of measurement methods and procedures to be applied:	None

Frequency of monitoring/recording:	Once for start date of supplement feeding and once for end date of supplement feeding, for each animal grouping
QA/QC procedures to be applied:	Management and quality control system to be established by the project proponent at the start of project. It could include data recording and verification procedures. The number of days could be less than 365. For example, in the case of young cattle the number of days represents the length of stay in a specific animal group.
Purpose of data:	• Calculation of baseline emissions • Calculation of emission reduction
Calculation method:	No calculations are needed
Comments:	N/A

Data / Parameter:	j
Data unit:	Animal grouping
Description:	Animals at each farm *i* should be grouped based on a homogenous ruminant population characterization
Equations	1,2, 3, 5, 6 and 7
Source of data:	Data records of livestock operations using project feed supplement.
Description of measurement methods and procedures to be applied:	Ruminant Population Characterization: Methane emissions from ruminants vary by animal type, weight, production phase (e.g., pregnant or lactating cow), feed type and seasonal conditions. Accounting for these variations in a ruminant population throughout the year is important to accurately characterize annual emissions. Project proponents must provide evidence at each validation and verification that emissions estimates are based on a homogenous population and the herd size and individual animal characteristics remain constant for a given period. Table 10.1 Representative Livestock Categories, in the IPCC 2006 report is an example of detailed characterization required for each livestock species.
Frequency of monitoring/recording:	Once for validation and at least once per monitoring period
QA/QC procedures to be applied:	Management and quality control system to be established by the project proponent at the start of project. It could include data recording and verification procedures.
Purpose of data:	• Calculation of baseline emissions • Calculation of emission reduction
Calculation method:	No calculations are needed

Comments:	N/A

Data / Parameter:	FM
Data unit:	Kg per month
Description:	Amount of feed supplement purchased by the farm *i* during the monitoring period
Equations	8,10
Source of data:	Data records of livestock operations purchasing project feed supplement
Description of measurement methods and procedures to be applied:	Monitoring is established at the feed purchaser level. An appropriate and unique identification system for the purchasers, e.g. Client name, unique invoice number and date, feed purchase receipts, weights, etc. and/or; feed delivery records. Delivery notes and invoices need to be reconciled between buyer and seller to verify records integrity. Sales records should be cross-checked with both buyer and seller of the feed supplemental to make sure records are consistent.
Frequency of monitoring/recording:	Monthly
QA/QC procedures to be applied:	Management and quality control system to be established by the project proponent at the start of project. It could include data recording and verification procedures. Farm records or third-party managed data showing both monthly-purchased complete feed and manufactured complete feed delivered to each grouping
Purpose of data:	Calculation of project emissions
Calculation method:	No calculations are needed
Comments:	Necessary to measure in order to determine monthly volumes of the feed supplement purchased.

Data / Parameter:	EF_P
Data unit:	tCO2e kg^{-1}
Description:	Emission factor for production of feed supplement. GHG emitted per kg of feed. All activities involved at the manufacturer's production facility of the feed supplement.
Equations	9

Source of data:	Records and documentation provided by the feed manufacturer.
Frequency of monitoring/recording:	Monthly
QA/QC procedures to be applied:	These values must be based on well-documented, reliable sources (e.g., national energy balances, government publications, industry associations, WRI/WBCSD GHG Protocol)
Purpose of Data	Determination and calculation of project emissions
Calculation method:	No calculations are needed
Comments	N/A

Data / Parameter:	EFT_i
Data unit:	tCO2
Description:	Emission factor for transportation of feed supplement to the feed mill or directly to the farm *i* during the monitoring period. GHG emitted per kg of feed.
Equations	10
Source of data:	Records and documentation provided by the feed manufacturer.
Frequency of monitoring/recording:	Monthly
QA/QC procedures to be applied:	The project proponent must provide evidence to demonstrate the level of emission the monitoring period. These values must be based on well-documented, reliable sources (e.g., national energy balances, government publications, industry associations, WRI/WBCSD GHG Protocol)
Purpose of Data	Determination and calculation of project emissions
Calculation method:	No calculations are needed
Comments	N/A

Data / Parameter:	Qelec
Data unit:	MWh kg^{-1}
Description:	Quantity of electricity used by production facility supplied by the grid per kg of feed supplement produced
Equations	9

Source of data:	Documentation and date provided by the feed manufacturer
Description of measurement methods and procedures to be applied:	Electric utility bills provided by the manufacturer. For the production of the feed supplement, the monitoring would be for the manufacturer to provide the electricity consumption at the specific production line used for the manufacturing of the monthly quantity. Alternatively, where product line level data is not available the manufacturer can use a ratio based on the percentage the feed supplement represents in the total volume produced by the facility.
Frequency of monitoring/recording:	Monthly
QA/QC procedures to be applied:	To confirm the production of feed supplement monthly production output data need to be available by the manufacturer.
Purpose of data:	Calculation of project emissions
Calculation method:	No calculations are needed
Comments:	N/A

Data / Parameter:	Qff
Data unit:	Volume or kg fuel/kg feed supplement
Description:	Quantity of fossil fuel used (L, m^3 or other of each type of fuel used) at the production facility per kg feed supplement produced.
Equations	9
Source of data:	Report provided by the feed manufacturer
Description of measurement methods and procedures to be applied:	Fossil fuel invoices provided by the manufacturer. For the production of feed supplement, the monitoring would be for the manufacturer to provide the quantity of fossil fuel used at the specific production line for the manufacturing of the monthly quantity. Alternatively, where product line level data is not available the manufacturer can use a ratio based on the percentage the feed supplement represents in the total volume produced by the facility.
Frequency of monitoring/recording:	Monthly
QA/QC procedures to be applied:	To confirm the production of feed supplement monthly production output data need to be available by the manufacturer.
Purpose of data:	Calculation of project emissions
Calculation method:	No calculations are needed
Comments:	N/A

Data / Parameter:	EF_{elec}
Data unit:	kg CO2 MWh^{-1}
Description:	Emission factor for electricity
Equations	9
Source of data:	Country-specific emission factors for grid electricity from a reputable regional or national source. Otherwise from an International organization like the International Energy Agency (IEA).
Description of measurement methods and procedures to be applied:	Default values must be sourced from recognized, credible sources and be geographically and temporally relevant to project specifics. Estimation, reference values must be obtained from the relevant national GHG inventory. The value used should be consistent with the source of generation. In the absence of local or regional data, reference values may be obtained from the most recent version of the IPCC guidelines for National Greenhouse Gas Inventories.
Frequency of monitoring/recording:	Annual
QA/QC procedures to be applied:	N/A
Purpose of data:	Calculation of project emissions
Calculation method:	No calculations are needed
Comments	The latest approved versions of CDM tools “Tool to calculate the emission factor for an electricity system” may be used to determine EFelec where country or state/province data are not available. https://cdm.unfccc.int/methodologies/PAmethodologies/tools/am-tool-07-v7.0.pdf

Data / Parameter:	FCa
Data unit:	TJ //volume or kg of fuel
Description:	Energy content per unit of fuel type *a*
Equations	9
Source of data:	Regional or national default values from recognized sources or IPCC reports
Description of measurement methods and procedures to be applied:	Where more than one recognized source is available, the most appropriate source must be selected, based on data quality indicators including technological appropriateness, regional specificity, and vintage of the data.

	These values must be based on well-documented, reliable sources (e.g., national energy balances, government publications, industry associations, WRI/WBCSD GHG Protocol) In the absence of local or regional data, reference values must be obtained from the most recent version of the IPCC guidelines for National Greenhouse Gas Inventories.
Frequency of monitoring/recording:	Annual
QA/QC procedures to be applied:	N/A
Purpose of data:	Calculation of project emissions
Calculation method:	No calculations are needed
Comments	N/A

Data / Parameter:	EF_{fuel}
Data unit:	kg GHG (CO_2, CH_4, N_2O) per L, m^3 or other of each type of fuel used
Description:	Emission factor for fuel combustion type
Equations	9
Source of data:	Regional or national default values from recognized sources or IPCC reports
Description of measurement methods and procedures to be applied:	Where more than one recognized source is available, the most appropriate source must be selected, based on data quality indicators including technological appropriateness, regional specificity, and vintage of the data.
Frequency of monitoring/recording:	Annual
QA/QC procedures to be applied:	Default values must be sourced from recognized, credible sources and be geographically and temporally relevant to project specifics. These values must be based on well-documented, reliable sources (e.g., national energy balances, government publications, industry associations, WRI/WBCSD GHG Protocol) In the absence of local or regional data, reference values must be obtained from the most recent version of the IPCC guidelines for National Greenhouse Gas Inventories.
Calculation method:	Calculation of project emissions
Comments	This parameter may be updated over the course of the crediting period (as a project description deviation) due to the availability of more recent information.

Data / Parameter:	TEF
Data unit:	Tonnes per km or miles per kg of feed (tCO2 $kg^{-1}km^{-1}$)
Description:	Emission factor values for each mode of transport m
Equations	10
Source of data:	Regional or national default values from recognized sources
Description of measurement methods and procedures to be applied:	Default values must be sourced from recognized, credible sources and be geographically and temporally relevant to project specifics. These values must be based on well-documented, reliable sources. The range of appropriate data must be documented and the chosen data must be justified, using criteria that include data source (recognized and authoritative sources); geographic, temporal and technology specificity; conservativeness (i.e., does not overestimate emission reduction); and where the data is peer reviewed (preferred)
Frequency of monitoring/recording:	Monthly
QA/QC procedures to be applied:	Where more than one recognized source is available, the most appropriate source must be selected, based on data quality indicators including technological appropriateness, regional specificity, and vintage of the data.
Purpose of data:	Calculation of project emissions
Calculation method:	No calculations are needed
Comments:	N/A

Data / Parameter:	D*i*
Data unit:	Distance unit (e.g. kilometers, miles)
Description:	Total distance travelled by transport mode m for farm i (km or miles)
Equations	10
Source of data:	Data provided by the project proponent or manufacturer
Description of measurement methods and procedures to be applied:	Distance travelled by transport mode m delivering feed supplement consumed during the monitoring period to the project location, farm. Where the feed supplement goes through a feedmill then the distance to the feedmill should be measured and not to the farm.
Frequency of monitoring/recording:	Monthly
QA/QC procedures to be applied:	N/A

Purpose of data:	Calculation of project emissions
Calculation method:	No calculations are needed
Comments:	N/A

9.3 Description of the Monitoring Plan

The project proponent must establish, maintain and apply a monitoring plan and GHG information system that includes criteria and procedures for obtaining, recording, compiling and analyzing data, parameters and other information important for quantifying and reporting GHG emissions. Where measurement and monitoring equipment is used, the project proponent must ensure the equipment is calibrated according to current good practice (e.g., relevant industry standards).

The project proponent must be able to demonstrate the ruminants for which it is claiming emission reductions have been fed with the appropriate quantity of feed supplement. In order to do so, project proponents must provide detailed feeding records as per manufacturer instructions (applicability condition 3c) for each farm as well as proof of purchase of an appropriate quantity of the feed supplement. Proof of purchase may be provided through delivery receipts and invoices, which must contain batch information, or other identification information, that can trace the feed supplement back to the manufacturer.

All necessary documents must be collected and centrally stored by the project proponent, and be available for verification at any time. The data subject to monitoring and required for the determination and further verification must be archived and stored in electronic format by the project proponent for at least two years after initial verification.

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APPENDIX I: JUSTIFICATION FOR ACTIVITY METHOD

This initial assessment of activity penetration indicates that there is not enough activity in any country that would put such penetration above the 5% threshold called for in the VCS Program requirements. It is known that no country has an activity penetration rate higher than 5% at this time due to the unique technology availability.

Per the VCS rules, Verra will reassess whether the activity penetration levels remain within the permitted threshold within three years of the initial approval of the methodology. At that time, Verra will base its assessment on national boundaries, focusing on countries where feed supplements that reduce methanogensis have been used. Also, and in the spirit of conservativeness, where sub-national regulations or policies may impact the likelihood of the project activity being implemented, Verra may use such boundaries as the basis of the reassessment of the activity penetration rate.

Positive List

This project activity in particular, and CH_4 enteric fermentation reduction in general, is a relatively recent field with few, if any, fully commercial technologies. Thus, the methodology uses an activity method for demonstrating additionality, with this technology (the natural feed supplement) as the basis for a positive list. This approach stipulates that the total number of ruminants fed with a supplement inhibiting methanogenesis does not amount to five percent of the total number of ruminants in agricultural settings worldwide. Five percent is the activity penetration threshold set by the *VCS Methodology Requirements v4.0*, and is determined by taking the Observed Activity (OA) divided by the Maximum Adoption Potential (MAP). Where the result of this equation is less than five percent, the project activity may be considered additional.

Activity penetration is given as:

$APy = OAy / MAPy$

Where:

APy = Activity penetration of the project activity in year y (percentage)

OAy = Observed adoption of the project activity in year y

$MAPy$ = Maximum adoption potential of the project activity in year y

Maximum adoption potential (MAP) of the project activity in year y

The *VCS Methodology Requirements v4.0* defines MAP as “the total adoption of a project activity that could currently be achieved given current resource availability, technological capability, level of service, implementation potential, total demand, market access and other relevant factors within the methodology's applicable geographically defined market." In this case, given the early stage of feed supplements for reducing enteric methane emissions, it is difficult to say that there are any resource (or other) constraints that would limit the adoption of this technology.

However, for the purposes of this methodology, the maximum adoption potential of this activity may be limited to ruminants that have been reared for the production of meat and dairy products worldwide. The reason for this selection is due to market access and implementation constraints (e.g., necessary infrastructure for getting the feed supplement to the farm, and appropriate facilities to administer the feed supplement to the animal on a regular basis).

The global ruminant livestock population is roughly 3.6 billion[10], of which approximately 2 billion represents the total number of livestock animals used for meat and dairy products. Figure 2 below illustrates the amount of livestock ruminants worldwide11. Table 5 below illustrates the number of livestock animals used for meat and dairy products:

Table 5 Total number of livestock animals used for meat and dairy products

Type of animal	Number of livestock animals
Dairy cattle[12]	278,000,000
Dairy sheep and goat[13]	463,444,034
Cattle for meat production[14]	300,074,797
Sheep, and goat for meat production[15]	989,247,558
TOTAL	2,030,766,389

10 For the purpose of this analysis the ruminant sector comprises cattle, sheep and goat, and buffalo. The global ruminant population in 2010 was estimated to be 3 612 million (FAOSTAT, 2012), with cattle making up nearly 40 percent, sheep and goat 55 percent, and buffalo the remaining 5 percent. (FAO (2017) and https://ourworldindata.org/meat-production#livestock-counts)

11 Data from 1961 onwards is sources from the UN Food and Agricultural Organization (FAO) statistics. Available at: http://www.fao.org/faostat/en/#data/QA

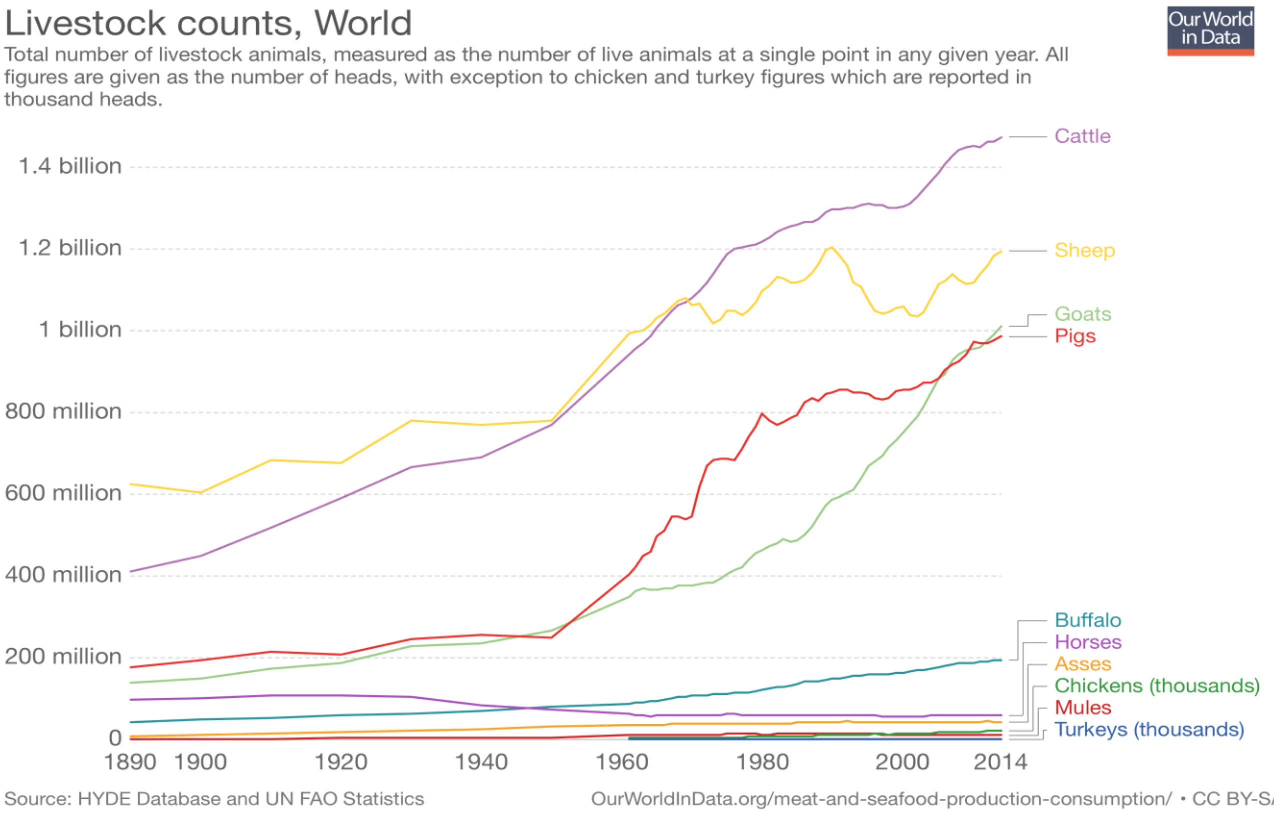
12 https://dairy.ahdb.org.uk/market-information/farming-data/cow-numbers/world-cow-numbers/#.XZxhmS-B2L4

13 Dairy small ruminants account for approximately 21% of all sheep and goats in the world (2'206'876'356 animals, https://ourworldindata.org/meat-production#livestock-counts);

14 Total number of livestock animals slaughtered for meat; FAO (2017) and https://ourworldindata.org/meat-production#number-of-animals-slaughtered-for-meat

15 https://www.sciencedirect.com/science/article/pii/S0022030218305290#targetText=There%20are%20approximately%202%2C200%20million,in%202016%20(799%20Mt)

Figure 2: Total Number of Livestock Animals in The World



According to FAO[16] grazing animals supply about 9 percent of the world's production of beef and about 30 percent of the world's production of sheep and goat meat. In grazing conditions, logistical limitations might occur due to accessibility. Considering that this project activity requires administration of the feed supplement to the animal on a regular basis, grazing animals should be excluded as feeding control cannot be exercised. Dairy animals are not excluded as they can have daily access to the feed in the milking parlour.

Therefore, for the purposes of this methodology, the maximum adoption potential of this activity is limited to MAPy= 1.707 billion.

Observed adoption of the project activity in year y

Few dietary strategies have been proposed to lower methane production in ruminants (Knapp et al, 2014; Boadi et al 2004). However, most of these are not commercially available and/or have no impact

16 http://www.fao.org/3/x5303e/x5303e00.htm#Contents

on enteric fermentation. Currently only a few products have been observed in the market.

Namely, linseed and alfalfa products containing high levels of omega-3 fatty acids can reduce the level of saturated fatty acids, and the elevation of dietary fat levels in ruminant diets may be a suitable way of lowering methane production. From a 2010 report,17 linseed and alfalfa were fed to approximately 50,000 cows. From an article published in 2018,18 a different product consisting of a blend of essential oils that claim to reduce methane production by cattle has reached approximately one million cattle. Neither of these publications report on the reduction of enteric emissions via a reduction of methanogenesis. However, for the purposes of this demonstration of additionality, it is assumed that the project activities are the same. To be conservative it is assumed that the published reports were only capturing half of all enteric emission reduction activities, which results in an estimated activity of 2.1 million ruminants.

Therefore:

APy = OAy / MAPy
APy = 2.1 million / 1'707 billion
APy = 0.123%
APy < 5%

Given the current ruminants population and the commercially available feed supplements, and in particular those which have a significant effect on reducing enteric methane emissions by direct inhibition of methanogens in the rumen, it is demonstrated that the activity penetration level of the project activity covered by this methodology is below the five percent threshold, and the project activity may be deemed additional.

Where the project activity has been commercially available in any area of the applicable geographic scope for less than three years (i.e., it uses a new technology or measure), it shall be demonstrated that the project activity faces barriers to its uptake, per the VCS rules. This proposed project activity faces technological barriers that prevent its implementation:

1. The project activity requires extra effort from the farmers to administer the feed supplement as per feeding instructions provided by the manufacturer. In some cases, this might require properly trained farmers to secure the default level of reduction of the enteric methane emissions, such as the feeding routine and dose, to maintain the technology in a way that does not lead to an unacceptably high risk of equipment disrepair and malfunctioning or other underperformance.

17 http://www.pinallet.com/data/FEEEDINFO%20Interviews%20VALOREX%20CEO.pdf

18 https://www.greenoptimistic.com/swiss-company-develops-new-cow-feed-fewer-farts-20181006/#.XF

2. This project activity implementation will require the purchase of feed supplement, which is an addition to the existing farmers' variable costs. Farmers make multiple decisions in the agricultural cycle about the adoption of products and practices. According to Loevinsohn et al. (2013), farmers' decisions about whether and how to adopt new technology are often the result of a comparison of the uncertain benefits of the new invention with the uncertain costs of adopting it. For adoption to occur, farmers need to know that a technology exists, believe that it will improve productivity, and understand how to use it effectively. Given the early stage of feed supplements for reducing enteric methane emissions, farmers willingness to adopt and carry on the activity increase the risk of technological failure due to the process.

3. Natural products occur during a certain time of year (seasonal crops). Therefore, working capital can fluctuate drastically which can lead to an unacceptably high risk of technology availability. Since this methodology is based on natural plant-based technology, the project activity implementation will require management of the seasonal effects on working capital. During the seasonal peak, the company will require higher net investment in short-term (current) assets.

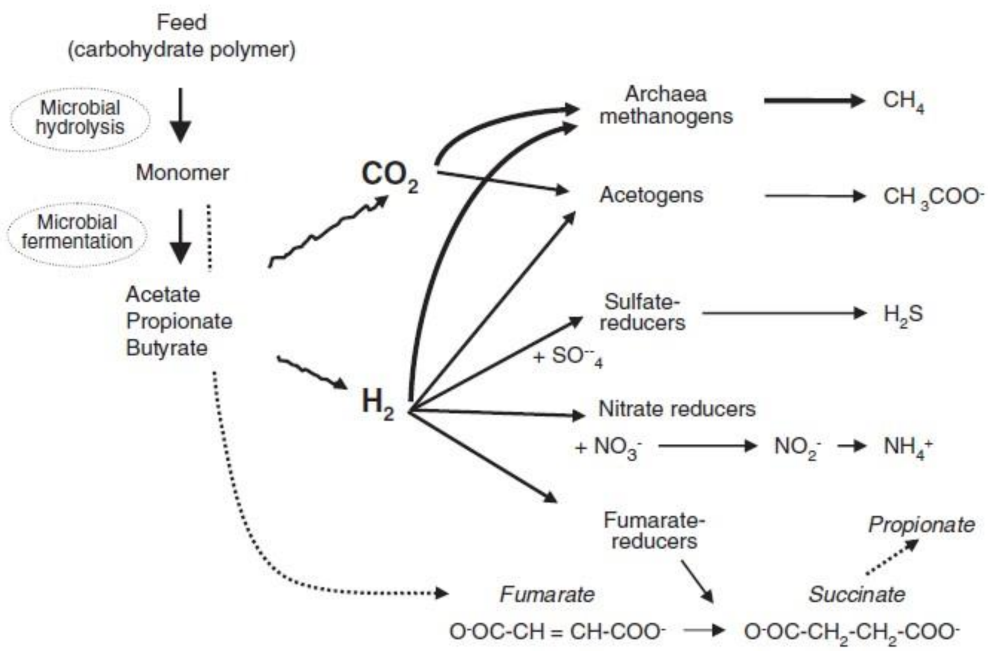
APPENDIX II: BACKGROUND INFORMATION ON PROJECT ACTIVITY

Enteric fermentation is the second largest source of global emissions from livestock supply chains, contributing about 40 percent of total emissions. Cattle emit 77 percent of all enteric methane (Gerber et al., 2013). Ruminants, in particular, release methane as a result of their digestion process of feed material in the rumen. These are enteric emissions from ruminants and are significant contributors to greenhouse gas emissions.

Research on various feed management activities has already been conducted to assess their ability to reduce methane production (Eger et al., 2018). Enteric methane is produced from microbial fermentation of feed (HOBSON et al., 1981; Whitford et al., 2001). Primary anaerobic microbiomes degrade organic matter into volatile fatty acids. In this process, hydrogen gas and carbon dioxide are produced as by-products. Methanogens metabolize hydrogen and carbon dioxide into methane (HEGARTY, 1999; Moss et al., 2000). Figure 1 provides an illustration of the microbial fermentation of feed polysaccharides and H_2 reduction pathways to CH_4 in the rumen.

The production of methane in the rumen can represent a loss of energy up to 12% (Johnson and Johnson, 1995). Therefore, production increases and energy efficiencies by the natural feed supplement could be seen as complementary outcomes when enteric methanogenesis is reduced (Graz et al., 2017). An additional goal of reducing enteric fermentation is to enable livestock producers to improve the environmental profile of meat and dairy products and provide consumers with sustainable climate-friendly products with a quantified carbon footprint reduction.

Figure 3: Schematic microbial fermentation of feed polysaccharides and H_2 reduction pathways to CH_4 in the rumen (Morgavi et al., 2010).



Direct enteric methane measurements

The direct enteric methane measurements for ruminants may be conducted using state of the art methods, well documented in the scientific literature. This includes respiration chambers as an established and widely used technique since 1958. However, some operations require measurements of CH_4 emissions of a larger number of animals, and therefore, short-term measurement techniques such as automated head chambers (e.g., the GreenFeed system) and (handheld) laser CH_4 detection (Hammond et al., 2016) are used to meet this objective with the spot measurement of gas concentrations in samples of exhaled air at certain time points. Repeated spot measurements can be taken whilst the animals are feeding or standing, and during the milking parlour for dairy operations. There are diverse technologies being used worldwide for quantifying enteric methane emission, however, there is no joined-up protocol covering all aspects, including, data collection, data extraction, data handling, and estimating methane volume from the measured concentration. Experience in animal studies is required to develop a protocol to generate accurate results.

In case the manufacturer of the natural feed supplement cannot provide sufficient documentation to support a default emission reduction factor, the project proponent must perform direct enteric methane measurements. The baseline emissions factors may still be set using option 2 or 3 as described in Section 8.1 above. Overall the chosen measurement technology and the measuring procedures must meet the following conditions:

1. The technology must be well documented in the scientific literature in peer-reviewed publications.

2. The technology enables measurements for animals in their ‘normal’ environment, which can be applied under conditions relevant to project livestock production.

3. The measurement error of the technology and sample error needs to be reported under the project conditions.

4. The project proponent or associated partner need to demonstrate technical skills and experience in operating direct enteric methane measurements to generate accurate results

5. The recommended measurement protocol needs to determine optimal sample size and recording duration.

6. The project proponent shall estimate the measurement uncertainty and apply confidence deductions to reduce bias and uncertainties as far as is practical. Methods used for estimating uncertainty shall be based on recognized statistical approaches such as those described in the *IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories*. Confidence deductions shall be applied using conservative factors such as those specified in the *CDM Meth Panel guidance on addressing uncertainty in its Thirty Second Meeting Report, Annex* 14

Table 6 provides a description of three different technologies for direct measurement of enteric methane emissions and, therefore, calculate the emission reductions following a specific scientific protocol. These three technologies are used for demonstration purposes and are not restrictive, as improving technologies could allow more accurate measurements in the future.

Table 6: Measurement technologies of enteric methane emissions

Type of measurement method/technology	Description of the method/technology
Respiration Chambers	Respiration chambers are used to measure CH_4 at an individual animal level under research conditions. The principle of the respiration chamber is to collect exhaled CH_4 emissions from all sources of enteric fermentation (mouth, nostrils and rectum) from the animal and measure the concentration. The cow needs to be in the chamber up to 4 days. All open-circuit chambers are characterized by an air inlet and exhaust fans. Each chamber is fitted with internal ventilation fans for efficient mixing of expired gases and incoming gases. The chamber is equipped with sensors for measuring relative humidity, temperature, barometric pressure and gas (CH_4, H_2, O_2, H_2S).
Automated head chambers – Infra-red method for methane measurements (e.g., GreenFeed – Large Animals)	Short-term CH_4 emissions can be measured by automated head chambers. One such device is the GreenFeed (GF) system (C-Lock Inc., Rapid City, South Dakota, USA). The GreenFeed (GF) system is a static short-term measurement device that measures CH_4 (and other gases including CO_2) emissions from individual ruminant by integrating measurements of airflow, gas concentration, and detection of head position during each animal’s visit to the unit (Zimmerman and Zimmerman, 2012).

Laser system for methane detection (LMD)	A handheld methane detector (LMD) is a tool for estimating the methane emissions from individual ruminants by measuring the profiles of the exhaled air. The method uses laser absorption spectroscopy to measure the methane concentration (ppm-m) in a distance of one meter, between the hand-portable instrument and the solid target (cow’s nostrils). The analysis is based on real-time breath analysis. The measurement time depends on the natural fluctuation, which arises around once in three minutes (Chagunda et al., 2013).

APPENDIX III: Y_M PERCENTAGE OF GROSS ENERGY IN FEED CONVERTED TO METHANE FOR A SPECIFIC ANIMAL GROUP

The Ym value is defined as the percentage of gross energy intake by the ruminant that is converted to methane in the rumen. As mentioned in section 9 for Ym, national environmental agencies or similar government and research institutions have accurate peer-reviewed studies that provide Ym values.

In the IPCC guidelines (1996) default values for the CH_4 conversion rates are provided for the different animal categories when no respective values are available from country-specific research (table 7). These estimates are based on the general feed characteristics and production practices found in either developed or developing countries. The associated uncertainty estimation of ± 1% of the Ym values reflects the fact that diets can alter the proportion of feed energy emitted as enteric methane. When the quality of the feed is good the lower bounds should be used (i.e., high digestibly and energy value). Higher bounds are more appropriate when poorer quality of feed is available. Neutral detergent fiber (NDF) is often considered a good determinant of quality. NDF measures total cell wall content of plant and indicates maturity; the higher the value, the more mature and lower quality the forage.

Table 7:Livestock CH_4 Conversion Factors[19,20]

Livestock category	Ym 21
Feedlot fed Cattle 22	3.0% ± 1.0%
Dairy Cows (Cattle and Buffalo) and their young	6.5% ±1.0%

19 When the quality of the feed is high the lower bounds should be used (i.e., high digestibly and energy value). Higher bounds are more appropriate when poorer quality of feed is available. The neutral detergent fiber (NDF) provides information to the quality of the feed. NDF within a given feed regime is a good measure of feed quality and plant maturity. For legume forages, NDF content below 40% would be considered high quality, while above 50% would be considered poor. For grass forages, NDF < 50% would be considered high quality and > 60% as low quality.

20 Note that in some cases, CH_4 conversion factors may not exist for specific livestock types. In these instances, CH_4 conversion factors from the reported livestock that most closely resembles those livestock types can be reported. For example, CH_4 conversion factors for other cattle or buffalo could be applied to estimate an emission factor for camels.

21 The methane conversion factor ± values represent the range.

22 When fed diets contain 90 percent or more concentrates

Other Cattle and Buffaloes that are primarily fed low quality crop residues and by- products	6.5% ±1.0%
Other Cattle or Buffalo – grazing	6.5% ± 1.0%
Lambs (<1 year old)	4.5% ± 1.0%
Mature Sheep	6.5% ± 1.0%
Source: 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 4, Chapter 10, table 10.12 and table 10.13.	

The following Table 8 may be used (as an alternative to Table 7) to estimate Ym. The values of the table are derived from cattle with diets containing various levels of NDF. The NDF values of the feed used in the project must be available in order to use Table 8.

Table 8: Estimates of the Percentage of Gross Energy in Feed Converted to Methane (Ym) for Various Diets (Grainger and Beauchemin, 2011 and Moate et al. 2011)

Various Diets	Ym (% of GEI)
Default (unknown diet composition)	6.50%
Diet with < 25% NDF	5.50%
Diet with 25-30% NDF	6.25%
Diet with 30-50% NDF	6.50%
Diet with >50% NDF	7%
Situations in which adjustments apply to YM values above*	
Feeding fats*	
Calcium salts of palm oil (or similar bypass fats)	No reduction
Other Fat Sources*, not to exceed 80 g fat/kg DM . Reduction of Ym for each 10g increase in fat content per kg of animal feed on a dry matter basis (10g fat/kg DMdiet)	-3.40%
*Corn DDGS cannot exceed 20% of dry matter of ration, and the higher protein content of the DDGS must be addressed in the ration formulation to prevent excess nitrogen excretion. The procedures to implement proper use of lipids and corn DDGS must be documented by the nutritionist Source: Alberta Offset System: Quantification protocol for reducing greenhouse gas emissions from fed cattle	