METHODOLOGY

GS4GG PAA M400-03

SDG 13

IN-SITU CAPTURE AND CONVERSION OF CATTLE ENTERIC METHANE

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SUMMARY

Cattle release methane (CH_4) as a result of digesting 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. The animals must remove this hydrogen, and to do so, they produce methane, which is released by respiration and eructation into the atmosphere. These emissions are called enteric emissions.

This methodology is to enable activities which capture methane produced by cattle from enteric fermentation and render these emissions neutral in situ through conversion into gases with lower global warming potentials (GWPs), such as carbon dioxide (CO_2).

ACKNOWLEDGEMENT

This methodology was developed by TREES Consulting and ZELP Ltd.

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1| KEY INFORMATION

1.1.1 | The following table describes the key information for the application of the methodology.

Table 1. Key information

Term	Description
Typical mitigation activity (project) type	This methodology focuses on activities which capture methane produced by cattle from enteric fermentation and render these emissions neutral in situ through conversion into gases with lower GWPs (e.g., carbon dioxide).
Activity Requirement	Land Use & Forests Activity Requirements
Mitigation activity (project) type	Agriculture (livestock)
Sectoral scope	SS 15: Agriculture
Applicable Gold Standard for Global Goals (GS4GG) products	☒ Gold Standard Verified Emissions Reduction (GS-VERs) ☒ Certified Impact Statement
Geographical applicability	Global
Applicable activity (project) scale	☒Micro scale ☒ Small scale ☒ Large scale An activity can claim emission removals less than or equal to: • 10,000 tCO_2 eq per year for micro-scale activity • 60,000 tCO_2 eq per year for small-scale activity • No emission per year cap for large-scale activity
Mitigation type	☒ Emission reduction ☐ Emission removal
Project activity start date	The project activity start date is the date of entry into operation of the methane capture and conversion system for the project.
Crediting period start date	The crediting period start date is the date of entry into operation of the first methane capture and conversion system or a maximum of three years prior to the date of activity design certification, whichever occurs later.
Crediting period length	A maximum of fifteen years; the mitigation activity follows five-year renewal cycle per latest version of GS4GG requirements for renewal of crediting period. The crediting period is limited by the earliest of the following: - The end of the chosen crediting period. or

	- The end of the technical lifetime of the project equipment, unless the project equipment is replaced by similar equipment. If any legal mandate requiring the mitigation activity comes into force during the crediting period, the activity can be credited only until the date the legal requirements take effect.

2| SCOPE, APPLICABILITY, AND ENTRY INTO FORCE

2.1 | Scope[1]

2.1.1 | This methodology focuses on activities which capture methane produced by cattle from enteric fermentation and render these emissions neutral in situ through conversion into gases with lower GWPs (e.g., carbon dioxide).

2.2 | Applicability

2.2.1 | The project activity shall comply with the applicable GS4GG Land Use & Forests Activity Requirements, Principles & Requirements and meet all of the requirements and conditions below for this methodology to be applicable for GS4GG certification.

2.2.2 | This methodology is applicable under the following conditions:

a. Core Project Requirements:

   i. **Geographic Scope:** Projects are eligible in all countries.

   ii. **Project Type:** Both standalone project and Programmes of Activities (PoAs) are eligible.

   iii. **Primary Activity:** The project activity shall reduce methane emissions from enteric fermentation in cattle through in situ methane capture and conversion.

b. **Technology and Data Integrity:**

   i. **Proven Efficacy:** The methane capture and conversion system shall have consistently proven efficacy of emissions reductions in in vivo application with cattle, and this shall be published in peer-reviewed scientific literature.

   ii. **Detailed Performance Data:** The published research shall quantify the specific system's emissions reductions. It shall also define applicability of the system, where dependencies on diet, animal type, age and weight, environmental and management conditions, and any other factors could impact the systems performance with regard to emission reductions.

1 Stakeholders are encouraged to submit requests for revisions to expand the applicability scope. For details, refer to the Procedure for Development, Revision, and Clarification of Methodologies and Methodological Tools.

iii. **Accurate Measurement:** The methane capture and conversion system shall provide accurate data on the total quantity of methane reduced.

iv. **Regulatory Approval:** The technology used in the project activity shall be permitted for use with cattle in the project country and provide evidence for such authorisation by the respective country authority.

   a. **Exception:** In countries without specific regulations, a system may be applied if its application is documented as non-harmful in peer-reviewed publications and is officially used in at least one other country with stringent regulations.

c. **Farm & Operator Eligibility:**

i. **Established Operations:** The methodology is applicable only to farms that have been producing livestock products, i.e., meat or milk, at least three years prior to the project activity start date.

ii. **Historical Data:** Farms shall provide reliable and verifiable data for the last three years, detailing:

   a. Herd size and

   b. Average productivity (e.g., animal weight gain or milk yield) per stratum (animal group).

iii. **Safety & Training:** All livestock managers and handlers participating in the project shall be trained on potential animal and human health risks related to the application of the methane capture and conversion system. The project shall establish and implement clear respective safety and mitigation protocols for all participants.

d. **Environmental & Legal Safeguards:**

i. **Voluntary Action:** The project activity shall not be mandated by any law or regulation.

e. **Scope Limitations:** The methodology shall not be applied to claim benefits from non-related benefits from other sources. If a project expects to generate benefits from the following – not limited to, a respective dedicated GS4GG approved methodology shall be applied instead:

i. increase in carbon pools (greenhouse gas [GHG] sequestration in biomass or soil organic carbon)

ii. emission reductions for feed production and transport, animal transport, or pasture or manure management accounted for under this methodology

iii. from reductions in herd size.

f. **Land Use:**

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

  ii. 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 one year of biomass removal).

  iii. 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).

g. **Deforestation-Free Sourcing:**

  i. The project activity shall not include pastures 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. Feed or feed concentrate use shall not be increased due to the project activity, unless evidence is provided that the feed originates from deforestation-free sources.

2.3 | Safeguards

2.3.1 | The animal health, welfare, and livestock management requirements (P 9.9) 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 | The local stakeholder consultation process shall include at least one veterinary expert or non-governmental organisation with knowledge of animal welfare requirements and practices in the project area.

2.3.3 | Gold Standard may decide to involve an animal welfare expert to review technologies and practices applied in an activity.

2.4 | Entry into Force

2.4.1 | This methodology comes into force on its publication date.

3| NORMATIVE REFERENCES

3.1.1 | This methodology refers to and uses 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 Gold Standard shall be applied.

a. **GS4GG Methodology/ TOOL/ Resources**

i. Procedure for Development, Revision, and Clarification of Methodologies and Methodological Tools V2.0
ii. Methodology Standard - Requirements for additionality demonstration V 1.0
iii. Methodology Standard - Requirements for Methodology Development – V1.0
iv. Land Use & Forests Activity Requirements
v. Land Use & Forests Risks & Capacities Guideline

b. Other documents and publications:

i. Intergovernmental Panel on Climate Change (IPCC) 2019: Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories. Calvo Buendia, E., Tanabe, K., Kranjc, A., Baasansuren, J., Fukuda, M., Ngarize S., Osako, A., Pyrozhenko, Y., Shermanau, P. and Federici, S. (eds). Published: IPCC, Switzerland.
ii. IPCC 2006: IPCC Guidelines for National Greenhouse Gas Inventories, prepared by the National Greenhouse Gas Inventories Programme. Eggleston, H.S., Buendia, L., Miwa, K., Ngara, T. and Tanabe, K. (eds). Published: IGES, Japan.
iii. IPCC 2014, Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II, and III to the Fifth Assessment Report of IPCC. Core Writing Team: Pachauri, R.K. and Meyer, L.A. (eds.)]. Published: IPCC, Geneva, Switzerland.

4| DEFINITIONS

4.1.1 | For the purposes of this methodology, the following definitions based on GS4GG apply.

Table 2. Terms and definitions

Term	Definition
Cattle	Multiple bovines of any gender or age, such as a herd of cattle for dairy or beef.
Enteric fermentation	A digestive process by which organic matter is broken down by microorganisms into simple molecules for absorption into the bloodstream of an animal.
Methane capture and conversion system	A technical system to capture methane produced by ruminant animals and convert the methane into gases with a lower GWP (e.g., carbon dioxide). Such a system commonly includes a capture and conversion unit (e.g., a “wearable” [see definition below] attached to an animal) and a data collection and processing system.

Wearable	An advanced electronic device that is incorporated into an accessory worn on the body or an item of clothing.

5| ACTIVITY BOUNDARY AND GHGS SOURCES/SINKS

5.1 | Activity Boundary

5.1.1 | Spatial and activity boundaries

a. The spatial boundary encompasses the project activities and related areas that are under the project developer's control and those directly influenced by the project that result in GHG emission reductions (Figure 1)

b. This includes all components of the methane capture and conversion system, i.e., mobile components (e.g., wearables) as well as fixed installations needed for operation (e.g., data transfer). For the methane capture and conversion system, this refers to cradle-to-grave emissions for the setup, operation, and end-of-life emissions.

c. Livestock operations (specifically emissions from enteric fermentation, pasture management, and manure management) are included as related sources, sinks, and reservoirs (SSR) to assess baseline emission levels and potential increases of these emissions in the project scenario.

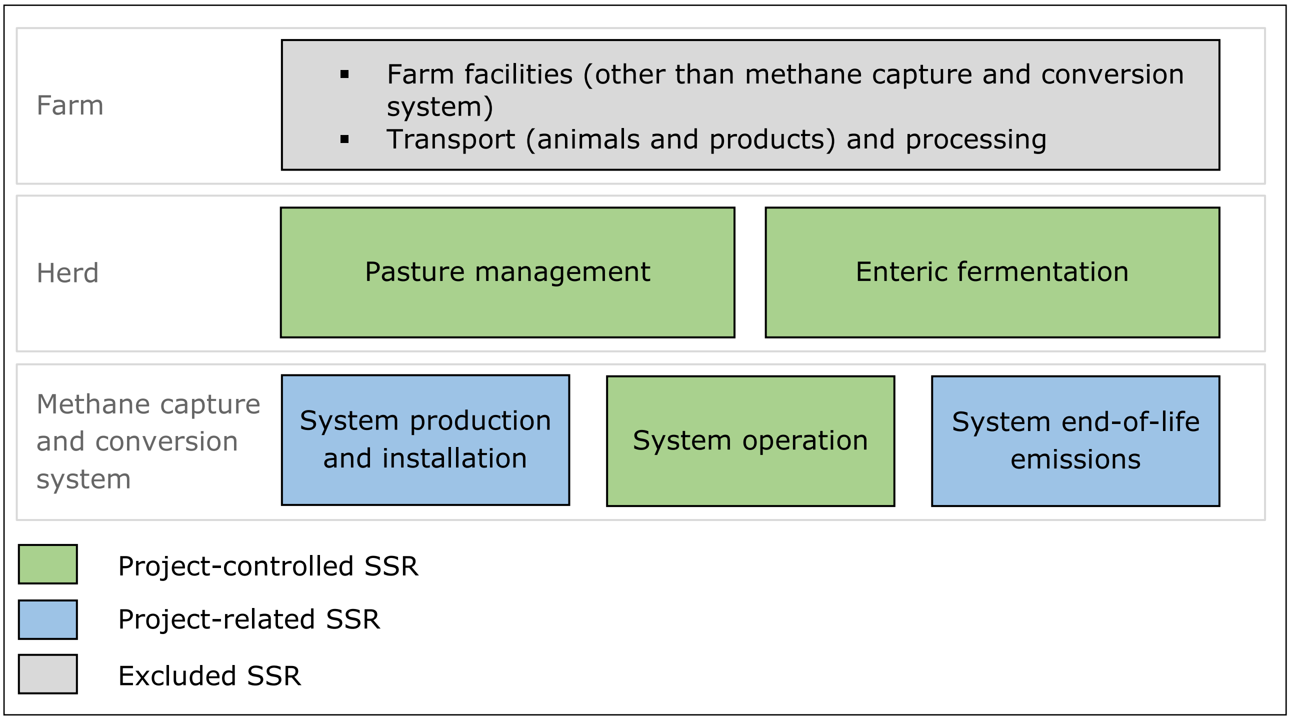

Figure 1. Activity boundaries and relevant GHG SSR

5.2 | Emissions sources included in the project boundary

5.2.1 | The emission sources and primary greenhouse gases (i.e., CO_2, CH_4, N_2O) to be accounted for within the project boundary are summarized in the table below.

Table 3. Emissions sources included in or excluded from the project boundary

Scenario	Source	Gas	Included?	Justification/Explanation
Baseline scenario	Enteric fermentation	CO_2	No	Not emitted in enteric fermentation
		CH_4	Yes	Emitted in enteric fermentation
		N_2O	No	Not emitted in enteric fermentation
	Pasture management	CO_2	No	CO_2 emissions in manure handling are biogenic
		CH_4	No	Not emitted from pasture (manure handling not in scope of methodology)
		N_2O	Yes	Emitted in manure application on pasture
Project scenario	Enteric fermentation	CO_2	No	Not relevant in enteric fermentation
		CH_4	Yes	Emitted in enteric fermentation and reduced in methane capture and conversion system
		N_2O	No	Not emitted in enteric fermentation
	Pasture management	CO_2	No	Not emitted in enteric fermentation
		CH_4	No	Not emitted from pasture (manure handling not in scope of methodology)
		N_2O	Yes	Emitted in manure application on pasture
	System production, operation, and end of life	CO_2	Yes	May be emitted in production process, including from use of fossil energy
		CH_4	Yes	May be emitted from combustion of fossil fuels
		N_2O	No	Not expected to be material in production process

6| DEMONSTRATION OF ADDITIONALITY

6.1.1 | The project developer shall demonstrate that the project could not or would not have been implemented without the benefits of carbon finance. Specific rules and guidelines on how to assess additionality can be found in the extant Gold Standard guidelines on Additionality.

6.1.2 | Additionality shall be demonstrated using the following steps:

A. Regulatory surplus analysis:

6.1.3 | The project activity type is not excluded or declared ineligible by the host country from its eligibility list (e.g., a negative list of activities, technologies, or measures, for issuance of carbon credits). Where no such list is available from the host country, the activity shall be assumed as – NOT excluded.

a. The project activity shall not be mandated by any existing or pending law, statute, regulation, standard, or legal requirement within the host Party's jurisdiction. Evidence shall be provided demonstrating that there is no legal obligation for in-situ capture of methane originating from enteric fermentation of livestock or meet the emission performance level achieved by the project.

b. The assessment shall be conducted at start of 1st crediting period and at each renewal of the crediting period.

6.1.4 | **Lock-in risk analysis:** Use of wearable devices for methane conversion does not lead to locking-in emissions levels or carbon emissions-intensive practices by prolonging the lifetime of emissions-intensive technologies or by new installations using emissions-intensive technologies. Lock-in risk analysis is not required to be carried out at the activity level as justified in Appendix A3, however the developer shall demonstrate compliance with the requirements as outlined in Appendix A3.

6.1.5 | **Common practice analysis:** The analysis in Appendix A4 concludes that the technology is not common practice. Therefore, projects that meet the applicability conditions of this methodology are considered to have satisfied the common practice test and are not required to conduct a project level common practice analysis.

B. Financial additionality:

6.1.6 | Activities would demonstrate that the mitigation activity is not financially viable or faces significant barriers without carbon credit revenue and that carbon credit revenue decisively improves the financial viability or elevate the barriers for the mitigation activity, and can make the activity viable. Project activities classified as 'Large scale' are required to demonstrate additionality using the Investment Analysis. 'Small scale' and 'Micro scale' activities may use either the Investment Analysis or the Barrier Analysis.

6.1.7 | **Investment Analysis (if used):** Conduct a comparative financial analysis (e.g., Net Present Value (NPV), Internal Rate of Return (IRR), Levelized Cost of Electricity (LCOE) production) of the project activity versus the baseline scenario. Demonstrate that the project activity, without the carbon revenues, is economically less favorable than the baseline and with carbon revenues, mitigation activity becomes the most financially attractive scenario. This is highly plausible given the current higher upfront costs associated with the technology under consideration. The analysis shall use realistic, documented, and conservative assumptions for capital costs, operating costs (including fuel prices), electricity prices, discount rates, etc. Sensitivity analysis shall be performed on key parameters.

6.1.8 | **Barrier analysis:** Barrier analysis may be applied for microscale and small-scale activities with or without a financial viability analysis. For large-scale activities, it may be applied in combination with financial viability analysis. Activity developers shall demonstrate that implementation of wearable devices for methane conversion would be prevented by barriers and that carbon credit revenue makes the determining difference for overcoming the barriers such as Institutional barriers, information barriers, financial barriers, investment barriers or other barriers that may be considered specific to the activity circumstances.

C. Ongoing Financial Needs Assessment:

6.1.9 | The activity developer shall conduct the ongoing financial needs at the time of renewal of crediting period to demonstrate compliance with:

a. Regulatory surplus (mandatory), AND
b. Financial viability analysis, performance analysis, or barrier analysis—whichever approach was applied for the mitigation activity's first crediting period.

7| BASELINE SCENARIO

7.1 | Selection of Baseline Approaches

7.1.1 | Choose one or more option(s):

☐ Best available technologies that represent an economically feasible and environmentally sound course of action, where appropriate.

☐ An ambitious benchmark approach where the baseline is set at least at the average emission level of the best performing comparable activities providing similar outputs and services in a defined scope in similar social, economic, environmental and technological circumstances.

☒ An approach based on existing actual or historical emissions, adjusted downwards (for example, using a baseline contraction factor).

7.2 | Justification for the Baseline Approach

7.2.1 | The selected approach, which determines the baseline using existing actual or historical emissions, is the most suitable for this methodology in accordance with the *GS4GG Methodological Standard – "Requirements for Methodology Development"*. The justification is as follows:

a. **Appropriateness to Activity Context:** The project activity involves reducing enteric methane emissions from specific cattle herds. These emissions are not uniform; they vary significantly based on herd-specific factors such as diet, animal type (age, weight), genetics, and local environmental and management conditions. Therefore, a "one-size-fits-all" benchmark would be inaccurate. An approach based on the actual historical emissions of the specific participating farms is the most appropriate and scientifically sound way to determine the baseline.

b. **Use of Best Available Data:** The methodology mandates the use of the best available data by requiring project participants to provide at least three years of reliable and verifiable historical records on herd size and productivity. This farm-specific data represents the most accurate and direct information for establishing what would have occurred without the activity intervention, ensuring the baseline is a true reflection of the pre-activity conditions.

c. **Conservativeness:** Using actual emissions from the specific project activity herd prevents non-conservative outcomes that could arise from applying a generic or regional benchmark, which might not accurately reflect the real-world performance of the specific farm. The methodology reinforces this conservative stance by including strict safeguards, such as requiring peer-reviewed evidence of the technology's efficacy and excluding unrelated benefits (e.g., from herd reduction or land-use change). This ensures that emission reductions are not overestimated.

7.2.2 | This approach ensures the baseline is a realistic representation of what would have continued to occur in the absence of the project activity and is fully aligned with the principles of accuracy, appropriateness, and conservativeness outlined in the *Requirements for Methodology Development*.

7.3 | Identification of the Baseline Scenario

7.3.1 | As per the justification provided above in 7.2 |, the baseline scenario is identified as the continuation of existing livestock management practices without the implementation of the methane capture and conversion system. The emissions from this scenario are calculated according to the procedures defined in the section 7.4 below.

7.3.2 | Baseline is always defined as current practices at project start, with differences to be measured by the wearable. Eligible baseline scenarios include livestock management systems for dairy and beef cattle in all growth and production phases.

7.3.3 | Pasture and feed production systems shall comply with the applicability conditions, specifically not undergoing expansion or intensification and leading to conversion of natural ecosystems (forest or natural grasslands). Management systems also shall comply with Gold Standard’s animal welfare requirements and safeguards as referenced in the applicability conditions.

7.3.4 | Baseline scenarios shall be the livestock management systems prior to the introduction of the wearable to capture and convert methane for dairy and beef cattle.

7.3.5 | The BAU scenario is designed to be conservative and replicable:

a. Temporal Scope: Based on the most recent three years of verifiable data to avoid speculative assumptions about future trends.

b. Data Sources: Relies on auditable data (e.g., national industry reports, livestock statistics, regulatory filings).

c. Evidence that respective project conditions are within the proven applicability range of the wearable shall be provided at the project level.

7.4 | Calculation of the Baseline emissions prior to Downward adjustments

7.4.1 | To monitor herd size and management, documentation of herd composition and pasture areas (as applicable) shall be provided annually for a baseline period of five years. Specifically, the following information shall be collected and documented in the baseline report:

7.4.2 | Herd size and composition: number of cattle, subdivided into groups (strata) by type (dairy or beef), age or weight class, and feeding system, e.g., pasture-fed, partial mixed ration (PMR), or total mixed ration (TMR).

7.4.3 | Pasture location, type, and management: geographic delineation of pasture fields in the baseline period (GPS coordinates or spatial data file), field size, carrying capacity, stocking rate, vegetation type (natural grassland, managed grassland, rotation with crops), annual inputs (e.g., manure), tillage practices (if any).

7.4.4 | Quantification for methane emissions under the baseline scenario shall follow an emission factor approach per head of cattle. For quantification of baseline methane emissions from enteric fermentation, Equation 1 shall be applied:

$$BE_{EF,Unadj,y} = \sum_G \left[EF_{EF,G,BSL} \times N_{G,BSL}\right] \qquad \textit{Eq. 1}$$

Where:

$BE_{EF,Unadj,y}$	=	Average annual methane emissions under the baseline scenario in year y [tCO_2e/yr]
$EF_{EF,G,BSL}$	=	Emission factor from enteric fermentation in animal group G under the baseline scenario [tCO2e/head]
$N_{G,BSL}$	=	Average annual number of animals in group G in the baseline scenario [head]
G	=	Animal group

7.4.5 | Emission factors for methane emissions from enteric fermentation ($EF_{EF,G,BSL}$) shall be based on credible and conservative sources with documented applicability to the respective animal group in the baseline scenario (i.e., climate, management system, feeding system, age), including national or sub-national factors (such as Tier 2 or Tier 3 calculations according to IPCC 2019) or information from published scientific research.

7.4.6 | The same quantification approach shall be used for project and baseline scenarios. IPCC 2019 default emission factors (Table A-01 in Appendix A1) may be applied only if more specific emission factors for the project area are not available. Priority shall be given to peer-reviewed, recent studies of emissions from localised systems reflective of the project area circumstances and only expand to sub-national and national sources when it has been demonstrated that more relevant and accurate sources are not available.

7.4.7 | For area-based quantification of baseline emissions from project activities, specifically pasture management, Equation 2 shall be applied:

$$BE_{PA,y} = \sum_{X} [EF_{PM,X,BSL} \times AP_{X,BSL}] \qquad \text{Eq. 2}$$

Where:

$BE_{PA,y}$	=	Average annual emissions from pasture management under the baseline scenario [tCO_2e]
$EF_{PM,X,BSL}$	=	Average annual emission factor from pasture management for pasture type X under the baseline scenario [tCO_2e/ha]
$AP_{X,BSL}$	=	Average annual pasture area for type X in the project boundary in the baseline scenario [ha]
X	=	Pasture type (e.g. natural grassland, intensive grassland)[2]

7.4.8 | Emission factor for pasture management ($EF_{PM,X,BSL}$) shall include relevant emissions from pastures, such as average change in carbon pools (woody and non-woody plant biomass, soil organic carbon), nitrous oxide (N_2O) emissions from fertiliser, including on-farm manure deposition and on-field excretions, and emissions from use of machinery. If available, sub-national or national emission factors shall be applied for each of these emission sources, in the order of priority. If no national data is available, IPCC Tier 1 or Tier 2 calculations and emission factors[3] may be applied in a conservative manner to estimate $EF_{PM,X,BSL}$, taking into account the respective uncertainties.

7.4.9 | Emission reductions from pasture management are not eligible for crediting under this methodology; however, they are assessed to determine whether the project scenario could result in additional emissions, and such emissions are accounted for accordingly. Owing to this, Downward Adjustment Factor is not required to be applied on emissions from pasture management.

7.5 | Application of downward adjustment

7.5.1 | The baseline emissions, which is determined using actual historical emissions from participating farms, shall be adjusted downward to ensure conservativeness and encourage ambition over time.

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[2] Pasture types are according to source for pasture emission factor ($EF_{PM,X}$).

[3] Tier 1 approach and references for nitrous oxide emission quantification for manure application are provided in Appendix A2.

Step 1 – Uncertainty Accounting

7.5.2 | Handled via rigorous uncertainty accounting as outlined in Section 14. As outlined in Section 14 of this methodology, the project developer must achieve a precision of 20% of the mean at a 90% confidence level for sampling efforts, in line with the Land Use & Forests Activity Requirements. Because conservativeness is directly addressed by constraining uncertainty at the project's start, no separate downward adjustment factor is applied to the baseline in the first year of the crediting period.

Step 2 – Application of the Downward Adjustment Factor (DAF)

7.5.3 | To ensure the baseline remains below 'Business-as-Usual' (BAU) and to encourage increasing ambition, a downward adjustment factor of 1.25% shall be applied annually to the baseline emissions, beginning in the 1st year of the crediting period.

Step 3 – Calculation of Adjusted Baseline Emissions (BE_y)

7.5.4 | The final Adjusted Baseline Emissions are calculated by applying the DAF to the unadjusted baseline emissions from enteric fermentation.

$$BE_{EF} = BE_{EF,Unadj,y} \times (1 - DAF_{NetZero} \text{ i.e.},1.25\%) \qquad Eq.\ 3$$

Where:

BE_{EF}	=	Average annual methane emissions under the baseline scenario in year y [tCO_2e/yr], adjusted downward
$BE_{EF,Unadj,y}$	=	Average annual methane emissions under the baseline scenario in year y [tCO_2e/yr], unadjusted
$DAF_{NetZero}$	=	Annual Downward Adjustment Factor (Please apply 1.25%)

7.5.5 | Downward Adjustment Factor is not required to be applied for emissions from pasture management as they are not credited in this methodology.

7.6 | Difference between BAU and baseline emissions

7.6.1 | For this methodology, the baseline scenario is the same as the Business-as-Usual (BAU) scenario. Therefore, the baseline emissions are equal to the BAU emissions, and no difference needs to be estimated.

8| ACTIVITY EMISSIONS

8.1.1 | The activity scenario introduces the methane capture and conversion system to the herd as a project activity. The project activity does not include changes in other activities, such as livestock or pasture or feed management. However, as such changes are part of normal farm dynamics, herd and management parameters are monitored to assess impact on emissions.

8.1.2 | To monitor herd size and management, documentation of herd composition and pasture areas (as applicable) shall be provided annually. Specifically, the following information shall be collected and documented in the baseline report:

a. Herd size and composition: number of cattle, subdivided into groups (strata) by type (dairy or beef), age or weight class, and feeding system, (e.g., pasture-fed, PMR, or TMR).

b. Pasture location, type, and management: geographic delineation of pasture fields in the project period (GPS coordinates or spatial data file), field size, carrying capacity, stocking rate, vegetation type (natural grassland, managed grassland, rotation with crops), annual inputs (e.g., manure), tillage practices (if any).

8.1.3 | Quantification for methane emissions under the project scenario shall follow an emission factor approach per head of cattle minus measured emission reductions in the methane capture and conversion system.

8.1.4 | For quantification of project methane emissions from enteric fermentation and reduction by the methane capture and conversion system, Equation 4 shall be applied (note limitation below):

$$AE_{EF,y} = \sum_{G}\left[EF_{EF,G,y} \times N_{G,y}\right] - \sum_{I} ER_{CH4,I,y} \qquad \textit{Eq. 4}$$

Where:

$AE_{EF,y}$	=	Methane emissions in year y of the reporting period [tCO_2e]
$EF_{EF,G,y}$	=	Emission factor from enteric fermentation in animal group G in year y of the reporting period [tCO2e/head]
$N_{G,y}$	=	Average number of animals equipped with the methane capture and conversion system in group G in year y of the reporting period [head]
$ER_{CH4,I,y}$	=	Methane emission reduction by the methane capture and conversion system for animal I in year y of the reporting period [tCO_2e]
G	=	Animal group
I	=	Animal specifier (e.g., ear tag)

8.1.5 | In accordance with applicability conditions of this methodology, no emission reductions shall be accounted for from reduction of herd size (number of animals equipped with the methane capture and conversion system). Thus, if the difference in calculated emissions for the herd in the project scenario against the baseline scenario ($\sum_G\left[EF_{EF,G,BSL} \times N_{G,BSL}\right] - \sum_G\left[EF_{EF,G,y} \times N_{G,y}\right]$) is negative, baseline emissions ($\sum_G\left[EF_{EF,G,BSL} \times N_{G,BSL}\right]$) shall be used in Equation 4 above instead of project emissions ($\sum_G\left[EF_{EF,G,y} \times N_{G,\mathrm{y}}\right]$).

8.1.6 | Emission factors for methane emissions from enteric fermentation ($EF_{EF,G,y}$) shall be based on credible and conservative sources with documented applicability to the respective animal group in the project scenario (i.e., climate, management system, feeding system, age), including national or sub-national factors (such as Tier 2 or Tier 3 calculations according to IPCC 2019) or information from published scientific research.

8.1.7 | The same quantification approach shall be used for project and baseline scenarios. IPCC 2019 default emission factors (Table A-01 in Appendix A1) may be applied only if more specific emission factors for the project area are not available. Priority shall be given to peer-reviewed, recent studies of emissions from localised systems reflective of the project area circumstances and only expand to sub-national and national sources when it has been demonstrated that more relevant and accurate sources are not available.

8.1.8 | Emission reduction by the methane capture and conversion system ($ER_{CH4,I,y}$) shall be measured per animal directly by the methane capture and conversion system, as required in the applicability conditions of this methodology. Measurement and data quality assurance processes as well as methane reduction calculations based on the data collected shall be documented for the project activity and methane capture and conversion system used.

8.1.9 | Quantification of project activity emissions ($AE_{PA,y}$) shall include emissions from pasture management as well as emissions from the methane capture and conversion system. Calculation shall follow Equation 5:

$$AE_{PA,y} = \sum_{X} \left[EF_{PM,X,y} \times AP_{X,y} \right] + AE_{CS,y} \qquad \textit{Eq. 5}$$

Where:

$AE_{PA,y}$	=	Project activity emissions in year y of the reporting period [tCO_2e]
$EF_{PM,X,y}$	=	Emission factor from pasture management for pasture type X in year y of the reporting period [tCO_2e/ha]
$AP_{X,y}$	=	Pasture area for type X in the project boundary in year y of the reporting period [ha]
X	=	Pasture type (e.g., natural grassland, intensive grassland)[4]
$AE_{CS,y}$	=	Emissions from the methane capture and conversion system in year y of the reporting period [tCO_2e]

8.1.10 | Emission factor for pasture management ($EF_{PM,X,y}$) shall include relevant emissions from pastures, such as average change in carbon pools (woody and non-woody plant biomass, soil organic carbon), nitrous oxide emissions from fertiliser, including on-farm manure deposition and on-field excretions, and emissions from use of machinery. If available, sub-national or national emission factors should be applied for each of these emission sources in the order of priority. If no national data is available, IPCC Tier 1 or Tier 2 calculations and

[4] Pasture types according to source for pasture emission factor ($EF_{PM,X}$)

emission factors[5] may be applied in a conservative manner to estimate $EF_{PM,X,y}$, taking into account the respective uncertainties.

8.1.11 | Emissions from the methane capture and conversion system ($AE_{CS,y}$) shall be quantified for the entire system, including mobile units (such as wearables) and static system infrastructure (such as data collection systems). Quantification shall include overall life cycle emissions, such as production, installation, operation (including replacement of components), and end-of-life emissions for the system. Energy consumption for operations shall be reported separately (Equation 6).

$$AE_{CS,y} = \frac{PE_{CS,LCA}}{OLT} + \sum_{e} \left(EU_{e,y} \times EF_{EU,e,y} \right) \quad \textit{Eq. 6}$$

Where:

$AE_{CS,y}$	=	Emissions from the methane capture and conversion system in year y of the reporting period [tCO_2e]
$PE_{S,LCA}$	=	Life cycle emissions from the methane capture and conversion system [tCO_2e]
OLT	=	Operational lifetime for the methane capture and conversion system [years]
$EU_{e,y}$	=	Fuel and energy use for the methane capture and conversion system per energy type e in year y of the reporting period [fuel or energy unit, e.g., litre, kilowatt-hour (kWh), terajoule (TJ)]
$EF_{EU,e,y}$	=	Fuel or energy emission factors per energy type e in year y of the reporting period [tCO_2e/fuel or energy unit]
e	=	Energy type used (e.g., solar electricity, grid electricity, gasoline, diesel)

9| LEAKAGE EMISSIONS

9.1 | Identifying and addressing leakages

9.1.1 | Leakage emissions refer to the changes in anthropogenic greenhouse gas (GHG) emissions that occur outside the defined project boundary but are attributable to the project activity. For projects reducing enteric methane from cattle, the following potential leakage sources are considered:

a. **Activity Shifting:** The project leads to a shift of cattle or production to other locations not monitored by the project, or to other producers, potentially increasing emissions elsewhere.

[5] Tier 1 approach and references for nitrous oxide emission quantification for manure application are provided in Appendix A2.

b. **Feed Sourcing:** The project indirectly causes an increase in emissions from the production and transport of animal feed, particularly if it leads to land-use change in the regions where the feed is grown.

c. **Manure Management:** The project causes a change in manure management practices that leads to an increase in GHG emissions (e.g., shifting from pasture deposition to anaerobic lagoons).

d. **Environmental GHG Release (Land-Use Change):** The project indirectly triggers land-use change outside the project boundary, such as the conversion of forests or grasslands to pasture or for feed cultivation.

e. **Yield-Related Leakage:** The project causes a decrease in agricultural productivity (e.g., milk or meat yield), which leads to compensatory production increases elsewhere to meet demand.

9.2 | Estimation of emission leakages

9.2.1 | Based on the applicability conditions of this methodology, the following leakage sources are addressed:

a. **Activity Shifting:** The applicability conditions require that projects are implemented on established farms with at least three years of historical data on herd size and productivity. This farm-level boundary and the use of historical data prevent leakage from the simple shifting of animals, as the baseline is tied to the specific farm's historical activity. Therefore, this leakage source is considered negligible.

b. **Feed Sourcing:** The applicability conditions explicitly state that "Feed or feed concentrate use shall not be increased due to the project activity, unless evidence is provided that the feed originates from deforestation-free sources." This requirement directly mitigates leakage from feed production. Therefore, this leakage source is considered to be zero.

c. **Manure Management:** The scope of this methodology is strictly limited to the reduction of enteric methane and explicitly excludes emission reductions from manure management. Project activities must not negatively alter existing manure management systems in a way that would increase emissions. Therefore, this leakage source is considered to be zero.

d. **Land-Use Change:** The applicability conditions provide strong safeguards against this leakage source. They prohibit any expansion of pasture area, any permanent decrease of woody biomass, and the use of pastures or cattle from lands converted from forests or grasslands within 10 years of the project start. These rules effectively prevent leakage from land-use change, and this source is therefore considered to be zero.

e. **Yield-Related Leakage:** As the system does not have an impact on productivity, no yield-related leakage is expected. Moreover, under GS4GG, projects shall not lead to a decrease in agricultural productivity;

thus, all projects shall be set up to maintain yield. Accordingly, this methodology's applicability conditions do not allow yield reduction. Therefore, this leakage source is considered to be zero.

9.2.2 | For project calculations, leakage emissions LE_y are thus considered equal to 0.

10| DETERMINATION OF EMISSIONS REDUCTIONS

10.1.1 |Annual emission reductions are calculated by applying Equation 7. Emission reductions due to conversion of methane from enteric fermentation are calculated separately from changes in other project emissions (pasture management and emissions from the methane capture and conversion system). The latter is limited to emission increase as no benefits shall be accounted for.

$$ER_y = \left(\left(BE_{EF,y} - AE_{EF,y}\right) - max\left\{0, \left(AE_{PA,y} - BE_{PA,y}\right)\right\}\right) \times (1 - UD) - LE_y \quad \textit{Eq. 7}$$

Where:

ER_y	=	Emission reductions in year y [tCO_2e]
$BE_{EF,y}$	=	Average annual adjusted baseline emissions from enteric fermentation [tCO_2e]
$AE_{EF,y}$	=	Project emissions from enteric fermentation in year y [tCO_2e]
$BE_{PA,y}$	=	Average annual baseline emissions from pasture management in year y [tCO_2e]
$AE_{PA,y}$	=	Project emissions in year y from project activities (including pasture management) [tCO_2e]
UD	=	Uncertainty deduction [dimensionless] (see Section 14)
LE_y	=	Leakage emissions in year y [tCO_2e]

11| METHODOLOGIES PRINCIPLES

11.1.1 |**Encouraging ambition over time:** The selected baseline approach, based on historical farm-level emissions, ensures the ambition of the host party is clearly embedded. The baseline is made conservative through rigorous uncertainty management and a required downward adjustment in subsequent years, ensuring it is below a 'Business-as-Usual' (BAU) level. Furthermore, risks of emissions lock-in are addressed to ensure the project contributes to long-term decarbonization pathways.

11.1.2 |**Contributing to the equitable sharing of mitigation benefits between participating Parties:** In this methodology, the selected baseline approach, which is adjusted downwards to be more stringent than BAU, represents a direct contribution to the host party's Nationally Determined Contributions (NDCs) and long-term climate goals. Furthermore, since livestock farming is a long-term activity, the improved practices and technological capacity built by the project will continue to deliver mitigation benefits to the host party well beyond the project's crediting period, fostering an equitable distribution of these benefits.

11.1.3 | **Aligning with the NDC of each participating Party, its LT-LEDS, and the long-term goals of the Paris Agreement:** The activity developer shall confirm that the project activity aligns with the host country's latest NDC and, where available, its Long-Term Low-Emission Development Strategy (LT-LEDS). The project should be presented as a contribution toward achieving these national goals and the long-term temperature goal of the Paris Agreement.

11.1.4 | **Encouraging broad participation:** This methodology is designed for global application and is applicable to eligible livestock farming systems in all countries, promoting widespread participation in agricultural methane mitigation.

11.1.5 | **Including data sources, accounting for uncertainty and monitoring:** This methodology document specifies the required data sources, procedures for accounting for uncertainty in line with Gold Standard requirements, and detailed monitoring protocols for all relevant parameters.

11.1.6 | **Taking into account policies and measures and relevant circumstances:** The methodology contains provisions to consider relevant national, regional, or local circumstances, including social, economic, environmental, and technological conditions, based on robust and verifiable information. The type of data and information necessary to demonstrate eligibility, set the baseline, and demonstrate additionality is specified throughout the methodology.

12| REVERSALS

12.1.1 | Not applicable, as the methodology does not cover removal activities.

13| MONITORING METHODOLOGY

13.1 | Data and Parameters Not Monitored

13.1.1 | The following baseline information on each project area (i.e., farm/ranch) within the project region shall be recorded.

Parameter ID	*1*
Data/Parameter:	*Farm ID*
Description:	Unique ID for each farm participating in the project
Data unit:	N/A
Value(s) applied:	A unique ID for each farm

Source of data:	Location IDs are allocated to each farm/ranch at the start of their project participation. Project developer shall ensure that Farm ID is unique and that a master dataset is maintained linking each Farm ID to the farm information (owner/contact person, address, GPS location). The master dataset linking to the Farm IDs may be marked confidential and thus not be included in public documentation. However, it shall be made available to the Validation and Verification Body (VVB) and Gold Standard at validation.
Choice of data or measurement methods and procedures:	Not Applicable
Treatment of uncertainty	Not Applicable
Additional comment:	PD shall ensure that there are no duplication of ID number, or any ambiguity in allocation of the IDs. In case, for some reason, any farm has more divisions, please allocate different IDs that can be used to clearly identify the unit.

Parameter ID	**2**
Data/Parameter:	$EF_{EF,G,BSL}$
Description:	Emission factor from enteric fermentation in animal group G under the baseline scenario
Data unit:	tCO_2e/head
Source of data:	$EF_{EF,G,BSL}$ shall be based on credible and conservative sources with documented applicability to the respective animal group in the baseline scenario (i.e., climate, management system, feeding system, age). The same quantification approach shall be used for project and baseline scenarios. IPCC 2019 default emission factors (Table A-01 in Appendix A1) may be applied if more specific emission factors for the project area are not available.
Additional comment:	Data and source(s) to be audited at validation

Parameter ID	**3**
Data/Parameter:	$N_{G,BSL}$
Description:	Number of animals in group G in the baseline scenario
Data unit:	Heads of cattle

Source of data:	Grower report: Each grower report shall individually list all animals participating in the program (i.e., those to be fitted with a wearable) and shall include Farm IDs, tag numbers, and allocations to animal groups. If animals are removed (e.g., sold or deceased), added, or moved between groups during an annual reporting period, it shall be clearly documented and allocated pro rata to the respective group. Documentation shall include a list (spreadsheet or database) of all animals and their strata allocations, including key information on changes. After consolidation, annual average number of animals and variance shall be calculated for each animal group G.
Additional comment:	List of animals and allocations to strata shall be reviewed by VVB at validation.

Parameter ID	**4**
Data/Parameter:	$EF_{PM,X,BSL}$
Description:	Emission factor from pasture management for pasture type X under the baseline scenario (annual average)
Data unit:	tCO_2e/ha
Source of data:	If available, sub-national or national emission factors shall be applied for each of these emission sources, in the order of priority. These emission factors shall be sourced from recent credible peer -reviewed scientific literature, national reports reflective of the project area circumstances. If no national data is available, IPCC Tier 1 or Tier 2 calculations and emission factors may be applied in a conservative manner to estimate $EF_{PM,X,BSL}$, taking into account the respective uncertainties. Emission factor for pasture management (EF_{PM}) shall include relevant emissions from pastures, such as average change in carbon pools (woody and non-woody plant biomass, soil organic carbon), methane and nitrous oxide emissions from fertiliser, including on-farm manure deposition and on-field excretions, and emissions from use of machinery. $EF_{PM,X,BSL}$ shall be reported as annual averages for the baseline period per pasture type.
Additional comment:	Data and source(s) shall be audited at validation.

Parameter ID	**5**
Data/Parameter:	$AP_{X,BSL}$
Description:	Pasture area for type X in the project boundary in the baseline scenario
Data unit:	Ha

Source of data:	Pasture area shall be reported based on geo-referenced data to be provided for review, reported as average annual pasture area per type X in the baseline period. Pasture type X shall be defined by pasture management and respective emission factors EF_{PM}.
Additional comment:	Documentation of pasture areas shall be provided as GPS boundary coordinates or spatial data file (kml/kmz, ESRI shapefile, or geo-package file) and should include (in the file or in a separate, referenced document): 1) Farm ID 2) Indication of each parcel's carrying capacity and average stocking rate for the baseline period 3) Description of management practices on the parcels, including tillage events and organic inputs (amount and frequency) 4) An assessment of tree cover to monitor potential loss of woody biomass Note: Acceptable evidence for tree cover and patches of woody biomass is 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's Tree Cover Change Map). For guidance, refer to the Land Use & Forests Activity Requirements, Appendix C. 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). Data and source(s) shall be audited at validation.

Parameter ID	**6**
Data/Parameter:	GWP_{CH4}
Description:	GWP of methane
Data unit:	tCO_2e/tCH_4
Source of data:	IPCC AR5 (IPCC 2014) Value applied: 28
Additional comment:	-

Parameter ID	**7**
Data/Parameter:	GWP_{N2O}
Description:	GWP of nitrous oxide

Data unit:	t CO_2e/t N_2O
Source of data:	IPCC AR5 (IPCC 2014) Value applied: 265
Additional comment:	-

13.2 | Data and Parameters Monitored

13.2.1 | The project developer shall submit a monitoring report at each performance review according to the performance certification requirements of the Principles & Requirements, the Monitoring Report Template, and the information listed in the below monitoring tables.

13.2.2 | The project developer shall, for each year without a completed third-party verification, submit the information on those parameters labelled as annually in the below monitoring tables, as part of the Annual Report Form., in addition to the information listed in Principles & Requirements. https://globalgoals.goldstandard.org/t-perfcert-annual-report/

13.2.3 | 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 and shall do the following:

a. Electronically archive all data collected as part of monitoring for a period lasting until two years after the end of the last crediting period.

b. Ensure that measuring equipment is certified to national or international standards and calibrated according to the national standards and reference points or to international standards and recalibrated at appropriate intervals according to manufacturer specifications.

Parameter ID	***8***
Data/Parameter:	$EF_{EF,G,y}$
Description:	Emission factor from enteric fermentation in animal group G in year y of the reporting period
Data unit:	tCO_2e/head
Source of data:	Emission factors for methane emissions from enteric fermentation ($EF_{EF,G,y}$) shall be based on credible and conservative sources with documented applicability to the respective animal group in the project scenario (i.e., climate, management system, feeding system, age). The same quantification approach shall be used for project and baseline scenario. IPCC 2019 default emission factors (Table A-01 in Appendix A1) may be applied if more specific emission factors for the project area are not available.
Monitoring frequency:	annual
QA/QC procedures:	Data and source(s) to be audited at verification
Additional comment:	-

Parameter ID	**9**
Data/Parameter:	$N_{G,y}$
Description:	Number of animals equipped with the methane capture and conversion system in group G in year y of the reporting period
Data unit:	Heads of cattle
Source of data:	Grower report: Each grower report shall individually list all animals with a wearable and shall include Farm IDs, tag numbers, and allocations to animal groups. If animals are removed (e.g., sold or deceased), added, or moved between groups during an annual reporting period, it shall be clearly documented and allocated pro rata to the respective group. Documentation shall include a list (spreadsheet or database) of all animals and strata allocations, including key information on changes.
Monitoring frequency:	Annually
QA/QC procedures:	Data and source(s) to be audited at verification
Additional comment:	List of animals and allocations to strata shall be reviewed by VVB at verification.

Parameter ID	**10**
Data/Parameter:	$ER_{CH4,I,y}$
Description:	Methane emission reduction by the methane capture and conversion system for animal I in year y of the reporting period
Data unit:	tCO_2e
Source of data:	Emission reduction by the methane capture and conversion system ($ER_{CH4,I,y}$) shall be measured per animal directly by the methane capture and conversion system, as required in the applicability conditions of this methodology. Emission reduction shall be recorded per wearable unit. For each unit, its operational state (active, inactive time) shall also be recorded.
Monitoring frequency:	Ongoing (reported annually)
QA/QC procedures:	Measurement and data quality assurance processes, including calibration, shall be documented for the project activity and methane capture and conversion system used. This shall include information on each unit's calibration (calibration dates and accuracy data) and performance state (active, inactive time). Data and process shall be audited at verification.
Additional comment:	Methane capture and conversion system of wearable devices shall be calibrated periodically as per manufacture's specifications. In case manufacture does not provide such specifications, calibration can be done annually. The

	calibration certificate shall clearly mention the validity of calibration. Data collected by the uncalibrated device shall not be considered for the period of delay. Errors for each calibrated device shall be considered for the final emission reduction estimate in a conservative manner. The efficacy of the wearable device for capturing enteric methane shall be tested periodically to establish that the methane reported does not include methane from the ambient environment. Such tests would be mandatory in the event that captured methane reported is higher than the upper limit of the uncertainty range of corresponding baseline emissions.

Parameter ID	**11**
Data/Parameter:	$EF_{PM,X,y}$
Description:	Emission factor from pasture management for pasture type X in year y of the reporting period
Data unit:	tCO_2e/ha
Source of data:	If available, sub-national or national emission factors shall be applied for each of these emission sources, in the order of priority. These emission factors shall be sourced from recent credible peer -reviewed scientific literature, national reports reflective of the project area circumstances. If no national data is available, IPCC Tier 1 or Tier 2 calculations and emission factors may be applied in a conservative manner to estimate $EF_{PM,X,y}$, taking into account the respective uncertainties. Emission factor for pasture management (EF_{PM}) shall include relevant emissions from pastures, such as average change in carbon pools (woody and non-woody plant biomass, soil organic carbon), methane and nitrous oxide emissions from fertiliser (not including on-farm manure deposition and on-field excretions, as these are covered in the sections detailing emissions from pasture management, and emissions from use of machinery.
Monitoring frequency:	Annually
QA/QC procedures:	Data and source(s) to be audited at verification
Additional comment:	-

Parameter ID	**12**
Data/Parameter:	$AP_{X,y}$
Description:	Pasture area for type X in the project boundary in year y of the reporting period.
Data unit:	ha

Source of data:	Pasture area shall be reported based on geo-referenced data to be provided for review, per type X in reporting year y. Pasture type X shall be defined by pasture management and respective emissions EF_{PM}.
Monitoring frequency:	Annually
QA/QC procedures:	Data and source(s) to be audited at verification
Additional comment:	Documentation of pasture areas shall be provided as GPS boundary coordinates or spatial data file (kml/kmz, ESRI shapefile, or geo-package file) and shall include (in the file or in a separate, referenced document): 1) Farm ID 2) Indication of each parcel's carrying capacity and average stocking rate for the project period 3) Description of management practices on the parcels, including tillage events and organic inputs (amount and frequency) 4) An assessment of tree cover to monitor potential loss of woody biomass Note: Acceptable evidence for tree cover and patches of woody biomass is 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's Tree Cover Change Map). For guidance, refer to the Land Use & Forests Activity Requirements, Appendix C. Temporary loss of trees (e.g., due to harvest and regrowth) may be permitted if evidence for sustainable management is provided, such as evidence of restocking trees (e.g., replanting or protection of natural regeneration) immediately following removal of biomass (i.e., within one year).

Parameter ID	**13**
Data/Parameter:	$PE_{CS,LCA}$
Data unit:	tCO_2e
Description:	Life cycle emissions from the methane capture and conversion system
Source of data:	System manufacturer information: The supplier of the wearable shall report emissions from production of the system following accepted methodologies, e.g., life cycle assessment (LCA) data according to International Organization for Standardization (ISO) 14040 and 14044, indicating quality assurance for quantification and author of

	LCA. Suppliers also shall 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 for changes in production process) when the wearables are acquired. Updates to $PE_{CS,LCA}$ data for the wearables during their application shall be applied only if: a) they are caused by improvements applied to all units in use (e.g., maintenance, software, or technology updates leading to improved energy efficiency), or b) wearables are replaced with newer versions. In this case, $E_{S,LCA}$ shall be applied pro rata for each generation (i.e., updated LCA data only accounted for replaced units). No retrospective recalculation shall be performed.
Monitoring frequency:	Annually
QA/QC procedures:	Data and source(s) to be audited at verification
Additional comment:	The latest version of the product's LCA report shall be assessed by an LCA expert who shall be part of the VVB's team at project validation. Annual monitoring is required if wearable is replaced and manufacturer delivers updated LCA data.

Parameter ID	**14**
Data/Parameter:	OLT
Description:	Operational lifetime (OLT) for the methane capture and conversion system
Data unit:	Years
Source of data:	System manufacturer information Updates to OLT data for the wearables during their application shall be applied only if they are caused by improvements applied to all units in use (e.g., maintenance, software or technology updates leading to extended lifetime) or if wearables are replaced with newer versions. In the latter case, OLT shall be applied pro rata for each generation (i.e., updated OLT only accounted for replaced units).
Monitoring frequency:	Annually
QA/QC procedures:	Data and source(s) to be audited at verification
Additional comment:	Annual monitoring required if wearable is replaced and manufacturer delivers updated lifetime data

Parameter ID	**15**

Data/Parameter:	$EU_{e,y}$
Description:	Fuel and energy use for the methane capture and conversion system per energy type e in year y of the reporting period
Data unit:	Fuel or energy unit (e.g., litre, kWh, TJ)
Source of data:	On-site measurement, supplier, or manufacturer data; fuel and energy consumption by the methane capture and conversion systems shall be quantified from any of the below sources (or a combination thereof): ▪ On-site measurement of energy use (i.e., in-line measurement of electricity or fuel) ▪ Data on energy consumption from energy or fuel supplier (e.g., invoices), allowing allocation to the methane capture and conversion system components ▪ Calculation from system power consumption (wattage) and running time
Monitoring frequency:	Annually
QA/QC procedures:	Data and source(s) to be audited at verification
Additional comment:	Energy consumption shall be quantified for all relevant system components, including stationary and mobile units for measurement, data transfer, processing, and storage. If emissions from energy consumption for system operations are included in LCA emissions ($PE_{CS,LCA}$) and evidence is provided that emission levels represent the project situation, $EU_{e,y}$ may be reported as 0.

Parameter ID	**16**
Data/Parameter:	$EF_{EU,e,y}$
Description:	Fuel or energy emission factors per energy type e in year y of the reporting period
Data unit:	tCO_2e/fuel or energy unit
Source of data:	One or a combination of the following: 1) Grid emission factors for electricity in the project area (national sources) 2) Fuel consumption and emission factors for stationary combustion (for generators) or mobile combustion (for transport and field machinery) using national emission factors 3) Emission factors and calculations according to IPCC Guidelines for National GHG Inventories (2019/2006), Volume 2 (Energy) 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)

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

13.3 | General Requirements for Data and Information Sources

13.3.1 |Unless otherwise stated in the methodology requirements or the parameter descriptions above, project developer shall use data from quality-ensured measurements and project field data, peer-reviewed scientific publications, or official national or sub-national data sources.

13.4 | General Requirements for Sampling

13.4.1 |No sampling-based quantification is applied in this methodology.

14| UNCERTAINTY QUANTIFICATION

14.1.1 |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 the Land Use & Forests Activity Requirements, Annex A: Uncertainty of Land Use & Forest Parameters.

14.1.2 |Due to the requirement for direct measurement of methane capture and conversion, only the system's measurement uncertainty shall be considered in the following uncertainty assessment for project emissions from enteric fermentation (AE_{EF}). For the baseline emissions factors (EF_{EF}), no uncertainty shall be considered when these are identical and thus cancelled out in the quantification of changes in emissions from enteric fermentation (term $(BE_{EF} - AE_{EF,y})$ in Equation 7).

14.1.3 |Overall uncertainty for calculation of emissions reduction is performed as follows.

Step 1: Calculate upper and lower confidence limits for all input parameters.

Calculate the mean $\bar{X}_p$ and standard deviation σ_p for each parameter and coefficient used in emissions calculations. The standard error of the mean is then given by Equation 8.

$$SE_p = \frac{\sigma_p}{\sqrt{n_p}} \qquad \textit{Eq. 8}$$

Where:

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

If SE_p (mean standard error) is available directly from the parameter source (e.g., literature, metadata), it shall be used directly in the following calculations (without the use of Equation 8).

If no information on standard deviation or standard error is known for a parameter, standard error 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. Exceptions to this rule are accepted default values that are considered constant (e.g., physical conversion rates, GWPs).

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 Equation 9.

$$\mathrm{Lower_p} = \overline{\mathrm{X}}_\mathrm{p} - \mathrm{t}_{np} \times \mathrm{SE_p}$$
$$\mathrm{Upper_p} = \overline{\mathrm{X}}_\mathrm{p} + \mathrm{t}_{np} \times \mathrm{SE_p}$$
Eq. 9

Where:

$\mathrm{Lower_p}$	=	Value at the lower end of the 90% confidence interval for parameter p
$\mathrm{Upper_p}$	=	Value at the upper end of the 90% confidence interval for parameter p
$\overline{\mathrm{X}}_\mathrm{p}$	=	Mean value for parameter p
$\mathrm{SE_p}$	=	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 observations n_p for parameter p. If no information is available on n_p, a conservative value of 1.675 (n=3) shall be used.

Step 2: Calculate reduction of emissions from cattle in the monitoring period ($\Delta E_{t\text{-}0}$) with the lower and upper confidence interval values of the input parameters.

Apply the lower and upper parameter values in the models for $\Delta E_{t\text{-}0}$, specifically equations for E_t and E_0, to achieve a lower and upper value for $\Delta E_{t\text{-}0}$.

$$\mathrm{Lower}_{\Delta \mathrm{E}t-0} = \mathrm{Model}_{\Delta \mathrm{E}t-0}\{\mathrm{Lower_p}\}$$
$$\mathrm{Upper}_{\Delta \mathrm{E}t-0} = \mathrm{Model}_{\Delta \mathrm{E}t-0}\{\mathrm{Upper_p}\}$$
Eq. 10

Where:

$\mathrm{Lower}_{\Delta \mathrm{E}t-0}$	=	Lower value of emissions change at a 90% confidence interval
$\mathrm{Upper}_{\Delta \mathrm{E}t-0}$	=	Upper value of emissions change at a 90% confidence interval
$\mathrm{Model}_{\Delta \mathrm{E}t-0}$	=	Calculation models for $\Delta E_{t\text{-}0}$, including models for E_t, E_0, and below
$\mathrm{Lower_p}$	=	Values at the lower end of the 90% confidence interval for all parameters p
$\mathrm{Upper_p}$	=	Values at the upper end of the 90% confidence interval for all parameters p

Step 3: Calculate the uncertainty in the model output, which is given by Equation 11.

$$\mathrm{UNC} = \frac{|\mathrm{Upper}_{\Delta \mathrm{Et}-0} - \mathrm{Lower}_{\Delta \mathrm{Et}-0}|}{2 \times \Delta \mathrm{E}_{t-0}} \qquad \textit{Eq. 11}$$

Where:

UNC	=	Model output uncertainty [%]
$\mathrm{Lower}_{\Delta \mathrm{Et}-0}$	=	Lower value of emissions change at a 90% confidence interval
$\mathrm{Upper}_{\Delta \mathrm{Et}-0}$	=	Upper value of emissions change at a 90% confidence interval
$\Delta \mathrm{E}_{t-0}$	=	Change in emissions [t CO_2e]

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

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

b. If the uncertainty of emission models is greater than 20% of the mean value, the project developer shall use the estimated emission reduction subject to an uncertainty deduction (UD) as calculated in Equation 12:

$$\mathrm{UD} = \mathrm{UNC} - 20\% \qquad \textit{Eq. 12}$$

Where:

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

14.1.4 | Uncertainty Deduction is to be applied in Equation 7 of this methodology.

15| APPLICATION TO PROGRAMME OF ACTIVITIES

15.1.1 |The methodology is applicable to Programme of Activities, and the extant requirements will be applicable.

16| CREDITING PERIOD

16.1 | Crediting Period and renewal requirements

16.1.1 |For activities applying this methodology, the crediting period shall be five years and may be renewed twice. The total crediting period, including after renewal, cannot be more than 15 years from start of the crediting period.

16.1.2 |The latest version of the methodology shall be applied at the time of crediting period renewal.

16.1.3 | The regulatory surplus shall be assessed by the activity at each crediting period renewal.

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

APPENDIX A1 | IPCC METHANE EMISSION FACTORS

Table A-01. Enteric fermentation emission factors for cattle [kg CH_4/head/yr] (extracted from IPCC 2019, Vol. 4, Ch. 10, Table 10.11; for buffalo, refer to original source)

Regional characteristics	Animal category	Emission Factor[1,2,3] [(kg CH_4)/ head/yr]	Comments
North America			
Highly productive commercialised dairy sector feeding high-quality forage and grain. Separate beef cow herd, primarily grazing with feed supplements seasonally. Fast-growing beef steers/heifers finished in feedlots on grain. Dairy cows are a small part of the population.	**Dairy cattle**	138	Average milk production of 10,250 kg $head^{-1}$ yr^{-1}
	Other cattle	64	Includes mature males, multi-purpose mature females, calves, growing steers/heifers, and feedlot cattle
Western Europe			
Highly productive commercialised dairy sector feeding high-quality forage and grain. Dairy cows also used for beef calf production. Very small, dedicated beef cow herd. Minor amount of feedlot feeding with grains.	**Dairy cattle**	126	Average milk production of 7,410 kg $head^{-1}$ yr^{-1}
	Other cattle	52	Includes mature males, calves, and growing steers/heifers
Eastern Europe			
Commercialised dairy sector feeding based on forages and gains. Separate beef cow herd, primarily grazing. Minor amount of feedlot feeding with grains.	**Dairy cattle**	93	Average milk production of 4,000 kg $head^{-1}$ yr^{-1}
	Other cattle	58	Includes mature males, mature females, growing and replacement animals, and calves
Oceania			
Commercialised dairy sector based on grazing. Separate beef cow herd, primarily grazing rangelands and hill country of widely varying quality. Growing amount of feedlot feeding with grains. Dairy cows are a small part of the population.	**Dairy cattle**	93	Average milk production of 4,400 kg $head^{-1}$ yr^{-1}
	Other cattle	63	Includes mature males, mature females, and young

Table A-01 (continued). Enteric fermentation emission factors for cattle [kg CH_4/head/yr] (extracted from IPCC 2019, Vol. 4, Ch. 10, Table 10.11; for buffalo, refer to original source)

Regional characteristics	Animal category	Emission Factor[1,2,3] [(kg CH_4)/ head/yr]	Comments
Latin America			
Commercialised dairy sector based on grazing. Separate beef cow herd grazing pastures and rangelands. Minor amount of feedlot feeding with grains. Growing non-dairy cattle comprise a large portion of the population.	**Dairy cattle**	87	Average milk production of 2,050 kg head^{-1} yr^{-1}
	High-productivity systems	103	Average milk production of 3,400 kg head^{-1} yr^{-1}
	Low-productivity systems	78	Average milk production of 1,250 kg head^{-1} yr^{-1}
	Other cattle	56	Includes mature females, mature males, growing steers/heifers, and calves
	High-productivity systems	55	
	Low-productivity systems	58	
Asia			
Commercialised dairy sector is experiencing fundamental changes due to increasing number of large farms with intensive production systems based on grains and forage. Cattle kept in traditional production systems are multi-purpose, providing draft power and some milk within farming regions. Cattle of all types are smaller than those found in most other regions.	**Dairy cattle**	78	Average milk production of 3,200 kg head^{-1} yr^{-1}
	High-productivity systems	96	Average milk production of 5,000 kg head^{-1} yr^{-1}
	Low-productivity systems	71	Average milk production of 2,600 kg head^{-1} yr^{-1}
	Other cattle	54	Includes mature males, mature females, growing and replacement animals, and calves
	High-productivity systems	43	
	Low-productivity systems	56	
Africa			
Commercialised dairy sector based on grazing with low production per cow. Most cattle are multi-purpose, providing draft power and some milk within farming regions. Some cattle graze over very large areas. Cattle are smaller than those found in most other regions.	**Dairy cattle**	76	Average milk production of 1,300 kg head^{-1} yr^{-1}
	High-productivity systems	86	Average milk production of 2,200 kg head^{-1} yr^{-1}
	Low-productivity systems	66	Average milk production of 500 kg head^{-1} yr^{-1}
	Other cattle	52	Includes mature males, multi-purpose mature females, growing and replacement animals, and calves
	High-productivity systems	60	
	Low-productivity systems	48	

Table A-01 (continued). Enteric fermentation emission factors for cattle [kg CH_4/head/yr] (extract from: IPCC 2019, Vol. 4, Ch. 10, Table 10.11; for buffalo, refer to original source)

Regional characteristics	Animal category	Emission Factor[1,2,3] [(kg CH_4)/ head/yr]	Comments
Middle East			
Majority of cattle population is still kept by small holders in the traditional production systems. The animals are fed primarily by crop residues and are grazed. Most animals are dual-purpose. In contrast to the small-scale farms, commercial dairy sector is generally intensive, mainly based on compound feed and grains.	**Dairy cattle**	76	Average milk production of 2,500 kg head^{-1} yr^{-1}
	High-productivity systems	94	Average milk production of 3,900 kg head^{-1} yr^{-1}
	Low-productivity systems	62	Average milk production of 1,300 kg head^{-1} yr^{-1}
	Other cattle	60	Includes mature males, multi-purpose mature females, growing and replacement animals, and calves
	High-productivity systems	61	
	Low-productivity systems	55	
India Subcontinent			
Commercialised dairy sector based on crop byproduct feeding with low production per cow. Most bullocks provide draft power, and cows provide some milk in farming regions. Cattle in this region are the smallest compared to cattle found in all other regions.	**Dairy cattle**	73	Average milk production of 1,900 kg head^{-1} yr^{-1}
	High-productivity systems	70	Average milk production of 2,600 kg head^{-1} yr^{-1}
	Low-productivity systems	74	Average milk production of 1,700 kg head^{-1} yr^{-1}
	Other cattle	46	Includes mature males, multi-purpose mature females, growing and replacement animals, and calves
	High-productivity systems	41	
	Low-productivity systems	47	

[1] Emission factors should be derived on the basis of the characteristics of the cattle and feed of the animals, and compilers should not base their decision of an emission factor entirely on regional characteristics.

[2] The values represent averages within region. Existing values were derived using Tier 2 method and the data in IPCC (2019), Tables 10A.1–10A.4.Data on a livestock population mix corresponding to low- and high-productivity systems were used.

[3] Uncertainty values from the previous guidelines were validated during the development of the emission factors using a Monte Carlo analysis in the 2019 Refinement, based on data compiled during the emission factor development process. It is recommended to continue to use Tier 1 emission factor uncertainty ranges as defined in Section 10.3.4 of the 2006 IPCC Guidelines.

APPENDIX A2 | NITROUS OXIDE EMISSIONS FROM ON-FARM MANURE APPLICATION

A2.1.1 | In the absence of regional or national data on nitrous oxide emissions from manure applied to pastures ($BE_{PM,N2O}$ and $PE_{PM,N2O}$), the following quantification approach simplified from IPCC 2006/2019 may be applied. Where no project-specific data is available to parametrise Equation A-1, default values provided in the following Tables A-02 through A-05 may be applied.

$$EM_{N2O,y} = \sum_G \left[N_{G,y} \times \left(Nex_{rate(G)} \times \frac{TAM_{G,y}}{1000} \times DAYS_{G,y}\right) \times \sum_P\left[MS_{G,P,y} \times EF_{N2O,P}\right]\right] \quad \textit{Eq. A-1}$$

Where:

$EM_{N2O,y}$	=	Average annual methane emissions from manure management in the baseline scenario [(kg N_2O)/yr]
$N_{G,y}$	=	Number of animals in group G in year y [head]
$Nex_{rate(G)}$	=	Default nitrogen excretion rate per animal per day in group G in year y [(kg N)/(1000kg animal mass)/day]
$TAM_{G,y}$	=	Typical animal mass for livestock in group G in year y [kg/head]
$DAYS_{G,y}$	=	Average days per year an animal belongs to group G in year y [day] (max 365)
$MS_{G,P,y}$	=	Fraction of total nitrogen excreted by animals in group G and deposited as manure application type P in year y [dimensionless]
$EF_{N2O,P}$	=	Emission factor for N_2O emissions from field deposition for application type P (direct or as manure) [(kg N_2O)/(kg N)]
G	=	Animal group
P	=	Manure application type

A2.1.2 | IPCC default parameters which may be used in Equation A-1 are summarised in the following Tables A-02 through A-05.

Table A-02. Default values for live weights for cattle (extracted from IPCC 2019, Volume 4, Chapter 10, Table 10A.5)

Region	Animal category	Live weight [kg animal mass]
North America	**Dairy cattle**	650
	Other cattle	407
Western Europe	**Dairy cattle**	600
	Other cattle	405
Eastern Europe	**Dairy cattle**	550
	Other cattle	389
Oceania	**Dairy cattle**	488
	Other cattle	359
Latin America	**Dairy cattle**	508
	High-productivity systems	520
	Low-productivity systems	500
	Other cattle	303
	High-productivity systems	329
	Low-productivity systems	295
Africa	**Dairy cattle**	260
	High-productivity systems	250
	Low-productivity systems	270
	Other cattle	236
	High-productivity systems	302
	Low-productivity systems	208
Middle East	**Dairy cattle**	349
	High-productivity systems	510
	Low-productivity systems	270
	Other cattle	275
	High-productivity systems	362
	Low-productivity systems	232
Asia	**Dairy cattle**	386
	High-productivity systems	485
	Low-productivity systems	355
	Other cattle	299
	High-productivity systems	310
	Low-productivity systems	296
India Subcontinent	**Dairy cattle**	285
	High-productivity systems	350
	Low-productivity systems	265
	Other cattle	226
	High-productivity systems	167
	Low-productivity systems	236

Table A-03. Manure application type (MS) regional averages for cattle [%] (consolidated from IPCC 2019, Volume 4, Chapter 10, Table 10A.6)

Animal category	Livestock manure management system	Manure application type (MS) regional averages for cattle and buffalo [%]								
		North America	Western Europe	Eastern Europe	Oceania	East Asia and Southeast Asia (Asia)	South Asia (India Subcontinent)	Latin America and the Caribbean	Near East (Middle East) and North Africa	Sub-Saharan Africa
Dairy cattle	Confided (spreading manure)	85	74	80	6	51	50	43	49	49
	Confined (not spreading manure)					11	20		5	6
	Pasture/Range/Paddock (direct deposition)	15	26	20	94	38	30	57	46	45
Non-dairy cattle	Confined (spreading manure)	58	52	69	0	57	50	8	51	45
	Confined (not spreading manure)					7	20		7	5
	Pasture/Range/Paddock (direct deposition)	42	48	31	100	36	30	92	42	50

Table A-04. Default Nitrogen excretion rate [(kg Nex) (1,000 kg animal mass)$^{-1}$ day^{-1}] (extracted from IPCC 2019, Volume 4, Chapter 10, Table 10.19)

Region	Animal category	Default nitrogen excretion rate [(kg Nex)/(1,000 kg animal mass)/day]
North America	**Dairy cattle**	0.60
	Other cattle	0.40
Western Europe	**Dairy cattle**	0.50
	Other cattle	0.42
Eastern Europe	**Dairy cattle**	0.42
	Other cattle	0.47
Oceania	**Dairy cattle**	0.72
	Other cattle	0.46
Latin America	**Dairy cattle**	0.39
	High-productivity systems	0.6
	Low-productivity systems	0.28
	Other cattle	0.31
	High-productivity systems	0.29
	Low-productivity systems	0.44
Africa	**Dairy cattle**	0.44
	High-productivity systems	0.41

	Low-productivity systems	0.45
	Other cattle	0.44
	High-productivity systems	0.42
	Low-productivity systems	0.45
Middle East	**Dairy cattle**	0.50
	High-productivity systems	0.49
	Low-productivity systems	0.51
	Other cattle	0.55
	High-productivity systems	0.51
	Low-productivity systems	0.58
Asia	**Dairy cattle**	0.44
	High-productivity systems	0.55
	Low-productivity systems	0.41
	Other cattle	0.38
	High-productivity systems	0.36
	Low-productivity systems	0.38
India Subcontinent	**Dairy cattle**	0.65
	High-productivity systems	0.51
	Low-productivity systems	0.70
	Other cattle	0.44
	High-productivity systems	0.63
	Low-productivity systems	0.40

Table A-05. N_2O emissions $E_{N2O,P}$ from manure deposition on managed lands (calculated based on IPCC 2019, Volume 4, Chapter 11, Tables 11.1 and 11.3)

Manure field deposition type		**N_2O emissions from manure deposition [(kg N_2O)/(kg N excreted or deposited)]**		
		Direct[1]	Indirect[2]	Total
On-field excretions (grazing cattle)	Wet climates[3]	0.009	0.009	0.018
	Dry climates[4]	0.003	0.002	0.005
Manure spreading on managed lands (grassland or cropland)	Wet climates[3]	0.009	0.009	0.018
	Dry climates[4]	0.008	0.002	0.010
No spreading		0	0	0

[1] calculated from IPCC 2019 Table 10.21

[2] calculated from IPCC 2019 Table 10.22

[3] Temperate and boreal zones: ratio of annual precipitation/potential evapotranspiration > 1
Tropical zones: annual precipitation > 1000 mm

[4] Temperate and boreal zones: ratio of annual precipitation/potential evapotranspiration < 1
Tropical zones: annual precipitation < 1000 mm

A2.1.3 | When applying the quantification approach described in paragraph A2.1.1, the following parameters shall be added to the data collection (Section 13.2) or monitoring methodology (Section 13), respectively.

A2.1.4 | Data and parameters not monitored:

Parameter ID	**A-1**
Data/Parameter:	$TAM_{G,BSL}$
Data unit:	Kg/head
Description:	Typical animal mass for livestock in group G in baseline scenario
Source of data:	If herd-specific weight data is available, this data shall be used (as average by animal group), reported as average across the baseline period. If no data is available, data from IPCC 2019 Vol. 4, Table 10A.5 may be applied. See Table A-02 in Appendix A2 of this methodology.
Additional comment:	

Parameter ID	**A-2**
Data/Parameter:	$DAYS_{G,BSL}$
Data unit:	Day
Description:	Average days per year an animal belongs to group G in the baseline scenario
Source of data:	Grower records Based on herd list (see details described for $N_{G,BSL}$), average number of days an animal spends in each stratum (group G) in year y is calculated. Variance of $DAYS_{G,BSL}$ also shall be calculated. Reported as annual average per group for baseline period; maximum value is 365 days.
Additional comment:	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 achieve required accuracy.

Parameter ID	**A-3**
Data/Parameter:	$MS_{G,P,BSL}$
Data unit:	Dimensionless
Description:	Fraction of total nitrogen excreted by animals in group G and deposited as manure application type P in the baseline scenario

Source of data:	IPCC 2019, Vol. 4, Table 10A.6, summarised in Table A-03 in Appendix A2 of this methodology. Reported as annual average in the baseline period per animal group and manure application type P.
Additional comment:	

Parameter ID	**A-4**
Data/Parameter:	$Nex_{rate(G)}$
Data unit:	(kg N)/(1,000 kg animal mass)/day
Description:	Default nitrogen excretion rate per animal per day in group G
Source of data:	IPCC 2019, Vol. 4, Table 10.19, summarised in Table A-04 in Appendix A2 of this methodology
Additional comment:	

Parameter ID	**A-5**
Data/Parameter:	$EF_{N2O,P}$
Data unit:	(kg N_2O)/(kg N)
Description:	Emission factor for total N_2O emissions from field deposition for application type P (direct or as manure) in animal group G
Source of data:	IPCC 2019, Vol. 4, Table 11.1 and 11.3, summarised in Table A-05 in Appendix A2 of this methodology
Additional comment:	

A2.1.5 | Data and parameters monitored:

Parameter ID	**A-6**
Data/Parameter:	$TAM_{G,y}$
Data unit:	kg $head^{-1}$
Description:	Typical animal mass for livestock in group G in year y of the reporting period
Source of data:	If herd-specific weight data is available, this data shall be used (as average by animal group). If no data is available, data from IPCC 2019, Vol. 4, Table 10A.5 may be applied. See Table A-02 in Appendix A2 of this methodology.
Monitoring frequency:	Annually
QA/QC procedures:	Data and source(s) to be audited at verification
Any comment:	

Parameter ID	**A-7**
Data/Parameter:	$DAYS_{G,y}$
Data unit:	Day
Description:	Average days per year an animal belongs to group G in year y of the reporting period

Source of data:	Grower records Based on herd list (see details described for $N_{G,y}$), average number of days an animal spends in each stratum (group G) in year y is calculated. Variance of $DAYS_{G,y}$ also shall be calculated. Maximum value is 365 days.
Monitoring frequency:	Annually
QA/QC procedures:	Data and source(s) to be audited at verification
Any comment:	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	**A-8**
Data/Parameter:	$MS_{G,P,y}$
Data unit:	Dimensionless
Description:	Fraction of total nitrogen excreted by animals in group G and deposited as manure application type P in year y of the reporting period
Source of data:	IPCC 2019, Vol. 4, Table 10A.6, summarised in Table A-03 in Appendix A2 of this methodology
Monitoring frequency:	Annually
QA/QC procedures:	Data and source(s) to be audited at verification
Any comment:	

APPENDIX A3 | LOCK IN RISK ANALYSIS

This Appendix presents a lock-in risk analysis of the wearable methane capture and conversion system. This assessment is conducted in accordance with the requirements of Section 6.2 of the Gold Standard's "Requirements for additionality demonstration". The analysis evaluates the technology's operational lifetime and physical characteristics to determine if its adoption poses a risk of irreversible capital investment that could impede future transitions to more advanced mitigation options.

Analysis of Technical and Operational Lifetime (OLT)

A clear quantitative threshold for assessing technology lock-in - a technical or operational lifetime (OLT) of 10 years or more is considered "long-lifetime" and triggers project level assessment.

Publicly available information regarding the ZELP device, the primary technology in this category, suggests an operational lifetime of up to four years per unit.

This places the device's OLT substantially below the 10-year threshold. Based on a interpretation of Section 6.2.5 of the Gold Standard requirements, it can be assumed that the physical technology itself does not pose a long-term lock-in risk, as it is a short-term asset that can be replaced or upgraded at relatively frequent intervals. The methodology reinforces this by requiring the OLT to be a monitored parameter based on verifiable manufacturer documentation.

Analysis of Resource Use and Life-Cycle Profile

While the OLT is the primary determinant of lock-in risk, a complete assessment of the physical technology also considers its resource footprint. The methodology requires the quantification of life-cycle emissions from the methane capture and conversion system, covering production, installation, operation, and end-of-life disposal.

The device is a piece of hardware containing electronic components, solar-charged batteries, fans, and chemical catalysts. The manufacturing and disposal of these components create a physical resource dependency and an electronic waste stream. A full Life Cycle Assessment (LCA), as specified by ISO 14040/14044, is the appropriate tool to quantify these impacts.

By requiring the project developer to quantify and report these life-cycle emissions, the methodology ensures transparency regarding the physical resource intensity of the technology. This allows for a clear accounting of the environmental trade-offs associated with manufacturing and deploying the hardware, but it does not in itself constitute a lock-in risk due to the short replacement cycle of the device.

Conclusion of Physical Technology Assessment

The primary determinant for technology lock-in risk is the operational lifetime of the asset. With a documented OLT of approximately four years, the wearable methane capture and conversion device is a short-term technology. It does not represent a long-term, irreversible capital investment that would be difficult or prohibitively expensive to replace with superior physical alternatives as they become available.

Therefore, based on a direct application of the Gold Standard rules, the physical technology itself does not present a lock-in risk. The methodology's requirements to monitor the OLT and report life-cycle emissions provide a robust framework for verifying the physical characteristics of the technology throughout the project's lifetime.

Stepwise Assessment of Technology Lock-In Risk

Project developers shall complete the following stepwise assessment to demonstrate that the project's physical technology does not lead to a lock-in risk, in accordance with Section 6.2 of the Gold Standard 'Requirements for additionality demonstration'. This assessment must be completed and submitted as part of the Project Design Document (PDD) at validation and shall be reassessed and updated at each crediting period renewal.

Step 1: Confirmation of Technology Lifetime

Requirement: The project developer shall provide official, verifiable documentation from the manufacturer(s) for each major component of the methane capture and conversion system (including wearables, data transfer hardware, and other essential infrastructure) specifying the designed Technical or Operational Lifetime (OLT).

Demonstration of Compliance: Provide copies of official manufacturer documentation (e.g., technical specification sheets, signed letters from the manufacturer, product warranty documents) that clearly state the OLT for all relevant components. The documentation shall be specific to the models being deployed in the project.

Assessment: The Validation and Verification Body (VVB) shall confirm that the documented OLT for all major components is less than 10 years. If the OLT for any single essential component is 10 years or more, the project is not eligible to apply the exemption under this methodology. If all components are confirmed to have an OLT of less than 10 years, this step is satisfied.

Step 2: Life-Cycle Emissions Reporting

Requirement: The project developer shall provide a transparent accounting of the physical resource footprint of the technology by reporting its life-cycle emissions.

Demonstration of Compliance: The project developer shall obtain and provide the Life Cycle Assessment (LCA) for the specific model of the methane capture and conversion system being used, as supplied by the manufacturer. This documentation will serve as the source for the parameter $PE_{CS,LCA}$, as required by the methodology. The LCA must be conducted in accordance with accepted international standards (e.g., ISO 14040/14044).

Step 3: Re-evaluation of Technology

Requirement: The project developer shall formally acknowledge the evolving nature of methane mitigation technology and conduct a comprehensive re-evaluation of the project's chosen technology against the state-of-the-art at each crediting period renewal.

Demonstration of Compliance:

The project developer acknowledges that the methane capture and conversion technology implemented in this project exists within a rapidly evolving technological landscape. The developer shall conduct, at each crediting period renewal, and present to the VVB a new assessment of the project activity against the then-current state-of-the-art for enteric methane mitigation.

APPENDIX A4 | COMMON PRACTICE ANALYSIS

This appendix conducts a common practice analysis at the methodology level The purpose is to assess the diffusion of the project activity—the use of wearable devices for methane capture and conversion on cattle—within relevant markets. The analysis concludes that the technology is not common practice. Therefore, projects that meet the applicability conditions of this methodology are considered to have satisfied the common practice test and are not required to conduct a separate analysis.

Approach and Selection of Indicator:

Approach: This analysis uses Market Penetration assessment. This approach is the most suitable as the project activity involves a new, discrete technology (a wearable device) whose adoption can be measured as a share of a target market.

Indicator of Common Practice: The indicator is count-based, defined as the number of individual cattle equipped with a wearable methane capture and conversion system.

Specification of the Geographical Area:

To ensure a robust analysis, the assessment is conducted for two major, distinct livestock sectors that represent primary target markets for this type of technology:

- The European Union (EU) Dairy Cattle Sector
- The United States (U.S.) Beef Cattle Sector

Determination of the Target Market Size:

The target market size is the total number of cattle within the specified geographical areas.

- EU Dairy Market: The total number of dairy cows in the European Union was 19,221,660 as of December 2024.[6]
- U.S. Beef Market: The total number of beef cows in the United States was 27,900,000 as of January 1, 2025.[7]

Determination of the Count of Similar Activities

A "similar activity" is defined as the commercial application of a wearable device on cattle that captures and converts enteric methane. A comprehensive review of market data, company statements, and news reports indicates that while the technology is under development, there is no evidence of widespread commercial deployment.

- The primary developer, ZELP Ltd., had plans for a commercial launch in 2022/2023 with partners like Cargill, but there are no public records of commercial sales or large-scale deployments having occurred as of mid-2025.

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[6] EUROSTAT. (2025, June 26). EU livestock populations continued to decrease in 2024.
[7] U.S. Department of Agriculture, National Agricultural Statistics Service. (2025, January 31). Cattle.

- A review of ZELP's corporate news and financial filings, as well as those of its partners, reveals no announcements of commercial sales figures (Cargill, 2025[8]; ZELP, n.d.).
- Independent market analyses and reports on methane mitigation technologies categorize wearables as an emerging or pre-commercial technology, in contrast to feed additives which have achieved limited commercial sales (Grand View Research, 2024[9]; Market Shaping Accelerator, 2024[10]).
- The technology remains in a pre-commercial or limited pilot phase.[11] Therefore, the number of cattle commercially equipped with this technology is effectively **zero**.

Calculation of the Common Practice Factor (F)
The common practice factor (F) is the market penetration, calculated as

F= **Count of Similar Activities/ Target Market Size**.

EU Dairy Market: F_{EU} = 0 / 19,221,660 =0%

U.S. Beef Market: F_{US} = 0 / 27,900,000 =0%

Comparison: In both analyzed markets, the calculated common practice factor of **F = 0%**.

Conclusion of Common Practice Analysis

The analysis demonstrates that the use of wearable methane capture and conversion devices on cattle is **not common practice** in key global markets. The market penetration is negligible (0%).

Based on this methodology-level assessment, any project activity that meets the applicability criteria outlined in Section 2 of this methodology is deemed "not common practice" and is therefore not required to undertake a separate common practice analysis.

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[8] Cargill. (2025). Press Releases.

[9] Grand View Research. (2024, October). *Ruminant Methane Reduction Market Report*.

[10] Market Shaping Accelerator. (2024, May 29). *The promise of an Advance Market Commitment to tackle methane from livestock*. University of Chicago.

[11] ZELP | Royal College of Art, accessed July 14, 2025, https://www.rca.ac.uk/business/terra-carta-design-lab-projects/zelp/

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