# Federal Offset Protocol: Reducing Enteric Methane Emissions from Beef Cattle

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Canada's Greenhouse Gas Offset Credit System

Environment and Climate Change Canada
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# Foreword

Canada's Greenhouse Gas (GHG) Offset Credit System is established under Part 2 of the *Greenhouse Gas Pollution Pricing Act* to provide an incentive to implement projects that result in domestic GHG reductions that would not have been generated in the absence of the project, that go beyond legal requirements and that are not subject to carbon pollution pricing mechanisms.

Canada's GHG Offset Credit System consists of:

- The *Canadian Greenhouse Gas Offset Credit System Regulations* (the Regulations), which establish the system, implement the operational aspects and set the general requirements applicable to all project types;
- Federal offset protocols, included in the *Compendium of Federal Offset Protocols* (the Compendium), each containing requirements for project implementation and methods for quantifying GHG reductions for a given project type; and
- The Credit and Tracking System (CATS) to register offset projects, issue and track offset credits, and share key information through Canada's GHG Offset Credit System Public Registry.

Only projects following a federal offset protocol included in the Compendium and meeting all requirements outlined in the Regulations can generate GHG reductions for which federal offset credits may be issued under the Regulations.

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# 1.0 Introduction

Enteric fermentation is a natural digestive process in ruminant animals like cattle whereby microbial populations in the digestive system assist in the breakdown of feed into more readily available molecules and nutrients. As part of this process, a portion of the feed is converted into methane ($CH_4$) and released back into the atmosphere by the cattle as enteric $CH_4$ emissions.

The *Reducing Enteric Methane Emissions from Beef Cattle* federal offset protocol is intended for use by a proponent implementing a project to reduce enteric $CH_4$ emissions in confined beef cattle feeding operations in order to generate greenhouse gas (GHG) emission reductions for which federal offset credits may be issued under the *Canadian Greenhouse Gas Offset Credit System Regulations* (the Regulations).

Carrying out eligible project activities will reduce the GHG emission intensity of beef production which is the quantity of GHGs emitted per mass of beef produced. The GHG emission intensity of beef production will be reduced by improving animal performance (e.g., improving feed efficiency or weight gain) or directly reducing enteric $CH_4$ emissions through diet reformulation. Improvements to animal performance may also result in decreased $CH_4$ and nitrous oxide ($N_2O$) emissions from avoided manure production.

The proponent must follow the methodology and requirements contained in this protocol, including those to quantify and report GHG emission reductions generated by eligible project activities. The requirements contained in this protocol are part of the Regulations and must be read in conjunction with provisions in the Regulations.

This protocol is designed to ensure a project generates GHG emission reductions that are real, additional, quantified, verified, unique and permanent. The protocol is also developed in accordance with the principles of ISO 14064-2:2019 *Greenhouse gases – Part 2 – Specification with guidance at the project level for quantification, monitoring and reporting greenhouse gas emission reductions or removal enhancements* to ensure reported GHG emission reductions generated as a result of implementing a project are relevant, complete, consistent, accurate, transparent, and conservative.

A project implemented using this protocol cannot generate GHG emission reductions during cattle grazing, from dairy cattle or from the use of novel anti-methanogenic feed additives or gut modifiers.

# 2.0 Terms and definitions

**Act**

means the *Greenhouse Gas Pollution Pricing Act*.

**Animal**

means one head of beef cattle.

**Animal group**

means a group of animals in a stratum that are all present at the project site for at least one day during a beef production period.

**Beef production period**

means the period of time an animal group remains continuously housed and fed at the project site starting on the date of entry for the first animal in the group and ending on the date of exit for the last animal in the group.

**Concentrate**

means a feed or feed ingredient that is high in energy and low in fiber.

**Confinement area**

means an indoor or outdoor enclosure for animals including, but not limited to, barns, corrals, feedlots, winter feeding yards, or other confined feeding areas.

**Daily dry matter intake (DDMI)**

means the quantity of feed consumed per day by animals on a dry mass basis.

**Diet**

means the feed ingredients or mixture of ingredients that are consumed by animals including the amount and composition of feed given to animals over a defined period of time.

**Dressing percentage**

means the un-chilled mass of the animal after slaughter and dressing (removal of internal organs and inedible portions) divided by the live weight.

**Enteric methane ($CH_4$) emissions**

means the $CH_4$ emissions produced in the rumen of an animal by enteric fermentation and eructated to the atmosphere.

**Forage**

means hay, silage, pasture, straw, or high-fiber crop by-products provided to animals as feed.

**GHG emission intensity**

means the ratio of the GHG emissions per unit mass of beef produced.

**Global warming potential (GWP)**

means a metric representing the ability of a GHG to trap heat in the atmosphere compared to carbon dioxide ($CO_2$), as set out in Schedule 3 to the Act.

**Grazing**

means the activity of allowing animals to directly seek out and consume feed such as grasses, forbs, legumes, stock-piled forage, or pre-placed bales (bale grazing) in a pasture or rangeland.

**Gross energy (GE)**

means the total quantity of energy contained in animal feed.

**Hot carcass weight**

means the measured mass of the un-chilled animal carcass after the head, hide and internal organs have been removed.

**Median date of animal exit**

means the median date animals in an animal group exit the project site.

**Neutral detergent fiber (NDF)**

means the total quantity of structural plant fibre, used as an indicator of animal feed quality and determined by boiling the forage in a neutral detergent solution and measuring the insoluble residue.

**Project site**

means the area and buildings used to house and feed animals and store manure in the baseline and project scenarios.

**Qualified professional**

means a person who has appropriate education, training, or experience and any accreditation, license or certification required to perform a task or make a decision relevant to requirements in this protocol. Qualified professionals include veterinarians, Professional Agrologists and feed nutritionists in good standing with the associated accreditation body, licensure, certification board, or other regulatory body if applicable.

**Regulations**

means the *Canadian Greenhouse Gas Offset Credit System Regulations*.

**Rumen**

means the reticulo-rumen and is the largest compartment in a ruminant animal’s stomach. Also referred to as the forestomach.

**Rumen-protected lipid**

means a lipid source fed to animals that is protected from microbial fermentation in the rumen. May also be referred to as rumen bypass lipid or rumen bypass fat.

**Stratum**

means a set of animals in the baseline or the project scenario identified by the proponent through stratification.

**Stratification**

means the process of identifying animals into strata for the purpose of quantifying GHG emission reductions using methods and procedures developed by the proponent following the requirements in Section 8.1.

**Supplemented lipid**

means a rumen-unprotected lipid that is added to the diet as a distinct feed ingredient for the purpose of inhibiting $CH_4$ emissions such as added fat, oilseeds, high oil meals, or edible oils.

**Total digestible nutrients (TDN)**

means the energy content of the digestible carbohydrate, protein, and lipid ingredients in an animal feed.

# 3.0 Baseline scenario

## 3.1 Baseline conditions

For a project to be eligible under this protocol, the following baseline conditions must be met before the project start date:

- Animals were present at the project site for at least three years.
- Animals used to determine the baseline scenario were:
    - Cattle raised for beef production;
    - Not lactating cattle involved in dairy production; and
    - Fed in a confinement area and not grazed for the period of time where GHG emissions are quantified.

## 3.2 Determining the baseline scenario

The baseline scenario for a project under this protocol is the release of GHGs that would most likely occur due to the business-as-usual management of beef cattle at the project site in absence of the project to produce the same quantity of beef as the project scenario. To determine the baseline scenario, the proponent must determine the baseline scenario GHG emission intensity of historical beef cattle management at the project site prior to the project start date for each stratum. The baseline scenario GHG emission intensity of a stratum is held static over the crediting period unless otherwise specified in Section 8.2.

The proponent must determine the baseline scenario GHG emission intensity for each stratum using historical reference data derived from animals and management activities carried out at the project site. Historical reference data for a stratum must include at least one animal group per year from at least three continuous years starting no more than five years prior to the project start date. Despite the previous provision, historical reference data for a stratum may include at least one animal group from three non-continuous years from within the past five years if the crude protein content of the diet for each animal group did not exceed 14%.

### 3.2.1 Updating the baseline scenario at renewal of the crediting period

If the proponent requests a renewal of the crediting period for a project, they must update the baseline scenario by determining the baseline scenario GHG emission intensity for each stratum using updated historical reference data. Updated historical reference data used to determine the baseline scenario GHG emission intensity for a stratum must include all animal groups for that stratum at the project site for the three calendar years immediately preceding the calendar year of the start date for the renewed crediting period.

# 4.0 Project scenario

## 4.1 Project conditions

To be eligible under this protocol, a project must meet the following project conditions on and after the project start date:

- Within the project site one or more eligible project activities are carried out as described in Section 4.2.
- Animals in the project scenario:
    - Are cattle raised for beef production;
    - Were not lactating cattle involved in dairy production; and
    - Are fed in a confinement area and not grazed for the period of time where GHG emissions are quantified.

## 4.2 Eligible project activities

As part of a project, the proponent must carry out at least one eligible project activity in the project scenario. To be considered eligible under this protocol, a project activity must:

- Be derived from one of the categories in Table 1; and,
- Reduce GHG emissions relative to the baseline scenario that can be quantified using the quantification methodology in Section 8.0.

Table 1 provides a description of each category of project activities, and a non-exhaustive list of project activity examples proponents may choose to carry out as part of a project.

**Table 1: Categories of project activities**

| Category of project activities | Description |
|---|---|
| Improved management | Activities that increase animal performance through improved animal management such as but not limited to, improved animal health, tracking, sorting, customized feeding, and pen-cleanliness. |
| Diet reformulation | Changes to the diet to improve digestion or supress $CH_4$ emissions such as reducing forage content of the diet, improving forage quality, or adding supplemented lipid to the diet.<br>Supplemented lipid must not be rumen-protected and must be added in addition to the normal lipid content of the diet. |
| Feed additives | The new addition or adjustments to the prescribed dose of minor ingredients to the diet to improve animal performance, feed efficiency, or weight gain such as ionophores, yeasts, essential oils, or other digestion enhancers. |
| Growth promoters | The use of growth promoters such as beta-agonists or hormonal implants to improve animal growth and / or feed efficiency. |
| Other innovative strategies | Other innovative strategies that improve the feed efficiency or animal performance. |

The proponent may also carry out genetic selection activities to breed or procure animals with genetics that directly reduce enteric $CH_4$ emissions and/or improve animal performance as part of the project provided that they also carry out at least one eligible project activity.

# 5.0 Additionality

## 5.1 Legal additionality

GHG emission reductions generated by a project must not occur as a result of federal, provincial, or territorial law (including regulations), municipal by-laws, or any other legally binding mandates. If at any time after project registration the GHG emission reductions generated by the project become required by law or the result of a legal requirement, the GHG emission reductions will no longer be additional and, therefore, federal offset credits can only be issued for GHG emission reductions generated up to the date immediately preceding the date on which the law or the legal requirement comes into force.

## 5.2 Provincial or federal pricing mechanisms for GHG emissions

GHG emission reductions from emission sources that are subject to federal or provincial pricing mechanism for GHG emissions are not eligible for federal offset credits.

## 5.3 Business-as-usual additionality

A project implemented following this protocol automatically meets the requirements for business-as-usual additionality. The requirements to determine the baseline scenario GHG emission intensity as described in Section 3.2 and to quantify the baseline scenario GHG emissions as described in Section 8.2 establish the GHG emissions most likely to occur at the project site in absence of the project based on business-as-usual beef cattle management. Eligible project activities which result in fewer GHG emissions than the business-as-usual beef cattle management are considered additional.

# 6.0 General requirements

## 6.1 Project start date

The start date of a project corresponds to the first day an eligible project activity is carried out at the project site. In the case of a project where an eligible project activity or multiple eligible project activities are carried out on different dates, the project start date is the day on which the first eligible project activity is carried out at the project site for the first stratum in the project scenario.

## 6.2 Project site location and geographic boundaries

The proponent must document the location and geographic boundaries of the project site and prepare a site plan. The site plan must show:

- The location of all buildings and confinement areas used to house or feed animals in the baseline and project scenarios; and,

- The location and type of each manure storage system used to manage manure within the project site in the baseline and project scenarios.

The site plan must also clearly communicate any differences in the buildings, confinement areas and manure storage systems between the baseline and project scenarios.

The geographic boundary of the project site cannot change after the first reporting period, but additional eligible project activities can be added to the project scenario within the boundary. Any changes to the site plan must be communicated as specified in the Regulations.

## 6.3 Environmental and social safeguards

The proponent must ensure that:

- The project site is in compliance with all applicable laws, including regulations and municipal by-laws, such as those related to the management of manure.
- All feed additives, growth promotors and drugs delivered to animals as part of the project must be approved for use in Canada and used in accordance with applicable legal requirements.
- The quantity of dietary lipid fed to animals at any given time during the project must not exceed 6% of the diet by dry mass unless attestation is provided by a qualified professional that the diet will not have negative health impacts to animals.

# 7.0 Project GHG boundary

The project GHG boundary (Figure 1) contains the GHG sources, sinks and reservoirs (SSRs) that must be included or excluded by the proponent in the baseline and project scenarios to determine the GHG emission reductions generated by the project.

Table 2 provides additional details on the SSRs identified for the baseline and project scenarios, as well as justification for their inclusion or exclusion in the quantification of GHG emission reductions.

Three GHGs are relevant to the SSRs in this protocol: carbon dioxide ($CO_2$), methane ($CH_4$), and nitrous oxide ($N_2O$).

**Figure 1: Illustration of the project GHG boundary**

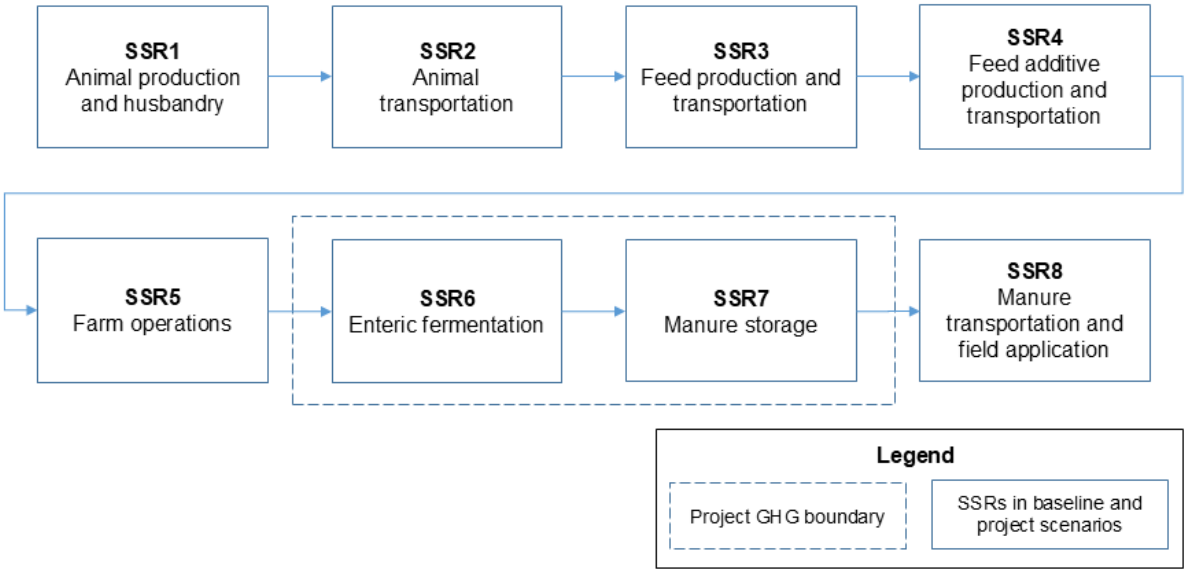


**Table 2: Details on baseline and project scenario SSRs**

| SSR | Title | Description | Type | Baseline or project scenario | GHG | Included or excluded |
|---|---|---|---|---|---|---|
| 1 | Animal production and husbandry | Birth, rearing, maintenance and growth of animals taking place upstream or downstream from the project site. | Related | Baseline (B1)<br>Project (P1) | $CO_2$<br>$CH_4$<br>$N_2O$ | **Excluded:** The difference in GHG emission intensity between the baseline and project scenarios as a result of the project activities is assumed to be negligible. |
| 2 | Animal transportation | Fossil fuel combustion associated with the movement and transport of animals to and from the project site. | Related | Baseline (B2)<br>Project (P2) | $CO_2$<br>$CH_4$<br>$N_2O$ | **Excluded:** The difference in GHG emission intensity between the baseline and project scenarios as a result of the project activities is assumed to be negligible. |
| 3 | Feed production | Upstream fossil fuel combustion, fertilizer | Related | Baseline (B3) | $CO_2$ | **Excluded:** The difference in GHG |

| SSR | Title | Description | Type | Baseline or project scenario | GHG | Included or excluded |
|---|---|---|---|---|---|---|
| | and transportation | use and other agricultural or land-use emissions associated with the primary production, processing, and transportation of animal feed to the project site. | | Project (P3) | $CH_4$<br>$N_2O$ | emission intensity between the baseline and project scenarios as a result of the project activities is assumed to be negligible. |
| 4 | Feed additive production and transportation | Upstream fossil fuel combustion and use of grid electricity to produce and transport feed additives delivered to animals at the project site. | Related | Baseline (B4)<br>Project (P4) | $CO_2$<br>$CH_4$<br>$N_2O$ | **Excluded:** Net change in GHG emissions is assumed to be negligible as feed additives are administered in small quantities and will displace feed. |
| 5 | Farm operations | Fossil fuel combustion and use of electricity to support the operation and maintenance of the farm operations such as heating buildings and the use of vehicles. | Controlled | Baseline (B5)<br>Project (P5) | $CO_2$ | **Excluded:** The difference in GHG emission intensity between the baseline and project scenarios as a result of the project activities is assumed to be negligible. |
| 6 | Enteric fermentation | Enteric fermentation of the feed consumed by animals at the project site. | Controlled | Baseline (B6)<br>Project (P6) | $CH_4$ | **Included:** Eligible project activities will affect $CH_4$ produced through enteric fermentation. |
| 7 | Manure storage | Decomposition of manure managed at the project site. | Controlled | Baseline (B7)<br>Project (P7) | $CH_4$<br>$N_2O$ | **Included:** Eligible project activities may affect GHG emissions due to changes in the composition and quantity of manure produced. |
| 8 | Manure transportation | Fossil fuel combustion and manure | Related | Baseline (B8) | $CO_2$ | **Excluded:** This SSR is |

| SSR | Title | Description | Type | Baseline or project scenario | GHG | Included or excluded |
|---|---|---|---|---|---|---|
| | and field application | decomposition from the transportation and field application of manure produced at the project site downstream at its final destination. | | Project (P8) | $CH_4$<br>$N_2O$ | conservatively excluded. |

# 8.0 Quantification methodology

This section contains the quantification methodology that the proponent must follow to quantify baseline and project scenario GHG emissions and subsequently, the GHG emission reductions generated by the project.

Baseline scenario GHG emissions are the GHG emissions from the SSRs within the project GHG boundary that would likely have been generated in the absence of the project from the business-as-usual management of beef cattle to produce the same amount of beef produced in the project scenario. Baseline scenario GHG emissions are quantified based on the GHG emission intensity of historical beef cattle management at the project site prior to the project start date and the beef production in the project scenario, as outlined in Section 8.2.

Project scenario GHG emissions are the GHG emissions from the SSRs within the project GHG boundary quantified as per Section 8.3. The GHG emission reductions generated by the project are quantified by deducting the project scenario GHG emissions from the baseline scenario GHG emissions as outlined in Section 8.5.

The quantification of both baseline and project scenario GHG emissions must include all the GHG emissions that were likely to occur in the absence of the project (baseline scenario) and did occur (project scenario) during the reporting period and must include sub-totals in tonnes of $CO_2$ equivalent (t $CO_2e$) for each full or partial calendar year to support issuance of the resulting offset credits by calendar year.

For the purposes of reporting GHG emission reductions and issuance of offset credits for projects under this protocol, GHG emission reductions are quantified and attributed to the reporting period and the calendar year in which the median date of animal exit of each stratum in the project scenario falls.

For an aggregation of projects, the proponent must quantify GHG emission reductions for each project separately. Subsequently, the GHG emission reductions for each project are to be summed together to determine the GHG emission reductions for the aggregation of projects.

Some emission factors and other reference values used in the quantification methodology are provided in the *Emission Factors and Reference Values* document. Raw data must be converted to align with the units presented in the quantification methodology, if necessary.

## 8.1 Stratification and animal groups

The proponent must identify strata for the project for the purpose of quantifying the baseline and project scenario GHG emissions. Strata must be identified based on stratification methods and procedures developed by the proponent. The methods and procedures may consider parameters such as but not limited to production system, diet, feeding system, breed, age class, gender, weight, and marketing program. Stratification must adhere to the following requirements:

- Each stratum in the project scenario must:
    - Consist of a single animal group;
    - Have a corresponding and comparable stratum in the baseline scenario; and,
    - Have the same eligible project activities applied to all animals in the stratum.
- Each stratum in the baseline scenario must consist of multiple animal groups, as per the requirements in Section 3.2.
- The difference in the maximum and minimum incoming weights for animals within a stratum in both the baseline and project scenarios must be no greater than 45.4 kg (100 lbs).
- When comparing strata between the baseline and project scenarios, the selected parameter type for determining the mean mass of animals at entry and exit in Equation 13 (live weight or hot carcass weight) must be the same selected parameter type used in Equation 23.

Parameters used for the quantification of GHG emissions must apply to all animals in an animal group in the baseline or project scenario. If physical separation of all animals in an animal group is not operationally possible, animals in different confinement areas within the project site may still be considered an animal group for the purpose of quantifying baseline and project scenario GHG emissions.

For an aggregation of projects, stratification cannot occur across projects in the aggregation.

## 8.2 Baseline scenario GHG emissions

The proponent must use Equation 1 and the subsequent equations in Section 8.2 to quantify the baseline scenario GHG emissions for each full or partial calendar year covered by the reporting period, based on the included SSRs in Table 2. Equation 1 is based on:

- The amount of beef produced from the strata in the project scenario with a median date of animal exit that falls within a specific calendar year covered by the reporting period; and,
- The GHG emission intensity of the corresponding baseline scenario strata.

Each project scenario stratum included in Equation 1 must have a corresponding stratum in the baseline scenario. Multiple strata in the project scenario may correspond to the same stratum in the baseline scenario and reference the same baseline scenario GHG emission intensity.

**Equation 1: Baseline scenario GHG emissions for a calendar year covered by the reporting period**

$$BE_C = \sum_{k}^{n} \left( EI_{BE,i} \times Production_{PE,k} \right)$$

| Parameter | Description | Units |
|---|---|---|
| $BE_C$ | GHG emissions from the strata in the baseline scenario that correspond to the strata in the project scenario with a median date of animal exit that falls within a calendar year covered by the reporting period | t $CO_2e$ |
| $EI_{BE,i}$ | GHG emission intensity from stratum i in the baseline scenario, as per Equation 2 | t $CO_2e$ $kg^{-1}$ |
| $Production_{PE,k}$ | Beef production for stratum k in the project scenario, as per Equation 23 | kg |
| $i$ | Specific stratum in the baseline scenario to which stratum k in the project scenario corresponds | unitless |
| $k$ | Specific stratum in the project scenario with a median date of animal exit that falls within a calendar year covered by the reporting period | unitless |
| $n$ | Number of strata k in the project scenario with a median date of animal exit that falls within a calendar year covered by the reporting period | unitless |
| $C$ | Calendar year | unitless |

The proponent must use Equation 2 to quantify the baseline scenario GHG emission intensity for each stratum in the baseline scenario. The baseline scenario GHG emission intensity for a stratum is an average GHG emission intensity based on historical reference data, as per Section 3.2.

**Equation 2: GHG emission intensity for a stratum in the baseline scenario**

$$EI_{BE,i} = \left( Enteric_{BE,i} + Manure_{BE,i} \right) \div Production_{BE,i}$$

| Parameter | Description | Units |
|---|---|---|
| $EI_{BE,i}$ | GHG emission intensity for stratum i in the baseline scenario | t $CO_2e$ $kg^{-1}$ |
| $Enteric_{BE,i}$ | Enteric $CH_4$ emissions from stratum i in the baseline scenario, as per Equation 3 (SSR B6) | t $CO_2e$ |

| Parameter | Description | Units |
|---|---|---|
| $\text{Manure}_{\text{BE,i}}$ | GHG emissions from manure storage for stratum i in the baseline scenario, as per Equation 5 (SSR B7) | t $CO_2e$ |
| $\text{Production}_{\text{BE,i}}$ | Beef production for stratum i in the baseline scenario, as per Equation 13 | kg |
| i | Specific stratum in the baseline scenario | unitless |

### 8.2.1 Enteric $CH_4$ emissions in the baseline scenario

Equation 3 must be used to quantify enteric $CH_4$ emissions associated with each stratum in the baseline scenario, which corresponds to SSR B6. Enteric $CH_4$ emissions must be quantified for each animal group in a stratum in the baseline scenario and then averaged over the total number of animal groups chosen to represent the stratum in the baseline scenario.

**Equation 3: Enteric $CH_4$ emissions for a stratum in the baseline scenario**

$$\text{Enteric}_{\text{BE,i}} = \sum_{\text{g}}^{\text{n}} \left( \text{AN}_{\text{g}} \times \text{GE}_{\text{g}} \times \text{DDMI}_{\text{g}} \times \text{Y}_{\text{m,g}} \times \text{EF}_{\text{lip,g}} \times \text{DOF}_{\text{g}} \div 55.65 \times \text{GWP}_{\text{CH4}} \div 1000 \right)$$

| Parameter | Description | Units |
|---|---|---|
| $\text{Enteric}_{\text{BE,i}}$ | Enteric $CH_4$ emissions for stratum i in the baseline scenario (SSR B6) | t $CO_2e$ |
| $\text{AN}_{\text{g}}$ | Mean number of animals in animal group g in stratum i | head |
| $\text{GE}_{\text{g}}$ | Default gross energy intake for the diet of animal group g in stratum i, equal to 19.10 MJ per kg of dry matter if the dietary lipid concentration is ≥4.0%, or to 18.45 MJ per kg of dry matter if the dietary lipid concentration is <4.0% | MJ $kg^{-1}$ |
| $\text{DDMI}_{\text{g}}$ | Mean daily dry matter intake per animal for animal group g in stratum i, as per Equation 4 | kg $head^{-1}$ $day^{-1}$ |
| $\text{Y}_{\text{m,g}}$ | Default enteric $CH_4$ conversion factor for the diet of animal group g in stratum i, as set out in the *Emission Factor and Reference Values* document | unitless |
| $\text{EF}_{\text{lip,g}}$ | Default emission factor for the addition of supplemented lipid fed to animal group g in stratum i, as set out in the *Emission Factor and Reference Values* document | unitless |
| $\text{DOF}_{\text{g}}$ | Days on feed for animal group g in stratum i | day |
| 55.65 | Specific energy content per kg of $CH_4$ | MJ $kg^{-1}$ |
| $\text{GWP}_{\text{CH4}}$ | GWP of $CH_4$, as set out in Schedule 3 to the Act | unitless |

| Parameter | Description | Units |
|---|---|---|
| $1000$ | Kilograms per metric tonne | kg $t^{-1}$ |
| $i$ | Specific stratum in the baseline scenario | unitless |
| $g$ | Specific animal group in stratum i | unitless |
| $n$ | Number of animal groups in stratum i | unitless |

**Equation 4: Mean daily dry matter intake in an animal group**

$$\mathrm{DDMI_g} = \mathrm{DM_g} \div \left(\mathrm{AN_g} \times \mathrm{DOF_g}\right)$$

| Parameter | Description | Units |
|---|---|---|
| $\mathrm{DDMI_g}$ | Mean daily dry matter intake per animal for animal group g in a stratum | kg $head^{-1}$ $day^{-1}$ |
| $\mathrm{DM_g}$ | Quantity of dry matter delivered to animal group g in a stratum | kg |
| $\mathrm{AN_g}$ | Mean number of animals in animal group g in a stratum | head |
| $\mathrm{DOF_g}$ | Days on feed for animal group g in a stratum | day |
| $g$ | Specific animal group in a stratum | unitless |

### 8.2.2 GHG emissions from manure storage in the baseline scenario

Equation 5 and the subsequent equations in Section 8.2.2 must be used to quantify GHG emissions from manure storage for each stratum in the baseline scenario.

**Equation 5: GHG emissions from manure storage for a stratum in the baseline scenario**

$$\mathrm{Manure_{BE,i}} = \mathrm{MM_{BE,i}} + \mathrm{SN_{BE,i}} + \mathrm{VN_{BE,i}} + \mathrm{LN_{BE,i}}$$

| Parameter | Description | Units |
|---|---|---|
| $\mathrm{Manure_{BE,i}}$ | GHG emissions from manure storage for stratum i in the baseline scenario (SSR B7) | t $CO_2e$ |
| $\mathrm{MM_{BE,i}}$ | $CH_4$ emissions from manure for stratum i in the baseline scenario, as per Equation 7 | t $CO_2e$ |
| $\mathrm{SN_{BE,i}}$ | Direct $N_2O$ emissions from manure for stratum i in the baseline scenario, as per Equation 9 | t $CO_2e$ |
| $\mathrm{VN_{BE,i}}$ | Indirect $N_2O$ emissions from volatilization of manure for stratum i in the baseline scenario, as per Equation 11 | t $CO_2e$ |

| Parameter | Description | Units |
|---|---|---|
| $LN_{BE,i}$ | Indirect $N_2O$ emissions from leaching of manure for stratum i in the baseline scenario, as per Equation 12 | t $CO_2e$ |
| i | Specific stratum in the baseline scenario | unitless |

Equations 7, 9, 11 and 12 rely on reference values based on the type of manure storage systems, which are contained in the *Emission Factors and Reference Values* document. They must apply to all animals within an animal group.

If manure was directed to multiple types of manure storage systems that have different reference values, a mean reference value weighted to the estimated proportion of manure contained in each system must be used, as per Equation 6.

**Equation 6: Weighted mean of reference values for multiple manure storage systems**

$$\mathrm{EFRV_{mean}} = \sum_{x}^{n} \mathrm{EFRV_x} \times \mathrm{Mass_x} \div \mathrm{Mass_{Total}}$$

| Parameter | Description | Units |
|---|---|---|
| $\mathrm{EFRV_{mean}}$ | Weighted mean for parameter MCF, $EF_{MS}$, $Frac_V$ or $Frac_L$ to be used in relevant equations when manure is directed into multiple types of manure storage systems | unitless |
| $\mathrm{EFRV_x}$ | Reference value for the parameter MCF, $EF_{MS}$, $Frac_V$ or $Frac_L$ corresponding to manure storage system x, as set out in the *Emission Factors and Reference Values* document | unitless |
| $\mathrm{Mass_x}$ | Estimated mass of manure entering manure storage system x | kg |
| $\mathrm{Mass_{Total}}$ | Total mass of manure entering all manure storages | kg |
| x | Type of manure storage system | unitless |
| n | Total number of manure storage systems with different default reference values | unitless |

If the manure storage system changes for a stratum in the project scenario after the initial baseline scenario GHG emission intensity was quantified (as per Equation 2), the baseline scenario GHG emission intensity for the corresponding stratum in the baseline scenario must be re-quantified using the updated information. The re-quantified baseline scenario GHG emission intensity is not retroactively applied. It must be used for the quantification of baseline scenario GHG emissions (as per Equation 1) starting in the calendar year in which the manure storage system changed and onwards.

**Equation 7: $CH_4$ emissions from manure for a stratum in the baseline scenario**

$$MM_{BE,i} = \sum_{g}^{n} \left( AN_g \times DOF_g \times VS_g \times 0.19 \times \rho_{CH4} \times MCF \times GWP_{CH4} \div 1000 \right)$$

| Parameter | Description | Units |
|---|---|---|
| $MM_{BE,i}$ | $CH_4$ emissions from manure for stratum i in the baseline scenario | t $CO_2e$ |
| $AN_g$ | Mean number of animals in animal group g in stratum i | head |
| $DOF_g$ | Days on feed for animal group g in stratum i | day |
| $VS_g$ | Daily volatile solids excreted per animal in animal group g in stratum i, as per Equation 8 | kg $head^{-1}$ $day^{-1}$ |
| $0.19$ | Maximum $CH_4$ producing capacity for manure expressed as a constant of 0.19 $m^3$ of $CH_4$ per kg of volatile solids excreted | $m^3$ $kg^{-1}$ |
| $\rho_{CH4}$ | $CH_4$ density conversion factor of 0.67 kg $m^{-3}$ | kg $m^{-3}$ |
| $MCF$ | $CH_4$ conversion factor for the manure storage system, as set out in the *Emission Factors and Reference Values* document | unitless |
| $GWP_{CH4}$ | GWP of $CH_4$, as set out in Schedule 3 to the Act | unitless |
| $1000$ | Kilograms per metric tonne | kg $t^{-1}$ |
| $i$ | Specific stratum the baseline scenario | unitless |
| $g$ | Specific animal group in stratum i | unitless |
| $n$ | Number of animal groups in stratum i | unitless |

**Equation 8: Daily volatile solids excreted for an animal group**

$$VS_g = \left[ DDMI_g \times \left(1 - TDN_g\right) + \left(UE \times DDMI_g\right) \right] \times (1 - ASH)$$

| Parameter | Description | Units |
|---|---|---|
| $VS_g$ | Daily volatile solids excreted per animal in animal group g in a stratum | kg $head^{-1}$ $day^{-1}$ |
| $DDMI_g$ | Mean daily dry matter intake per animal for animal group g in a stratum, as per Equation 4 | kg $head^{-1}$ $day^{-1}$ |

| Parameter | Description | Units |
|---|---|---|
| $TDN_g$ | Percentage of total digestible nutrients for animal group g in a stratum expressed as a decimal, determined as per Section 9.0 | unitless |
| $UE$ | Default factor for urinary energy. Use 0.04 for diets with less than 85% concentrates and 0.02 for diets with greater than or equal to 85% concentrates | unitless |
| $ASH$ | Default factor of 0.08 for ash content of manure | unitless |
| $g$ | Specific animal group in a stratum | unitless |

**Equation 9: Direct $N_2O$ emissions from manure for a stratum in the baseline scenario**

$$SN_{BE,i} = \sum_{g}^{n} \left( AN_g \times DOF_g \times NEX_g \times EF_{MS} \times \frac{44}{28} \times GWP_{N2O} \div 1000 \right)$$

| Parameter | Description | Units |
|---|---|---|
| $SN_{BE,i}$ | Direct $N_2O$ emissions from manure from stratum i in the baseline scenario | t $CO_2e$ |
| $AN_g$ | Mean number of animals in animal group g in stratum i | head |
| $DOF_g$ | Days on feed for animal group g in stratum i | day |
| $NEX_g$ | Daily mean nitrogen (N) excreted in manure per animal for animal group g in stratum i, as per Equation 10 | kg $head^{-1}$ $day^{-1}$ |
| $EF_{MS}$ | Emission factor for direct $N_2O$ emissions from the manure storage system to determine the kg $N_2O$-N per kg N stored, as set out in the *Emission Factors and Reference Values* document | unitless |
| $44/28$ | Conversion of $N_2O$-N to $N_2O$ emissions based on molecular mass of $N_2O$ and $N_2O$-N | unitless |
| $GWP_{N2O}$ | GWP of $N_2O$, as set out in Schedule 3 to the Act | unitless |
| $1000$ | Kilograms per metric tonne | kg $t^{-1}$ |
| $i$ | Specific stratum in the baseline scenario | unitless |
| $g$ | Specific animal group in stratum i | unitless |
| $n$ | Number of animal groups in stratum i | unitless |

**Equation 10: Daily mean N excreted in manure for an animal group**

$$NEX_g = DDMI_g \times CP_g \times CF_p \times (1 - NR)$$

| Parameter | Description | Units |
|---|---|---|
| $NEX_g$ | Daily mean N excreted in manure per animal for animal group g in a stratum | kg head$^{-1}$ day$^{-1}$ |
| $DDMI_g$ | Mean daily dry matter intake per head for animal group g in a stratum, as per Equation 4 | kg head$^{-1}$ day$^{-1}$ |
| $CP_g$ | Percentage of crude protein in the diet of animal group g in a stratum expressed as a decimal, determined as per Section 9.0 | unitless |
| $CF_p$ | Default protein conversion factor to describe the conversion of dietary protein to dietary N. Equal to 1 kg-dietary N per 6.25 kg of protein | unitless |
| $NR$ | Default factor of 0.07 for the fraction of kg-N retained per kg-N consumed | unitless |
| $g$ | Specific animal group in a stratum | unitless |

**Equation 11: Indirect $N_2O$ emissions from volatilization of manure for a stratum in the baseline scenario**

$$VN_{BE,i} = \sum_{g}^{n} \left( AN_g \times DOF_g \times NEX_g \times Frac_V \times EF_V \times \frac{44}{28} \times GWP_{N2O} \div 1000 \right)$$

| Parameter | Description | Units |
|---|---|---|
| $VN_{BE,i}$ | Indirect $N_2O$ emissions from volatilization of manure for stratum i in the baseline scenario | t $CO_2e$ |
| $AN_g$ | Mean number of animals in animal group g in stratum i | head |
| $DOF_g$ | Days on feed for animal group g in stratum i | day |
| $NEX_g$ | Daily mean N excreted in manure per animal for animal group g in stratum i, as per Equation 10 | kg head$^{-1}$ day$^{-1}$ |
| $Frac_V$ | Fraction of N excreted in manure that volatilizes as ammonia ($NH_3$) and nitrogen oxides ($NO_x$) from the manure storage system, as set out in the *Emission Factors and Reference Values* document | unitless |
| $EF_V$ | Emission factor for indirect $N_2O$ emissions from volatilization of manure by ecozone to determine kg $N_2O$-N | unitless |

| Parameter | Description | Units |
|---|---|---|
| | per kg N deposited, as set out in the *Emission Factors and Reference Values* document | |
| $44/28$ | Conversion of $N_2O$-N to $N_2O$ emissions based on molecular mass of $N_2O$ and $N_2O$-N | unitless |
| $GWP_{N2O}$ | GWP of $N_2O$, as set out in Schedule 3 to the Act | unitless |
| $1000$ | Kilograms per metric tonne | kg $t^{-1}$ |
| $i$ | Specific stratum in the baseline scenario | unitless |
| $g$ | Specific animal group in stratum i | unitless |
| $n$ | Number of animal groups in stratum i | unitless |

**Equation 12: Indirect $N_2O$ emissions from leaching of manure for a stratum in the baseline scenario**

$$LN_{BE,i} = \sum_{g}^{n} \left( AN_g \times DOF_g \times NEX_g \times Frac_L \times EF_L \times \frac{44}{28} \times GWP_{N2O} \div 1000 \right)$$

| Parameter | Description | Units |
|---|---|---|
| $LN_{BE,i}$ | Indirect $N_2O$ emissions from leaching of manure from stratum i in the baseline scenario | t $CO_2e$ |
| $AN_g$ | Mean number of animals in animal group g in stratum i | head |
| $DOF_g$ | Days on feed for animal group g in stratum i | day |
| $NEX_g$ | Daily mean N excreted in manure per animal for animal group g in stratum i, as per Equation 10 | kg $head^{-1}$ $day^{-1}$ |
| $Frac_L$ | Fraction of N excreted in manure leached from the manure storage system, as set out in the *Emission Factors and Reference Values* document | unitless |
| $EF_L$ | Emission factor for indirect $N_2O$ emissions from leaching and runoff of manure set at 0.0075 kg $N_2O$-N per kg N leached | unitless |
| $44/28$ | Conversion of $N_2O$-N to $N_2O$ emissions based on molecular mass of $N_2O$ and $N_2O$-N | unitless |
| $GWP_{N2O}$ | GWP of $N_2O$, as set out in Schedule 3 to the Act | unitless |
| $1000$ | Kilograms per metric tonne | kg $t^{-1}$ |
| $i$ | Specific stratum in the baseline scenario | unitless |

| Parameter | Description | Units |
|---|---|---|
| g | Specific animal group in stratum i | unitless |
| n | Number of animal groups in stratum i | unitless |

### 8.2.3 Beef production in the baseline scenario

The proponent must use Equation 13 to quantify the beef production for each stratum in the baseline scenario, which represents the average mass gained by the stratum. The value used for the mean mass of animals at entry and exit in Equation 13 is determined by stratum based on the destination of the animals exiting the project site.

For a stratum that is not sent directly to a meat processing facility upon exiting the project site (e.g., backgrounding operation), the mean mass of animals upon entry and exit is determined by the measure of mean live weight of animals entering ($LW_{enter,g}$) and exiting ($LW_{exit,g}$) the project site.

For a stratum sent directly to a meat processing facility after exiting the project site (e.g., finishing operation), the mean mass of animals upon entry and exit is determined by the calculation of the hot carcass weight (HCW) as per Equation 14. If the mean mass of animals for a stratum in the baseline scenario is determined through Equation 14, the mean mass of animals for the corresponding stratum in the project scenario must also be determined through Equation 14. The same approach and metric (LW or HCW) must be used for all groups in a stratum.

**Equation 13: Beef production for a stratum in the baseline scenario**

$$\text{Production}_{\text{BE,i}} = \sum_{\text{g}}^{\text{n}} (\text{Mass}_{\text{exit,g}} - \text{Mass}_{\text{enter,g}})$$

| Parameter | Description | Units |
|---|---|---|
| $\text{Production}_{\text{BE,i}}$ | Beef production for stratum i in the baseline scenario | kg |
| $\text{Mass}_{\text{exit,g}}$ | Mean mass of animals exiting the project site for animal group g in stratum i, determined by either live weight, or hot carcass weight as per Equation 14 | kg |
| $\text{Mass}_{\text{enter,g}}$ | Mean mass of animals entering the project site for animal group g in stratum i, determined by either live weight, or hot carcass weight as per Equation 14 | kg |
| i | Specific stratum in the baseline scenario | unitless |
| g | Specific animal group in stratum i | unitless |
| n | Number of animal groups in stratum i | unitless |

Equation 14 must be used to calculate both $HCW_{exit,g}$ and $HCW_{enter,g}$. For the purposes of quantification, it is assumed that the dressing percentage is the same at animal entry and exit from the project site. Therefore, the dressing percentage provided by the meat processing facility must be used to calculate both the entry and exit value of $HCW_g$.

**Equation 14: Hot carcass weight for an animal group at either entry or exit from the project site**

$$\mathrm{HCW_g} = \mathrm{Dressing_g} \times \mathrm{LW_g}$$

| Parameter | Description | Units |
|---|---|---|
| $\mathrm{HCW_g}$ | Mean hot carcass weight of animals entering ($HCW_{enter,g}$) or exiting ($HCW_{exit,g}$) the project site for animal group g | kg |
| $\mathrm{Dressing_g}$ | Dressing percentage for animal group g, either directly provided by the meat processing facility or quantified using Equation 15. If data is not available a default value of 0.59 must be used | unitless |
| $\mathrm{LW_g}$ | Mean live weight of animals entering ($LW_{enter,g}$) or exiting ($LW_{exit,g}$) the project site for animal group g | kg |
| g | Specific animal group in a stratum | unitless |

If the meat processing facility does not provide a dressing percentage and only provides hot carcass weight (applicable only to animals exiting the project site, $HCW_{exit,g}$), Equation 15 must be used to solve for dressing percentage and perform the final calculation for $HCW_{enter,g}$. If sufficient data is not available from the meat processing facility, the proponent must use a default dressing percentage of 59%.

Mean values for animal mass entering and exiting the project site and dressing percentage must be quantified using data from all animals within a stratum.

**Equation 15: Dressing percentage of an animal group**

$$\mathrm{Dressing_g} = \mathrm{HCW_{exit,g}} \div \mathrm{LW_{exit,g}}$$

| Parameter | Description | Units |
|---|---|---|
| $\mathrm{Dressing_g}$ | Dressing percentage for animal group g | unitless |
| $\mathrm{HCW_{exit,g}}$ | Mean hot carcass weight of animals exiting the project site for animal group g | kg |
| $\mathrm{LW_{exit,g}}$ | Mean live weight of animals exiting the project site for animal group g | kg |
| g | Specific animal group in a stratum | unitless |

## 8.3 Project scenario GHG emissions

The proponent must use Equation 16 and the subsequent equations in Section 8.3 to quantify the project scenario GHG emissions for each full or partial calendar year of the reporting period based on the included SSRs outlined in Table 2. Equation 16 must include all strata with a median date of animal exit that falls within a calendar year covered by the reporting period. Each stratum in the project scenario must consist of a single animal group.

**Equation 16: Project scenario GHG emissions for a calendar year covered by the reporting period**

$$\mathrm{PE_c} = \sum_{k}^{n} \left(\mathrm{Enteric_{PE,k}} + \mathrm{Manure_{PE,k}}\right)$$

| Parameter | Description | Units |
|---|---|---|
| $\mathrm{PE_C}$ | GHG emissions for the strata in the project scenario with a median date of animal exit that falls within a calendar year covered by the reporting period | t $CO_2e$ |
| $\mathrm{Enteric_{PE,k}}$ | Enteric $CH_4$ emissions for stratum k in the project scenario, as per Equation 17 (SSR P6) | t $CO_2e$ |
| $\mathrm{Manure_{PE,k}}$ | GHG emissions from manure storage for stratum k in the project scenario, as per Equation 18 (SSR P7) | t $CO_2e$ |
| $\mathrm{k}$ | Specific stratum in the project scenario with a median date of animal exit that falls within a calendar year covered by the reporting period | unitless |
| $\mathrm{n}$ | Number of strata in the project scenario with a median date of animal exit that falls within a calendar year covered by the reporting period | unitless |
| $\mathrm{C}$ | Calendar year | unitless |

### 8.3.1 Enteric $CH_4$ emissions in the project scenario

Equation 17 must be used to quantify the enteric $CH_4$ emissions associated with each stratum for the project scenario.

**Equation 17: Enteric $CH_4$ emissions for a stratum in the project scenario**

$$\mathrm{Enteric_{PE,k}} = \mathrm{AN_g} \times \mathrm{GE_g} \times \mathrm{DDMI_g} \times \mathrm{Y_{m,g}} \times \mathrm{EF_{lip,g}} \times \mathrm{DOF_g} \div 55.65 \times \mathrm{GWP_{CH4}} \div 1000$$

| Parameter | Description | Units |
|---|---|---|
| $\mathrm{Enteric_{PE,k}}$ | Enteric $CH_4$ emissions for stratum k in the project scenario (SSR P6) | t $CO_2e$ |

| Parameter | Description | Units |
|---|---|---|
| $AN_g$ | Mean number of animals in the animal group in stratum k | head |
| $GE_g$ | Default gross energy intake for the diet of the animal group in stratum k, equal to 19.10 MJ per kg of dry matter if the dietary lipid concentration is ≥4.0%, or 18.45 MJ per kg of dry matter if the dietary lipid concentration is <4.0% | MJ $kg^{-1}$ |
| $DDMI_g$ | Mean daily dry matter intake per animal for the animal group in stratum k, as per Equation 4 | kg $head^{-1}$ $day^{-1}$ |
| $Y_{m,g}$ | Default enteric $CH_4$ conversion factor for the diet of the animal group in stratum k, as set out in the *Emission Factors and Reference Values* document | unitless |
| $EF_{lip,g}$ | Default emission factor for the addition of supplemented lipid for the animal group in stratum k, as set out in the *Emission Factors and Reference Values* document | unitless |
| $DOF_g$ | Days on feed for the animal group in stratum k | day |
| $55.65$ | Specific energy content per kg of $CH_4$ | MJ $kg^{-1}$ |
| $GWP_{CH4}$ | GWP of $CH_4$, as set out in Schedule 3 to the Act | unitless |
| $1000$ | Kilograms per metric tonne | kg $t^{-1}$ |
| $g$ | The animal group in stratum k | unitless |
| $k$ | Specific stratum in the project scenario with a median date of animal exit that falls within a calendar year covered by the reporting period | unitless |

### 8.3.2 GHG emissions from manure storage in the project scenario

Equations 18 and the subsequent equations in Section 8.3.2 must be used to quantify GHG emissions from manure storage for each stratum in the project scenario.

**Equation 18: GHG emissions from manure storage for a stratum in the project scenario**

$$Manure_{PE,k} = MM_{PE,k} + SN_{PE,k} + VN_{PE,k} + LN_{PE,k}$$

| Parameter | Description | Units |
|---|---|---|
| $Manure_{PE,K}$ | GHG emissions from manure storage for stratum k in the project scenario (SSR P7) | t $CO_2e$ |
| $MM_{PE,k}$ | $CH_4$ emissions from manure for stratum k in the project scenario, as per Equation 19 | t $CO_2e$ |

| Parameter | Description | Units |
|---|---|---|
| $SN_{PE,k}$ | Direct $N_2O$ emissions from manure for stratum k in the project scenario, as per Equation 20 | t $CO_2e$ |
| $VN_{PE,k}$ | Indirect $N_2O$ emissions from volatilization of manure for stratum k in the project scenario, as per Equation 21 | t $CO_2e$ |
| $LN_{PE,k}$ | Indirect $N_2O$ emissions from leaching of manure for stratum k in the project scenario, as per Equation 22 | t $CO_2e$ |
| $k$ | Specific stratum in the project scenario with a median date of animal exit that falls within a calendar year covered by the reporting period | unitless |

Equations 19 to 22 rely on reference values based on the type of manure storage system, which are contained in the *Emission Factors and Reference Values* document. They must apply to all animals within an animal group.

If manure was directed to multiple types of manure storage systems that have different reference values, a mean factor weighted to the estimated proportion of manure contained in each system must be used, as per Equation 6.

**Equation 19: $CH_4$ emissions from manure for a stratum in the project scenario**

$$MM_{PE,k} = AN_g \times DOF_g \times VS_g \times 0.19 \times \rho_{CH4} \times MCF \times GWP_{CH4} \div 1000$$

| Parameter | Description | Units |
|---|---|---|
| $MM_{PE,k}$ | $CH_4$ emissions from manure from stratum k in the project scenario | t $CO_2e$ |
| $AN_g$ | Mean number of animals in the animal group in stratum k | head |
| $DOF_g$ | Days on feed for the animal group in stratum k | day |
| $VS_g$ | Daily volatile solids excreted per head in the animal group in stratum k, as per Equation 8 | kg $head^{-1}$ $day^{-1}$ |
| $0.19$ | Maximum $CH_4$ producing capacity for manure expressed as a constant of 0.19 $m^3$ of $CH_4$ per kg of volatile solids excreted | $m^3$ $kg^{-1}$ |
| $\rho_{CH4}$ | $CH_4$ density conversion factor of 0.67 kg $m^{-3}$ | kg $m^{-3}$ |
| $MCF$ | $CH_4$ conversion factor for the manure storage system, as set out in the *Emission Factors and Reference Values* document | unitless |
| $GWP_{CH4}$ | GWP of $CH_4$, as set out in Schedule 3 to the Act | unitless |
| $1000$ | Kilograms per metric tonne | kg $t^{-1}$ |

| Parameter | Description | Units |
|---|---|---|
| $g$ | The animal group in stratum k | unitless |
| $k$ | Specific stratum the project scenario with a median date of animal exit that falls within a calendar year covered by the reporting period | unitless |

**Equation 20: Direct $N_2O$ emissions from manure for a stratum in the project scenario**

$$SN_{PE,k} = AN_g \times DOF_g \times NEX_g \times EF_{MS} \times \frac{44}{28} \times GWP_{N2O} \div 1000$$

| Parameter | Description | Units |
|---|---|---|
| $SN_{PE,k}$ | Direct $N_2O$ emissions from manure for stratum k in the project scenario | t $CO_2e$ |
| $AN_g$ | Mean number of animals in the animal group in stratum k | head |
| $DOF_g$ | Days on feed for the animal group in stratum k | day |
| $NEX_g$ | Daily mean N excreted in manure per animal for the animal group in stratum k, as per Equation 10 | kg $head^{-1}$ $day^{-1}$ |
| $EF_{MS}$ | Emission factor for direct $N_2O$ emissions from the manure storage system to determine the kg $N_2O$-N per kg N stored, as set out in the *Emission Factors and Reference Values* document | unitless |
| $44/28$ | Conversion of $N_2O$-N to $N_2O$ emissions based on molecular mass of $N_2O$ and $N_2O$-N | unitless |
| $GWP_{N2O}$ | GWP of $N_2O$, as set out in Schedule 3 to the Act | unitless |
| $1000$ | Kilograms per metric tonne | kg $t^{-1}$ |
| $g$ | The animal group in stratum k | unitless |
| $k$ | Specific stratum in the project scenario with a median date of animal exit that falls within a calendar year covered by the reporting period | unitless |

**Equation 21: Indirect $N_2O$ emissions from volatilization of manure for a stratum in the project scenario**

$$VN_{PE,k} = AN_g \times DOF_g \times NEX_g \times Frac_V \times EF_V \times \frac{44}{28} \times GWP_{N2O} \div 1000$$

| Parameter | Description | Units |
|---|---|---|
| $VN_{PE,k}$ | Indirect $N_2O$ emissions from volatilization of manure for stratum k in the project scenario | t $CO_2e$ |
| $AN_g$ | Mean number of animals in the animal group in stratum k | head |
| $DOF_g$ | Days on feed for the animal group in stratum k | day |
| $NEX_g$ | Daily mean N excreted in manure per animal for the animal group in stratum k, as per Equation 10 | kg $head^{-1}$ $day^{-1}$ |
| $Frac_V$ | Fraction of N excreted in manure that volatilizes as ammonia ($NH_3$) and $NO_x$ from the manure storage system, as set out in the *Emission Factors and Reference Values* document | unitless |
| $EF_V$ | Emission factor for indirect $N_2O$ emissions from volatilization of manure based on ecozone to determine kg $N_2O$-N per kg N deposited, as set out in the *Emission Factors and Reference Values* document | unitless |
| $44/28$ | Conversion of $N_2O$-N to $N_2O$ emissions based on molecular mass of $N_2O$ and $N_2O$-N | unitless |
| $GWP_{N2O}$ | GWP of $N_2O$, as set out in Schedule 3 to the Act | t $CO_2e$ t $N_2O^{-1}$ |
| $1000$ | Kilograms per metric tonne | kg $t^{-1}$ |
| $g$ | The animal group in stratum k | unitless |
| $k$ | Specific stratum in the project scenario with a median date of animal exit that falls within a calendar year covered by the reporting period | unitless |

**Equation 22: Indirect $N_2O$ emissions from leaching of manure for a stratum in the project scenario**

$$LN_{PE,k} = AN_g \times DOF_g \times NEX_g \times Frac_L \times EF_L \times \frac{44}{28} \times GWP_{N2O} \div 1000$$

| Parameter | Description | Units |
|---|---|---|
| $LN_{PE,k}$ | Indirect $N_2O$ emissions from leaching of manure for stratum k in the project scenario | t $CO_2e$ |
| $AN_g$ | Mean number of animals in the animal group in stratum k | head |
| $DOF_g$ | Days on feed for the animal group in stratum k | day |
| $NEX_g$ | Daily mean N excreted in manure per animal by the animal group in stratum k, as per Equation 10 | kg $head^{-1}$ $day^{-1}$ |

| Parameter | Description | Units |
|---|---|---|
| $\mathrm{Frac_L}$ | Fraction of N excreted in manure leached from the manure storage system, as set out in the *Emission Factors and Reference Values* document | unitless |
| $\mathrm{EF_L}$ | Emission factor for indirect $N_2O$ emissions from leaching and runoff of manure set at 0.0075 kg $N_2O$-N per kg N leached | unitless |
| $44/28$ | Conversion of $N_2O$-N to $N_2O$ emissions based on molecular mass of $N_2O$ and $N_2O$-N. | unitless |
| $\mathrm{GWP_{N2O}}$ | GWP of $N_2O$, as set out in Schedule 3 to the Act | unitless |
| $1000$ | Kilograms per metric tonne | kg $t^{-1}$ |
| $\mathrm{g}$ | The animal group in stratum k | unitless |
| $\mathrm{k}$ | Specific stratum in the project scenario with a median date of animal exit that falls within a calendar year covered by the reporting period | unitless |

### 8.3.3 Beef production in the project scenario

The proponent must use Equation 23 to quantify the beef production value for each stratum in the project scenario, which represents the average mass gained by the stratum. The value used for the mean mass of animals at entry and exit in Equation 23 is determined by stratum based on the destination of the animals exiting the project site.

For a stratum that is not sent directly to a meat processing facility upon exiting the project site (e.g. backgrounding operation), the mean mass of animals upon entry and exit is determined by the measure of mean live weight of animals entering ($LW_{enter,g}$) and exiting ($LW_{exit,g}$) the project site.

For a stratum sent directly to a meat processing facility after exiting the project site (e.g. finishing operation), the mean mass of animals upon entry and exit is determined by the calculation of the hot carcass weight (HCW) as per Equation 14. If the mean mass of animals for a stratum in the project scenario is determined through Equation 14, the mean mass of animals for the corresponding stratum in the baseline scenario must also be determined through Equation 14.

**Equation 23: Beef production for a stratum in the project scenario**

$$\mathrm{Production_{PE,k}} = \mathrm{Mass_{exit,g}} - \mathrm{Mass_{enter,g}}$$

| Parameter | Description | Units |
|---|---|---|
| $\mathrm{Production_{PE,k}}$ | Beef production for stratum k in the project scenario | kg |

| Parameter | Description | Units |
|---|---|---|
| $\mathrm{Mass}_{\mathrm{exit,g}}$ | Mean mass of animals exiting the project site for the animal group in stratum k, determined by either the live weight, or the hot carcass weight as per Equation 14 | kg |
| $\mathrm{Mass}_{\mathrm{enter,g}}$ | Mean mass of animals entering the project site for the animal group in stratum k, determined by either the live weight or the hot carcass weight as per Equation 14 | kg |
| $\mathrm{g}$ | The animal group in stratum k | unitless |
| $\mathrm{k}$ | Specific stratum in the project scenario with a median date of animal exit that falls within a calendar year covered by the reporting period | unitless |

## 8.4 Leakage

A project that reduces the quantity of beef produced in the project scenario compared to the baseline scenario poses a leakage risk. This leakage risk is avoided in this protocol by quantifying GHG emissions in the baseline scenario relative to the mass of beef produced in the project scenario to ensure functional equivalency between the baseline and project scenarios.

As a result, there is no leakage discount factor (which corresponds to variable $C_i$ in the formula in subsection 20(2) of the Regulations) to be applied for the quantification of GHG emission reductions generated by a project implemented following this protocol.

## 8.5 Project GHG emission reductions

The proponent must use Equation 24 to quantity the GHG emission reductions ($ER_C$) generated by the project, which correspond to the GHG reductions determined in accordance with section 20 of the Regulations.

**Equation 24: Project GHG emission reductions for a calendar year covered by the reporting period**

$$\mathrm{ER_C} = \mathrm{BE_C} - \mathrm{PE_C}$$

| Parameter | Description | Units |
|---|---|---|
| $\mathrm{ER_C}$ | Project GHG emission reductions for a calendar year covered by the reporting period | t $CO_2$e |
| $\mathrm{BE_C}$ | GHG emissions from the strata in the baseline scenario that correspond to the strata in the project scenario with a median date of animal exit that falls within a calendar year covered by the reporting period, as per Equation 1 | t $CO_2$e |

| Parameter | Description | Units |
|---|---|---|
| $PE_C$ | GHG emissions for the strata in the project scenario with a median date of animal exit that falls within a calendar year covered by the reporting period, as per Equation 16 | t $CO_2e$ |
| $C$ | Calendar year | unitless |

# 9.0 Measurement and data

## 9.1 Measurement method and frequency

Table 3 identifies the parameters in the quantification methodology that must be measured and provides details regarding their measurement method and frequency.

**Table 3: Measurement method and frequency for measured parameters**

| Parameter | Description | Units | Measurement method and frequency | Equations |
|---|---|---|---|---|
| $AN$ | Mean number of animals in an animal group | head | Determined by counting the number of animals on feed each day and then dividing by the number of days in the beef production period as described in Section 9.2. | 3, 4, 7, 9, 11, 12, 17, 19, 20, 21, 22 |
| $DOF$ | Days on feed | day | Determined at the end of the beef production period. Starts on the first day an animal in an animal group is fed and ends on the last day an animal in an animal group is fed. | 3, 4, 7, 9, 11, 12, 17, 19, 20, 21, 22 |
| $DM$ | Quantity of dry matter delivered to animals | kg | Weighed daily as feed is delivered to animals and added together for an animal group at the end of the beef production period. Separation required by forage and concentrate content to inform enteric $CH_4$ conversion factor ($Y_m$). | 4 |
| $GE$ | Default gross energy intake for the diet per unit of dry mass of feed delivered | MJ $kg^{-1}$ | Default value based on the concentration of dietary lipid. Dietary lipid must be determined through feed analysis, as per Section 9.3. Dietary lipid is measured once for each unique diet or each feed ingredient in the diet fed to an animal group. | 3, 17 |
| $Y_m$ | Default enteric $CH_4$ conversion factor for | - | Forage content determined by mass of dry matter (DM) delivered | 3, 17 |

| Parameter | Description | Units | Measurement method and frequency | Equations |
|---|---|---|---|---|
| | a diet based on forage content and quality | | to animals and diet quality (TDN) determined through feed analysis, as per Section 9.3. | |
| $EF_{lip}$ | Default emission factor based on percentage of supplemented lipid added to the diet | - | Determined through feed analysis, as per Section 9.3. Measured once for each unique diet or each feed ingredient in the diet fed to an animal group. | 3, 17 |
| CP | Percentage of crude protein in the diet fed expressed as a decimal | - | Determined through feed analysis, as per Section 9.3. Measured once for each unique diet or each feed ingredient in the diet fed to an animal group. | 10 |
| TDN | Percentage of total digestible nutrients in the diet fed expressed as a decimal | - | Determined through feed analysis, as per Section 9.3. Measured once for each unique diet or each feed ingredient in the diet fed to an animal group. Also used to inform enteric $CH_4$ conversion factor ($Y_m$). | 8 |
| Mass | Mean mass of animals in an animal group entering or exiting the project site determined by either live weight or hot carcass weight | kg | If live weight is used, animals are weighed at the start and end of the beef production period, and the mean is determined for the animal group. If hot carcass weight is used, mass is determined using Equation 14. | 13, 23 |
| Dressing | Dressing percentage of the animal | % | Determined once at the end of the beef production period and the mean is determined for the animal group. Measured by meat processing facility or quantified using Equation 15. | 14, 15 |
| LW | Mean live weight of animals in an animal group entering or exiting the project site | kg | Animals are weighed at the start and end of the beef production period, and the mean is determined for the animal group. | 14, 15 |

Parameters GE, $Y_m$ and $EF_{lip}$ use default values and are not directly measured. These default values must be selected based on the composition and quantity of certain feed ingredients which require measurement. Some Table 3 parameters require measurement by animal or diet and must be averaged as per Section 9.3.

Dressing percentage is determined by the meat processing facility and may not be applicable to all strata. A default factor may be used instead of measurement under the conditions described in Sections 8.2.3 and 8.3.3.

## 9.2 Animal inventory and diet information

The proponent must use a head-days animal inventory method to track the number of animals being housed and fed at the project site in an animal group each day. For each animal group, the proponent must document the number of animals fed, the type of diet, and the quantity of dry matter delivered for each day on feed. The daily number of animals must not include animals that were permanently or temporarily removed from a group for reasons such as death or sickness.

The head-days animal inventory is used to calculate the mean number of animals in an animal group. The diet and dry matter delivery information is also used to support the calculations for the weighted value of feed parameters in Section 9.3.

## 9.3 Feed analysis

### 9.3.1 Parameters requiring feed analysis

Several equations in Section 8.0 use parameters that are based on the composition of the diet delivered to an animal group. These parameters must be determined through feed analysis, as identified in Table 3.

Feed analysis of the diet must be completed using one of the following methods:

1. Sampling and laboratory analysis:
    - Feed samples collected and sent for laboratory analysis must be representative of the selected feed, ingredient, or diet.
    - Sampling must be completed by a qualified professional.
    - Laboratory analysis of dietary lipid content must be based on total ether extract concentration.
2. On-farm near infrared spectroscopy analysis:
    - The proponent must follow the requirements in Section 9.4.
3. Guaranteed analysis for nutrients provided by the feed manufacturer.
4. If values for TDN are not available using methods one to three above, proponents may use reference values sourced by a qualified professional.

All feed parameters must be calculated on a dry mass basis.

### 9.3.2 Weighted values for feed parameters

Values for the parameters in Table 3 must be representative of the entire diet for the animal group. If the diet of an animal group varies in source or nutrient composition during the beef production period, a mean value must be used and weighted to the dry matter delivered to the animal group for each unique diet. The proponent must use Equation 25 to determine the

weighted mean for each parameter determined by feed analysis identified in Table 3 for use in any applicable equations in Section 8.0.

**Equation 25: Weighted mean of Table 3 parameters requiring feed analysis**

$$WM_g = \sum_{x}^{n} FP_x \times DM_x \div DM$$

| Parameter | Description | Units |
|---|---|---|
| $WM_g$ | Weighted mean of the feed parameter in Table 3 for an animal group | Units of Table 3 parameter |
| $FP_x$ | Feed parameter value for diet x measured, or mean calculated as per Equation 26 | Units of Table 3 parameter |
| $DM_x$ | Quantity of dry matter delivered to an animal group, for diet x | kg |
| $x$ | Specific diet fed to an animal group | unitless |
| $n$ | Number of different diets fed to an animal group | unitless |
| $DM$ | Total quantity of dry matter delivered to an animal group for the beef production period | kg |

If on-farm near infrared spectroscopy or feed manufacturer guarantees are used to determined feed parameter values ($FP_x$), feed analysis must be conducted for each unique diet (x). If sampling and laboratory analysis is used to determine the feed parameter values ($FP_x$) for each unique diet (x), feed analysis may be conducted by diet or by each individual feed ingredient in the diet. For feed analysis conducted by sampling each feed ingredient, the proponent must use Equation 26 to calculate the mean value of the unique diet for input into Equation 25.

**Equation 26: Mean value of a specific diet fed to an animal group weighted to the dry matter of each feed ingredient contained in the diet**

$$FP_x = \sum_{y}^{n} (FI_y \times DM_y) \div DM_x$$

| Parameter | Description | Units |
|---|---|---|
| $FP_x$ | Mean feed parameter value for diet x | Units of Table 3 parameter |
| $FI_y$ | Measured value of feed ingredient y | Units of Table 3 parameter |
| $DM_y$ | Dry matter of feed ingredient y | kg |
| $DM_x$ | Dry matter of all feed ingredients in diet x | kg |

| Parameter | Description | Units |
|---|---|---|
| x | Specific diet fed to an animal group | unitless |
| y | Specific feed ingredient in diet x | unitless |
| n | Number of different feed ingredients in diet x | unitless |

## 9.4 Quality assurance and quality control

The proponent must have documented quality assurance and quality control (QA/QC) procedures and must implement them to ensure that all measurements and calculations are made in accordance with this protocol and can be verified.

For feed analysis conducted using on-farm near infrared spectroscopy, the proponent must check each on-farm near infrared spectroscopy device for accuracy by following manufacturer specifications at least once each calendar year. On-farm near infrared spectroscopy devices must also be calibrated by the manufacturer or by a third party certified for that purpose and in accordance with the manufacturer specifications, or every 5-years which ever is sooner.

The measurement accuracy of all on-farm near infrared spectroscopy devices must show that each device provides a reading that is within a ± 5% accuracy range compared to laboratory analysis. When the accuracy of an on-farm near infrared spectroscopy device deviates from the ± 5% range, the appropriate corrective action(s) must be taken, in accordance with the manufacturer specifications.

After the corrective action(s), the on-farm near infrared spectroscopy device must be rechecked for accuracy. If the accuracy of the on-farm near infrared spectroscopy device is still not within the ± 5% range, it must be calibrated by the manufacturer or by a third party certified for that purpose and following manufacturer specifications, no more than two months after the end of the reporting period.

For the entire period from the last time the on-farm near infrared spectroscopy device showed a reading within ± 5% accuracy, until the time it shows a return to ± 5% accuracy:

- When the inaccuracy of the on-farm near infrared spectroscopy device indicates an under-reporting, the measured values must be used without correction.
- When the inaccuracy of the on-farm near infrared spectroscopy device indicates an over-reporting, the measured values must be corrected by the percentage that the accuracy of the device deviated from the ± 5% range.

# 10.0 Records

## 10.1 General records

In addition to the record keeping requirements specified in the Regulations, the proponent must keep records of all data and information that supports the implementation of the project and verification, including invoices, contracts, maintenance records, calculations, databases,

photographs, and accuracy checks and/or calibration records for on-farm near infrared spectroscopy devices. The records must be kept and retained at the location and for the period of time specified in the Regulations. If a proponent chooses to work with a third party to collect, store and manage data for the project, they must have access to all data for the project.

The proponent must keep records from qualified professionals to support the project documentation where listed.

## 10.2 Animal inventory and performance

The proponent must keep a record of the information about the animals and their performance, including:

- Documentation that allows for the identification of every animal in both the baseline and project scenarios using radio-frequency identification (RFID) tags.
    - For animals with lost or damaged RFID tags, records must be kept demonstrating the animal was removed from the project or the tag was retired and replaced for each animal to which this situation applies.
- Documentation demonstrating the date of animal entry and exit from the project site in a format that confirms the number of days on feed for each animal group.
- Documentation identifying the number of animals in an animal group at the project site each day as per Section 9.2.
- Documentation demonstrating the mean incoming and outgoing mass of animals in an animal group at the project site.
    - Documentation can be based on individual animal weights or on the weight of more than one animal, such as purchase information or weigh scale tickets.
    - Documentation must only apply to animals within an animal group.
- Documentation from the meat processing facility confirming hot carcass weight and/or dressing percentage for an animal group unless a default value or live weights are used.

## 10.3 Project activities and diet

The proponent must keep a record of the information prescribed in Table 4.

**Table 4: Information required to support project activities and diet**

| Required information | | Source and description |
|---|---|---|
| Project activities | Improved management | • Description of the improved management activities carried out to reduce GHG emission intensity.<br>• An attestation from a qualified professional indicating the activities are expected to reduce the GHG emission intensity of the project as quantified in Section 8.0.<br>• Documentation that demonstrates that the activities have been carried out. |
| | Diet reformulation | • Documentation outlining the dietary changes undertaken to reduce GHG emission intensity. |

| Required information | | Source and description |
|---|---|---|
| | Feed additives | • Documentation regarding the feed additives administered to animals in both the baseline and project scenarios.<br>• Documentation must include the name of the additive, quantity, date(s) administered and method of delivery.<br>• If the eligible project activity is modifying or adjusting the dosage of a feed additive, an attestation must be provided from a qualified professional indicating the newly prescribed dosage is expected to reduce the GHG emission intensity of the project as quantified in Section 8.0. |
| | Growth promoters | • Documentation regarding the growth promoters administered to animals in both the baseline and project scenarios.<br>• Documentation must show the name of the product, quantity, date(s) administered and method of delivery. |
| | Other innovative strategies | • Documentation outlining the innovative activity or activities carried out to reduce GHG emission intensity.<br>• Information must be supported by an attestation from a qualified professional indicating the activity or activities are expected to reduce the GHG emission intensity of the project as quantified in Section 8.0. |
| Feed delivered | Dry matter intake | • Documentation showing the dry mass of feed delivered and consumed for each day, as per Section 9.2.<br>• Documentation, including procedures, demonstrating the conversion of wet mass feed to dry mass, if applicable. |
| | Days on each diet | • Documentation showing the days each unique diet was fed to an animal group, as per Section 9.2. |
| Diet composition | Feed analysis | • Dated documentation from a laboratory, near infrared spectroscopy device, or feed manufacturer confirming the values for parameters in Table 3 requiring feed analysis for each unique diet or feed ingredient.<br>• If applicable, dated documentation from a qualified professional confirming the reference value of TDN for the diet and the source of the reference value. |

If on-farm near infrared spectroscopy is used in the project, the proponent must also keep the following:

- Maintenance records for the on-farm near infrared spectroscopy devices used, including accuracy checks records;
- Documentation describing the corrective measures applied if a on-farm near infrared spectroscopy device fails to meet the requirements for measurement accuracy; and
- The calibration certificates and/or other records from either the manufacturer or a third-party certified for that purpose for each on-farm near infrared spectroscopy device which indicate calibration date, time, and results.

## 10.4 Environmental and social safeguards

The proponent must keep a record of the information relevant to the environmental and social safeguards required in Section 6.3 including:

- Documentation demonstrating the manure produced by the animals in the baseline and project scenarios was managed according to any federal, provincial, or territorial regulations and municipal by-laws applicable to the project site such as, but not limited to, manure handling plans or nutrient management plans.
- If the quantity of dietary lipid fed to animals exceeds 6%, the proponent must keep documentation from a qualified professional attesting that the diet is not expected to have negative animal health impacts.

## 10.5 Stratification and animal groups

The proponent must keep records outlining the methods, procedures and rationale used for stratification decisions. Animals in each animal group must be identifiable using the animal inventory records outlined in Section 10.2. Records must also indicate if all animals in each animal group were physically separated from other animals on the project site, or if the animal group exists solely for the purpose of quantifying GHG emissions.

# 11.0 Reporting

In addition to the reporting requirements specified in the Regulations, the proponent must include the following in a project report:

- A clear description of eligible project activities carried out for each full or partial calendar year of a reporting period which must include:
    - All project activities being carried out at the project site and the strata for which they apply.
    - Whether genetic selection to reduce enteric $CH_4$ and / or improve animal performance is being carried out at the project site.
    - The dates on which each identified eligible project activity was carried out at the project site for each stratum.
    - How each eligible project activity contributed to reduce GHG emissions intensity compared to the baseline scenario.
- Rationale to explain stratification decisions including justification for how strata in the baseline and project scenarios are comparable for the purposes of quantifying GHG emission reductions.
- The quantified GHG emissions for the baseline and project scenarios in t CO2e in each full or partial calendar year covered by the reporting period.
- The GHG emissions from each included SSR in t CO2e and the beef production in kg for all strata included in the baseline and project scenarios.

# 12.0 Verification

## 12.1 Competency requirements for verification teams

In addition to the verification requirements specified in the Regulations, the verification team must include an individual with knowledge and experience with confined beef cattle feeding systems to conduct a verification for a project under this protocol.