Quantification Protocol for Reducing Greenhouse Gas Emissions from Fed Cattle

Specified Gas Emitters Regulation

Version 3.0

February 2016

.

Title:	**Quantification Protocol for Reducing Greenhouse Gas Emissions from Fed Cattle**
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Summary of Revisions

Version	Date	Summary of Revisions

3.0	February 2016	• The Name was changed to Quantification Protocol for Reducing Greenhouse Gas Emissions from Fed Cattle.
		• The **Protocol Scope** is updated to remove the indicator for a reduction in the number of days cattle are fed in the feedlot and recognizes a number of feeding practices and animal management can result in increased feed use efficiencies. Project developers will need to quantify emissions reductions according to the protocol's quantification procedures to determine whether there is a net reduction in the feedlot (across all animal groupings) due to changes in feed use efficiency[1]. It is the net reduction, summed across all relevant animal groupings in the project year, that determines whether the project developer has a claim.
		• Addition of a **Flexibility Mechanism** that allows for a streamlined implementation option using the more conservative enteric methane emissions factor for both baseline and project. The flexibility mechanism also allows for flexibility on the way the feedlot operator sorts animals for feeding and performance purposes (e.g., incoming lots of animals can be grouped according to gender, animal type and placed into discrete pens) and the way the project developer may group animals for calculation purposes.
		• The **Project Condition** now takes into account reductions possible from feeding edible oils or other fat sources to cattle.
		• The **Quantification Methodology** has been updated to:
		  o use of the inventory calculations for determining weighted averages (animals multiplied by head days) of key quantification variables;
		  o restore the indirect N_2O equations for the project baseline condition;
		  o improve guidance on how to account for production equivalency and carbon equivalency; and
		  o clarify terms and equations throughout the document.
		• The **Data Management** requirements and the role of the professional agrologist has been updated.

2.0	July 2011	• Quantification Protocol for Reducing Days on Feed for Beef Cattle was published for use in the Alberta offset system.

[1] The feeding efficiencies of animals in a feedlot are based on a number of factors – weather, animal health, condition, frame, animal diets, feeding strategies, additives and animal husbandry. Therefore, it is the net reduction, summed across of all relevant animal groupings in the project year that determines whether a feedlot has a claim.

		• Ownership of offset credits generated under this protocol is assigned to the project developer (e.g.: feedlot operator). • Manure must be managed according to the *Agricultural Operation Practices Act* requirements for confined feeding operations. • Additional details on quantification methodology and records required to support the project condition are provided. • The flexibility mechanism that allows the project developer to establish a baseline with less than 3 years of data has been removed. Where a project developer wishes to proceed with a project, but is not able to establish a 3 year baseline, they must contact the government to discuss options. • For the purposes of this protocol, a licensed animal nutritionist is a Doctor of Veterinary Medicine or Professional Agrologist. • The project developer must disclose the legal land location of the feedlot, or lots where the cattle are finished. This information is collected by the Alberta Emissions Offset Registry in a spatial locator template and is used to track aggregated projects on the registry. • Liability clauses for aggregated projects stipulate the project developer cannot pass on liability for errors resulting from errors in the project developer's data management system.
1.0	May 2008	• Quantification Protocol For Reducing Days on Feed of Beef Cattle was published for use in the Alberta offset system.

Table of Contents

List of Tables

List of Figures

List of Appendices

Alberta Climate Change Office Related Publications

- *Climate Change and Emissions Management Act*
- Technical Guidance for Completing Annual Compliance Reports
- Technical Guidance for Completing Baseline Emissions Intensity Applications
- Technical Guidance for Offset Project Developers
- Technical Guidance for Offset Protocol Developers
- Specified Gas Emitters Regulation
- Specified Gas Reporting Regulation

1.0 Offset Project Description

Agricultural activities, including the production of livestock, result in greenhouse gas emissions into the atmosphere. Beef cattle, in particular, release methane (CH4) as a result of the digestion of feed materials in the rumen. These emissions are called enteric emissions and are a contributor to greenhouse gas emissions from agricultural activities. Methane and nitrous oxide (N2O) emissions are also generated from manure storage and handling within beef cattle operations. These emissions are called manure emissions.

This protocol for reducing greenhouse gas emissions in fed cattle addresses digestion and manure storage/handling sources of livestock greenhouse gas emissions. The protocol allows users to quantify greenhouse gas reductions using scientifically valid methodology and emission factors resulting from alterations in feeding strategies and other technologies in the finishing stages of beef cattle at feedlots in Alberta.

1.1 Protocol Scope

Through the Intergovernmental Panel on Climate Change[2] and Canada's National Emissions Inventory[3], industry experts and agricultural scientists have developed Tier 2 accounting procedures for enteric and manure emissions generated by different cattle classes in Canada. This science has been adapted to Alberta through the standardized quantification approach provided in this protocol.

The scope[4] of this protocol includes a number of innovative feeding practices and management strategies that can be implemented to increase feed use efficiency in cattle and reduce greenhouse gas emissions. Increasing feed use efficiency in beef cattle means more efficient use of feed energy and less production of methane due to enteric fermentation. Further, less manure is excreted, resulting in reduced manure emissions. Both of these mechanisms result in emission reductions per kilogram of beef produced, resulting in more efficient production of beef and fewer greenhouse gas emissions. Thus, emission reductions are compared using a functionally equivalent[5] unit of emission reductions per kilogram hot carcass weight produced in the feedlot finishing stage.

This protocol does not prescribe any one technique or combination of techniques needed to increase feed use efficiency in cattle because it is recognized that different feedlot operators may use different techniques, alone or in combination, and may vary them over time.

The kinds of innovative strategies that could cause increased efficiencies include, but are not limited to:

(1) Performance Tracking and Cattle Sorting Improvements – implementing individual animal performance management tracking and improved sorting for customized feeding by animal grouping;

(2) Feeding Strategies – addition of feed components to the diet that inhibit uptake of electrons and hydrogen by rumen methanogenic bacteria, like fats, oils[6], and others, thereby suppressing enteric methane emissions;

(3) Feeding Technologies - beta-agonists and growth promoters which improve lean tissue growth and feed conversion or use of ionophores at newly prescribed dosage increases;

(4) Genetic Improvements – breeding for or procurement of animals which have naturally better feed conversion efficiencies; and

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[2] Intergovernmental Panel on Climate Change (IPCC) 2006. Guidelines for National Greenhouse Gas Inventories, Chapter 10: Emissions from livestock and manure management.

[3] Environment Canada 2015. National Emissions Inventory Report 1990-2013: Greenhouse gas sources and sinks in Canada.

[4] Scope is an eligibility criterion that refers to the carbon offset project requirements stated in Section 7 of the Specified Gas Emitters Regulation.

[5] Functional equivalence is the comparison of a project's baseline and project emissions using the same metric, normalized to the same level of products or services (for example, per GJ of energy, tonne of wheat produced, acre of carbon stored, etc.).

[6] Feeding of edible oils at concentrations greater than 6 per cent will not yield any incremental greenhouse gas reductions and may result in compromising the health of the animal.

(5) Other innovative techniques being employed or that will be employed in the future, with justification as to how they impact the feed-to-gain ratio, reduced days on feed or decreased carbon intensity of beef production.

The project developer (e.g., feedlot operator) must demonstrate through feedlot documentation, records and the metrics employed in this protocol that cattle in the project condition are showing decreased carbon intensity (amount of greenhouse gas emissions per kilogram of hot carcass weight) than cattle in the baseline condition. This protocol outlines the necessary measurement and monitoring parameters needed to quantify resulting emission reductions.

The scope of this protocol includes activities that occur during the latter third of the life of beef cattle and that primarily occur in feedlots. The feedlot operator is required to collect and maintain data and records to support the offset project implementation and is assumed to be the project developer for the project.

Baseline Condition for Reducing Greenhouse Gas Emissions of Fed Cattle

A baseline condition is a reference case against which the performance of an offset project is measured. The baseline condition for this protocol defines what was happening before the feedlot implemented improvements in feeding and management strategies. That is, the baseline represents the normal business operations of the feedlot. Baseline data include the feeding regimes and information typically found in feedlot close-out data, such as dry matter intake of animal groups, number of days required to complete a finishing diet and carcass weight of the animals shipped to market.

The baseline condition for this protocol is the feeding regime, time period and animal performance required to finish beef cattle before implementing changes in the feedlot that increase feed use efficiency and thus improves animal performance.

The Quantification Protocol for Reducing Greenhouse Gas Emissions of Fed Cattle uses a static historic approach to determine the baseline condition. This means that, once determined, the three-year average baseline emissions are held constant and compared to the annual project emissions.

The baseline quantification approach is explained further in Section 2.0.

Project Condition for Reducing Greenhouse Gas Emissions of Fed Cattle Protocol

Generally, project condition is defined as an action targeted at reducing, removing or storing greenhouse gas emissions at a project. Specific to this protocol, the project condition is defined as the feeding and management strategies that result in increased feed use efficiency and therefore reduced carbon intensity of fed cattle before being sent to harvest, as compared to the baseline condition. The project activities can be a number of feeding practices and/or feed and management technologies that increase the feed use efficiency of cattle during the latter stages of finishing. Examples[7] include:

- electron acceptors that compete for hydrogen;
- compounds that inhibit uptake of electrons and hydrogen by ruminal methanogens;
- growth promotants and beta-agonists that improve the efficiency of lean tissue growth; and
- genetic improvements that improve feed efficiency.

Other strategies include better sorting and individual animal performance management, phenotypic selection for animals with higher feed use efficiency, or increasing concentrates in the diet sooner than under the baseline condition. These other techniques can be included where there is sufficient information to support the project condition.

[7] Basarab, J.A., Baron, V.S. and Okine, E.K. September 23-24, 2009. Discovering nutrition related opportunities in the carbon credit system for beef cattle. In, Proceedings of the 30th Western Nutrition Conference.

More information on project emissions quantification is available in Section 3.0. Information on global warming potentials (GWPs) can be found in the Carbon Offset Emission Factors Handbook[8].

1.2 Protocol Applicability

The project developer must meet the following requirements to apply this protocol:

(1) Diets and feeding strategies for animals in the baseline and project conditions can be demonstrated to show reduced greenhouse gas emissions of fed cattle in the finishing stages at a feedlot. Records (see Section 5) and project level documentation for the content and quantity of feed, including additives/technologies and animal performance per animal grouping, are necessary in order to quantify enteric and manure emissions;

(2) Animal grouping criteria for the quantification of emissions must be shown to be similar between the baseline and project conditions;

(3) Manure must be managed in accordance with the requirements of the *Agricultural Operation Practices Act* for confined feeding operations;

(4) Sampling of baseline and project conditions is allowed under this protocol and must be done according to the statistical sampling methodology provided in Appendix B;

(5) The quantification of reductions achieved by the project must be based on actual measurement and monitoring as indicated by the proper application of this protocol; and

(6) The project must meet the eligibility criteria stated in Section 7 of the Specified Gas Emitters Regulation. In order to qualify, emission reductions must:
- occur in Alberta;
- result from actions not otherwise required by law;
- result from actions taken on or after January 1, 2002;
- be real, demonstrable, and quantifiable;
- have clearly established ownership including, if applicable, documented transfers of ownership from the land owner to land lessee;
- be counted once for compliance; and
- be implemented according to ministerial guidelines.

The general data requirements for this protocol are shown in Table 1. This table is for summary purposes only. Detailed and official data and documentation requirements are found in Sections 4.0 and 5.0.

Table 1: General Overview of Data Requirements to Justify the Baseline and Project Conditions

Data Requirements:	Type of Data Required:	Why the Data are Needed:
Animal identifier tag	Canadian Cattle Identification Agency or unique tag identifier	To track animals as they move through the feedlot
Characterization of the animal grouping methods in the baseline condition and similar grouping methodology in the project years Average number of	Documented feedlot records of: • animal grouping/lot entry and exit records that show average weights of the group in and out; • average date of entry (by production system, quality grid	The methods used to define an animal grouping (i.e., sex, age, weight, breed, etc.) must be similar between the project and baseline conditions to ensure like groupings are compared for the offset calculations.

[8] Alberta Environment and Parks March 2015. Carbon Offset Emission Factors Handbook.

animals per grouping/lot based on animal*head days calculations (Section 4.3)	program, sex, breed or custom feedlot records); • average number of animals in each grouping/lot; and • average daily dry matter intake of animals in each grouping/lot	
Documented proof of: • what was fed to the cattle per animal grouping/lot in the feedlot; • days on feed for each diet; and • diet composition feed additives, management strategies or technologies employed for those groupings/lots (based on animal*head days calculations (Section 4.3)	Records include: • feed purchase receipts or scale tickets, weights, etc.; • feed delivery records for a pen/lot; • diet formulations signed off by a doctor of veterinary medicine or professional agrologist, identifying the diet including diet ingredients; • diet ingredients must include dry matter content, total digestible nutrients, crude protein content, ether extract, and level of concentrates in the diet; and • proof the diet was fed to the animals as indicated by internal record keeping systems and/or third party files (such as Feedlot Health Management, ComputerAid or others)	To support calculation of the offset claim and for third party verification. The verifier will need evidence of diets and total mixed diets fed to cattle groupings for the baseline and project conditions.
Incoming and outgoing average weight of each grouping of animals being included in the baseline and project conditions. Based on animal*head days calculations (Section 4.3)	Documented feedlot records of animal grouping/lot records that show: • average weight of the grouping in and out; • average date of entry and exit of the animal grouping; • average number of animals in each grouping; and • average hot carcass weight of harvested animals	To determine average daily gain and animal performance to support offset calculations.
Manure managed	Feedlot documentation to show that	To demonstrate that no major changes

according to the *Agriculture Operation Practices Act* (AOPA)	a permit from the Natural Resource Conservation Board (NRCB) is in place and no major changes in manure management have occurred since the baseline period (for those operations built or expanded after 2002), including Manure Handling Plans or Nutrient Management Plans and record keeping systems	in how manure is managed have occurred since the baseline period. Major changes include: • switching storage types • instituting a composting system • installing an anaerobic digester A major change is a signal to contact Alberta's Climate Change Office for clarification on how to proceed
Legal land location of the feedlot operation and proof the animals were fed in the feedlot	• Legal land description for the registration of the project; and • Proof that the animals fed in the project were under the control of the feedlot operator in question (see Section 5.5)	To register the project on the Alberta Emissions Offset Registry

1.3 Protocol Flexibility

Flexibility in applying the quantification protocol is provided to project developers in the following ways:

(1) Where the required data for this protocol vary across animal groupings (i.e. weight class, age, sex, breed, diets) in a feedlot, the animals may be grouped in discrete units for the purposes of calculating greenhouse gas emissions in this protocol rather than in groupings that occur in the feedlot. It is important to note that exercising this flexibility option will require documentary evidence that similar groupings between baseline and project were used for the calculations.[9]

(2) Corn-dried distillers' grains and solubles have been identified as an acceptable source of dietary fat that suppresses methanogenesis in the rumen. If these grains and solubles are included in the project condition, the diet that is signed off by a qualified animal nutritionist must continue to meet the dietary fat maximum of 4 to 6 per cent on a dry matter basis to reduce enteric emissions.

(3) To streamline implementation and ensure conservativeness in the carbon offset calculations, the project developer may estimate the amount of concentrate in the cattle's diet for the entire time the cattle are in the feedlot according to Table 2. These emission factors are conservative because they assume the lowest possible emission in the baseline scenario, and the highest possible emissions in the project scenario.

[9] If using the flexibility option of defining discrete cattle groupings for calculation purposes, the project developer must use a range of incoming weights of no more than 45.4 kg (100 lbs) within each grouping. As an example, calf-fed steers on a quality grid program coming on feed between 272.2 kg (600 lb) and 317.5 kg (700 lb) and leaving the feedlot for slaughter between 601.0 (1325 lbs) and 635.0 kg (1400 lbs) may be an animal grouping, while another part of the project may use yearling-fed heifers on a quality grid program coming on feed between 340.2 kg (750 lb) and 385.6 kg (850 lb) and leaving the feedlot for slaughter between 657.7 kg (1450 lb) and 703.1 kg (1550 lb).

Table 2: Enteric Emission Factors to be used in the Streamlined Approach

Scenario	Edible Oils less than 4%	Edible Oils between 4% and 6%
Baseline	4.0%	3.2%
Project	6.5%	5.8%

1.4 Glossary of New Terms

Animal groupings	Specific groupings of cattle in a feedlot as they move through to the finishing stage. Groupings are typically based on production system and may be classified according to calf-fed, yearling-fed, gender (heifer, steers, bulls), weight and marketing program (e.g., Lean's Lean, natural, grass-finished). A feedlot may contain more than one pen with the same animal grouping.
Animal head*days	A basic unit that must be used to calculate the weighted averages of number of head, daily dry matter intake and days on feed for a particular animal grouping (see Section 4.3).
Carcass weight	Weight of the carcass of an animal following slaughter as it hangs on the rail, expressed as warm (hot) carcass weight or weight of the dead animal after removal of the hide, head, tail, forelegs, internal organs, digestive complex, kidney knob and channel fat.
Concentrates	A broad classification of feedstuffs which are high in energy and low in crude fibre (<18 per cent crude fibre). Concentrates can include grains and protein supplements, but exclude feedstuffs like hay, silage or other roughage.
Custom feedlot records	The records kept on a group of cattle by a feedlot. These cattle are owned by someone other than the feedlot.
Diet	Feed ingredients or mixture of ingredients, including water, consumed by beef cattle[10]. Diet includes the amount of and composition for feed supplied to an animal for a defined period of time.
Edible oils[11]	Oils derived from plants that are composed primarily of triglycerides. These oils are typically extracted from the seeds of oilseed plants, but may be extracted from different parts of a variety of plants. Whole seeds may also be applied as a feed ingredient as long as the oil content is calculated on a dry matter basis to achieve a 4 to 6 per cent content in the diet.
Enteric emissions	Emissions of methane (CH_4) from the cattle as part of the digestive process of feed materials.

[10]Ensminger, E.M., and Olentine Jr., C.G. 1980. Feeds and Nutrition - Complete. Ensminger Publishing Company, Clovis, California 93612.
[11]There are other edible oil-containing products such as unstabilized rice bran or walnut oils extracted oil form dried distillers grains or even beef tallow where available. The onus is on the project developer to work with their nutritional specialist to ensure the ration formulation fits the requirements of this protocol.

Feeding cycle	The combination of diets fed to beef cattle over a set period of time. This is then repeated for similar groupings of cattle.
Feeding periods	Animal groupings typically have a series of diets for a specified number of days on feed.
Feeding regime	The whole system of diets fed to beef cattle over the baseline/project period.
Land application	The beneficial use of agricultural manures and/or digestate applied to cropland based upon crop needs as a source of soil amendment and/or fertility.
Quality grid program	A set of quality attributes (carcass weight, marbling, back fat thickness) for which a packing plant or a food processor is willing to pay a premium or give a discount to a feedlot operator.
Yardage	Overhead or the cost of depreciation on original capital investment and interest, upkeep of pens, water, electricity, fuel, manure handling, equipment repairs, hired labour and operator labour.

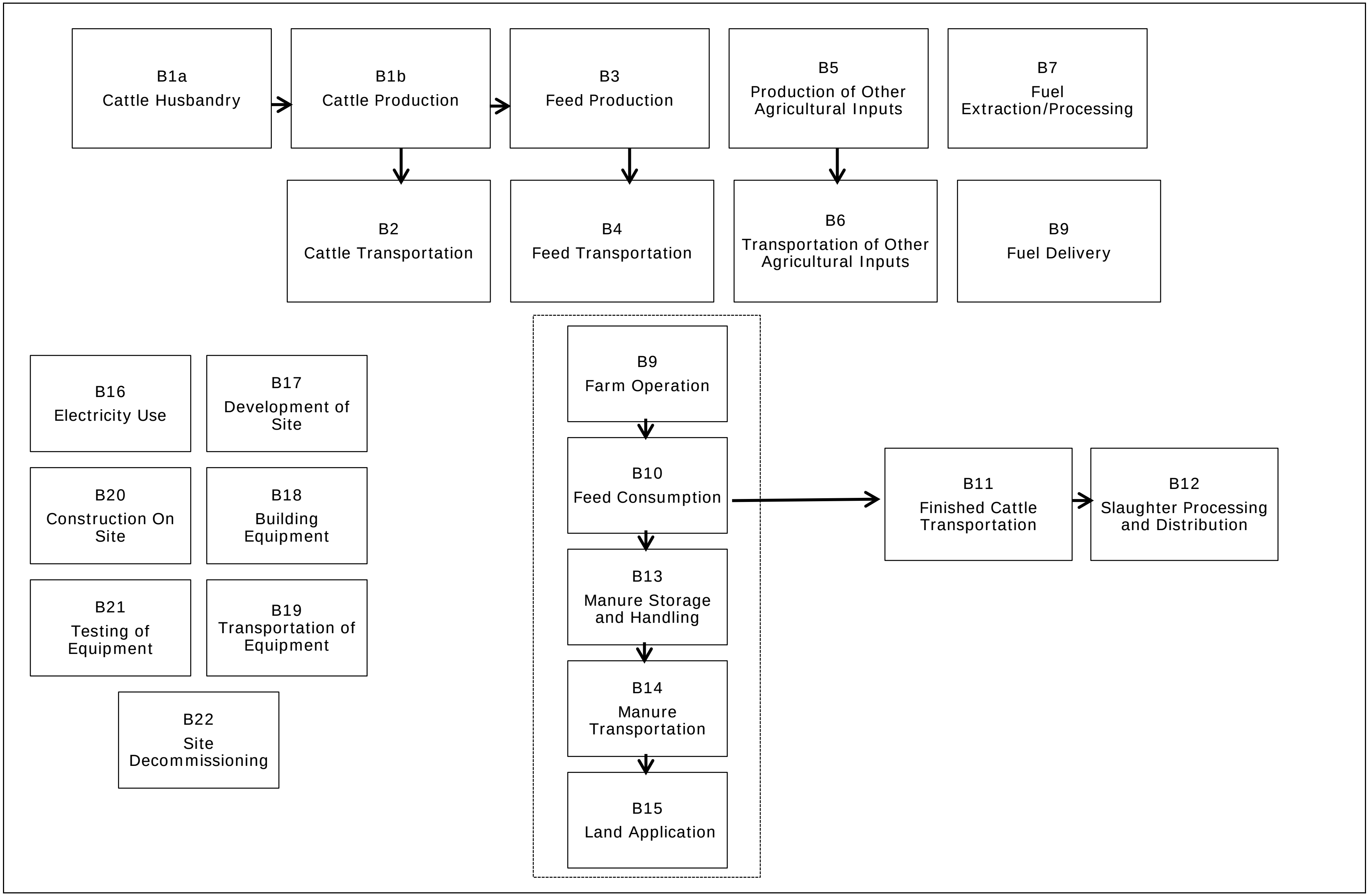
2.0 Baseline Condition

A baseline condition is a reference case against which the performance of a project is measured. This protocol uses a static historic benchmark baseline condition. The baseline condition is calculated as the greenhouse gas intensity per kilogram of average hot carcass weight gained over the course of the animals' stay in the feedlot (kg CO_2e per kg hot carcass weight). Each animal grouping's[12] average greenhouse gas intensity is calculated for animals that pass through the feedlot defined by group over a period of three years. This allows project developers to maintain a static baseline over the life of their projects that is representative of the baseline practices for their specific operation(s).

Sources and sinks were identified for the under the federal-provincial-territorial initiative called the National Offset Quantification Team (NOQT) and the Alberta protocol review process. This process confirmed that the sources and sinks in the process flow diagrams covered the full scope of eligible activities under the protocol. The full process flow diagram is presented in Figure 1.

[12] Groups are defined by certain physical animal characteristics such as sex, age, weight and breed.

Figure 1: Process Flow Diagram for Baseline Condition



2.1 Identification of Baseline Condition Sources and Sinks

The identification of sources and sinks in the baseline condition is based on ISO 14064-2[13] specification with guidance at the project level for quantification, monitoring and reporting of greenhouse gas emission reductions or removal enhancements (International Organization for Standardization 2006). Sources and sinks are determined to be either controlled, related or affected by the project and are defined as follows:

Controlled	A source or sink where the source or sink's behaviour or operation is under the direction and influence of a project developer through financial, policy, management or other instruments.
Related	A source or sink that has material and/or energy flows into, out of or within a project but is not under the reasonable control of the project developer.
Affected	A source or sink influenced by the project activity through changes in market demand or supply for products or services associated with the project.

Baseline sources and/or sinks were identified by reviewing the relevant process flow diagrams, consulting with technical experts, national greenhouse gas inventory scientists and reviewing good practice guidance. This iterative process confirmed that the sources and sinks in the process flow diagrams cover the full scope of eligible project activities under the protocol.

Based on the process flow diagram provided in Figure 1, the baseline sources and sinks were organized into life cycle categories in Figure 2. Descriptions of each of the sources and sinks and their classification as controlled, related or affected are provided in Table 3.

[13] International Organization for Standardization 2006. ISO 14064-2: Specification with guidance at the project level for quantification, monitoring and reporting of greenhouse gas emission reductions or removal enhancements.

Figure 2: Baseline Condition Sources and Sinks for Reducing GHG Emissions of Fed Cattle

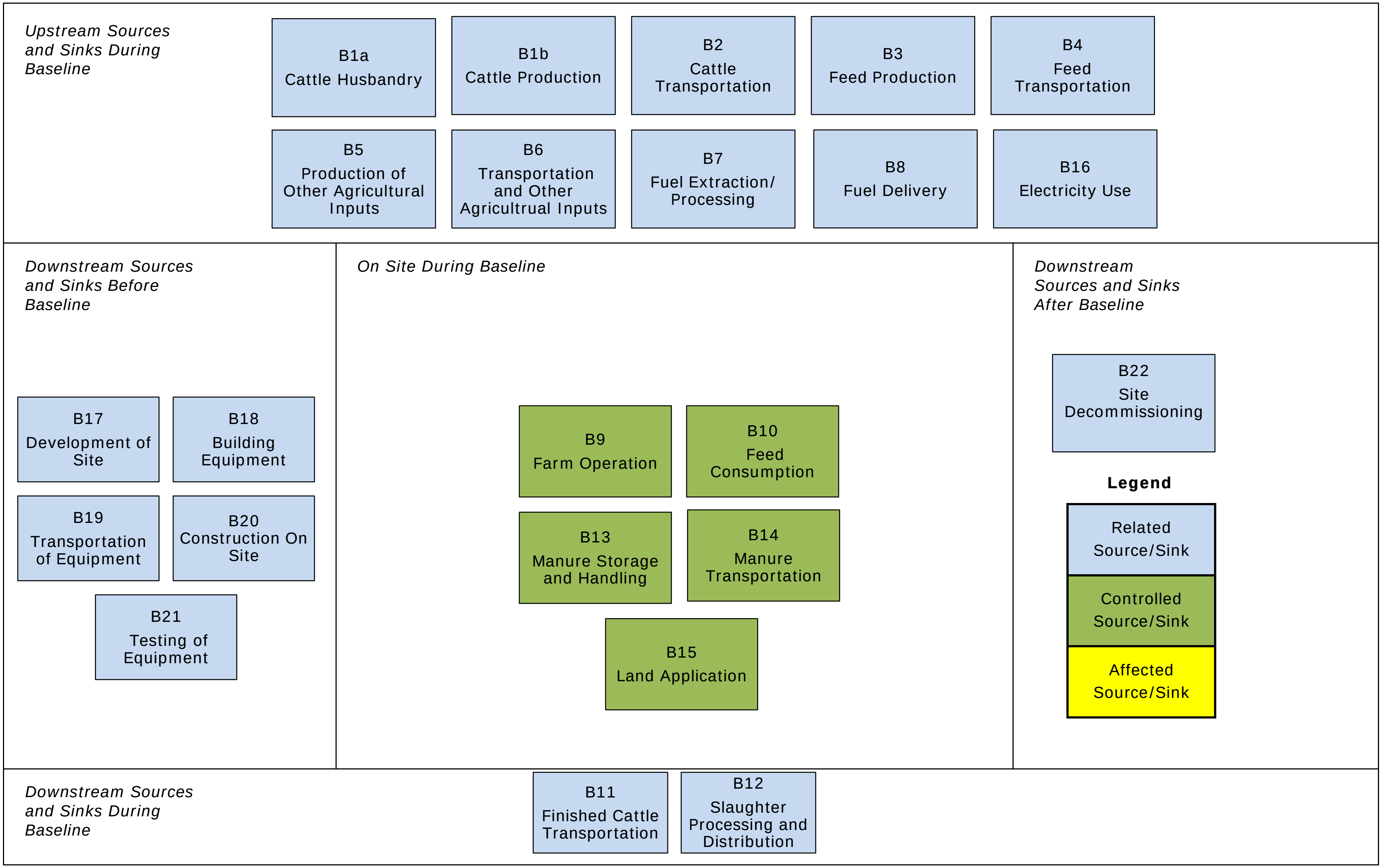


Table 3: Baseline Condition Sources and Sinks

Source/Sink	Description	Controlled, Related, Affected
Upstream Sources and Sinks During Baseline Operation		
B1a - Cattle Husbandry	Cattle husbandry may include insemination and all other practices prior to the birth of the calf. Quantities and types for each of the energy inputs would be contemplated to evaluate functional equivalence with the project condition.	Related
B1b - Cattle Production	Cattle production may include raising calves, including time in pasture, that are input to the enterprise. Feed consumption includes the enteric emissions from the cattle and related manure production. The feed composition would need to be tracked to ensure functional equivalence with the project condition. Length of each type of feeding cycle would need to be tracked.	Related
B2 - Cattle Transportation	Cattle may be transported to the project site by truck, barge and/or train. The related energy inputs for fuelling this equipment are captured under this source/sink for the purpose of calculating the resulting greenhouse gas emissions. Type of equipment, number of loads and distance travelled would be used to evaluate functional equivalence with the project condition.	Related
B3 - Feed Production	Feed may be produced from agricultural materials and amendments. The processing of the feed may include a number of chemical, mechanical and amendment processes. This requires several energy inputs such as natural gas, diesel and electricity. Quantities and types for each of the energy inputs would be contemplated to evaluate functional equivalence with the project condition.	Related
B4 - Feed Transportation	Feed may be transported to the project site by truck, barge and/or train. The related energy inputs for fuelling this equipment are captured under this source/sink, for the purposes of calculating the resulting greenhouse gas emissions. Type of equipment, number of loads and distance travelled would be used to evaluate functional equivalence with the project condition.	Related
B5 - Production of Other Agricultural Inputs	Other agricultural inputs, such as feed supplements, bedding, etc., may be produced from agricultural materials and amendments. The processing of the feed may include a number of chemical, mechanical and amendment processes. This requires several energy inputs such as natural gas, diesel and electricity. Quantities and types for each of the energy inputs would be contemplated to evaluate functional equivalence with the project condition.	Related

B6 - Transportation of Other Agricultural Inputs	Feed may be transported to the project site by truck, barge and/or train. The related energy inputs for fuelling this equipment are captured under this source/sink, for the purpose of calculating the resulting greenhouse gas emissions. Type of equipment, number of loads and distance travelled would be used to evaluate functional equivalence with the project condition.	Related
B7 - Fuel Extraction and Processing	Each of the fuels used throughout the on-site component of the project will need to sourced and processed. This will allow for calculation of the greenhouse gas emissions from the various processes involved in the production, refinement and storage of the fuels. The total volumes of fuel for each of the on-site sources/sinks are considered under this source/sink. Volumes and types of fuels are the important characteristics to be tracked.	Related
B8 - Fuel Delivery	Each of the fuels used throughout the on-site component of the project will need to be transported to the site. This may include shipments by tanker or by pipeline, resulting in the emission of greenhouse gases. It is reasonable to exclude fuel sourced by taking equipment to an existing commercial fuelling station as the fuel used to take the equipment to the site is captured under other sources/sinks and there is no other delivery.	Related
B16 - Electricity Use	Electricity may be required for operating the facility. This power may be sourced from internal generation, connected facilities, or the local electricity grid. Metering of electricity may be netted in terms of the power going to and from the grid. Quantity and source of power are the important characteristics to be tracked as they directly relate to the quantity of greenhouse gas emissions.	Related
On-Site Sources and Sinks During Baseline Operation		
B9 – Farm Operation	Greenhouse gas emissions may occur that are associated with the operation and maintenance of the beef production facility operations. This may include running vehicles and facilities at the project site for the distribution of the various inputs. Quantities and types for each of the energy inputs would be tracked.	Controlled
B10 – Feed Consumption	Feed consumption includes the enteric emissions from the cattle and related manure production. The feed composition would need to be tracked as would the length of each type of feeding cycle.	Controlled
B13 – Manure Storage and Handling	Greenhouse gas emissions can result from the operation of manure storage and handling facilities. This could include emissions from energy use and from the emissions of methane and nitrous oxide from the manure being stored and processed. Operational aspects of the manure storage and handling systems may need to be tracked.	Controlled
B14 – Manure Transportation	Manure may need to be transported from storage to the field for land application. Transportation equipment would be fuelled by diesel, gas or natural gas. Quantities for each of the energy inputs would be tracked to	Controlled

	evaluate functional equivalence with the project condition.	
B15 – Land Application	Manure may then be land applied. This may require the use of heavy equipment and mechanical systems. This could include emissions from energy use and from the emissions of methane and nitrous oxide from the manure being stored and processed. Operational aspects of manure land application systems may need to be tracked.	Controlled
Downstream Sources and Sinks During Baseline Operation		
B11 – Finished Cattle Transportation	Finished cattle may be transported from the project site by truck, barge and/or train. The related energy inputs for fuelling this equipment are captured under this source/sink for the purpose of calculating the resulting greenhouse gas emissions. Type of equipment, number of loads and distance travelled would need to be tracked.	Related
B12 – Slaughter, Processing and Distribution	Greenhouse gas emissions may occur that are associated with the slaughter, processing and distribution components downstream of the cattle finishing facility. This may include running vehicles and facilities at other sites. Quantities and types for each of the energy inputs would be tracked.	Related
Other Sources and Sinks		
B17 – Development of Site	The site of the facility may need to be developed. This could include infrastructure such as access to electricity, gas and water supply, sewer, etc. Development may also include clearing, grading, building access roads, etc. There will also need to be some building of structures for the facility such as storage areas, storm water drainage, offices, vent stacks, firefighting water storage lagoons, etc., as well as structures to enclose, support and house the equipment. Greenhouse gas emissions would be primarily attributed to the use of electricity and fossil fuels used to power equipment required to develop the site such as graders, backhoes, trenching machines, etc.	Related
B18 – Building Equipment	Equipment may need to be built either on or off site. This includes all the components of the storage, handling, processing, combustion, air quality control, system control and safety systems. These may be sourced as pre-made standard equipment or custom built to specification. Greenhouse gas emissions would be primarily attributed to the use of fossil fuels and electricity used to power equipment for the extraction of the raw materials, processing, fabricating and assembly.	Related
B19 – Transportation of Equipment	Equipment built off site and the materials to build equipment on site will all need to be delivered to the site. Transportation may be completed by train, truck, by some combination, or even by courier. Greenhouse gas emissions would be primarily attributed to the use of fossil fuels to power the equipment delivering the	Related

	equipment to the site.	
B20 – Construction On Site	The process of construction at the site will require a variety of heavy equipment, smaller power tools, cranes and generators. The operation of this equipment will have associated greenhouse gas emissions from the use of fossil fuels and electricity.	Related
B21 – Testing of Equipment	Equipment may need to be tested to ensure that it is operational. This may result in running the equipment using fossil fuels in order to ensure that the equipment works properly. These activities will result in greenhouse gas emissions associated with the combustion of fossil fuels and the use of electricity.	Related
B22 – Site Decommissioning	Once the facility is no longer operational, the site may need to be decommissioned. This may involve the disassembly of the equipment, demolition of on-site structures, disposal of some materials, environmental restoration, re-grading, planting or seeding, and transportation of materials off site. Greenhouse gas emissions would be primarily attributed to the use of fossil fuels and electricity used to power equipment required to decommission the site.	Related

3.0 Project Condition

In the context of this protocol, project condition is defined as enteric and manure emission reductions in Alberta feedlots through incorporation of innovative feeding and management strategies. Specifically, these strategies include, but are not limited to:

(1) Performance Tracking and Cattle Sorting Improvements – implementing individual animal performance management tracking and improved sorting for customized feeding by animal grouping;

(2) Feeding Strategies – addition of feed components to the diet that inhibit uptake of electrons and hydrogen by rumen methanogenic bacteria, like fats, oils[14] and others, thereby suppressing enteric methane emissions;

(3) Feeding Technologies – beta-agonists and growth promoters which improve lean tissue growth and feed conversion and use of ionophores at newly prescribed dosage increases;

(4) Genetic Improvements – breeding for or procure animals which have naturally better feed conversion efficiencies; and

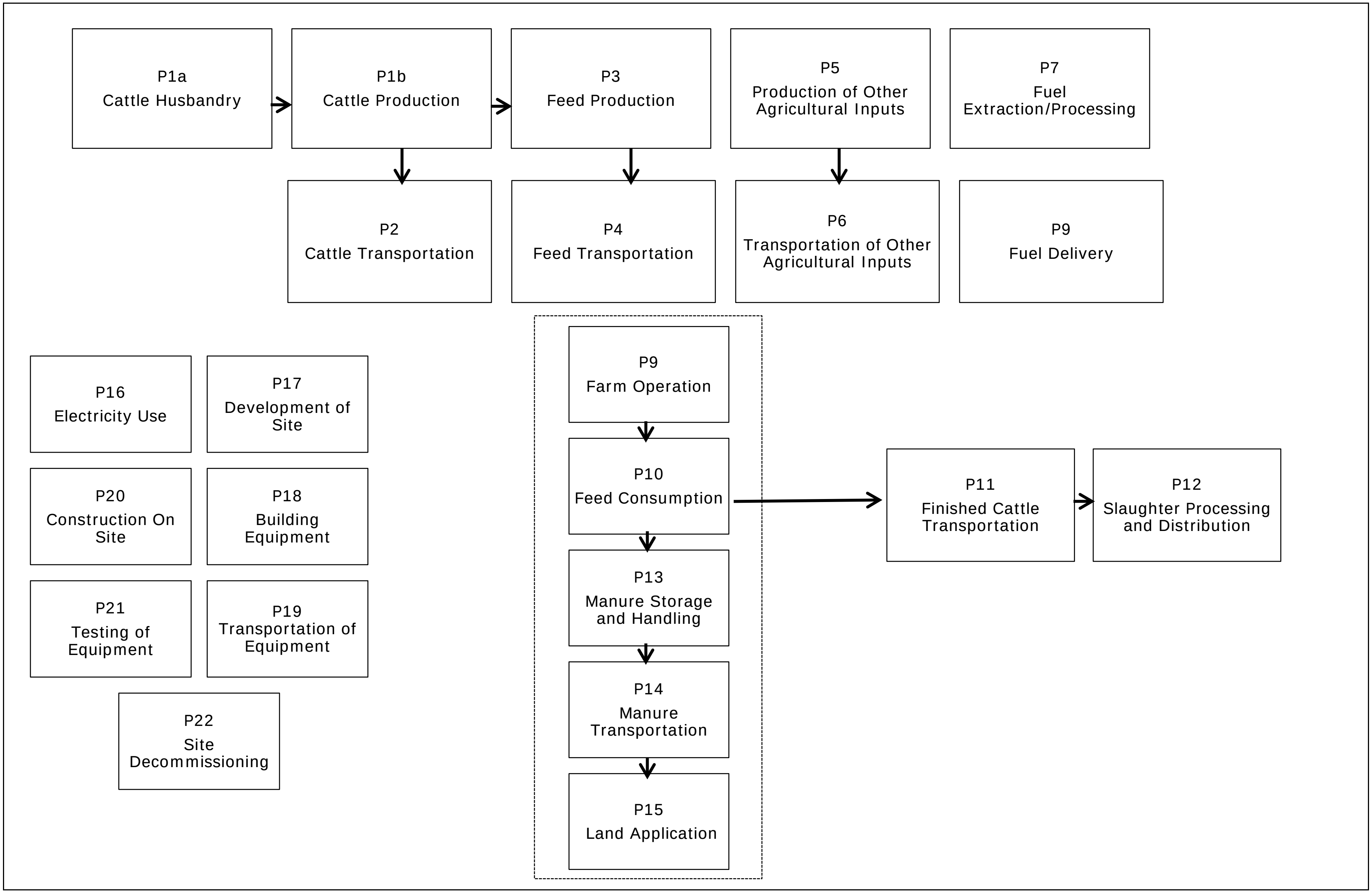
(5) Other innovative techniques being employed or that will be employed in the future, with justification as to how they impact the feed-to-gain ratio, reduced days on feed, or decreased carbon intensity of beef production.

Although enteric and manure-based emissions are produced by cattle during the project condition, just as they are during the baseline condition, use of the above strategies will lower the volume of greenhouse gases emitted per kilogram of hot carcass weight (i.e., weight gain occurring in the feedlot). The total amount of emission reductions generated by the project is equal to the difference in emissions in the project and baseline conditions after adjustment for production equivalency.

Project sources and sinks were identified by reviewing the relevant process flow diagrams, consulting with technical experts, national greenhouse gas inventory scientists and reviewing good practice guidance. The process flow diagram for the project condition is shown in Figure 3.

[14] Feeding of edible oils at concentrations greater than six per cent will not yield any incremental greenhouse gas reductions and may result in compromising the health of the animal.

Figure 3: Process Flow Diagram for the Project Condition



3.1 Identification of Project Condition Sources and Sinks

Sources and sinks for reducing days on feed of beef cattle were identified through scientific review. The review confirmed that the sources and sinks in the process flow diagram (Figure 3) covered the full scope of eligible project activities under this protocol. The boundary[15] for the project condition associated with these sources and sinks includes the feedlot(s) where the cattle are finished, the facility where manure is stored and the land where the manure is spread.

These sources and sinks have been further refined according to the life cycle categories identified in Figure 4. They have been further classified as controlled, related, or affected as described in Table 4.

The same quantification approach must be used in both the baseline and project conditions. That is, animal diets, animal grouping characteristics, dry matter intake and animal performance are all factors that must be documented in order to justify the project condition.

[15] A project boundary is a conceptual line drawn around a project which defines the greenhouse gas sources and sinks that will be included in the project for emission reduction calculations.

Figure 4: Project Condition Sources and Sinks for Reducing GHG Emissions of Fed Cattle

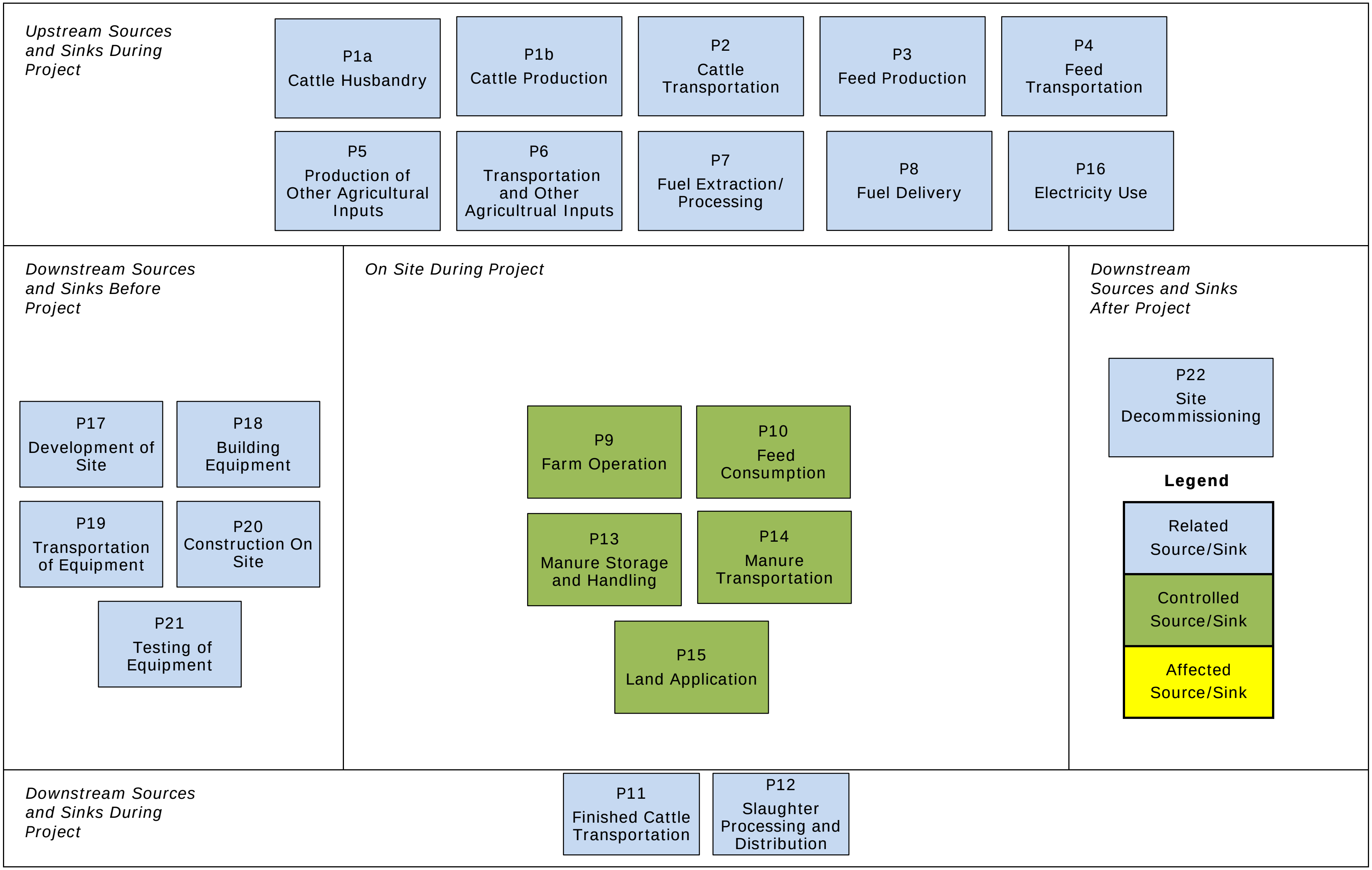


Table 4: Project Condition Sources and Sinks

Sources and Sinks	Description	Controlled, Related or Affected
Upstream Sources and Sinks During Project Operation		
P1a – Cattle Husbandry	Cattle husbandry may include insemination and all other practices prior to the birth of the calf. Quantities and types for each of the energy inputs would be contemplated to evaluate functional equivalence with the baseline condition.	Related
P1b – Cattle Production	Cattle production may include raising calves, including time in pasture, that are input to the enterprise. Feed consumption includes the enteric emissions from the cattle and related manure production. The feed composition would need to be tracked to ensure functional equivalence with the baseline condition. Length of each type of feeding cycle would need to be tracked.	Related
P2 – Cattle Transportation	Cattle may be transported to the project site by truck, barge and/or train. The related energy inputs for fuelling this equipment are captured under this source/sink for the purposes of calculating the resulting greenhouse gas emissions. Type of equipment, number of loads and distance travelled would be used to evaluate functional equivalence with the baseline condition.	Related
P3 – Feed Production	Feed may be produced from agricultural materials and amendments. The processing of the feed may include a number of chemical and mechanical amendment processes. The processes require several energy inputs such as natural gas, diesel and electricity. Quantities and types for each of the energy inputs would be tracked to evaluate functional equivalence with the baseline condition.	Related
P4 – Feed Transportation	Feed may be transported to the project site by truck, barge and/or train. The related energy inputs for fuelling this equipment are captured under this source/sink for the purposes of calculating the resulting greenhouse gas emissions. Type of equipment, number of loads and distance travelled would be used to evaluate functional equivalence with the baseline condition.	Related
P5 – Production of Other Agricultural Inputs	Other agricultural inputs, such as feed supplements, bedding, etc., may be produced from agricultural materials and amendments. The processing of these inputs may include a number of chemical, mechanical and amendment processes. These processes require several energy inputs such as natural gas, diesel and electricity. Quantities and types for each of the energy inputs would be tracked to evaluate functional equivalence with the baseline condition.	Related

P6 – Transportation of Other Agricultural Inputs	Feed may be transported to the project site by truck, barge and/or train. The related energy inputs for fuelling this equipment are captured under this source/sink for the purposes of calculating the resulting greenhouse gas emissions. Type of equipment, number of loads and distance travelled would be used to evaluate functional equivalence with the baseline condition.	Related
P7 – Fuel Extraction and Processing	Each of the fuels used throughout the on-site component of the project will need to sourced and processed. This will allow for the calculation of the greenhouse gas emissions from the various processes involved in the production, refinement and storage of the fuels. The total volume of fuel for each of the on-site sources/sinks is considered under this source/sink. Volumes and types of fuels are the important characteristics to be tracked.	Related
P8 – Fuel Delivery	Each of the fuels used throughout the on-site component of the project will need to be transported to the site. This may include shipments by tanker or by pipeline, resulting in the emissions of greenhouse gases. It is reasonable to exclude fuel sourced by taking equipment to an existing commercial fuelling station as the fuel used to take the equipment to the site is captured under other sources/sinks and there is no other delivery.	Related
P16 – Electricity Use	Electricity may be required for operating the facility. This power may be sourced from internal generation, connected facilities, or the local electricity grid. Metering of electricity may be netted in terms of the power going to and from the grid. Quantity and source of power are the important characteristics to be tracked as they directly relate to the quantity of greenhouse gas emissions.	Related
On-Site Sources and Sinks during Project Operation		
P9 – Farm Operation	Greenhouse gas emissions may occur that are associated with the operation and maintenance of the cattle feeding facility. This may include running vehicles and facilities at the project site for the distribution of the various inputs. Quantities and types for each of the energy inputs would be tracked.	Controlled
P10 – Feed Consumption	Feed consumption includes the enteric emissions from the cattle and related manure production. The feed composition would need to be tracked as would the length of each type of feeding cycle.	Controlled
P13 – Manure Storage and Handling	Greenhouse gas emissions can result from the operation of manure storage and handling facilities. This could include emissions from energy use and from the emissions of methane and nitrous oxide from the manure being stored and processed. Operational aspects of the manure storage and handling systems may need to be tracked.	Controlled

P14 – Manure Transportation	Manure may need to be transported to the field for land application from storage. Transportation equipment would be fuelled by diesel, gas or natural gas. Quantities for each of the energy inputs would be contemplated to evaluate functional equivalence with the baseline condition.	Controlled
P15 - Land Application	Land application of manure may require the use of heavy equipment and mechanical systems. This could include emissions from energy use and from the emissions of methane and nitrous oxide from the manure being stored and processed. Operational aspects of the manure land application systems may need to be tracked.	Controlled
Downstream Sources and Sinks During Project Operation		
P11 - Finished Cattle Transportation	Finished cattle may be transported from the project site by truck, barge and/or train. The related energy inputs for fuelling this equipment are captured under this source/sink for the purpose of calculating the resulting greenhouse gas emissions. Type of equipment, number of loads and distance travelled would need to be tracked.	Related
P12 - Slaughter, Processing and Distribution	Greenhouse gas emissions may occur that are associated with the slaughter, processing and distribution components downstream of the cattle finishing facility. This may include running vehicles and facilities at other sites. Quantities and types for each of the energy inputs would be tracked.	Related
Other Sources and Sinks		
P17 - Development of Site	The site of the facility may need to be developed. This could include infrastructure such as access to electricity, gas and water supply, as well as sewer, etc. Development may also include clearing, grading, building access roads, etc. There will also need to be some building of structures for the facility such as storage areas, storm water drainage, offices, vent stacks, firefighting water storage lagoons, etc., as well as structures to enclose, support and house the equipment. Greenhouse gas emissions would be primarily attributed to the use of the electricity and fossil fuels used to power equipment required to develop the site such as graders, backhoes, trenching machines, etc.	Related
P18 - Building Equipment	Equipment may need to be built either on site or off site. This includes all the components of the storage, handling, processing, combustion, air quality control, system control and safety systems. These may be sourced as pre-made standard equipment or custom built to specification. Greenhouse gas emissions would be primarily attributed to the use of fossil fuels and electricity used to power equipment for the extraction of the raw materials, processing, fabricating and assembly.	Related

P19 - Transportation of Equipment	Equipment built off site and the materials to build equipment on site will all need to be delivered to the site. Transportation may be completed by truck, barge and/or train. Greenhouse gas emissions would be primarily attributed to the use of fossil fuels to power the equipment delivering the equipment to the site.	Related
P20 - Construction On Site	The process of construction at the site will require a variety of heavy equipment, smaller power tools, cranes and generators. The operation of this equipment will have associated greenhouse gas emissions from the use of fossil fuels and electricity.	Related
P21 - Testing of Equipment	Equipment may need to be tested to ensure that it is operational. This may result in running the equipment using fossil fuels in order to ensure that the equipment works properly. These activities will result in greenhouse gas emissions associated with the combustion of fossil fuels and the use of electricity.	Related
P22 - Site Decommissioning	Once the facility is no longer operational, the site may need to be decommissioned. This may involve the disassembly of the equipment, demolition of on-site structures, disposal of some materials, environmental restoration, re-grading, planting or seeding, and transportation of materials off site. Greenhouse gas emissions would be primarily attributed to the use of fossil fuels and electricity used to power equipment required to decommission the site.	Related

4.0 Quantification

In creating this protocol, baseline and project conditions were assessed against each other to determine the scope for reductions quantified under the protocol. Sources and sinks were either included or excluded depending on how they were impacted by the project condition. Sources that were not expected to change between the baseline and project condition were excluded from the project quantification. It was assumed that excluded activities would occur at the same magnitude and emission rate during the baseline and project and so would not be impacted by the project.

All sources and sinks identified in Table 3 and are listed in Table 5. Each source and sink is listed as included or excluded. Justification for the inclusion or exclusion is also provided.

Table 5: Comparison of Sources and Sinks for Baseline and Project Conditions

Identified Sources and Sinks	Baseline (C, R,A)*	Project (C, R,A)*	Include or Exclude	Justification
Upstream Sources/Sinks				
P1a - Cattle Husbandry	N/A	R	Exclude	Excluded as animal husbandry is functionally equivalent to the baseline scenario.
B1a - Cattle Husbandry	R	N/A	Exclude	
P1b - Cattle Production	N/A	R	Exclude	Excluded as cattle production upstream of the feedlot is functionally equivalent to the baseline scenario.
B1b - Cattle Production	R	N/A	Exclude	
P2 - Cattle Transportation	N/A	R	Exclude	Excluded as the emissions from transportation are likely functionally equivalent to the baseline scenario.
B2 - Cattle Transportation	R	N/A	Exclude	
P3 - Feed Production	N/A	R	Exclude	Excluded as upstream production of other agricultural inputs are not impacted by the implementation of the project and as such the baseline and project conditions will be functionally equivalent.
B3 - Feed Production	R	N/A	Exclude	
P4 - Feed Transportation	N/A	R	Exclude	Excluded as the emissions from transportation are likely functionally equivalent to the baseline scenario.
B4 - Feed Transportation	R	N/A	Exclude	
P5 - Production of Other Agricultural Inputs	N/A	R	Exclude	Excluded as upstream production of other agricultural inputs is not impacted by the implementation of the project and, as such, the baseline and project conditions will be functionally equivalent.
B5 - Production of Other Agricultural Inputs	R	N/A	Exclude	
P6 - Transportation of Other Agricultural Inputs	N/A	R	Exclude	Excluded as the emissions from transportation are likely functionally equivalent to the baseline scenario.
B6 - Transportation of Other Agricultural Inputs	R	N/A	Exclude	

P7 - Fuel Extraction and Processing	N/A	R	Exclude	Excluded as these sources/sinks are not impacted by the implementation of the project and, as such, the baseline and project conditions will be functionally equivalent.
B7 - Fuel Extraction and Processing	R	N/A	Exclude	
P8 - Fuel Delivery	N/A	R	Exclude	Excluded as these sources/sinks are not impacted by the implementation of the project and, as such, the baseline and project conditions will be functionally equivalent.
B8 - Fuel Delivery	R	N/A	Exclude	
P16 - Electricity Use	N/A	R	Exclude	Excluded as these sources/sinks are not impacted by the implementation of the project and, as such, the baseline and project conditions will be functionally equivalent.
B16 - Electricity Use	R	N/A	Exclude	
On Site Sources/Sinks				
P9 - Farm Operation	N/A	C	Exclude	Excluded as farm operation for beef production is not materially impacted by the implementation of the project since feed transportation and delivery is only modified to a negligible degree. As such, the baseline and project conditions will be functionally equivalent.
B9 - Farm Operation	C	N/A	Exclude	
P10 - Feed Consumption	N/A	C	Include	Included because emissions between the baseline and project conditions are materially different.
B10 - Feed Consumption	C	N/A	Include	
P13 - Manure Storage and Handling	N/A	C	Include	Included because emissions between the baseline and project conditions are materially different.
B13 - Manure Storage and Handling	C	N/A	Include	
P14 - Manure Transportation	N/A	C	Exclude	Excluded as the emissions from transportation are likely functionally equivalent to the baseline condition.
B14 - Manure Transportation	C	N/A	Exclude	
P15 - Land Application	N/A	C	Include	Included because emissions between the baseline and project conditions are materially different.
B15 - Land Application	C	N/A	Include	

Downstream Sources/Sinks				
P11 - Finished Cattle Transportation	N/A	R	Exclude	Excluded as the emissions from transportation are likely functionally equivalent to the baseline condition.
B11 - Finished Cattle Transportation	R	N/A	Exclude	
P12 - Slaughter, Processing and Distribution	N/A	R	Exclude	Excluded as the emissions from slaughter, processing and distribution are likely functionally equivalent to the baseline condition.
B12 - Slaughter, Processing and Distribution	R	N/A	Exclude	
Other Sources/Sinks				
P17 - Development of Site	N/A	R	Exclude	Excluded as the emissions from site development are not material given the long project life and the minimal site development typically required.
B17 - Development of Site	R	N/A	Exclude	Excluded as the emissions from site development are not material for the baseline condition given the minimal site development typically required.
P18 - Building Equipment	N/A	R	Exclude	Excluded as the emissions from building equipment are not material given the long project life and the minimal building equipment typically required.
B18 - Building Equipment	R	N/A	Exclude	
P19 - Transportation of Equipment	N/A	R	Exclude	Excluded as the emissions from transportation of equipment are not material given the long project life and the minimal transportation of equipment typically required.
B19 - Transportation of Equipment	R	N/A	Exclude	
P20 - Construction On Site	N/A	R	Exclude	Excluded as the emissions from construction on site are not material given the long project life and the minimal construction on site typically required.
B20 - Construction On	R	N/A	Exclude	

Site				
P21 - Testing of Equipment	N/A	R	Exclude	Excluded as the emissions from testing of equipment are not material given the long project life and the minimal testing of equipment typically required.
B21 - Testing of Equipment	R	N/A	Exclude	
P22 - Site Decommissioning	N/A	R	Exclude	Excluded as the emissions from decommissioning are not material given the long project life and the minimal decommissioning typically required.
B22 - Site Decommissioning	R	N/A	Exclude	

4.1 Quantification Methodology

Quantification of the reductions, removals and reversals of relevant sources/sinks for each of the greenhouse gases are to be completed using the methodologies outlined in Table 6 and Table 7. These calculation methodologies serve to complete the following three equations for calculating the emission reductions through comparison of the baseline and project conditions.

Emission Reduction	=	$\sum_{\text{cattle grouping } i}$ [Emissions Intensity $_{\text{Baseline } i}$ – Emissions Intensity $_{\text{Project } i}$] * total carcass weight produced in the project
Emissions Intensity $_{\text{Baseline}}$	=	$\sum_{\text{cattle grouping } i}$ [(Emissions $_{\text{Cattle } i}$+ Emissions $_{\text{Manure } i}$)/ average hot carcass weight gain $_i$]
Emissions Intensity $_{\text{Project}}$	=	$\sum_{\text{cattle grouping } i}$ [(Emissions $_{\text{Cattle } i}$ + Emissions $_{\text{Manure } i}$)/ average hot carcass weight gain $_i$]

Where:

Cattle Grouping$_i$	=	Index number for tracking cattle groupings;
Emissions Intensity $_{\text{Baseline}}$	=	sum of the emissions under the baseline condition, divided by average hot carcass weight produced;
Emissions Intensity $_{\text{Project}}$	=	sum of the emissions under the project condition, divided by average hot carcass weight produced;
Emissions $_{\text{Cattle}}$	=	emissions under Feed Consumption for each grouping of cattle;
Emissions $_{\text{Manure}}$	=	emissions under Manure Storage and Handling and Land Application for each grouping of cattle; and
Average Hot Carcass Weight Gain	=	dressing percentage multiplied by the average weight of the finished cattle less the dressing percentage multiplied by the average weight of the cattle coming into the feedlot.

4.2 Standardized Quantification Approach

Quantification of emission reductions of relevant sources and sinks for each relevant greenhouse gas are to be completed using the methodologies outlined in Tables 7 and 8 in Section 4.3. These methodologies serve to complete the following equations for calculating the emission reductions from the baseline and project conditions.

The definitions for each variable in the following eight equations are explained below. For examples of how to apply these equations, see Appendix A.

Enteric Methane Emissions from Cattle

Equation 1: Enteric Methane Emissions

Cattle Enteric Methane ($kg\ CH_4$/feeding period) =	=	Σ [Number Production$_i$ * DOF * DDMI$_i$* GE Diet * (EF Enteric$_i$ / 100%) / EC Methane]

Where:

Number Production$_i$	=	the average number of head in each animal grouping per lot. Estimated using the animal head*days factor (see Section 4.3);
i	=	each animal grouping in the set of equations;
DOF (Days on Feed)	=	the average number of days that the animal grouping is being fed a specific diet, calculated using the date in and date out for the grouping;
DDMI (Dry Matter Intake)	=	average daily dry matter intake per head is calculated by dividing the total kg DM delivered to the pen/lot for the days on that diet, divided by the animal head*days for that diet;
GE Diet (Gross Energy Content of Diet)	=	a default factor, depending on the concentration of edible oils/fats: use 19.10 MJ per kg of dry matter feed if the edible oil/fat concentration is between 4.0 and 6.0 per cent; or use 18.45 MJ per kg of dry matter feed if the edible oil/fat concentration is less than 4 per cent; and
EF Enteric (Enteric Emissions)	=	a default factor, depending on the level of concentrates in the diet and edible oil/fat content: For diets with less than 4 per cent edible oils/fat (DM basis): 4.0 per cent for diets with greater than or equal to 85 per cent concentrates ; or 6.5 per cent for diets with less than 85 per cent concentrates; For diets with edible oils/fats in the 4 to 6 per cent range: 3.2 per cent for diets with greater than or equal to 85 per cent concentrates; or 5.8 per cent for diets with less than 85 per cent concentrates;
EC Methane (Methane Energy Content)	=	a default factor of 55.65 MJ per kg of methane.

Equation 2: Manure Methane Emissions (Handling, Storage, and Application)

Manure CH4 ($kg\ CH_4$)	=	Σ [Number Production$_i$ * DOF$_i$ * VS$_i$ * Bo * $\rho_{Methane}$ * (MCF / 100%)]

Where:

Manure CH_4 (Manure Methane)	=	The sum of methane emissions from manure handling, storage and land application for each cattle grouping within the baseline and project conditions;
VS (Volatile Solids)	=	The calculated average daily volatile solid excreted per head for each of the feeding periods in each animal grouping;
Bo (Methane Producing Capacity)	=	The maximum methane-producing capacity for manure. Is a constant of 0.19 m^3 CH_4/kg VS excreted;
$\rho_{Methane}$ (Conversion Factor for Density of Methane)	=	Use the density conversion factor for m^3 methane to kg of methane, at normal temperature (20^oC) and pressure (1 Atm) which is 0.67 kg/m^3; and
MCF (Methane Conversion Factor)	=	A factor specific to each manure management system. It is set at 1.0 per cent for pasture, range, and/or paddock systems or 2.0 per cent for solid storage systems. Two percent would apply in this protocol.

Equation 3: Daily Volatile Solids Excreted in Manure

VSi (kg volatile solids/animal/day)	=	$[(DDMI_i * GE_{Diet} * (1 – (TDN_i / 100\%)) + (UE * DDMI_i * GE_{Diet})] * (1 – (Ash / 100\%)) / GE_{Diet}$

Where :

TDN_i (Total Digestible Nutrients)	=	The total digestible nutrients for the diet provided to each grouping of cattle must be recorded as a percentage (%) and is used in calculating the daily volatile solids excreted in cattle manure;
UE (Urinary Energy)	=	Urinary Energy is used in calculating the daily volatile solids excreted per animal in each weight grouping. Use the default factors of 0.04 for diets with less than 85 per cent concentrates and 0.02 for diets with greater than or equal to 85 per cent concentrates; and
Ash	=	A default factor extracted from international guidance and used in estimating daily excretion of volatile solids. Use 8 per cent for forage based diets and 2 per cent for grain based (high concentrate) diets.

Manure-Based Nitrous Oxide Emissions from Cattle:

Equation 4: Direct Nitrous Oxide (N_2O) Emissions from Manure

Manure N_20_{direct} (kg N_20)	=	Σ [Number $Production_i$ * DOF_i * NEx_i * CF_{manure} * (44 / 28)]

Where:

Manure N_20_{direct}	=	The sum of direct emissions of nitrous oxide from manure decomposition for each grouping of cattle;
CF $_{Manure}$ (Conversion Factor)	=	Use 0.02 kg N_2O-N per kilogram of nitrogen excreted; and
44/28 (Conversion Factor)	=	Use the quotient of 44 divided by 28 to convert (N_2O-N) emissions to N_2O emissions.

Equation 5: Daily Nitrogen Excreted in Manure

NE_{Xi} (kg nitrogen excreted/animal/day)	=	$DDMI_i$ * (CP_i / 100%) / $CF_{protein}$ * (1 – NR)

Where:

NE_X (Nitrogen Excreted)	=	The average amount of nitrogen excreted by in each animal grouping is expressed as kg of nitrogen per head per day. Used in calculating direct and indirect nitrous oxide emissions;
CP (Crude Protein)	=	A required component in the diet fed to each grouping of cattle and is expressed as a percentage (%);
CF $_{protein}$ (Protein Conversion Factor)	=	A default coefficient which represents the mass of dietary protein which is converted to dietary nitrogen and is equal to 6.25 kg of protein per kg of dietary nitrogen; and
NR (Nitrogen Retention)	=	The fraction of nitrogen intake that is retained by each animal grouping and is 0.07 kg N retained/kg N consumed.

Equation 6: Direct Nitrous Oxide (N_2O) Emissions from Manure Storage

Manure N_20 $_{direct\ storage}$ (kg N_20)	=	Σ (Number $Production_i$* DOF_i * NEX_i * $Frac_{storage}$* EF Storage) * 44 / 28

Where:

Manure N_20 $_{direct\ storage}$	=	The sum of direct emissions of nitrous oxide from manure storage for each grouping of cattle;
Frac $_{storage}$	=	The fraction of total nitrogen excreted for each animal grouping that is managed in a particular manure management system and is set at 0.6; and
EF (Storage)	=	An emission factor related to the direct N_2O emissions from a manure management system and set at 0.007 kg N_2O -N/kg nitrogen excreted.

Equation 7: Indirect Nitrous Oxide (N_2O) Emissions from Volatilization of Manure

Manure $N_20_{indirect\ volatilization}$ (kg N_20)	=	Σ (Number $Production_i$ * DOF_i * NEX_i * $Frac_{Volatilization}$* EF Volatilization) * 44 / 28

Where:

Manure $N_20_{indirect\ volatilization}$	=	The sum of indirect emissions of nitrous oxide from manure volatilization for each grouping of cattle;
Frac $_{volatilization}$	=	The fraction of manure N that is lost as volatilized NO_X and NH_3 and is set at 0.420; and
EF (Volatilization)	=	An emission factor related to the indirect N_2O emission from atmospheric deposition of nitrogen in soils/water surfaces and is set at 0.01 kg N_2O -N/kg N deposited.

Equation 8: Indirect Nitrous Oxide (N_2O) Emissions from Leaching of Manure Nitrogen

Manure $N_20_{indirect\ leaching}$ (kg N_20)	=	Σ (Number Production $_i$ * DOF_i * NE_{Xi} * $Frac_{Leaching}$ * EF Leaching) * 44 / 28

Where:

Manure $N_20_{indirect\ leaching}$	=	The sum of indirect emissions of nitrous oxide for each grouping of cattle;
Frac $_{Leaching}$	=	The fraction of manure N that is added to soils in regions where leaching and runoff occurs that is lost as leaching and runoff and is set at 0.1; and
EF (Leach)	=	An emission factor for N_2O emissions from N leaching and runoff and is set at 0.025 kg N_2O -N/kg N leached.

Equation 9:Average Hot Carcass Weight Gain

Where:

Average Hot Carcass Weight Gain	=	(average hot carcass weight of the finished cattle in the group) – (dressing percentage * average weight of cattle entering the feedlot in that group);
Hot carcass weight gain	=	Hot carcass weight (kg) for each grouping of cattle;
Dressing percentage[16]	=	Hot Carcass Weight / Live Weight * 100;
Average Weight finished cattle in the group	=	Average live weight of cattle exiting the feedlot (kg); and
Average weight entering the feedlot in that group	=	Average live weight of cattle entering the feedlot (kg).

[16] The Dressing Percentage will be given to the feedlot operator by the packer, on an average basis or by lot or grouping

4.3 Cattle Inventories and Data Collection

Transparent and accurate data are needed to support project implementation and facilitate third party verification of the emission reductions. How animals are tracked is critical to this protocol and must be consistent between the baseline and project conditions. Appendix B provides further detail.

Table 6: Quantification Methodology for Baseline Condition

Baseline Sources/ Sinks	Parameter / Variable	Unit	Measured / Estimated	Method	Frequency	Justify Measurement or Estimation and Frequency
B10- Feed Consumption	*Equation #1 Enteric Methane Emissions:* $Emissions_{Cattle} = \Sigma\ [Number\ Production_I * DOF * DDMI_I * GE_{Diet} * (EF_{Enteric\ I} / 100\%) / EC_{Methane})]$					
	Enteric emissions from cattle for each feeding regime within each animal grouping / $Emissions_{Cattle}$	kg CH_4	N/A	N/A	N/A	Quantity being calculated.
	Number of cattle in grouping i / $Number\ Production_i$	Head	Measured	Calculated as Number of cattle in grouping = animal head*days/days on feed	Continuous	Direct measurement is the highest level possible.
	Days on feed for each feeding regime for cattle in grouping i / DOF_i	Days	Measured	Average for cattle in specific animal grouping over the three years prior to the implementation of the project This value is calculated from animal head*days Days on feed (days) = average date out – average date in	Annual	Based on feedlot records.

Baseline Sources/ Sinks	Parameter / Variable	Unit	Measured / Estimated	Method	Frequency	Justify Measurement or Estimation and Frequency
	Average daily dry matter intake for each feeding regime for cattle in grouping i / $DDMI_i$	kg dry matter / head / day	Estimated	Estimated based on average mass of feed provided to cattle during period on diet The amount of feed provided to a pen of animals expressed as kilograms of feed per animal per day calculated from animal head*days Dry Matter Intake (kg/head/day) = (Total quantity of feed for a specific diet) x (dry matter content of diet) / animal head*days	Continuous	Based on actual feed delivery records to each pen.
	Default value gross energy content (GE) of the diet GE_{Diet}	MJ / kg dry matter	Estimated	19.10 MJ / kg dry matter for diets including edible oils in the range of 4 to 6% 18.45 MJ / kg dry matter for diets with edible oils below the range of 4 to 6%	Annual	Default value taken from IPCC 2006 guidance (Section 10.4.2).

Baseline Sources/ Sinks	Parameter / Variable	Unit	Measured / Estimated	Method	Frequency	Justify Measurement or Estimation and Frequency
	Emission factor for enteric emissions for each feeding regime in grouping I / $EF_{Enteric\ i}$	%	Estimated	For diets with less than 4% edible oils/fat (DM basis): • 4.0% for diets with greater than or equal to 85% concentrates; or • 6.5% for diets with less than 85% concentrates For diets with edible oils/fats in the 4 to 6% range: • 3.2% for diets with greater than or equal to 85% concentrates; or • 5.8% for diets with less than 85% concentrates	Continuous	Set based on best available science and in reference to the IPCC 2006 guidance.
	Energy content of methane / $EC_{Methane}$	MJ / kg methane	Estimated	55.65 MJ / $kg_{methane}$	Annual	Conversion factor taken from IPCC 2006 guidance (Section 10.3.2).
B13 - Manure Storage and B15 - Land Application	$Emissions_{Manure} = \Sigma\ ((Emissions_{Manure\ CH4}\ x\ GWP_{CH4}) + (Emissions_{Direct\ Nitrous\ Oxide} + Nitrogen_{Excreted\ I} + Emissions_{Direct\ Storage} + Emissions_{Indirect\ Volatilization} + Emissions_{Indirect\ Leaching})\ x\ GWP_{N2O})$					
	$Emission_{Manure}$	kg CH_4	N/A	N/A	Annual	Quantity being calculated.
	Methane emissions from manure / $Emissions_{Manure\ CH4}$	See equation#2				

Baseline Sources/ Sinks	Parameter / Variable	Unit	Measured / Estimated	Method	Frequency	Justify Measurement or Estimation and Frequency
	Global Warming Potential for Methane / GWP_{CH4}	n/a	Estimated	Carbon Offset Emission Factors Handbook	n/a	Must use most current factors published in Carbon Offset Emission Factors Handbook.
	Direct emissions of nitrous oxide from manure for each feeding regime within each animal grouping / $Emissions_{Direct\ Nitrous\ Oxide}$	See equation #4				
	Nitrogen excreted by the cattle in grouping I / Nitrogen $Excreted_i$	See equation #5				
	Direct emissions of nitrous oxide from manure storage / $Emissions_{Direct\ Storage}$	See equation #6				

Baseline Sources/ Sinks	Parameter / Variable	Unit	Measured / Estimated	Method	Frequency	Justify Measurement or Estimation and Frequency
	Indirect emissions of nitrous oxide from leaching for each feeding regime within each animal grouping / $Emissions_{Indirect\ Volatilization}$	See equation #7				
	Indirect emissions of nitrous oxide from leaching for each animal grouping / $Emissions_{Indirect\ Leach}$	See equation #8				
	Global Warming Potential for Methane / GWP_{N20}	n/a	Estimated	Carbon Offset Emission Factors Handbook	n/a	Must use most current factors published in Carbon Offset Emission Factors Handbook.
	Equation #2 Manure Methane Emissions (Handling, Storage and Application): $Emissions_{Manure\ CH4} = \Sigma\ (Number\ Production_I * DOF_I * VS_I * Bo * \rho_{Methane} * (MCF / 100\%))$					

Baseline Sources/ Sinks	Parameter / Variable	Unit	Measured / Estimated	Method	Frequency	Justify Measurement or Estimation and Frequency
	Methane emissions from manure storage and handling for each feeding regime within each animal grouping / $Emissions_{Manure\ CH4}$	kg CH_4	N/A	N/A	N/A	Quantity being calculated.
	Number of cattle in grouping I / $Number\ Production_i$	Head	Measured	This value is calculated from animal head*days Days on feed (days) = average date out – average date in	Continuous	Direct measurement is the highest level possible.
	Days on feed for each feeding regime for cattle in grouping I / DOF_i	Days	Estimated	This value is calculated from animal head*days. Days on feed (days) = average date out – average date in	Annual	Based on feedlot records.
	Average daily volatile solid excreted for cattle in grouping I and each feeding regime / VS_i	See equation #3				

Baseline Sources/ Sinks	Parameter / Variable	Unit	Measured / Estimated	Method	Frequency	Justify Measurement or Estimation and Frequency
	Maximum methane producing capacity for manure produced / Bo	m^3 CH_4 / kg VS Excreted	Estimated	0.19 m^3 CH_4 / kg VS Excreted	Annual	Conversion factor taken from IPCC 2006 guidance (Table 10A-5).
	Density conversion factor for m^3 methane to kg of methane / $\rho_{Methane}$	kg/m^3	Estimated	0.67 kg/m^3	Annual	Physical property of methane at standard temperature (20^{O}C) and pressure (1 atm).
	Methane conversion factor / MCF	%	Estimated	1 per cent for pasture, range, and/or paddock systems or 2 per cent for solid storage systems	Annual	Set based on best available science and in reference to the IPCC 2006 guidance.
	Equation #3 Daily Volatile Solids Excreted in Manure: $VS_i = [(DDMI_I * GE_{Diet} * (1 – (TDN_I / 100\%))) + (UE * DDMI_I * GE_{Diet})] * ((1 – (Ash / 100\%)) / GE_{Diet})$					
	Average daily volatile solid excreted for cattle in grouping I and each feeding regime / VS_i	kg / head / day	N/A	N/A	N/A	Quantity being calculated.

Baseline Sources/ Sinks	Parameter / Variable	Unit	Measured / Estimated	Method	Frequency	Justify Measurement or Estimation and Frequency
	Average daily dry matter intake for each feeding regime for cattle in grouping I / $DDMI_i$	kg dry matter / head / day	Estimated	Estimated based on average mass of feed provided to cattle during period on diet	Continuous	Based on actual feed delivery records to each pen.
	Default value gross energy content (GE) of the diet GE_{Diet}	MJ / kg dry matter	Estimated	19.10 MJ / kg dry matter for diets including edible oils in the range of 4 to 6% 18.45 MJ / kg dry matter for diets with edible oils below the range of 4 to 6%	Annual	Conversion factor taken from IPCC 2006 guidance (Section 10.4.2).
	Total digestible nutrients for each feeding regime for cattle in grouping I / TDN_I	%	Estimated	Estimated based on composition of feed provided to cattle during period on diet	Continuous	Estimation based on diet composition and/or from direct analysis of the total mixed diet.
	Urinary energy / UE	N/A	Estimated	0.04 for diets with less than 85 % concentrates 0.02 for diets with greater than or equal to 85% concentrates	Annual	Set based on best available science and in reference to the IPCC 2006 guidance (Section 10.4.2).

Baseline Sources/ Sinks	Parameter / Variable	Unit	Measured / Estimated	Method	Frequency	Justify Measurement or Estimation and Frequency
	Ash content of manure calculated as a fraction of the dry matter feed intake for cattle / Ash	%	Estimated	1 per cent for pasture, range, and/or paddock systems or 2 per cent for solid storage systems 2 per cent would apply in this protocol	Annual	Set based on best available science and in reference to the IPCC 2006 guidance.
	*Equation #4 Direct Nitrous Oxide (N_20) Emissions from Manure: Emissions $_{Direct\ Nitrous\ Oxide}$ = Σ (Number Production $_I$ * DOF $_I$ * Nitrogen $_{Excreted\ I}$ * CF $_{Manure}$) * 44 / 28*					
	Direct emissions of nitrous oxide from manure for each feeding regime within each animal grouping / Emissions $_{Direct\ Nitrous\ Oxide}$	kg N_2O	N/A	N/A	N/A	Quantity being calculated.
	CF $_{Manure}$	kg N_2O-N / kg Nitrogen Excreted	Estimated	0.02 kg N_2O-N / kg Nitrogen Excreted	Annual	Set based on best available science and in reference to the IPCC.
	44/28	-	Default – molecular mass ratio of N_20 to N_20 as N	Use the quotient of 44 divided by 28 to convert (N_2O-N) emissions to N_2O emissions	N/A	
	*Equation #5 Daily Nitrogen Excreted in Manure: Nitrogen Excreted $_I$ = Σ DDMI $_I$ * (CP $_I$ / 100%) / CF $_{Protein}$ * (1 – NR)*					

Baseline Sources/ Sinks	Parameter / Variable	Unit	Measured / Estimated	Method	Frequency	Justify Measurement or Estimation and Frequency
	Nitrogen excreted by the cattle in grouping I / Nitrogen Excreted $_i$	kg N/ head / day	N/A	N/A	N/A	Quantity being calculated.
	Average daily dry matter intake for each feeding regime for cattle in grouping I / DDMI $_i$	kg dry matter / head / day	Estimated	Estimated based on average mass of feed provided to cattle This value is calculated from animal head*days. Days on feed (days) = average date out – average date in Dry Matter Intake (kg/head/day) = (Total quantity of feed for a specific diet) x (dry matter content of diet) / animal head*days	Continuous	Estimation based on farm records.
	Percent crude protein in diet for each feeding regime in cattle in grouping I / CP $_i$	%	Estimated	Estimated based on composition of feed provided to cattle during period on diet	Continuous	Estimation based on diet composition and/or from direct analysis of the total mixed diet.

Baseline Sources/ Sinks	Parameter / Variable	Unit	Measured / Estimated	Method	Frequency	Justify Measurement or Estimation and Frequency
	Conversion from mass of dietary protein to mass of dietary nitrogen/ $CF_{protein}$	kg feed protein / kg nitrogen	Estimated	6.25 kg feed protein / kg nitrogen	Annual	Conversion factor taken from IPCC 2006 guidance (Section 10.5.2).
	Fraction of annual nitrogen intake retained / NR	kg N retained / kg intake	Estimated	0.07 kg N retained / kg intake	Annual	Factor taken from IPCC 2006 guidance (Table 10.20).
	Equation #6 Direct Nitrous Oxide (N_2O) Emissions from Manure Storage: $Emissions_{Direct\ Storage} = \Sigma\ (Number\ Production_I * DOF_I * Nitrogen\ Excreted_I * Frac_{Storage} * EF_{Storage}) * 44 / 28$					
	Direct emissions of nitrous oxide from manure storage / $Emissions_{Direct\ Storage}$	kg N_2O	N/A	N/A	N/A	Quantity being calculated.
	$Frac_{Storage}$	N/A	Estimated	0.6	Annual	Set based on best available science and in reference to the IPCC.

Baseline Sources/ Sinks	Parameter / Variable	Unit	Measured / Estimated	Method	Frequency	Justify Measurement or Estimation and Frequency
	EF $_{Storage}$	kg N_2O-N / kg Nitrogen Excreted	Estimated	0.007 kg N_2O-N / kg Nitrogen excreted	Annual	Emission factor related to the direct N_2O emissions from a manure management system. Set based on best available science and in reference to the IPCC.
	*Equation #7 Indirect Nitrous Oxide (N_2O) Emissions from Volatization of Manure: Emissions $_{Indirect\ Volatilization}$ =Σ (Number $_{Production\ I}$ * DOF $_I$ * Nitrogen $_{Excreted\ I}$ * Frac $_{Volatilization}$ * EF $_{Volatilization}$) * 44 / 28*					
	Indirect emissions of nitrous oxide from leaching for each feeding regime within each animal grouping / Emissions $_{Indirect\ Volatilization}$	kg N_2O	N/A	N/A	N/A	Quantity being calculated.
	Frac $_{Volatilization}$	N/A	Estimated	0.42	Annual	Set based on best available science and in reference to the IPCC.
	EF $_{Volatilization}$	kg N_2O-N / kg Nitrogen Deposited	Estimated	0.01 kg N_2O-N / kg Nitrogen deposited	Annual	Set based on best available science and in reference to the IPCC.

Baseline Sources/ Sinks	Parameter / Variable	Unit	Measured / Estimated	Method	Frequency	Justify Measurement or Estimation and Frequency
	*Equation #8 Indirect Nitrous Oxide (N2O) Emissions from Leaching of Manure Nitrogen: Emissions $_{Indirect\ Leaching}$ = Σ (Number $_{Production\ I}$ * DOF $_{I}$ * Nitrogen Excreted $_{I}$ * Frac $_{Leach}$ * EF $_{Leach}$) * 44 / 28*					
	Indirect emissions of nitrous oxide from leaching for each feeding regime within each animal grouping / Emissions $_{Indirect\ Leach}$	kg N_2O	N/A	N/A	N/A	Quantity being calculated.
	Frac $_{Leach}$	N/A	Estimated	0.1	Annual	Set based on best available science and in reference to the IPCC.
	EF $_{Leach}$	kg N_2O-N / kg Nitrogen Leached	Estimated	0.025 kg N_2O-N / kg Nitrogen leached	Annual	Set based on best available science in National Inventory Report.
	*Equation #9 Average hot carcass weight gain =(average hot carcass weight of the finished cattle in the group) – (dressing percentage * average weight of cattle entering the feedlot in that group)*					
	Average hot carcass weight gain	Kg	Estimated	Comparison of initial weight to finished weight for a cattle grouping	Finish Intervals	Based on best available data.

Baseline Sources/ Sinks	Parameter / Variable	Unit	Measured / Estimated	Method	Frequency	Justify Measurement or Estimation and Frequency
	Average weight of cattle entering feedlot	Kg	Measured	Scale	Once per entry to feedlot	Best available methodology.
	Average hot carcass weight of finished cattle	Kg	Measured	Scale	Once from packer	Best available methodology.
	Average weight of cattle exiting the feedlot	Kg	Measured	Scale	Once on exit from feedlot	Best available methodology.
	Dressing percentage	%	Calculated	Average hot carcass weight of finished cattle / average weight of cattle exiting the feedlot	Finish Intervals	Best available methodology.

Table 7: Quantification Methodology for Project Condition

Project Sources/ Sinks	Parameter / Variable	Unit	Measured / Estimated	Method	Frequency	Justify measurement or estimation and frequency
P10 Feed Consumption	*Equation #1 Enteric Methane Emissions: $Emissions_{Cattle} = \Sigma (Number\ Production_i * DOF_i * DDMI_i * GE_{Diet} * (EF_{Enteric\ i} / 100\%) / EC_{Methane})$*					
	Enteric emissions from cattle for each feeding regime within each weight grouping / $Emissions_{Cattle}$	kg CH_4	N/A	N/A	N/A	Quantity being calculated.
	Number of cattle in grouping i / $Number\ Production_i$	Head	Measured	Calculated as number of cattle in grouping = animal head*days/days on feed	Continuous	Direct measurement is the highest level possible.
	Days on feed for each feeding regime for cattle in Grouping i / DOF_i	Days	Measured	Average for cattle in specific animal grouping over the three years prior to the implementation of the project This value is calculated from animal head*days Days on feed (days) = average date out – average date in	Continuous	Direct measurement is the highest level possible.

	Average daily dry matter intake for each feeding regime for cattle in Grouping i / $DDMI_i$	kg dry matter / head / day	Estimated	Estimated based on average mass of feed provided to cattle during period on diet The amount of feed provided to a pen of animals expressed as kilograms of feed per animal per day calculated from animal head*days Dry Matter Intake (kg/head/day) = (Total quantity of feed for a specific diet) x (dry matter content of diet) / animal head*days	Continuous	Based on actual feed delivery records to each pen.
	Default value gross energy content (GE) of the diet GE_{Diet}	MJ / kg dry matter	Estimated	19.10 MJ / kg dry matter for diets including edible oils in the range of 4 to 6% 18.45 MJ / kg dry matter for diets with edible oils below the range of 4 to 6%	Annual	Default value taken from IPCC 2006 guidance (Section 10.4.2).

	Emission factor for enteric emissions for each feeding regime in Grouping i / $EF_{Enteric\ i}$	%	Estimated	For diets with less than 4% edible oils/fat (DM basis): • 4.0% for diets with greater than or equal to 85% concentrates ; or • 6.5% for diets with less than 85% concentrates For diets with edible oils/fats in the 4 to 6% range: • 3.2% for diets with greater than or equal to 85% concentrates; or • 5.8% for diets with less than 85% concentrates	Continuous	Set based on best available science and in reference to the IPCC 2006 guidance.
	Energy content of methane / $EC_{Methane}$	MJ / kg methane	Estimated	55.65 MJ / kg methane	Annual	Conversion factor taken from IPCC 2006 guidance (Section 10.3.2).
P13- Manure Storage and P15 - Land Application	$Emissions_{Manure} = \Sigma\ ((Emissions_{Manure\ CH4}\ x\ GWP_{CH4}) + (Emissions_{Direct\ Nitrous\ Oxide} + Nitrogen_{Excreted\ i} + Emissions_{Direct\ Storage} + Emissions_{Indirect\ Volatilization} + Emissions_{Indirect\ Leaching})\ x\ GWP_{N2O})$					
	$Emission_{Manure}$	kg CH_4	N/A	N/A	Annual	Quantity being calculated.
	Methane emissions from manure / $Emissions_{Manure\ CH4}$	See equation#2				

	Global Warming Potential for Methane / GWP_{CH4}	n/a	Estimated	Carbon Offset Emission Factors Handbook	n/a	Must use most current factors published in Carbon Offset Emission Factors Handbook.
	Direct emissions of nitrous oxide from manure for each feeding regime within each animal grouping / $Emissions_{Direct\ Nitrous\ Oxide}$	See equation #4				
	Nitrogen excreted by the cattle in grouping I / $Nitrogen\ Excreted_i$	See equation #5				
	Direct emissions of nitrous oxide from manure storage / $Emissions_{Direct\ Storage}$	See equation #6				

	Indirect emissions of nitrous oxide from leaching for each feeding regime within each animal grouping / Emissions $_{Indirect\ Volatilization}$	See equation #7				
	Indirect emissions of nitrous oxide from leaching for each animal grouping / Emissions $_{Indirect\ Leach}$	See equation #8				
	Global Warming Potential for Methane / GWP $_{N20}$	n/a	Estimated	Carbon Offset Emission Factors Handbook	n/a	Must use most current factors published in Carbon Offset Emission Factors Handbook.
	*Equation #2 Manure Methane Emissions (Handling, Storage, and Application): Emissions Manure CH4 = Σ (Number Production i * DOF i * VS i * Bo * ρ Methane * (MCF / 100%))*					

	Methane emissions from manure handling, storage and land application for each feeding regime within each animal grouping / Emissions $_{Manure\ CH4}$	kg CH_4	N/A	N/A	N/A	Quantity being calculated.
	Number of cattle in grouping i / Number Production $_i$	Head	Measured	This value is calculated from animal head*days Days on feed (days) = average date out – average date in	Continuous	Direct measurement is the highest level possible.
	Days on feed for each feeding regime for cattle in grouping i / DOF $_i$	days	Measured	This value is calculated from animal head*days Days on feed (days) = average date out – average date in	Continuous	Based on feedlot records.
	Maximum methane producing capacity for manure produced / Bo	m^3 CH_4 / kg VS Excreted	Estimated	0.19 m^3 CH_4 / kg versus excreted	Annual	Conversion factor taken from IPCC 2006 guidance (Table 10A-5).

Density conversion factor for m^3 methane to kg of methane of methane / $\rho_{Methane}$	kg/m^3	Estimated	0.67 kg/m^3	Annual	Physical property of methane at standard temperature and pressure.
Methane conversion factor / MCF	%	Estimated	1 per cent for pasture, range, and/or paddock systems or 2 per cent for solid storage systems	Annual	Set based on best available science and in reference to the IPCC 2006 guidance.
Equation #3 Daily Volatile Solids Excreted in Manure: $VS_i = [(DDMI_i * GE_{Diet} * (1 - (TDN_i / 100\%))) + (UE * DDMI_I * GE_{Diet})] * ((1 - (Ash / 100\%)) / GE_{Diet})$					
Average daily volatile solid excreted for livestock in grouping i and each feeding regime / VS_i	kg / head / day	N/A	N/A	N/A	Quantity being calculated.
Average daily dry matter intake for each feeding regime for cattle in grouping i / $DDMI_i$	kg dry matter / head / day	Estimated	The amount of feed provided to a pen of animals expressed as kilograms of feed per animal per day calculated from animal head*days Days on feed (days) = average date out – average date in	Continuous	Based on actual feed delivery records to each pen.

	Default value gross energy content (GE) of the diet GE_{Diet}	MJ / kg dry matter	Estimated	19.10 MJ / kg dry matter for diets including edible oils in the range of 4 to 6% 18.45 MJ / kg dry matter for diets with edible oils below the range of 4 to 6%	Annual	Conversion factor taken from IPCC 2006 guidance (Section 10.4.2).
	Total digestible nutrients for each feeding regime for cattle in grouping i / TDN_i	%	Estimated	Estimated based on composition of feed provided to cattle during period on diet	Continuous	Estimation based on diet composition and/or from direct analysis of the total mixed diet.
	Urinary energy / UE	N/A	Estimated	0.04 for diets with less than 85 per cent concentrates 0.02 for diets with greater than or equal to 85 per cent concentrates	Annual	Set based on best available science and in reference to the IPCC 2006 guidance (Section 10.4.2).
	Ash content of manure calculated as a fraction of the dry matter feed intake for cattle / Ash	%	Estimated	1 per cent for pasture, range, and/or paddock systems, or 2 per cent for solid storage systems	Annual	Set based on best available science and in reference to the IPCC 2006 guidance.
	Equation #4 Direct Nitrous Oxide (N_2O) Emissions from Manure: $Emissions_{Direct\ Nitrous\ Oxide} = \Sigma\ (Number\ Production_i * DOF_i * Nitrogen\ Excreted_i * CF_{Manure}) * 44 / 28$					

	Direct emissions of nitrous oxide from manure for each feeding regime within each animal grouping / Emissions $_{Direct\ Nitrous\ Oxide}$	kg N_2O	N/A	N/A	N/A	Quantity being calculated.
	CF $_{Manure}$	kg N_2O-N / kg Nitrogen Excreted	Estimated	0.02 kg N_2O-N / kg Nitrogen excreted	Annual	Set based on best available science and in reference to the IPCC.
	44/28	-	Default – molecular mass ratio of N_2O to N_2O as N	Use the quotient of 44 divided by 28 to convert (N_2O-N) emissions to N_2O emissions based on molar mass	N/A	
	Equation #5 Daily Nitrogen Excreted in Manure: $Nitrogen\ Excreted_i = DDMI_i * (CP_i / 100\%) / CF_{Protein} * (1 – NR)$					
	Nitrogen excreted by the livestock in grouping i / Nitrogen Excreted $_i$	kg / head / day	N/A	N/A	N/A	Quantity being calculated.

	Average daily dry matter intake for each feeding regime for cattle in grouping i / $DDMI_i$	kg dry matter / head / day	Estimated	This value is calculated from animal head*days Days on feed (days) = average date out – average date in	Continuous	Based on actual feed delivery records to each pen.
	Percent crude protein in diet for each feeding regime in cattle in Grouping i / CP_i	%	Estimated	Estimated based on composition of feed provided to cattle during period on diet	Continuous	Estimation based on diet composition and/or from direct analysis of the total mixed diet.
	Conversion from mass of dietary protein to mass of dietary nitrogen / $CF_{Protein}$	kg feed protein / kg nitrogen	Estimated	6.25 kg feed protein / kg Nitrogen	Annual	Conversion factor taken from IPCC 2006 guidance (Section 10.5.2).
	Fraction of annual nitrogen intake retained / $Nitrogen_{Retention}$	kg N retained / kg intake	Estimated	0.07 kg Nitrogen retained / kg intake	Annual	Factor taken from IPCC 2006 guidance (Table 10.20).
	Equation #6 Direct Nitrous Oxide (N_2O) Emissions from Manure Storage: $Emissions_{Direct\ Storage} = \Sigma (Number_{Production\ i} * DOF_i * Nitrogen\ Excreted_i * Frac_{Storage} * EF_{Storage}) * 44 / 28$					

	Direct emissions of nitrous oxide from manure storage / Emissions $_{Direct\ Storage}$	kg N_2O	N/A	N/A	N/A	Quantity being calculated.
	Frac $_{Storage}$	N/A	Estimated	0.6	Annual	Set based on best available science and in reference to the IPCC.
	EF $_{Storage}$	kg N_2O-N / kg Nitrogen Excreted	Estimated	0.007 kg N_2O-N / kg Nitrogen excreted	Annual	Set based on best available science and in reference to the IPCC.
	*Equation #7 Indirect Nitrous oxide (N_2O) Emissions from Volatilization of Manure: Emissions $_{Indirect\ Volatilization}$ =Σ (Number $_{Production\ i}$ * DOF $_i$ * Nitrogen $_{Excreted\ i}$ * Frac $_{Volatilization}$ * EF $_{Volatilization}$) * 44 / 28*					
	Indirect emissions of nitrous oxide from volatilization for each feeding regime within each animal grouping / Emissions $_{Indirect\ Volatilization}$	kg N_2O	N/A	N/A	N/A	Quantity being calculated.

	Frac $_{Volatilization}$	N/A	Estimated	0.42	Annual	Set based on best available science and in reference to the IPCC.
	EF $_{Volatilization}$	kg N_2O-N / kg Nitrogen Deposited	Estimated	0.01 kg N_2O-N / kg Nitrogen deposited	Annual	Set based on best available science and in reference to the IPCC.
	*Equation #8 Indirect Nitrous Oxide (N_2O) Emissions from Leaching of Manure Nitrogen: Emissions $_{Indirect\ Leaching}$ = Σ (Number Production $_i$ * DOF $_i$ * Nitrogen Excreted $_i$ * Frac $_{Leach}$ * EF $_{Leach}$) * 44 / 28*					
	Indirect emissions of nitrous oxide from leaching for each feeding regime within each animal grouping / Emissions $_{Indirect\ Leach}$	kg N_2O	N/A	N/A	N/A	Quantity being calculated.
	Frac $_{Leach}$	N/A	Estimated	0.1	Annual	Set based on best available science and in reference to the IPCC.
	EF $_{Leach}$	kg N_2O-N / kg Nitrogen Leached	Estimated	0.025 kg N_2O-N / kg Nitrogen leached	Annual	Set based on best available science and in reference to the IPCC and Canada's National Inventory Report.

*Equation #9 Average hot carcass weight gain =(average hot carcass weight of the finished cattle in the group) – (dressing percentage * average weight of cattle entering the feedlot in that group)*					
Average hot carcass weight gain	Kg	Estimated	Comparison of initial weight to finished weight for a cattle grouping	Finish Intervals	Based on best available data.
Average weight of cattle entering feedlot	Kg	Measured	Scale	Once per entry to feedlot	Best available methodology.
Average hot carcass weight of finished cattle	Kg	Measured	Scale	Once from packer	Best available methodology.
Average weight of cattle exiting the feedlot	Kg	Measured	Scale	Once on exit from feedlot	Best available methodology.
Dressing percentage	%	Calculated	Average hot carcass weight of finished cattle / average weight of cattle exiting the feedlot	Finish Intervals	Best available methodology.

4.4 Ensuring Functional Equivalence between Baseline and Project

Functional equivalence is a comparison of a project's baseline and project emissions using the same metric, normalized to the same level of products and services (for example, per GJ of energy, tonne of wheat produced, acres of carbon stored, etc.). Emissions related to the baseline and project conditions must be calculated in a similar manner to account for reductions in enteric and manure emissions. In order to maintain carbon equivalence, both sources of emissions (enteric and manure) for the baseline and project conditions need to be adjusted for the production equivalency of the cattle. For the purpose of quantifying greenhouse gas reductions in this protocol, the production equivalency is set as emissions per kilogram of average hot carcass weight gain once the emissions are calculated for all animal groupings. This is determined by dividing the total emissions for each gas in the baseline and project conditions (summed for enteric and manure CH_4 and N_2O) by the total number of animals in production and the average carcass weight of the animals for that grouping when they are sent to market.

For each animal grouping, the following parameters are calculated:

Baseline CH_4 Emissions Intensity (kg CH_4 /kg carcass weight gain during the Baseline Condition)	=	Σ [(CH_4 Emissions$_i$) / (Total Number in Production$_i$ * Average Hot Carcass Weight Gain of Cattle$_i$ sent to market (kg))]
Baseline N_2O Emissions Intensity (kg N_2O /kg carcass weight gain during the Baseline Condition)	=	Σ [(N_20 Emissions$_i$) / (Total Number in Production$_i$ * Average Hot Carcass Weight Gain of Cattle$_i$ sent to market (kg))]
Project CH_4 Emissions Intensity (kg CH_4 /kg carcass weight gain during the Project Condition)	=	Σ [(CH4 Emissions$_i$) / (Total Number in Production$_i$ * Average Hot Carcass Weight Gain of Cattle$_i$ sent to market (kg))]
Project N_2O Emissions Intensity (kg N_2O /kg carcass weight gain during the Project Condition)	=	Σ [(N_20 Emissions$_i$) / (Total Number in Production$_i$ * Average Hot Carcass Weight Gain of Cattle$_i$ sent to market (kg))]

The intensities for each of these gases must be calculated and reported separately for the purpose of annually reporting emission reductions. Sample calculations are provided in Appendix A.

5.0 Data Management

Data collection, records and data quality management must be able to support verification by an independent third party in order to support quantification of greenhouse gas emissions and reductions. In all cases, greenhouse gas emission reductions must be substantiated with records and must meet the minimum data requirements specified in Table 8. Alberta's Climate Change Office cannot accept offset credits for compliance purposes that are not supported by records.

Feedlot operators participating in reducing greenhouse gas emissions of fed cattle projects must collect and maintain records and proof of practice consistent with the requirements stated in Table 8. Cattle inventory data must be tracked for each specific lot/animal grouping in the baseline and project conditions to support the quantification and verification[17] of emission reductions being claimed. Feedlots will track number of head*days, dry matter intake, gain and performance for each feeding period and each animal grouping in their close-out sheets. This level of detail facilitates the calculations and verification of a project's greenhouse gas assertion[18].

Additional evidence other than that collected for business reasons may be required to substantiate claims of greenhouse gas emission reductions and to provide positive proof of feeding and management strategies to support a verification to a reasonable level of assurance[19]. Each type of data requirement listed in Table 8 provides examples of records collected from feedlot operations to substantiate reduction claims. Feedlot operations with incomplete or unverifiable records cannot be included in a reducing greenhouse gas emission of fed cattle project.

Consistent with the requirements stated in Table 8, project developers and/or feedlot operators (note these may be the same entity as described in Table 8) are required to retain copies of farm operators' records and any additional records needed to support their greenhouse gas assertions.

The project developer/feedlot operator must also establish and apply data management procedures to manage data and information within the project. Written procedures must be established for each management task outlining responsibility, timing, quality control and quality assurance checks, records and record location requirements. These procedures must be documented in a procedures manual, and must be made available to the third party verifier[20] and government auditors upon request. More rigorous data management systems can facilitate third party verification and government audit and help to reduce overall transaction costs for the project.

The third party verifier is required to assess the data management system, the internal procedures manual, quantification and project records as part of the project verification. A third party verifier cannot sign off on a project with incomplete or missing data and/or records.

5.1 Role of Professional Agrologist / Doctor of Veterinary Medicine

Veterinarians (DVM) and/or Professional Agrologists (P.Ag.) may work directly for the participating feedlot, the project developer, or be an independent third party that is consulted during project implementation. DVMs or P.Ag. may have familiarity with a farm enterprise and must have specific knowledge of confined beef feeding systems. They can provide additional support for project implementation. However, sign-off by a DVM or P.Ag. cannot be used as a substitute for farm records or third party verification.

Project developers/feedlot operators may elect to have a D.V.M. or a P.Ag. sign off on their opinion regarding practices being claimed in the project. This sign-off provides a secondary source of corroborating evidence of the beef feedlot's practices.

Sign-off by a DVM/P.Ag. does not replace record keeping requirements, but rather, can provide an added level of due diligence to emission reduction claims. All parties (DVM/P.Ag., feedlot operator/project developer) are required to maintain copies of records needed to support the greenhouse gas assertion. Examples of minimum records are provided in Table 8. Responsibilities for the professionals involved in a sign-off are listed in Table 9.

The DVM or P.Ag. must collect and keep copies of the records needed to support their professional opinion presented in the sign off statement.

5.2 Project Documentation and Evidence

Data requirements and minimum records have been outlined in Table 8. Project developers/feedlot operators are required to obtain and retain copies of records for each year of the project in their data management

[17] Verification is an independent third party review of a project to assess project operating conditions against the baseline condition to confirm the offset credits being claimed in the project's greenhouse gas assertion.
[18] A greenhouse gas assertion is a document that identifies the greenhouse gas emission reductions/removals and offset credits being claimed by a project over a defined period of time.
[19] Assurance is the systematic process of objectively obtaining and evaluating evidence regarding a project's greenhouse gas assertion to ascertain the degree of correspondence between the assertion and established verification criteria.
[20] A third party verifier is a person or organization that meets the requirements of a third party auditor as stated in Section 18 of the Specified Gas Emitters Regulation.

system as outlined in Table 9. They must also disclose these records to a third party verifier and government auditor upon request. They may be asked to produce records during a site visit conducted by a third party verifier or government auditor. Data collection and record retention responsibilities by party are outlined in Table 9.

Table 8: Data Requirements and Minimum Records to Prove Reduced GHG Emissions of Fed Cattle

Data Requirement	Minimum Records Needed	Rationale
Animal Inventory		
Animal Identifier Tags	• Feedlot records or third party records showing unique tag numbers for each animal recorded in animal inventory databases; and • Feedlot records showing animals with lost tags were either removed from the project or the lost tag was retired and a replacement tag registered with that individual animal.	To ensure the animals in feeding/ commercial agreements are fed in the feedlot in question and can be tracked, if necessary, in and out of the feedlot and dead animals are confirmed as removed from the project.
Animal Groupings	• Documented procedures by the feedlot for methods used to sort and group animals to manage their production and performance. or • Documented procedures by the project developer, if using flexibility mechanism number 1 in Section 1.3, which show the animal grouping procedures for GHG calculations for baseline and project conditions.	The methods used to define an animal grouping (e.g., lots or pens based on sex, age, weight, breed or quality grid programs) must be similar between project and baseline conditions to ensure the offset calculations are valid and functionally equivalent.
Number in Production - for Animal Groupings – Entry and Exit numbers	• Feedlot inventory records (e.g., close-out data) that show the average number of animals in each grouping, taking into account animal entry and exit movements from the grouping; this is a weighted average approach using the animal head*days factor; and • Feedlot records or shipping manifests or packing plant receipts that show the lots exited the feedlot destined for a packing plant. or • Third party managed data for production and performance, documenting weighted averages per animal grouping and shipping	To ensure an accurate average number of head per animal grouping for offset calculation purposes and as evidence animals were being finished for market purposes and, so, being shipped to packing plants (i.e., not being backgrounded in the feedlot).

Data Requirement	Minimum Records Needed	Rationale
	manifests to a packing plant or receipts from a packing plant, with sign-off by an authorized signatory of the third party agency.	
Incoming and Outgoing Weights	• Date stamped feedlot records showing average incoming and outgoing weights for animal groupings; and • Associated weigh scale tickets from a licensed scale at the feedlot per animal grouping; and feedlot records or third party managed data showing corrected carcass weights for the animal groupings on an outgoing basis.	Animal groupings will be sorted by weight classes within gender and animal type (e.g., fall calves, yearlings, winter calves, etc.), thus the weights will need to be known. GHG reductions are calculated according to animal groupings and on a kilogram of live weight or kilogram of carcass weight basis, so an adjustment for production equivalency between baseline and project conditions will need to be made in accordance with the protocol.
Feeding Management		
Number of Days on Feed	• Feedlot records or third-party-managed data, date stamped, that show the average number of days a group of animals spent on diets while in the feedlot; and if only feedlot records exist (i.e., no third party managed data); and • Sign-off by a P.Ag. or DVM who reviewed and collected supporting farm records that confirm the number of days on feed for each diet for baseline and project conditions.[21]	Required to calculate the enteric- and manure-based GHG emissions from feed intake of a particular diet for a particular period of time.
Composition of Each Diet or Classes of Diet	• Date stamped feedlot ration and nutrient analysis sheets that show the diet ingredients on a dry matter basis, including: o Level of concentrates in the diet (%); o Total digestible nutrients (%); o Crude protein content (%);	Key diet ingredients are required for GHG emissions to ensure that calculations have taken into account: • The right enteric emission factor (EF – percent of gross energy intake lost as methane in the rumen) is being used depending

[21] It is acceptable to streamline implementation of a project according to flexibility mechanism number 3, in Section 1.3 of this protocol. In this case, the project developer can treat the entire time the cattle are in the feedlot as though they were on a ≥ 85% concentrate diet. To ensure conservativeness, the 4 percent emission factor for methane emissions, needs to be applied in both the baseline and project conditions. The project developer must justify to the verifier how the required diet ingredients are statistically representative for the animals in the feedlot in question for both baseline and project conditions.

Data Requirement	Minimum Records Needed	Rationale
	o Fat content (% ether extract) ; and o Incidence and inclusion of feed additives or supplements that will reduce days on feed (e.g. beta-agonists) as part of the project activity or • Third-party-managed data that include all of the above, with sign-off by an authorized signatory of the third party agency; and/or If feedlot records only (i.e., no third-party-managed data), sign off by a P.Ag. or D.V.M. confirming the diet composition in the ration and nutrient analysis sheets. and/or If the flexibility mechanism number 3 is being applied (see footnote below), then: • Documented procedures by the project developer on how the average diet ingredients for the groupings were derived; and • Justification and sign off by the P.Ag. or DVM on the representativeness of the average diets for the particular animal grouping, and how they are tracked to the animal grouping for the year in question.	on the concentrate level of the diet (i.e., an EF of 4% for diets ≥ 85% concentrates and an EF of 6.5% for < 85% if fat content of the diet is below 4% dry matter); and • The right gross energy (GE) content of the diets is being used depending on the fat level of the diets (i.e., 19.10 MJ per kg of DM fed if between 4 and 6%, or 18.5 MJ per kg of DM fed if less than 4%). Further, if the fat content of the diet is in the 4 to 6 % range, the right enteric emission factor (EF) is being used according to the concentrate level of the diet (i.e. ≥ to 85% concentrates uses 3.2% EF while < 85% uses 5.8%).
Dry Matter Intake	• Date stamped feedlot records, or third party managed data, that document the average daily dry matter intake by animal grouping in the project including: o Records showing kilograms of feed delivered to each animal grouping in the project for each diet/diet grouping. o Records/procedures showing the dry matter conversion of wet feed to dry; and o If feedlot records only (i.e., no third party managed data), and sign-off by a	Average Daily Dry Matter Intake is derived using animal*head days records by: • Dry Matter Intake (kg / head / day) = (Total quantity of feed for a specific diet x dry matter content of diet) / animal head*days.

Data Requirement	Minimum Records Needed	Rationale
	P.Ag. or DVM who reviewed and collected supporting farm records that confirm the daily dry matter intake for each animal grouping in the baseline and project.	
Manure Management		
Manure Managed According to the *Agriculture Operation Practices Act*	• Feedlot documentation to show that a permit from the Natural Resource Conservation Board is in place and no major changes in manure management have occurred since the baseline period (for those operations built or expanded after 2002), including: o Manure Handling Plans or Nutrient Management Plans and record keeping systems for those operations that exceed the land base requirements; o Manure storage and collection areas; and o Application guidelines. or o Sign-off by a P.Ag. who collected and reviewed supporting farm records that confirm the manure management conforms to *Agriculture Operation Practices Act* requirements and that no major changes in manure management have occurred since the baseline period.	Needed to demonstrate that no major changes in how manure is managed have occurred since the baseline period. Major changes include: • switching storage types • instituting a composting system; or • installing an anaerobic digester. The intent is to verify that a permit is in place and is current and no major changes in manure handling have occurred. A major change is a signal to contact Alberta's Climate Change Office for clarification on how to proceed.
Legal Claim to the Offsets		
Location of the Feedlot Operation(s)	• Legal land description for the land parcel(s) upon which the feedlot(s) are located.	For registration and serialization of greenhouse gas reductions when the project is registered on the Alberta Emissions Offset Registry
Animals Existed at the Feedlot for the Project Years	Feedlot records that demonstrate animals are entering and exiting the feedlot for each individual animal by radio-frequency identification (RFID) tag. If the feedlot operator is a corporation, the seal of the corporation needs to be affixed to the	To prove that the animals being fed in the project were at the feedlot in question and being finished for market.

Data Requirement	Minimum Records Needed	Rationale
	documentation.	

Table 9 provides clarity on the responsibilities of each party involved in collecting and maintaining data for a project.

Table 9: Responsibilities for Data Collection and Record Retention

Entity	Data Collection and Record Retention Responsibilities
Feedlot Operator	The feedlot operator has primary responsibility for record keeping and record coordination to support project implementation and due diligence, and will be the primary information source for third party verification if they are the sole project developer; or If a feedlot operator is part of a larger project (see below), the feedlot operator must provide copies of farm records and documentation to the project developer. In either case, feedlot operators must retain original records for their files.
Project Developer (if different than the above)	The project developer has primary responsibility for record keeping and record coordination to support project implementation and due diligence, and will be the primary information source for third party verification. The project developer is required to collect and manage copies of the feedlot records and supporting documentation outlined in Table 9 above.
Professional Agrologist/DVM	The professional agrologist/DVM can provide a third party opinion on a project, based on project records. Records must be collected and maintained consistent with this protocol, and support his/her professional opinion of the farm management practices.

5.3 Record Keeping

Alberta's Climate Change Office requires that project developers maintain appropriate supporting information for their projects, including all raw data for a period of seven years after offsets are used for compliance. If the project developer is different than the person implementing the activity, as in the case of an aggregated project, the feedlot operators and the project developer must maintain records (see Table 9) to support the offset project. The project developer and/or the feedlot operators must keep the information listed below and disclose all information to the third party verifier and/or government auditor upon request. For more information on data management and record keeping, see Technical Guidance for Offset Project Developers[22].

Record keeping requirements include:

- Records, as listed in Table 8, for all applicable years in which offset credits are being claimed;
- A record of all adjustments made to the project data with justifications;
- A list of equipment included and any changes that occurred during the project's crediting period;
- Common practices relating to possible greenhouse gas reduction scenarios discussed in this protocol (feedlot management practices);

[22] Alberta Environment and Parks 2013. Technical Guidance for Offset Project Developers.

- All calculations applying to the greenhouse gas assertion and emission factors listed in this protocol; and
- Initial and annual verification records and audit results.

In order to support the third party verification and a potential supplemental government audit, the project developer must put in place a system that meets the following criteria:

- All records must be kept in areas that are easily located;
- All records must be legible, dated and revised as needed;
- All records must be maintained in an orderly manner;
- All documents must be retained for seven years after offsets are used for compliance;
- Project developers must maintain electronic records while feedlot operators must maintain original records, which may include hardcopy records; and
- Copies of records should be stored in two locations to prevent loss of data.

Attestations will not be considered as evidence that an activity took place and will not meet verification requirements.

5.4 Quality Assurance / Quality Control Considerations

Project developers are required to ensure sufficient and appropriate quality assurance/quality control (QA/QC) procedures are developed to support project implementation. Principles applied by verifiers and auditors are described in Technical Guidance for Offset Project Developers[23]. QA/QC can also be applied to add confidence that all measurements and calculations have been made correctly and include outlining the process related to data management and record keeping for offset credits including:

- Data process flow charts for each feedlot operation describing: data collection systems and input systems for animal grouping close-out data; production performance databases; ration/nutrient tracking and animal identifier tag systems; and validation points in the data flow (data oversight, second party checks, supervisor sign-off);
- Data process flow charts for the overall project describing how data collected from each feedlot are being inputted to the data management systems, with same data flow and controls as in above;
- Restriction of user access to offset claim calculations and data;
- Filtering procedures on production, performance, and close-out data for animal groupings; descriptions of techniques used to scrub the raw data to remove erroneous values/outliers;
- Ensuring that changes to operational procedures (including manure management, etc.) continue to function as planned and achieve greenhouse gas reductions;
- Ensuring that the measurement and calculation system and greenhouse gas reduction reporting remain in place and accurate;
- Applying any statistical sampling procedures as per the protocol, with a description of the procedure to ensure the protocol's guidance is met;
- Checking the validity of all data before the data are processed, including emission factors, static factors and acquired data;
- Exception reports for identification of duplicate records, incorrect emission factors, or records with values outside of expected ranges;
- Performing recalculations of quantification procedures to reduce the possibility of mathematical errors;
- Storing the data in its raw form so it can be retrieved for verification;
- Protecting records of data and documentation by keeping both a hard and soft copy of all documents;

[23] Ibid.

- Recording and explaining any adjustment made to raw data in associated reports and files;
- A contingency plan for potential data loss; and
- Management review and approval of agreements, records, completeness of feedlot activity information, consistency with underlying data as well as linkage between base data and claims.

5.5 Liability

Offset projects must be implemented according to a government-approved protocol and in accordance with government regulations. Alberta's Climate Change Office reserves the right to audit offset credits and associated projects registered in the Alberta Emission Offset Registry and may require corrections based on audit findings.

5.6 Registration and Claim to Offsets

Emission reductions associated with reducing days on feed/increasing feed conversion in beef cattle occur specifically at feedlot operations. This is where the majority of the data for documenting the activities takes place. There must be clear, legal claim of the greenhouse gas reductions achieved from the project in order to have the offsets verified and registered. Emission reductions are tracked through the Alberta Emissions Offset Registry. The registry relates the reduction to a specific land location.

Projects developers must ensure the parcel used to create the reduction (i.e., where the animal is finished or achieves an acceptable marketable weight prior to harvest) is the actual parcel of land registered in the spatial locator template. Emission reductions cannot be consolidated to the parcel where the business entity is legally located.

Figure 5: Example of One Feedlot, Two Registry Parcels

The owner of the offset credits under this protocol is the feedlot operator, where the animals in the project spend the final stage prior to harvest. As indicated in Table 11, feedlot operators can be a project developer if they have enough animals to be economically viable in the carbon market, or they can be aggregated under a project developer in order to bring offset credits to market.

The project developer/feedlot operator needs to ensure that they can justify the claim to the offsets to the satisfaction of the third party verifier. For purposes of verification, this includes the ability to provide feeding agreements for the animals in the project to substantiate the project developer fed the cattle in question.

6.0 References

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International Organization for Standardization 2006. ISO 14064-2: Specification with guidance at the project level for quantification, monitoring and reporting of greenhouse gas emission reductions or removal enhancements.

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The combinations of strategies utilized in this case study are the following:

- Feeding a beta-agonist (e.g., Optaflexx) in the last 28 days before slaughter. The feeding of beta-agonists during the last 28 to 42 days before slaughter has been shown to improve average daily gain and gain to feed ratio by 20 per cent, final slaughter weight by 1.2 to 2.1 per cent, carcass weight by 1.9 to 2.8 per cent and dressing percentage by 0.5 per cent with no effect on dry matter intake. Therefore, feeding ractopamine hydrochloride (RAC) to youthful beef cattle, in this case under 24 months of age, 28 days prior to slaughter has been documented to increase hot carcass weight and ribeye area and decrease fat deposition in cattle sent to market.
- Yearling-fed steers were on implant regimen, consisting of implants of 200 mg progesterone and 20 mg estradiol benzoate (Component E-S, Elanco-Animal Health) at weaning, and re-implanted with 120 mg trenbolone acetate and 24 mg estradiol (Component TE-S, Elanco-Animal Health) approximately 90 to 100 days before slaughter.
- Animals in the feedyard were sorted and fed according to individual performance curves, monitored three times and rations adjusted for maximum performance gain before final pen assignments.

Baseline Condition:

British x Continental crossbred steers entered the feedlot averaging 317.5 kg (700 lbs) in body weight. They were adjusted to a high barley grain diet during the adjustment period. Steers entered the final finishing period weighing 345.5 kg and were fed a diet consisting of 84.2 per cent barley, 10.5 per cent barley silage, 3.60 per cent feedlot supplement and 1.60 per cent molasses (on a dry matter basis, 13.10 per cent crude protein, 80.0 per cent total digestible nutrients and a level of concentrates ≥ 85.0 per cent) for the remainder of the finishing period. Steers consumed 10.0 kg dry matter/head/day (dry matter intake) until they were harvested at 612.5 kg live slaughter weight or 355.3 kg hot carcass weight.

The baseline group of 15,000 animals took, on average, 145 days to achieve market weight. Animals gained 295.0 kg while in the feedlot or gained 171.1 kg of hot carcass weight.

Project Condition:

The same feeding regimes as the baseline was applied to the project condition and the strategies above were employed. Steers averaging 317.5 kg (700 lbs) consumed 10.5 kg DM/head/day. Final live slaughter weights were 641.5 kg or 372.1kg of hot carcass weight.

The project group of 25,000 animals took, on average, 145 days to finish similar to the baseline animals. The animals gained 324.0 kg while in the feedlot, or gained 187.9 kg of hot carcass weight on average.

The following case study applies flexibility mechanism number 3 where it is assumed the entire time the animals are in the feedyard they are on a diet of greater than or equal to 85.0 per cent concentrates as listed above. Hot carcass weights in this study translated into 58.0 per cent of the live animal weight at slaughter. The quantification in Table A1 shows the application of the functional equivalence calculation (i.e. dividing emissions by average kilogram of hot carcass weight gained in the feedlot) throughout each step. This can also be applied at the end of the calculations as shown in Section 4.4 of this protocol.

Table 10: Case Study Emission Reduction Calculations for 700 lb Yearling Steers

Cattle Enteric Emissions = (Number Production*DOF * $DDMI_i$ * GE Diet * (EF $Enteric_i$ / 100%) / EC Methane)/ (Number Production* Average Gain in Carcass Weight of Cattle)	
DOF (Days on Feed)	An average of 145 days in both the baseline and the project
Concentrates	86% in both baseline and project
DDMI (Dry Matter Intake)	An average of 10 kg DM / head / day in the baseline and 10.5 kg DM / head / day in the project
GE Diet (Gross Energy Content of Diet)	Default factor of 18.5 MJ per kg of dry matter fed to each head
EF Enteric (Enteric Emissions Factor)	4% (default based on level of concentrates)
EC Methane (Methane Energy Content)	Default factor of 55.65 MJ per kg of methane
Average Carcass Weight Gained While in the Feedlot	Baseline – 171.1 kg Project – 187.9 kg
Enteric Emissions $_{BASELINE}$ = (((15,000 head)(145 days)*(10.0 kg DDMI/hd/day) * (18.45 MJ/kg DM diet) * (4/100))/(55.65 MJ/kg CH_4))/(15,000 head*171.1 kg hot carcass weight gain per head) = 0.1/12 kg CH_4 per kg of hot carcass weight* [24]	
Enteric Emissions $_{PROJECT}$ = (((25,000 head)(145 days)*(10.5 kg DDMI/hd/day) * (18.45 MJ/kg DM diet) * (4/100))/(55.65 MJ/kg CH4))/ (25,000 head*187.9 kg hot carcass weight gain per head) = 0.1/07 kg CH_4 per kg of hot carcass weight*	
*Daily Volatile Solids Excreted in cattle manure = VSi = ($DDMI_i$ * GE_{Diet} * (1 – (TDN_i / 100%)) + (UE * $DDMI_i$ * GE_{Diet}) * ((1 – (ASH / 100%)) / GE_{Diet})*	
TDN_i (Total Digestible Nutrients)	80% in the baseline and project
UE (Urinary Energy)	Default factor of 0.02 for both baseline and project diets as the level of concentrates is equal to or greater than 85%
ASH	Default factor of 2% as this is a grain based diet
Volatile Solids $_{BASELINE}$ = [(10 kg DM/day x 18.45 MJ/kg DM of diet x (1-(80/100))) + (0.02 x 10 kg DM/day x 18.45 MJ/kg DM of diet)] x ((1-(2/100))/18.45 MJ/kg DM of diet) = 2/.16 kg/hd/day	
Volatile Solids $_{PROJECT}$ = [(10.5 kg DM/day x 18.45 MJ/kg DM of diet x (1-(80/100))) + (0.02 x 10.5 kg DM/day x 18.45 MJ/kg DM of diet)] x ((1-(2/100))/18.45 MJ/kg DM of diet) = 2/.26 kg/hd/day	
Cattle Manure Handling, Storage, and Application Methane Emissions = (Number in ProductionDOF_i * VS_i * Bo * ρ Methane * (MCF / 100%))/ (Number Production* Average Gain in Carcass Weight of Cattle)*	
Bo (Methane Producing Capacity)	Constant factor of 0.19 m3 CH4/kg VS excreted
ρMethane (Conversion Factor for Density of	Constant of 0.67 kg/m3

[24] The line in the intermediary results is used to show where the significant digits end. Two insignificant figures should be carried in intermediary calculations to avoid rounding error.

Methane)	
MCF (Methane Conversion Factor)	This factor is specific to each manure management system and is set at 1.0% for pasture, range and/or paddock systems and at 2.0% for solid storage systems (this example has a solid storage system)
Manure CH_4 $_{BASELINE}$ = ((15,000 head)(145 days)*(2.16 kg volatile solids excreted/hd/day)*(0.19 m^3 CH_4/kg VS)*(0.67 m^3/kg)*(2/100))/ (15,000 head*171.1 kg hot carcass weight gain per head) = 0.00466 kg CH_4 per kg of hot carcass weight*	
Manure CH_4 $_{PROJECT}$ = ((25,000 head)(145 days)*(2.26 kg volatile solids excreted/hd/day)*(0.19 m^3 CH_4/kg VS)*(0.67 m^3/kg)*(2/100))/ (25,000 head*187.9 kg hot carcass weight gain per head) = 0.00444 kg CH_4 per kg of hot carcass weight*	
*Daily Nitrogen Excreted in Manure = NE_{Xi} = $DDMI_i$ * (CP_i / 100%) / $CF_{protein}$ * (1 – NR)*	
CP (Crude Protein)	13.1% in both the baseline and the project
$CF_{Protein}$ (Protein Conversion Factor)	Default of 6.25 kg of protein per kg of dietary nitrogen
NR (Nitrogen Retention)	Default of 0.07 kg N retained/kg N consumed
Daily Nitrogen Excreted $_{BASELINE}$ = 10.0 kg DM/day x ((13.1/100)/6.25 kg feed protein /kg N)) x (1-0.07 kg N retained/kg N consumed) = 0.195 kg N excreted/hd/day	
Daily Nitrogen Excreted $_{PROJECT}$ = 10.5 kg DM/day x ((13.1/100)/6.25 kg feed protein /kg N)) x (1-0.07 kg N retained/kg N consumed) = 0.205 kg N excreted/hd/day	
Manure N_20_{direct} = [Number in ProductionDOF_i * NE_{Xi} * CF_{manure} * (44 / 28)] / Number Production* Average Gain in Carcass Weight of Cattle*	
CF (Conversion Factor)	Default of 0.02 kg N_2O-N per kilogram of nitrogen excreted
44/28 (Conversion Factor)	Default factor 44/28 to convert $(N_2O\text{-}N)_{(mm)}$ emissions to $N_2O_{(mm)}$emissions
Manure $N_20_{direct\ BASELINE}$ = ((15,000 head)(145 days)*(0.195 kg N excreted/hd/day)*(0.02 kg N_2O-N/kg N excreted)*(44/28))/ (15,000 head*171.1 kg hot carcass weight gain per head) = 0.00519 kg N_2O per kg of hot carcass weight*	
Manure $N_20_{direct\ PROJECT}$ = ((25,000 head)(145 days)*(0.205 kg N excreted/hd/day)*(0.02 kg N_2O-N/kg N excreted)*(44/28))/ (25,000 head*187.9 kg hot carcass weight gain per head) = 0.00497 kg N_2O per kg of hot carcass weight*	
Manure $N_20_{direct\ storage}$ = ((Number in Production)(DOF_i)*(NE_{Xi})*($Frac_{Storage}$)*(EF Storage)* (44 / 28)) / (Number Production* Average Gain in Carcass Weight of Cattle)*	
$Frac_{Storage}$	Default of 0.6
EF (Storage Emissions Factor)	Default of 0.007 kg N_2O-N/kg nitrogen excreted
Manure $N_20_{direct\ storage\ BASELINE}$ = ((15,000 head)(145 days)*(0.195 kg N/hd/day)*(0.6)*(0.007 kg N_2O-N/kg nitrogen excreted)*(44/28)) / (15,000 head*171.1 kg hot carcass weight gain per head) = 0.00109 kg N_2O*	

per kg of hot carcass weight	
Manure $N_20_{direct\ storage\ PROJECT}$ = ((25,000 head)(145 days)*(0.2/05 kg N/hd/day)*(0.6)*(0.007 kg N_2O-N/kg nitrogen excreted)*(44/28))/ (25,000 head*187.9 kg hot carcass weight gain per head) = 0.001/04 kg N_2O per kg of hot carcass weight*	
Manure $N_20_{indirect\ volatilization}$ = ((Number in Production)(DOF_i)*(NE_{Xi})* ($Frac_{Volatilization)}$*($EF_{Volatilization}$)*(44/ 28)) / (Number Production* Average Gain in Carcass Weight of Cattle)*	
$Frac_{Volatilization}$	Default of 0.42 kg N_2O-N/kg nitrogen excreted
$EF_{Volatilization}$ (Volatilization Emissions Factor)	Default of 0.01 kg N_2O-N/kg nitrogen excreted
Manure $N_20_{indirect\ volatilization\ BASELINE}$ =((15,000 head)(145 days)*(0.1/95 kg N/hd/day)*(0.42 kg N_20-N/kg nitrogen excreted)*(0.01 kg N_2O-N/kg nitrogen excreted)*(44/28)) / (15,000 head*171.1 kg hot carcass weight gain per head) = 0.001/09 kg N_2O per kg of hot carcass weight*	
Manure $N_20_{indirect\ volatilization\ PROJECT}$ =((25,000 head)(145days)*(0.2/05 kg N/hd/day)*(0.42 kg N_20-N/kg nitrogen excreted)*(0.01 kg N_2O-N/kg nitrogen excreted)*(44/28)) / (25,000 head*187.9 kg hot carcass weight gain per head)= 0.001/04 kg N_2O per kg of hot carcass weight*	
Manure $N_20_{indirect\ leaching}$ = ((Number in Production) (DOF_i)*(NE_{Xi})* ($Frac_{Leach}$)*(EF Leaching)*(44 / 28)) / (Number Production* Average Gain in Carcass Weight of Cattle)*	
$Frac_{Leach}$	Default of 0.1 kg N_2O-N/kg nitrogen excreted
EF (Leach Emissions Factor)	Default of 0.025 kg N_2O-N/kg nitrogen excreted
Manure $N_20_{indirect\ leaching\ BASELINE}$ = ((15,000 head)(145 days)*(0.1/95 kg N/hd/day)*(0.1)*(0.025 kg N_2O-N/kg nitrogen excreted)*(44/28)) / (15,000 head*171.1 kg hot carcass weight gain per head) = 0.0006/49 kg N_2O per kg of hot carcass weight*	
Manure $N_20_{indirect\ leaching\ PROJECT}$ = ((25,000 head)(145 days)*(0.2/05 kg N/hd/day)*(0.1)*(0.025 kg N_2O-N/kg nitrogen excreted)*(44/28)) / (25,000 head*187.9 kg hot carcass weight gain per head) = 0.0006/21 kg N_2O per kg of hot carcass weight*	

Table 11: Calculating emissions reductions from the project

Total Hot Carcass Weight Gained in Baseline = 2,566,483 kg

Total Hot Carcass Weight Gained in Project = 4,698,011 kg

Factor	Total CH_4 Emissions Intensity (kg CH_4/kg Hot Carcass weight gain)	Total N_2O Emissions Intensity (kg N_2O/ kg Hot Carcass weight gain)	Total CO_2e Methane Emissions Intensity (kg CO_2e/kg Hot Carcass Wt gain)	Total CO_2e Nitrous Oxide Emissions Intensity (kg CO_2e/kg Hot Carcass Wt gain)
Baseline	0.117	0.00802	2.93	2.39
Project	0.111	0.00767	2.78	2.29
Total Emissions Intensity Reduction (kg CO_2e/kg Carcass Weight)			0.25[25]	
Total Credits (t CO_2e)			1,174	

[25] In this protocol, rounding to significant digits in intermediate calculations should not be done. All intermediary calculation steps should carry 3 significant digits to avoid round-off error. Then the final intensity reduction must be rounded to 1 significant digit since this is the number of significant digits justified by the calculation inputs.

APPENDIX B: Cattle Inventories and Data Collection

Transparent and accurate data are needed to support project implementation and facilitate third party verification of the emission reductions. How animals are tracked is critical to this protocol and must be consistent between the baseline and project conditions. If the protocol developer is using weight class or some other criterion, they must ensure that the classes are clearly defined (i.e.: group 1 = x kg to x kg) in both the baseline and project conditions. Any deaths that occur as cattle progress or if animals are removed from a weight grouping due to sickness must be accounted for in the animal head*day calculations.

The data points to be collected for cattle inventory under the project and baseline conditions include:

- the number of head of cattle within each animal grouping (or individually);
- the average weight of cattle entering the animal grouping (or individually);
- the average weight of cattle exiting the animal grouping (or individually);
- the average weight in kilograms of dry matter feed per day provided to each group (for the entire grouping); and
- the average number of days the group of cattle are fed a specific diet.

Cattle inventory data must be derived by using a matrix commonly applied by feedlot operators and referred to as animal head*days. Many feedlots use this approach to calculate their yardage where animal head*days is a basic unit used to account for the number of days cattle were on feed in a specific animal grouping, calculated as the sum of the number of days each animal spent on a specific diet as it moved through the feedlot pens for that animal grouping. This is demonstrated in Table B1.

Table 12: Using Animal Head* days to Track Cattle Inventory Data for a Given Lot on a Given Diet

Days on Feed	Number of Head	Head Days	DDMI (kg)
1	100	100	1000
2	105	210	2100
3	102	306	3060
4	106	424	4240
5	106	530	5300
6	106	636	6360
7	106	742	7420
8	115	920	9200
9	120	1080	10800
10	125	1250	12500
11	125	1375	13750
12	125	1500	15000
13	124	1612	16120
14	120	1680	16800
Total: 14	**Average: 113**	**Animal Head* days=1585**	**Total : 15850**

Project developers can record this table in pounds (lbs) or imperial measurements, so long as the calculation steps consistently use imperial measures throughout. Final results, however, must be converted to metric.

An animal head*days factor is used to extrapolate a number of cattle inventory data points including:

- Days on Feed: can be extrapolated from animal head*days if the average number of animals in a pen/lot under a specific diet and the animal head*days are known;
- Average Days on Feed (days) = average date out – average date in;
    - Referencing Table B1 above, days on feed would be extrapolated by taking the quotient of 1,585 animal head*days / 113 animals, with a result of 14 days on feed;
- Average Number in Production (head) = animal head*days / days on feed;
    - Referencing Table B1 above, Number in Production for Diet 1 would be extrapolated by taking the quotient of 1,585 animal head*days / 14 days, with a result of 113 animals;
- Daily Dry Matter Intake: the amount of feed provided to a pen/lot of animals under a particular diet expressed as kilograms of feed per animal per day is extrapolated from animal head*days if the total quantity of feed diets provided to a grouping of animals over the feeding periods is known. Feed is provided to cattle on an as-fed basis and must be converted to a dry matter basis. This is accomplished by multiplying the feed intake by the dry matter content of the total mixed diet. The dry matter content of the diet can be obtained from a feed analysis of the total mixed diet or from a diet-balancing program used by the feedlot; and
- Average Daily Dry Matter Intake (kg / head / day) = (total quantity of feed for a specific diet x dry matter content of diet) / animal head*days.