QUANTIFICATION PROTOCOL FOR REDUCING DAYS ON FEED FOR BEEF CATTLE

Version 2.0 **July 2011**

Specified Gas Emitters Regulation

Government of Alberta

Alberta

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The information provided in this document is intended as guidance only and is subject to revisions as learnings and new information comes forward as part of a commitment to continuous improvement. This document is not a substitute for the law. Please consult the *Specified Gas Emitters Regulation* and the legislation for all purposes of interpreting and applying the law. In the event that there is a difference between this document and the *Specified Gas Emitters Regulation* or legislation, the *Specified Gas Emitters Regulation* or the legislation prevail.

All Quantification Protocols approved under the *Specified Gas Emitters Regulation* are subject to periodic review as deemed necessary by the Department, and will be re-examined at a minimum of every 5 years from the original publication date to ensure methodologies and science continue to reflect best-available knowledge and best practices. This 5-year review will not impact the credit duration stream of projects that have been initiated under previous versions of the protocol. Any updates to protocols occurring as a result of the 5-year and/or other reviews will apply at the end of the first credit duration period for applicable project extensions.

Any comments, questions, or suggestions regarding the content of this document may be directed to:

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SUMMARY OF CHANGES

Below is a summary of key changes from version 1.1 to version 2.0 of this protocol. All changes apply as of the date of release of version 2.0.

- This protocol has been adapted to the new Alberta Environment quantification protocol format.
- 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 in section 4.0 and section 5.
- 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 Alberta Environment 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 (see section 5.5).
- 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 (see section 5.4).

1.0 Offset Project Description

Agricultural activities, including the production of livestock, result in greenhouse gas emissions to the atmosphere. Beef cattle, in particular, release methane (CH_4) as a result of the digestion of feed materials in the rumen. These emissions are called enteric emissions and are a significant contributor to greenhouse gas emissions from agricultural activities. Other emission sources for cattle include methane and nitrous oxide (N_2O) emissions are generated from manure storage and handling within beef cattle operations.

This protocol for reducing the number of days on feed for beef cattle addresses both digestion and manure storage and handling emission sources for livestock greenhouse gas emissions. It allows users to quantify greenhouse gas reductions using scientifically valid equations and emission factors resulting from a reduction in the number of days required to complete the finishing stage of beef cattle in a feedlot resulting in a decrease in both enteric and manure emissions.

1.1 Protocol Scope

Industry experts and agricultural scientists have developed, through the Intergovernmental Panel on Climate Change (IPCC 2006) and Canada's National Emissions Inventory (NIR 2009), Tier 2 accounting procedures for enteric and manure emissions generated by different cattle classes in Canada. This science forms the basis for the quantification methodologies used in this protocol.

The scope of this protocol includes a number of innovative feeding practices and feed additives that can be implemented to reduce the number of days beef cattle are on a finishing diet. Emissions reductions are compared using a functionally equivalent unit of emissions reductions per kilogram live cattle weight.

This protocol does not prescribe any one technique or combination of techniques needed to reduce the days on feed of cattle because it is recognized that different techniques will be used by different feedlot operators and several techniques may be used at once and may very over time. In all cases, the project developer (feedlot operator) must demonstrate through feedlot documentation and records that cattle in the project condition are finishing sooner than the baseline condition. The protocol outlines the necessary measurement and monitoring parameters needed to quantify resulting emission reductions.

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

The baseline condition defines what was happening before the change in practice and must represent normal business operations for the feedlot. The project condition defines the actions taken at the feedlot to reduce the number of days needed for an animal to reach market weight and must meet the requirements of this protocol.

Baseline Condition for Reducing Days on Feed of Beef Cattle:
The baseline condition for the reduced days on feed protocol is the feeding regime and time period required to complete a finishing diet regimen before implementing changes in the feedlot that reduce the number of days on feed required to bring cattle to market.

This protocol uses a **static historic approach to determine the baseline.** This means that the 3-year average baseline emissions, once determined, 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 Days on Feed of Beef Cattle:
The project condition is the implementation of a revised feeding regime that results in a reduction in the number of days cattle are on finishing diets before being sent to harvest. The project activities are new feeding practices and/or feed additives that increase the feed conversion efficiency of cattle during the later stages of finishing. These practices must be new to the feedlot operations and must demonstrate a reduction in the number of days in the feedlot while maintaining or improving feed efficiency, carcass weight and lean meat yield. Examples (Basarab et al., 2009) include:

- electron acceptors that compete for hydrogen (e.g.: fumarate, malate, oxaloacetic, beta hydroxybutyric acid, propyonic acid, and butynoic acid);
- 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 marker panels that reduce days on feed and/or to improve feed efficiency (e.g., leptin genetic marker).

There may be other strategies like phenotypic selection for animals with higher feed use efficiency or increasing concentrates in the diet sooner than under the baseline conditions. These other techniques can be included where there is sufficient information to support the project condition.

More information on project emissions quantification is available in section 3.0.

Table 1: Relevant Greenhouse Gases Applicable for Reducing Days on Feed for Beef Cattle

Specified Gas	Formula	100-year GWP	Applicable to Project
Carbon Dioxide	CO_2	1	N
Methane	CH_4	21	Y
Nitrous Oxide	N_2O	310	Y
Sulphur Hexafluoride	SF_6	23,900	N
Perfluorocarbons*	PFCs	Variable	N
Hydrofluorocarbons*	HFCs	Variable	N

* A complete list of perfluorocarbons and hydrofluorocarbons regulated under the *Specified Gas Emitters Regulation* is available in Technical Guidance for Offset Project Developers.

1.2 Protocol Applicability

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

1. Diets fed to animals in the baseline and project can be demonstrated to show a reduction in the number of days animals are on a finishing diet regimen. Sufficient records and project level documentation for the content and quantity of feed per animal grouping is necessary in order to quantify enteric and manure emissions;

2. Animal grouping criteria must be shown to be similar between the baseline and project based on feeding practices and diets under both baseline and project conditions,

3. Manure must be managed according to the *Agricultural Operation Practices Act* requirements for confined feeding operations.

4. Sampling of baseline and project 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 is based on actual measurement and monitoring as indicated by the proper application of this protocol; and,

6. The project meets the eligibility criteria stated in section 7.0 of the *Specified Gas Emitters Regulation.* In order to qualify, emissions 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, appropriate, 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 2 below. Additional details are provided in sections 4.0 and 5.0.

Table 2: General Overview of Data Requirements to Justify the Baseline and Project Condition

Data Requirements:	**What is needed:**	**Why it is needed:**
Animal identifier tag	CCIA, 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 animals per pen.	Documented feedlot records of: • animal pen entry and exit records that show average weights of the group in and out, • date of entry (by production system, quality grid program, sex, breed or custom feeding lots records) for both the baseline and project condition; and • the average number of animals in each pen.	The methods used to define an animal grouping (ie: sex, age, weight, breed, etc.) must be similar between project and baseline to ensure like groupings are compared for the offset calculations.
Documented proof of: • what was being fed to the cattle per animal grouping/pen in the feedlot; • days on feed for each diet; and • diet composition	Records include: • feed purchase receipts or scale tickets, weights, etc. • delivery records for a pen; • diet formulations signed off by a Doctor of Veterinarian Medicine or Professional Agrologist indentifying the diet including any additive and edible oil content in the diet; • proof from internal record keeping systems or third party files (such as Feedlot Health Management or ComputerAid or others). This must include dry matter content, kilograms of feed per day delivered to each pen, total digestible nutrients, crude protein content, number of days on the diets, and level of concentrate in the diet.	To support calculations of the offset claim and for third party verification. Note, a verifier will need evidence of diets and total mixed diets fed to cattle groupings for the baseline and project condition.
Incoming and outgoing average weight of each grouping of animals being fed	Documented feedlot records of: • animal pen entry and exit records that show average weights of the group in and out, • date of entry (by production	To determine average daily gain as a check for the verifier to determine if the diet is stated correctly.

	system, quality grid program, sex, breed or custom feeding lots records) for both the baseline and project condition; and the average number of animals in each pen.	
Legal land location of the feedlot operation and feeding agreements for the animals in the project	• Legal land description for the registration of the project; • Proof that the animals fed in the project were under control of the feedlot operator in question (see section 5.5)	Registration of the project on the Alberta Emissions Offset Registry.

This protocol is only applicable to emission reductions generated through the implementation of innovate feeding regimes to reduce the number of days beef cattle are on feed in confined feeding operations (feedlots). Other emission reduction opportunities may be applicable to feedlot operations in Alberta. These opportunities are summarized in Table 3 below.

Table 3: Stackable Emission Project Opportunities for Cattle Producers

Activity:	**Protocol:**
Incorporation of Edible Oils in Beef Cattle Finishing Diets	Quantification Protocol for Including Edible Oils in Cattle Feeding Regimes
Use of anaerobic digesters in handling cattle manure waste at feedlots.	Quantification Protocol for the Anaerobic Decomposition of Agricultural Materials
Selecting for Low Residual Feed Intake in Beef Cattle	Quantification Protocol for Residual Feed Intake Markers in Beef Cattle

1.3 Protocol Flexibility

1. Where the required data for this protocol vary across groups of animals (ie: weight class, age, sex, breed, diets) in a feedlot, the animals can be grouped in discreet units and tracked individually rather than in groupings of similar animals as discussed in the protocol. It is important to note that exercising this flexibility option will require data tracking each individual head of cattle through its specific feeding regimes at the feedlot.

2. Greenhouse gas reductions are calculated on a ‘kilogram of live weight’ unit of production. Emission reductions may be calculated based on dressing percentages (kilograms of carcass weight) as long as the same unit is applied to the baseline and project conditions and the data can be substantiated (i.e. packing plant receipts).

1.4 Glossary of New Terms

Animal groupings	Specific groupings of cattle in the feedlot, as they move through to the finishing stage. They are typically based on production system (calf-fed, yearling-fed, gender - heifer, steers, bulls - weight and marketing program (e.g., Lean's Lean, natural, grass finished). Note: there can be many pens within a feedlot containing the same animal grouping[1].
Animal head days	A basic unit used to account for the number of days animals were on feed in a specific animal grouping and is the sum of the number of days each individual animal spends on a specific feeding diet. The reason for the unit is for tracking animals as they move in and out of feedlot pens for that animal grouping.
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 hide, head, tail, forelegs, internal organs, digestive complex and 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). This can include grains and protein supplements, but excludes feedstuffs like hay or silage or other roughage.
Diet	Is feed ingredients or mixture of ingredients, including water, which is consumed by animals (Ensminger and Olentine (1980). It includes the amount of and composition for feed supplied to an animal for a defined period of time.
Custom feeding lot records	The records kept on a group of cattle by the feedlot for cattle owned by someone other than the feedlot.

[1] The range of incoming weight should be no more than 45.4 kg (100 lb) 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 lb) and 635.0 kg (1400 lb) may be an animal grouping for part of a specific project. However, another part of the project or even a different project site 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). Groupings of cattle will typically have a series of rations, for a specified number of days on feed called *feeding periods* in this protocol

Edible oils[2]:	Are oils derived from plants that are composed primarily of triglycerides. Although many different parts of plants may yield oil, in commercial practice oil is extracted primarily from the seeds of oilseed plants. Whole seeds can be applied as a feed ingredient so long as the oil content is calculated on a dry matter basis to achieve the 4 to 6 per cent content in the diet.
Enteric emissions	Emissions of methane (CH_4) from the cattle as part of the digestion of the feed materials.
Feeding cycle	The combination of diets fed to animals over a set period of time. This is then repeated for a similar grouping of animals.
Feeding periods	Groupings of cattle will typically have a series of diets for a specified number of days on feed; this is termed *feeding periods* in this protocol.
Feeding regimes	The whole system of diets fed to animals over the baseline/project period.
Land application	Is defined as 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) that the cattle processor is willing to pay a premium for or give a discount.
Yardage	Yardage is 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.

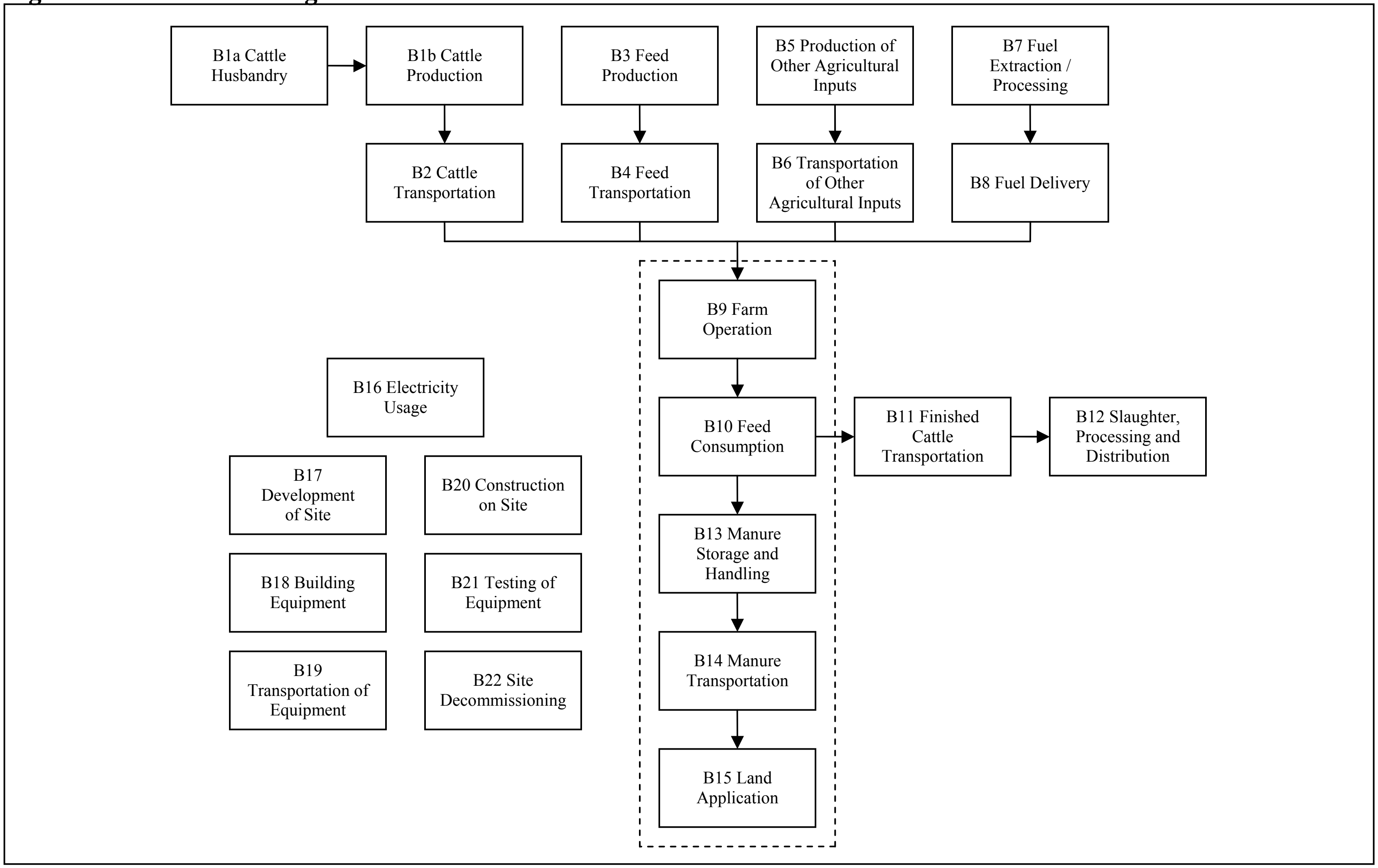
[2] Note there are other edible oil-containing products such as unstabilized rice bran, or walnut oils, extracted oil form Dried Distillers Grains, or even beef tallow where available. The onus is on the project developer to work with their nutritional specialist to ensure the ration formulation fits the requirements of this protocol.

2.0 Baseline Condition

The protocol uses a **static historic benchmark** baseline condition. Under this scenario, a baseline greenhouse gas emissions intensity per kg of live weight (kg CO2e per kg live weight) is quantified for each animal grouping and averaged over a period of 3 years prior to any changes in feeding regimes. This protocol allows the project developer to maintain a static baseline over the project life that is representative of the baseline practices for their operations recognizing that baseline emissions will vary as a function of the number of animals included under the project condition. Information on establishing a statistically representative baseline is included in Appendix B.

Sources and sinks were identified for the project by reviewing the seed documents and relevant process flow diagram developed by the Beef Technical Working Group under the federal-provincial-territorial initiative called the National Offset Quantification Team and work completed during the Alberta protocol review process. This process confirmed that the sources and sinks in the process flow diagrams covered the full scope of eligible baseline activities under the protocol (Figure 1).

Figure 1: Process Flow Diagram for the Baseline Condition



2.1 Identification of Baseline Sources and Sinks

Sources and sinks for an activity are assessed based on Guidance provided by Environment Canada and are classified as follows:

Controlled:	The behavior or operation of a controlled source and/or sink is under the direction and influence of a Project Developer through financial, policy, management, or other instruments.
Related:	A related source and/or sink 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:	An affected source and/or sink is influenced by the project activity through changes in market demand or supply for projects 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/or sinks in the process flow diagrams covered the full scope of eligible project activities under the protocol.

Based on the process flow diagram provided above, the baseline sources and/or sink were organized into life cycle categories in Figure 2. Descriptions of each of the sources/sinks and their classification as controlled, related or affected are provided in Table 4.

Figure 2: Baseline Condition Sources and Sinks for Reducing the Days on Feed for Beef Cattle

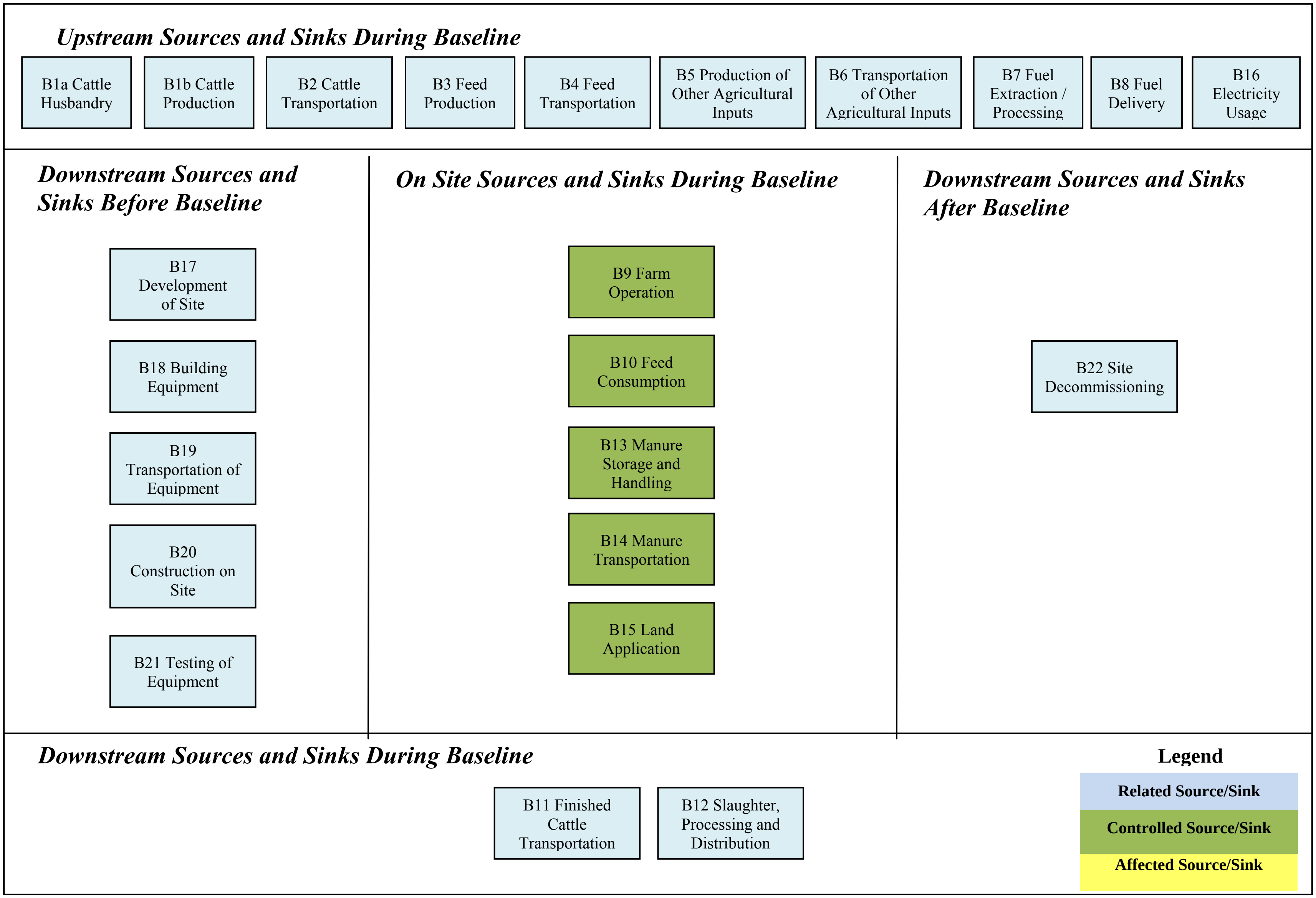


Table 4: Baseline Condition Sources and Sinks		
1. Source/Sink	**2. Description**	**3. Controlled, Related or Affected**
Upstream Sources and Sinks During Baseline Operation		
B1a Cattle Husbandry	Cattle husbandry may include insemination and all other practices prior to the birth of the calf. Quantities 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 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
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 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
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 the 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	Related

Table 4: Baseline Condition Sources and Sinks

1. Source/Sink	2. Description	3. Controlled, Related or Affected
	fuels are the important characteristics to be tracked.	
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 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
B16 Electricity Usage	Electricity may be required for operating the facility. This power may be sourced either 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
Onsite 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 to 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 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 tracked to evaluate functional equivalence with the project condition.	Controlled
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 the manure land application systems may need to be tracked..	Controlled
Downstream Sources and Sinks During Baseline Operation		

Table 4: Baseline Condition Sources and Sinks		
1. Source/Sink	**2. Description**	**3. Controlled, Related or Affected**
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 purposes 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 operations. 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 civil infrastructure such as access to electricity, gas and water supply, as well as sewer etc. This 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 fossil fuels and electricity 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-site or off-site. This includes all of 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 equipment to the site.	Related
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 emission 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 runs properly. These activities will result in greenhouse gas emissions associated with the combustion of fossil fuels and the use of electricity.	Related

Table 4: Baseline Condition Sources and Sinks		
1. Source/Sink	**2. Description**	**3. Controlled, Related or Affected**
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

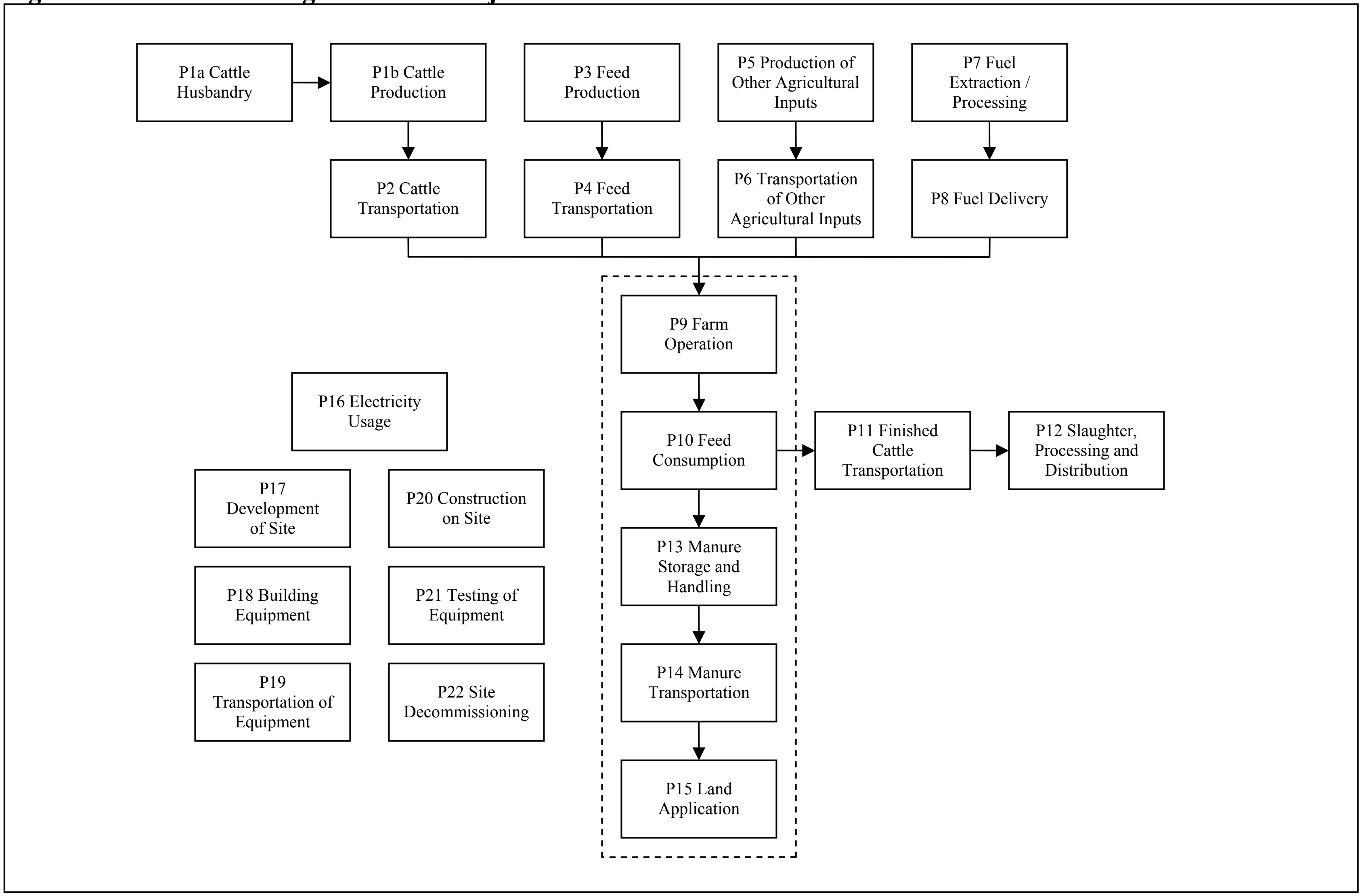
The project condition is defined by incorporating innovative feeding practices in the finishing diets of beef cattle to reduce the number of days required to bring beef cattle to market weight. Innovative feeding practices are not prescribed in this protocol, but can include feed additives, revised diets, and new feeding technologies which improve feed conversion efficiencies.

Although enteric emission are produced from cattle during the project condition, the reduction in the number of days required to bring cattle to market weight results in a lower quantity of greenhouse gases being emitted in the finishing stages of beef production.

Further, fewer days on feed translates to a reduction in manure produced including volatile solids and nitrogen excreted by the animals. This reduction in manure contributes to a reduction in greenhouse gas emissions under the project when compared to the baseline condition

Project 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. The process flow diagram for the project condition is given in Figure 3.

Figure 3: Process Flow Diagram for the Project Condition



3.1 Identification of Project Sources and Sinks

Sources and sinks for reducing days on feed of beef cattle were identified based on a scientific review. This process confirmed that sources and sinks in the process flow diagram covered the full scope of eligible project activities under this protocol. The boundary for the project condition 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. These sources and sinks were further classified as controlled, related, or affected as described in Table 5 below.

The approach to quantifying emissions in the project does not differ from the baseline. That is, animal diets, animal grouping characteristics, and days on feed are all factors that must be documented in order to justify the project condition.

Figure 4: Project Condition Sources and Sinks for Reducing Days on Feed for Beef Cattle

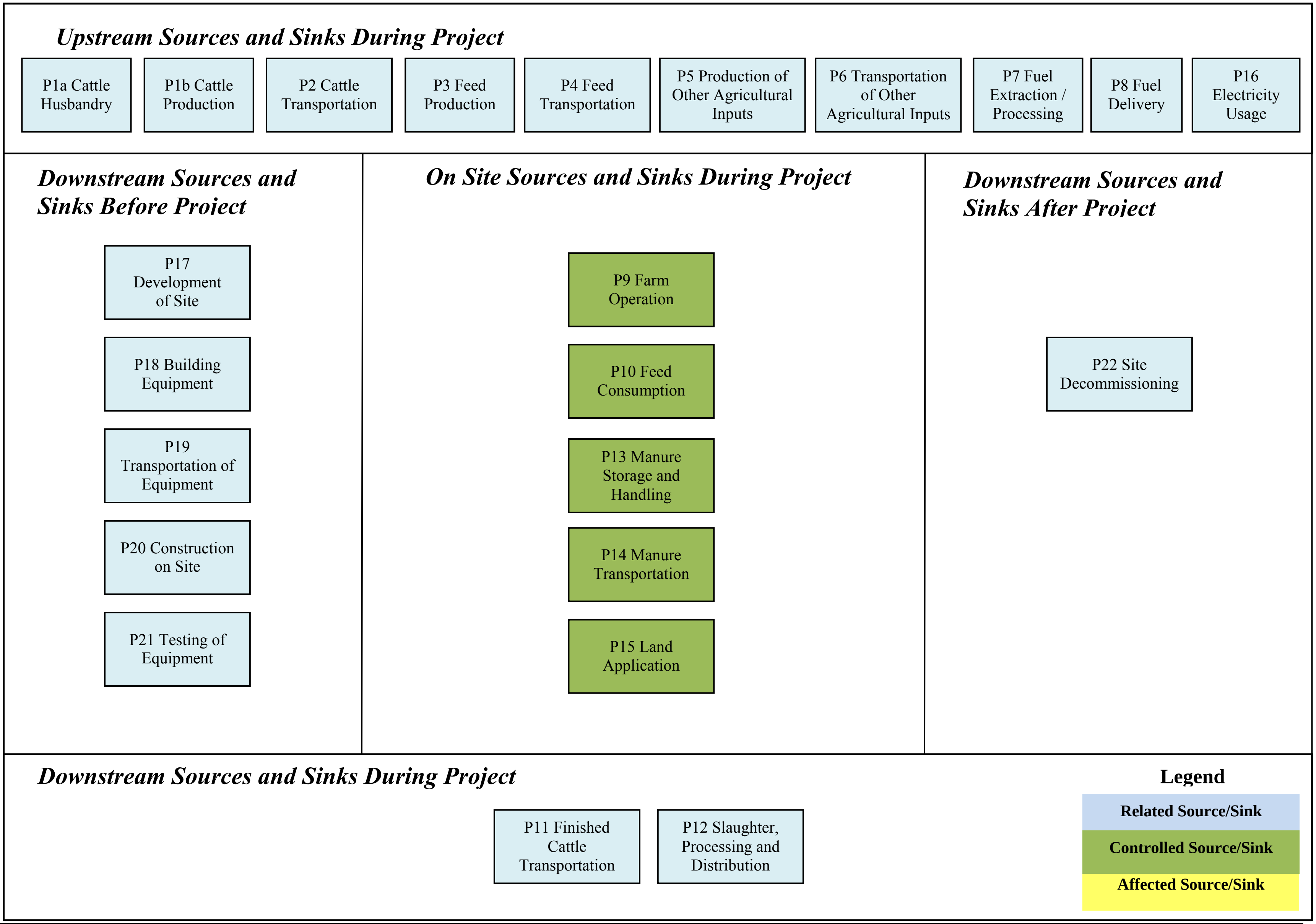


Table 5: Project Condition Sources and Sinks		
1. Sources and Sinks	**2. Description**	**3. Controlled, Related or Affected**
Upstream Sources and Sinks During Project Operation		
P1a Cattle Husbandry	Cattle husbandry may include insemination and all other practices prior to the birth of the calf. Quantities 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. This requires 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. This requires 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 volumes of fuel for each of the on-site sources/sinks are considered under this source/sink. Volumes and types of	Related

Table 5: Project Condition Sources and Sinks

1. Sources and Sinks	2. Description	3. Controlled, Related or Affected
	fuels are the important characteristics to be tracked.	
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 Usage	Electricity may be required for operating the facility. This power may be sourced either 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
Onsite 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 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
P10 Feed Consumption	Feed consumption includes the enteric emissions from the cattle and related manure production. The feed composition would need to be tracked to 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	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 the manure land application systems may need to be tracked.	Controlled

Table 5: Project Condition Sources and Sinks

1. Sources and Sinks	2. Description	3. Controlled, Related or Affected
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 SS, for the purposes 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 operations. 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 civil infrastructure such as access to electricity, gas and water supply, as well as sewer etc. This 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 fossil fuels and electricity 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 of 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 emission from the use of fossil fuels and electricity.	Related

Table 5: Project Condition Sources and Sinks		
1. Sources and Sinks	**2. Description**	**3. Controlled, Related or Affected**
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 runs 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

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

Emissions that increase or decrease as a result of the project must be included and associated greenhouse gas emissions must be quantified as part of the project condition.

All sources and sinks identified in Table 4 and Table 5 above are listed in Table 6 below. Each source and sink is listed as included or excluded. Justification for these choices is provided.

Table 6: Comparison of Sources and Sinks

1. Identified Source/Sink	2. Baseline (A, C, R)*	3. Project (A, C, R)*	4. Include or Exclude from Quantification	5. 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 are 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	

Table 6: Comparison of Sources and Sinks				
1. Identified Source/Sink	**2. Baseline (A, C, R)***	**3. Project (A, C, R)***	**4. Include or Exclude from Quantification**	**5. Justification**
P16 Electricity Usage	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 Usage	R	N/A	Exclude	
Onsite 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 as 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 from the baseline to project are materially different.
B10 Feed Consumption	C	N/A	**Include**	
P13 Manure Storage and Handling	N/A	C	**Include**	Included because emissions from the baseline to project 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 scenario.
B14 Manure Transportation	C	N/A	Exclude	
P15 Land Application	N/A	C	**Include**	Included because emissions from the baseline to project 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 scenario.
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 scenario.
B12 Slaughter, Processing and Distribution	R	N/A	Exclude	
Other Sources/Sinks				
P17 Development of Site	N/A	R	Exclude	Emissions from site development are not material given the long project

Table 6: Comparison of Sources and Sinks				
1. Identified Source/Sink	**2. Baseline (A, C, R)***	**3. Project (A, C, R)***	**4. Include or Exclude from Quantification**	**5. Justification**
				life, and the minimal site development typically required.
B17 Development of Site	R	N/A	Exclude	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	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	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	Emissions from construction on site are not material given the long project life, and the minimal construction on site typically required.
B20 Construction on Site	R	N/A	Exclude	
P21 Testing of Equipment	N/A	R	Exclude	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	Emissions from decommissioning are not material given the long project life, and the minimal decommissioning typically required.
B22 Site Decommissioning	R	N/A	Exclude	

*Where C is Controlled, R is Related, and A is Affected.

4.1 Quantification Methodology

Quantification of the reductions, removals and reversals of relevant sources/sinks for each of the greenhouse gases will be completed using the methodologies outlined in Table 9 below. These calculation methodologies serve to complete the following three equations for calculating the emission reductions from the comparison of the baseline and project conditions.

$$\textbf{Emission Reduction} = \textbf{Emissions}_{\textbf{Baseline}} - \textbf{Emissions}_{\textbf{Project}}$$

$$\text{Emissions}_{\text{Baseline}} = \text{Emissions}_{\text{Cattle}} + \text{Emissions}_{\text{Manure}}$$

$$\text{Emissions}_{\text{Project}} = \text{Emissions}_{\text{Cattle}} + \text{Emissions}_{\text{Manure}}$$

Where:

$\text{Emissions}_{\text{Baseline}}$ = sum of the emissions under the baseline condition.
$\text{Emissions}_{\text{Cattle}}$ = emissions under B10 Feed Consumption
$\text{Emissions}_{\text{Manure}}$ = emissions under B13 Manure Storage and Handling and B15 Land Application

$\text{Emissions}_{\text{Project}}$ = sum of the emissions under the project condition.
$\text{Emissions}_{\text{Cattle}}$ = emissions under P10 Feed Consumption
$\text{Emissions}_{\text{Manure}}$ = emissions under P13 Manure Storage and Handling and P15 Land Application

4.2 Standardized Quantification Approach

Quantification of emission reductions of relevant sources and sinks for each of the greenhouse gases will be completed using methodologies outlined in Table 8. These calculation methodologies serve to complete the following equations for calculating the emission reductions from a comparison of 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 please see Appendix C: sample case study calculations.

Equation 1: Calculating Enteric Methane Emissions

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

Equation 2: Calculating Daily Volatile Solids Excreted in Manure

$$\mathbf{VS_i\ (kg\ volatile\ solids/animal/day) =}$$
$$[(DMI_i * GE_{Diet} * (1 - (TDN_i / 100\%)) + (UE * DMI_i * GE_{Diet})] * (1 - (ASH / 100\%) / GE_{Diet})$$

Equation 3: Calculating Manure Methane Emissions for the Project (Handling, Storage, and Application)

$$\mathbf{Manure\ CH_4\ (kg\ CH_4) =}$$
$$\Sigma\ [Number\ Production_i * DOF_i * VS_i * Bo * \rho_{Methane} * (MCF / 100\%)]$$

Equation 4: Calculating Daily Nitrogen Excreted in Manure

$$\mathbf{NE_i\ (kg\ nitrogen\ excreted/animal/day)} = [DMI_i * (CP_i / 100\%) / CF_{protein} * (1 - NR)]$$

Equation 5: Calculating Direct Nitrous Oxide (N_2O) Emissions from Manure

$$\mathbf{Manure\ N_20_{direct}\ (kg\ N_20) =}$$
$$\Sigma\ (Number\ Production_I * DOF_i * NE_i * CF_{manure} * (44 / 28))$$

Decomposition

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

$$\mathbf{Manure\ N_20_{direct\ storage}\ (kg\ N_20) =}$$
$$\Sigma\ (Number\ Production_i * DOF_i * NE_i * MS_\alpha * EF\ Storage) * 44 / 28$$

Storage

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

$$\mathbf{Manure\ N_20_{indirect\ volatilization}\ (kg\ N_20) =}$$
$$\Sigma\ (Number\ Production_i * DOF_i * NE_i * MS_\beta * EF\ Volatilization) * 44 / 28$$

Equation 8: Calculating Indirect Nitrous Oxide (N_2O) Emissions from Manure N in the Soil Profile

$$\mathbf{Manure\ N_20_{indirect\ profile}\ (kg\ N_20) =}$$
$$\Sigma\ (Number\ Production_i * DOF_i * NE_i * MS_\gamma * EF\ Leaching) * 44 / 28$$

Where

Number $Production_i$	This is the number of head in each animal grouping/pen and can be estimated using the animal head.days factor.
DOF (Days on Feed)	This is the number of days that the animal grouping is being a being fed a specific diet. This can be estimated using the animal head.days factor.
DMI (Dry Matter Intake)	The dry matter intake is calculated in CALC Step 1, by dividing the total kg DM delivered to the pen for the days on that diet, divided by the animal head days for that diet.
GE Diet (Gross Energy Content of Diet)	This is 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 concentration is between 4.0 and 6.0 per cent. • Use 18.5 MJ per kg of dry matter fed to each head if the edible oil/fat concentration is less than 4 per cent.
EF Enteric (Enteric Emissions Factor)	A default factor, depending on level of concentrates in the diet and edible oil/fat content: • Use 3.2 per cent for diets with ≥ 85 per cent concentrates and edible oils/fats as per above; and, • Use 5.2 per cent for diets with less than 85 per cent concentrates and edible oils/fats as per above.
EC Methane (Methane Energy Content)	This is a default factor of 55.65 MJ per kg of methane.

Calculating Daily Volatile Solids Excreted by Cattle – for use in Manure Methane Calculations

VS (Volatile Solids)	This is the calculated daily volatile solid excreted for each head of cattle for each of the feeding periods in each grouping of animals.
TDN_i (Total Digestible Nutrients)	The total digestible nutrients for the diet provided to each grouping of cattle must be recorded 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 85 per cent concentrates.
ASH	This is a default factor extracted from international guidance and is 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.

Calculating Cattle Manure Handling, Storage, and Application Emissions.

Manure CH_4 (Manure Methane)	This is the sum of methane emissions from manure handling, storage and land application for each cattle grouping within Baseline and is expressed as kg CH_4 per head.
Bo (Methane Producing Capacity)	Bo is the maximum methane producing capacity for manure and is a constant of 0.19 m^3 CH_4/kg VS excreted.
$\rho_{Methane}$ (Density of Methane)	Use the density of methane at normal temperature (20°C) and pressure (1 Atm) which is 0.67 m^3/kg
MCF (Methane Conversion Factor)	This factor is specific for each manure management system and is set at 1.0% for pasture, range, and/or paddock systems or 2.0% for solid storage systems. Two percent would apply in this protocol.

Calculating Nitrogen Excreted in Cattle Manure –for use in calculating N_20 Emissions.

NE (Nitrogen Excreted)	The nitrogen excreted by each head in each specific weight grouping of animals is expressed at kg of Nitrogen per head per day. This is the factor used in calculating direct and indirect nitrous oxide emissions.
CP (Crude Protein)	The crude protein content of the diet fed to each grouping of cows is required and is expressed as a percentage (%).
$CF_{protein}$ (Protein Conversion Factor)	This is 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.
NR (Nitrogen Retention)	This is the fraction of N intake that is retained by each animal grouping and is 0.07 kg N retained/kg N consumed.

Calculating Direct Nitrous Oxide (N_2O) emissions from Manure Decomposition.

Manure $N_20_{direct\ storage}$	This is the sum of direct emissions of nitrous oxide from manure storage for each grouping of cattle and is expressed as kg N_2O per head of cattle.
CF (Conversion Factor)	Use 0.02 kg N_2O-N per kilogram of nitrogen excreted.
44/28 (Conversion Factor)	Use the quotient of 44 divided by 28 to convert $(N_2O\text{-}N)_{(mm)}$ emissions to $N_2O_{(mm)}$emissions.

Calculating direct nitrous oxide (N_2O) emissions from manure storage.

Manure $N_20_{direct\ storage}$	This represents the sum of direct emissions of nitrous oxide from manure storage for each grouping of cattle and is expressed as kg N_2O per head of cattle.
MS_α (Management System)	This represents the fraction of total nitrogen excreted for each cattle group that is managed in a particular manure management system and is set at 0.8.
EF (Storage Emissions Factor)	This emission factor is related to the direct N_2O emissions from manure management system and is set at 0.007 kg N_2O -N/kg nitrogen excreted.

Calculating indirect emissions from manure volatilization.

Manure $N_20_{indirect\ volatization}$	This represents the sum of indirect emissions of nitrous oxide from manure volatilization for each grouping of cattle and is expressed as kg N_2O per head of cattle.
MS_β (Management System)	This emission factor is related to the direct N_2O emissions from manure management system and is set at 0.2 kg N_2O -N/kg nitrogen excreted.
EF (Storage Emissions Factor)	This emission factor is related to the percent of managed manure nitrogen for each cattle group that volatilizes as NH_3 and NO_x in the manure management system and is set at 0.01 kg N_2O -N/kg nitrogen excreted.

Calculating indirect nitrous oxide (N2O) emissions from manure N in the Soil Profile.

Manure $N_20_{indirect\ volatization}$	This represents the sum of indirect emissions of nitrous oxide for each grouping of cattle and is expressed as kg N_2O per head of cattle.
MS_γ (Management System)	This emission factor is related to the direct N_2O emissions from manure management system and is set at 0.1 kg N_2O -N/kg nitrogen excreted.
EF (Storage Emissions Factor)	This emission factor is related to the percent of managed manure nitrogen for each cattle group due to runoff and soil profile N during solid and liquid storage of manure and is set at 0.0125 kg N_2O -N/kg nitrogen excreted.

4.3 Cattle Inventories and Data Collection

The protocol allows cattle inventories to be collected in 2 ways: tracking distinct groupings of animals daily, based on the general animal/weight class they belong to, or by tracking each animal individually.

Transparent and accurate data is needed to support project implementation and facilitate third party verification of the emission reductions. How animals are tracked is critical for to this protocol and must be consistent between the baseline and project conditions. If the protocol developer is using weight groupings or some other criteria, they must ensure that the groupings are clearly defined (i.e.: Class 1 = x kg to x kg) in both the baseline and project. 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 (see below).

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

Cattle inventory data can 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 the sum of the product of the number of days an individual animal is on a particular feeding regime. This is demonstrated in Table 7 below:

Table 7: Using Animal Head.Days to Track Cattle Inventory Data

Pen		Days on Feed	No. of Head	Head.days	DMI (kg)*
A	Diet 1	1	119	119	1190
A		2	126	126	1260
A		3	126	126	1260
A		4	125	125	1250
A		5	125	125	1250
A		6	124	124	1250
A		7	124	124	1240
A		8	124	124	1240
A		9	124	124	1240
A		10	124	124	1240
A		11	124	124	1240
A		12	124	124	1240
A		13	124	124	1240
A		14	124	124	1240
Total		**14**	**124**	**1,736**	**17,380**

*Note-this table could be recorded in pounds (lbs) or imperial measurements, so long as the calculation steps are consistent with the imperial metrics throughout, and converted to metric at the end.

An animal head.days factor can be used to extrapolate a number of cattle inventory data points including:

a) **Days on feed**: can be extrapolated from animal head.days if the average number of animals in a pen under a specific diet and the animal head.days is known.

Days on Feed (days) = animal head.days / average number of animals in production

Referencing Table 7 above, days on feed would be extrapolated by taking the quotient of 1,736 animal head.days / 124 animals, with a result of 14 days on feed.

b) **Number in production**: can be extrapolated from animal head.days if the days on feed (feeding periods) are known.

Number in Production (head) = animal head.days / days on feed

Referencing Table 7 above, Number in Production for diet 1 would be extrapolated by taking the quotient of 1,736 animal head.days / 14 days, with a result of 124 animals.

c) **Dry matter intake**: the amount of feed provided to a pen of animals under a particular diet regimen expressed as kilograms of feed per animal per day can be extrapolated from animal head.days if the total quantity of feed diets provided to a grouping of animals over the feeding periods are 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, from a feed analysis of the total mixed diet, or from a diet-balancing program used by the feedlot.

Dry Matter Intake (kg / head / day) = (Total quantity of feed for a specific diet x dry matter content of diet) / animal head.days

Statistical Sampling Approach Allowed under this Protocol

Appendix B describes a statistical sampling method that can be used to support project development. Biological traits in beef cattle lend themselves well to sampling approaches because they typically follow a normal distribution curve. To sample the feedlot or feedlots for a statistically valid sample, the feedlot has to be sufficiently large to support the method and the sampling method within the animal groupings needs to follow random selection procedures to prevent bias. The sampling method used must be documented and will be reviewed by the third party verifier.

Sampling a subset of pens in the feedlot for greenhouse gas estimation involves taking measurements of the desired data in a number of pens. The average values of the data when all the pens are combined are then representative of the larger population. The confidence interval becomes the range within which the actual greenhouse gas reductions will occur. This protocol requires a confidence interval of 95 per cent. If the interval is small, then the estimation is more precise.

Table 8: Quantification Methodology

1.0 Project/ Baseline Sources/Sinks	2. Parameter / Variable	3. Unit	4. Measured / Estimated	5. Method	6. Frequency	7. Justify measurement or estimation and frequency
Baseline Sources and Sinks						
B10 Feed Consumption	$Emissions_{Cattle} = \Sigma (Number_{Production\ i} * DOF * DMI_{i} * GE_{Diet} * (EF_{Enteric\ i} / 100\%) / EC_{Methane})$					
	Enteric Emissions from Cattle for each feeding regime within each animal grouping / $Emissions_{Cattle}$	kg CH_4 / day / per animal grouping	N/A	N/A	N/A	Quantity being calculated.
	Number of Cattle in Grouping i / $Number_{Production\ i}$	Head	Measured	Direct measurement of number of head sent to slaughter within each grouping of animals. This value can also be extrapolated from animal head.days if the days on feed (otherwise termed feeding periods) are known. Number in Production (head) = animal head.days/days on feed	Continuous	Direct measurement is the highest level possible.

Table 8: Quantification Methodology						
1.0 Project/ Baseline Sources/Sinks	**2. Parameter / Variable**	**3. Unit**	**4. Measured / Estimated**	**5. Method**	**6. Frequency**	**7. Justify measurement or estimation and frequency**
	Days on Feed for Each Feeding Regime for Cattle in Grouping i / DOF_i	Days	Estimated	Average for cattle in specific animal grouping over the three years prior to the implementation of the project. This value can be extrapolated from animal head.days if the average number of animals in a pen under a specific diet and the animal head.days is known. Days on Feed (days) = animal head.days/average number of animals in production.	Annual	Based on feedlot records.
	Dry Matter Intake for Each Feeding Regime for Cattle in Grouping i / DMI_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 under a particular diet regimen, expressed as kilograms of feed per animal per day can be extrapolated from animal head.days if the total quantity of feed diets provided to a grouping of animals over the feeding periods are known. 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).

Table 8: Quantification Methodology

1.0 Project/ Baseline Sources/Sinks	2. Parameter / Variable	3. Unit	4. Measured / Estimated	5. Method	6. Frequency	7. Justify measurement or estimation and frequency
	Emission Factor for Enteric Emissions for Each Feeding Regime in Grouping i / $EF_{Enteric\ i}$	%	Estimated	3.2% for diets with greater than or equal to 85% concentrates including edible oils in the range of 4 to 6%. 5.2% for diets with less than 85% concentrates including edible oils in the range of 4 to 6%.	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	$VS_i = [(DMI_i * GE_{Diet} * (1 – (TDN_i / 100\%))) + (UE * DMI_I * GE_{Diet})] * ((1 – (Ash / 100\%)) / GE_{Diet})$					
	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.
	Dry Matter Intake for Each Feeding Regime for Cattle in Grouping i / DMI_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	$18.45\ MJ / kg_{dry\ matter}$	Annual	Conversion factor taken from IPCC, 2006 guidance (Section 10.4.2).

Table 8: Quantification Methodology

1.0 Project/ Baseline Sources/Sinks	2. Parameter / Variable	3. Unit	4. Measured / Estimated	5. Method	6. Frequency	7. Justify measurement or estimation and frequency
	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	-	Estimated	0.04 for diets with less than 85 % concentrates. 0.02 for diets with greater than 85 % 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	2 %	Annual	Set based on best available science and in reference to the IPCC, 2006 guidance.
	$Emissions_{Manure\ CH4} = \Sigma\Sigma\ (Number_{Production\ i} * DOF_i * VS_i * Bo * \rho_{Methane} * (MCF / 100\%))$					
	Methane Emissions from Manure Storage and Handling for each feeding regime within each animal grouping / $Emissions_{Manure\ CH4}$	kg CH_4 / day / per animal grouping	N/A	N/A	N/A	Quantity being calculated.

Table 8: Quantification Methodology

1.0 Project/ Baseline Sources/Sinks	2. Parameter / Variable	3. Unit	4. Measured / Estimated	5. Method	6. Frequency	7. Justify measurement or estimation and frequency
	Number of Cattle in Grouping i / $Number_{Production\ i}$	Head	Measured	Direct measurement of number of head sent to slaughter within each grouping of animals.	Continuous	Direct measurement is the highest level possible.
	Days on Feed for Each Feeding Regime for Cattle in Grouping i / DOF_i	Days	Estimated	Average for cattle in weight grouping over the three years prior to the implementation of the project.	Annual	Based on feedlot records.
	Maximum Methane Producing Capacity for Manure Produced / Bo	m^3_{CH4} / $kg_{VS\ Excreted}$	Estimated	0.19 m^3_{CH4} / $kg_{VS\ Excreted}$	Annual	Conversion factor taken from IPCC, 2006 guidance (Table 10A-5).
	Density of Methane / $\rho_{Methane}$	m^3 / kg	Estimated	0.67 m^3 / kg	Annual	Physical property of methane at standard temperature and pressure.
	Methane Conversion Factor / MCF	%	Estimated	1.6 %	Annual	Set based on best available science and in reference to the IPCC, 2006 guidance.
	$Nitrogen_{Excreted\ i} = DMI_i * (CP_i / 100\%) / CF_{Protein} * (1 – Nitrogen_{Retention})$					
	Nitrogen Excreted by the Livestock in Grouping i / $Nitrogen_{Excreted\ i}$	kg / head / day	N/A	N/A	N/A	Quantity being calculated.

Table 8: Quantification Methodology

1.0 Project/ Baseline Sources/Sinks	2. Parameter / Variable	3. Unit	4. Measured / Estimated	5. Method	6. Frequency	7. Justify measurement or estimation and frequency
	Dry Matter Intake for Each Feeding Regime for Cattle in Grouping i / DMI_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 under a particular diet regimen, expressed as kilograms of feed per animal per day can be extrapolated from animal head.days if the total quantity of feed diets provided to a grouping of animals over the feeding periods are known. 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.
	Conversion from Mass of Dietary Protein to Mass of Dietary Nitrogen	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 $_{retained}$ / kg $_{intake}$	Estimated	0.07 kg $_{retained}$ / kg $_{intake}$	Annual	Factor taken from IPCC, 2006 guidance (Table 10.20).

Table 8: Quantification Methodology

1.0 Project/ Baseline Sources/Sinks	2. Parameter / Variable	3. Unit	4. Measured / Estimated	5. Method	6. Frequency	7. Justify measurement or estimation and frequency
Project Sources and Sinks						
P10 Feed Consumption	$Emissions_{Cattle} = \Sigma (Number_{Production\ i} * DOF_i * DMI_i * GE_{Diet} * (EF_{Enteric\ i} / 100\%) / EC_{Methane})$					
	Enteric Emissions from Cattle for each feeding regime within each weight grouping / $Emissions_{Cattle}$	kg CH_4 / day / per animal grouping	N/A	N/A	N/A	Quantity being calculated.
	Number of Cattle in Grouping i / $Number_{Production\ i}$	Head	Measured	Direct measurement of number of head sent to slaughter within each grouping of animals. This value can also be extrapolated from animal head.days if the days on feed (otherwise termed feeding periods) are known. Number in Production (heads) = 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 for the project year. This value can be extrapolated from animal head.days if the average number of animals in a pen under a specific diet and the animal head.days is known. Days on Feed (days) = animal head.days/average number of animals in production.	Continuous	Direct measurement is the highest level possible.

Table 8: Quantification Methodology						
1.0 Project/ Baseline Sources/Sinks	**2. Parameter / Variable**	**3. Unit**	**4. Measured / Estimated**	**5. Method**	**6. Frequency**	**7. Justify measurement or estimation and frequency**
	Dry Matter Intake for Each Feeding Regime for Cattle in Grouping i / DMI_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 under a particular diet regimen, expressed as kilograms of feed per animal per day can be extrapolated from animal head.days if the total quantity of feed diets provided to a grouping of animals over the feeding periods are known. 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	18.45 MJ / $kg_{dry\ matter}$	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	4.0 % for diets with greater than or equal to 85 % concentrates. 6.5 % 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	$VS_i = [(DMI_i * GE_{Diet} * (1 – (TDN_i / 100\%))) + (UE * DMI_I * GE_{Diet})] * ((1 – (Ash / 100\%)) / GE_{Diet})$					

Table 8: Quantification Methodology						
1.0 Project/ Baseline Sources/Sinks	**2. Parameter / Variable**	**3. Unit**	**4. Measured / Estimated**	**5. Method**	**6. Frequency**	**7. Justify measurement or estimation and frequency**
Storage and P15 Land Application	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.
	Dry Matter Intake for Each Feeding Regime for Cattle in Grouping i / DMI_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 under a particular diet regimen, expressed as kilograms of feed per animal per day can be extrapolated from animal head.days if the total quantity of feed diets provided to a grouping of animals over the feeding periods are known. 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	18.45 MJ / $kg_{dry\ matter}$	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.

Table 8: Quantification Methodology

1.0 Project/ Baseline Sources/Sinks	2. Parameter / Variable	3. Unit	4. Measured / Estimated	5. Method	6. Frequency	7. Justify measurement or estimation and frequency
	Urinary Energy / UE	-	Estimated	0.04 for diets with less than 85 % concentrates. 0.02 for diets with greater than 85 % 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	2 %	Annual	Set based on best available science and in reference to the IPCC, 2006 guidance.
	$Emissions_{Manure\ CH4} = \Sigma (Number_{Production\ i} * DOF_i * VS_i * Bo * \rho_{Methane} * (MCF / 100\%))$					
	Methane Emissions from Manure Handling, Storage and Land Application for each feeding regime within each animal grouping / $Emissions_{Manure\ CH4}$	kg CH_4 / day / per animal grouping	N/A	N/A	N/A	Quantity being calculated.
	Number of Cattle in Grouping i / $Number_{Production\ i}$	Head	Measured	Direct measurement of number of head sent to slaughter within each grouping of animals.	Continuous	Direct measurement is the highest level possible.

Table 8: Quantification Methodology

1.0 Project/ Baseline Sources/Sinks	2. Parameter / Variable	3. Unit	4. Measured / Estimated	5. Method	6. Frequency	7. Justify measurement or estimation and frequency
	Days on Feed for Each Feeding Regime for Cattle in Grouping i / DOF_i	days	Measured	Direct measurement of days at the feed lot.	Continuous	Direct measurement is the highest level possible.
	Maximum Methane Producing Capacity for Manure Produced / Bo	m^3_{CH4} / $kg_{VS Excreted}$	Estimated	0.19 m^3_{CH4} / $kg_{VS Excreted}$	Annual	Conversion factor taken from IPCC, 2006 guidance (Table 10A-5).
	Density of Methane / $\rho_{Methane}$	m^3 / kg	Estimated	0.67 m^3 / kg	Annual	Physical property of methane at standard temperature and pressure.
	Methane Conversion Factor / MCF	%	Estimated	1.6 %	Annual	Set based on best available science and in reference to the IPCC, 2006 guidance.
	$Nitrogen_{Excreted\ i} = DMI_i * (CP_i / 100\%) / CF_{Protein} * (1 - Nitrogen_{Retention})$					
	Nitrogen Excreted by the Livestock in Grouping i / $Nitrogen_{Excreted\ i}$	kg / head / day	N/A	N/A	N/A	Quantity being calculated.

Table 8: Quantification Methodology

1.0 Project/ Baseline Sources/Sinks	2. Parameter / Variable	3. Unit	4. Measured / Estimated	5. Method	6. Frequency	7. Justify measurement or estimation and frequency
	Dry Matter Intake for Each Feeding Regime for Cattle in Grouping i / DMI_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 under a particular diet regimen, expressed as kilograms of feed per animal per day can be extrapolated from animal head.days if the total quantity of feed diets provided to a grouping of animals over the feeding periods are known. 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.
	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	$kg_{feed\ protein}$ / $kg_{nitrogen}$	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 / $Nitrogen_{Retention}$	$kg_{retained}$ / kg_{intake}	Estimated	0.07 $kg_{retained}$ / kg_{intake}	Annual	Factor taken from IPCC, 2006 guidance (Table 10.20).
	$Emissions_{Direct\ Nitrous\ Oxide} = \Sigma (Number_{Production\ i} * DOF_i * Nitrogen_{Excreted\ I} * CF_{Manure}) * 44 / 28$					

Table 8: Quantification Methodology

1.0 Project/ Baseline Sources/Sinks	2. Parameter / Variable	3. Unit	4. Measured / Estimated	5. Method	6. Frequency	7. Justify measurement or estimation and frequency
	Direct Emissions of Nitrous Oxide from Manure for each feeding regime within each animal grouping / $Emissions_{Direct\ Nitrous\ Oxide}$	kg N_2O / day / per animal grouping	N/A	N/A	N/A	Quantity being calculated.
	CF_{Manure}	-	Estimated	0.02 $kg_{N2O\text{-}N}$ / $kg_{Nitrogen\ Excreted}$	Annual	Set based on best available science and in reference to the IPCC.
	$Emissions_{Direct\ Storage} = \Sigma (Number_{Production\ i} * DOF_i * Nitrogen_{Excreted\ i} * Frac_{Storage} * EF_{Storage}) * 44 / 28$					
	Direct Emissions of Nitrous Oxide from Manure Storage / $Emissions_{Direct\ Storage}$	kg N_2O / day / per weight grouping	N/A	N/A	N/A	Quantity being calculated.
	$Frac_{Storage}$	-	Estimated	0.8	Annual	Set based on best available science and in reference to the IPCC
	$EF_{Storage}$	$kg_{N2O\text{-}N}$ / $kg_{Nitrogen\ Excreted}$	Estimated	0.007 $kg_{N2O\text{-}N}$ / $kg_{Nitrogen\ Excreted}$	Annual	Set based on best available science and in reference to the IPCC
	$Emissions_{Indirect\ Volatization} = \Sigma (Number_{Production\ i} * DOF_i * Nitrogen_{Excreted\ i} * Frac_{Volatization} * EF_{Volatization}) * 44 / 28$					

Table 8: Quantification Methodology						
1.0 Project/ Baseline Sources/Sinks	**2. Parameter / Variable**	**3. Unit**	**4. Measured / Estimated**	**5. Method**	**6. Frequency**	**7. Justify measurement or estimation and frequency**
	Indirect Emissions of Nitrous Oxide from Volatization for each feeding regime within each animal grouping / Emissions $_{Indirect\ Volatization}$	kg N_2O / day / per animal grouping	N/A	N/A	N/A	Quantity being calculated.
	Frac $_{Volatization}$	-	Estimated	0.2	Annual	Set based on best available science and in reference to the IPCC
	EF $_{Volatization}$	kg $_{N2O\text{-}N}$ / kg $_{Nitrogen\ Excreted}$	Estimated	0.01 kg $_{N2O\text{-}N}$ / kg $_{Nitrogen\ Excreted}$	Annual	Set based on best available science and in reference to the IPCC
	Emissions $_{Indirect\ Leaching}$ = Σ (Number $_{Production\ i}$ * DOF $_i$ * Nitrogen $_{Excreted\ i}$ * Frac $_{Leach}$ * EF $_{Leach}$) * 44 / 28					
	Indirect Emissions of Nitrous Oxide from Soil Profile Leaching for each feeding regime within each animal grouping / Emissions $_{Indirect\ Leach}$	kg N_2O / day / per animal grouping	N/A	N/A	N/A	Quantity being calculated.
	Frac $_{Leach}$	-	Estimated	0.1	Annual	Set based on best available science and in reference to the IPCC

Table 8: Quantification Methodology

1.0 Project/ Baseline Sources/Sinks	2. Parameter / Variable	3. Unit	4. Measured / Estimated	5. Method	6. Frequency	7. Justify measurement or estimation and frequency
	EF_{Leach}	$kg_{N2O\text{-}N}$ / $kg_{Nitrogen\ Excreted}$	Estimated	0.0125 $kg_{N2O\text{-}N}$ / $kg_{Nitrogen\ Excreted}$	Annual	Set based on best available science and in reference to the IPCC

4.4 Ensuring Functional Equivalence Between Baseline and Project

Emissions related to the baseline and project conditions must be calculated in a similar manner to account for enteric emissions and manure emissions.

Both sources of emissions (enteric and manure) must be expressed on the basis of carbon equivalence and must be functionally equivalent (emissions per kilogram live weight of cattle). This is determined by dividing the total emissions for each gas in baseline and project (summed for enteric and manure CH_4 and N_20) by the total number of animals in production and the average live weight of the animals as finishing is completed and they are determined ready for market.

Baseline CH_4 Emissions Intensity (kg CH_4 /kg live weight during the Baseline Condition) =
Σ [(CH_4 Emissions$_i$) / (Total Number in Production$_i$ * Average Live Weight of Cattle$_i$ sent to market (kg))]

Baseline N_20 Emissions Intensity (kg N_20 /kg live weight during the Baseline Condition) =
Σ [(N_20 Emissions$_i$) / (Total Number in Production$_i$ * Average Live Weight of Cattle$_i$ sent to market (kg))]

Project CH_4 Emissions Intensity (kg CH_4 /kg live weight during the Project Condition) =
Σ [(CH_4 Emissions$_i$) / (Total Number in Production$_i$ * Average Live Weight of Cattle$_i$ sent to market (kg))]

Project N_20 Emissions Intensity (kg N_20 /kg live weight during the Project Condition) =
Σ [(N_20 Emissions$_i$) / (Total Number in Production$_i$ * Average Live Weight of Cattle$_i$ sent to market (kg))]

The intensities for each of these gasses must be calculated and reported separately for the purposes of annual reporting requirements of emission reductions.

Sample calculations are provided in Appendix A.

5.0 Data Management

Data quality management must be of sufficient quality to support quantification requirements and must be substantiated by company records. Alberta Environment cannot accept offset credits for compliance purposes that are not supported by actual records.

The project developer shall establish and apply quality management procedures to manage data and information. Written procedures must be established for each measurement task outlining responsibility, timing and record location requirements. The greater the rigor of the management system, the more robust the overall project will be. This can help reduce the potential for errors and facilitate third party verification.

5.1 Project Documentation

A number of records and data points are required to justify a greenhouse gas emissions assertion for the purposes of verification and registration of reduced days on feed projects on the Alberta Emissions Offsets Registry.

To facilitate quantification and verification of emission reductions, cattle inventory data must be tracked for each specific pen within a feedlot. Feedlots must track number of head.days and the dry matter intake for each of the feeding periods and each pen/animal grouping in their close-out sheets to facilitate the calculations and justification for verification of an assertion of emission reductions.

Specifically, justification is required for the following data points involved in the project:

- Animal ID tag registered with the Canadian Cattle Identification Agency (CCIA) or a unique identifier with the ability to internally track the animal);
- Methods used to group cattle in the feedlot; must be similar for baseline and project;
- Method applied for statistical sampling of animal groupings in the feedlot(s);
- Records of entry and exit records for cattle in groupings;
- Records of the amount of feed fed to each grouping on a dry matter basis;
- Diet composition of the diets/total mixed diet including any additives fed to the cattle groupings;
- Records of the days on feed for each diet;
- Legal land location of the feedlot operation(s); and,
- Copies of feeding agreements for cattle in the project, where applicable.

Justification for the greenhouse gas assertion must be supported by evidence.

Note: *Attestations from land owners or feedlot operators with regards to any factor related to the quantification of emission reductions are not considered sufficient evidence that an activity took place and will not be accepted by Alberta Environment.*

Table 9 below is a summary of sources of evidence in providing adequate justification for emission reduction assertions associated with reduced days on feed projects.

Table 9: Evidence Sources for Reduced Days on Feed

Data Point	Evidence
Animal ID tag number	Registered with the Canadian Cattle Identification Agency or a unique tag identifier.
Methods for grouping animals	Documented methods used in the feedlot, since baseline period onwards; must show that grouping methods are similar in the project years.
Statistical sampling method	Procedures used to identify the number of pens to be sampled within each animal grouping according to the method outlined in Appendix B. Demonstration of an unbiased, randomized selection of initial sampling of pens to determine precision level.
Pen entry and exit records	Feedlot records or third party managed data for average weights of the group in and out of the pens; date of entry; average number of animals in each pen;
Average daily dry matter intake for each diet	Feedlot records or third party managed data for the amount of dry matter the animals in each pen/grouping take in, on average, on a daily basis; these should be supplemented with feed purchase receipts and kg of feed delivered to each pen, either daily or monthly.
Composition of each diet	Feedlot records or third party managed data for the composition of each diet on a dry matter basis; this should include kg of dry matter; total digestible nutrients, crude protein content; level of concentrates in the diet, and any additives being mixed in. The diet should be signed off by a Doctor of Veterinarian Medicine or Professional Agrologist.
Number of days on feed for each diet	Feedlot records or third party managed data for the number of days animals or animal groupings spend on each diet
Legal land location for the feedlot operation(s)	See end of this section for guidance
Commercial agreements.	Feeding agreements showing the Project Developer was feeding the animals involved in the project.

5.2 Record Keeping

Alberta Environment requires that project developers maintain appropriate supporting information for the project, including all raw data for the project for a period of 7 years **after** the end of the project credit period. Where the project developer is different from the person implementing the activity, as in the case of an aggregated project, the individual farmer and the aggregator, must both maintain sufficient records to support the offset project. The project developer (farmer and aggregator) must keep the information listed below and disclose all information to the verifier and/or government auditor upon request.

A list of minimum records required is provided in section 5.1 above.

In order to support the third party verification and the 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 7 years after the project crediting period;
- Electronic and paper documentation are both satisfactory; and
- Copies of records should be stored in two locations to prevent loss of data.

5.3 Quality Assurance/Quality Control Considerations

Quality Assurance/Quality Control can also be applied to add confidence that all measurements and calculations have been made correctly. These include, but are not limited to:

- Ensuring that the changes to operational procedures (including feed intake, 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 remains in place and accurate
- Checking the validity of all data before it is processed, including emission factors, static factors, and acquired data
- 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
- Recording and explaining any adjustment made to raw data in the associated report and files.
- A contingency plan for potential data loss.

5.4 Liability and Risk

Offset projects must be implemented according to the approved protocol and in accordance with government regulations. Alberta Environment reserves the right to audit offset credits and associated projects submitted to Alberta Environment for compliance under the *Specified Gas Emitters Regulation* and may request corrections based on audit findings.

Notwithstanding any agreement between a project developer and the farmer, the project developer shall not and cannot pass on any regulatory liable for errors in design of the project developer's data management system.

5.5 Registration and Claim to Offsets

It is important to note that the emission reductions associated with reducing days on feed in beef cattle occur specifically at feedlot operations – this is where the activity 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 2: One Feedlot, 2 Registry Parcels Example

The project developer is designated in this protocol as the operation where the animal spends the final stage prior to harvest (e.g.: a feedlot operator). Ownership of offset credits generated under this protocol is assigned to the project developer.
The project developer/feedlot operator will need to ensure that they can justify the claim to the offsets to the satisfaction of the third party verifier. This will include the ability to provide feeding agreements for the animals in the project, to substantiate the project developer fed the cattle in question, for the purposes of verification.

6.0 References

Alberta Environment. Technical Guidance for Offset Project Developers http://environment.alberta.ca/02278.html.

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7.0 Appendices

Appendix A: Alberta Case Study - Reducing Days on Feed by using Ractopamine Hydrochloride

Ractopamine hydrochloride (RAC) is the chemical name for a product which increases muscle mass in cattle through increased protein synthesis with minimal effect on protein breakdown. In Canada, RAC is fed to cattle at 200 mg/animal/day over the last 28 days before slaughter. The feeding of RAC during the last 28-42 days before slaughter has been shown to improve average daily gain and gain to feed ratio by 20 per cent, final slaughter weight by 1.2-2.1 per cent, carcass weight by 1.9-2.8 per cent and dressing percentage by 0.5 per cent with no effect on dry matter intake. Therefore, feeding RAC to youthful beef cattle, under 24 months of age, 28 days prior to slaughter has been documented to increase hot carcass weight, ribeye area, decreases fat deposition and the total number of days required to bring beef cattle to market weight. The reduction in the number of days on feed results in a measurable decrease in the greenhouse gas emissions associated with the cattle production.

The following section explores the potential emission reduction opportunity of a case study which applies adding Ractopamine Hydrochloride to the final 28 days of a finishing diet with a step-by-step discussion on the approach to quantifying reductions.

NOTE: The following is a simplified case study where feed diets were the same in the baseline and project. The project condition (reduced days on feed) was achieved by adding RAC during the beef cattle diets for the final 28 days of feeding before the cattle were sent to harvest.

Step 1: Defining the Baseline & Project Conditions
The following is a description of the baseline and project condition data requirements listed above.

Baseline Condition:
British x Continental crossbred yearling steers entered the feedlot averaging 317.5 kg (700 lb) in body weight. They were adjusted to a high barley grain diet over 28 days and grew at 1 kg/day 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, 3.6 per cent feedlot supplement and 1.6 per cent molasses (dry matter basis; 13.1 per cent crude protein; 80 per cent total digestible nutrients and a level of concentrates ≥ 85 per cent) for the remainder of the finishing period. Steers grew at 1.50 kg/day and consumed 10 kg dry matter/head/day (dry matter intake) over the next 178 days until they were harvested at 612.5 kg live slaughter weight or 355.25 kg hot carcass weight.

The baseline group of 1,000 animals took, on average, 178 days to achieve market weight.

Project Condition:
The same feeding regimes as the baseline was applied to the project condition and Ractopamine hydrochloride was added to the diet and fed to steers at 200 mg/animal/day for the last 28 days before they were harvested. Steers grew at 1.50 kg/day during the first 144.4 days of finishing and 1.80 kg/day during the last 28 days before slaughter and consumed 10 kg DM/head/day. Final live slaughter and hot carcass weights were 612.5 kg and 357.03 kg**.**

The project group of 1,500 animals took, on average, 172.4 days to achieve market weight.

Calculating Potential Emission Reductions per number of heads processed during the project.

Table 10: Reduced Days on Feed – Base Study Emission Reduction Calculations	
Cattle Enteric Emissions = [Number Production*DOF * DMIi * GE Diet * (EF Enteric i / 100%) / EC Methane/(Number Production*Live Weight Per Head)]	
DOF (Days on Feed)	As feed diets did not change between the project and baseline conditions, this number is simply the difference in days on feed between the project and baseline condition, which totals 5.6 days.
Concentrates	≥85%
DMI (Dry Matter Intake)	10 kg DM / head / day
GE Diet (Gross Energy Content of Diet)	This is a 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)	This is a default factor of 55.65 MJ per kg of methane.
Enteric Emissions $_{\text{BASELINE}}$ = ((1,000 head)*(178 days)*(10 kg DMI/hd/day) * (18.45 MJ/kg DM diet) * (4 /100))/(55.65) MJ/kg CH_4)/(1,000 head*612.5 kg live weight/head) = **0.039 kg CH_4 per kg of live cattle weight**	
Enteric Emissions $_{\text{PROJECT}}$ = ((1,500 head)*(172.4 days)*(10 kg DMI/hd/day) * (18.45 MJ/kg DM diet) * (4 /100))/(55.65) MJ/kg CH_4)/(1,500 head*612.5 kg live weight/head) = **0.037 kg CH_4 per kg of live cattle weight**	
Daily Volatile Solids Excreted in cattle manure = VSi = [(DMIi * GEDiet * (1 – (TDNi / 100%))) + (UE * DMIi * GEDiet)] * ((1 – (ASH / 100%)) / GEDiet)	
TDN_i (Total Digestible Nutrients)	80%
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	This is a default factor of 2% as this is a grain based diet.
Volatile Solids $_{\text{BASELINE}}$ = [(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) = **2.156 kg/hd/day for both baseline and project**	
Cattle Manure Handling, Storage, and Application Methane Emissions = [Number in Production*DOFi * VSi * Bo * ρ Methane * (MCF / 100%)/(Number Production*Live Weight Per Head)]	
Bo (Methane Producing Capacity)	Constant factor of 0.19 m^3 CH_4/kg VS excreted.
$\rho_{Methane}$ (Density of Methane)	Constant of 0.67 m^3/kg.
MCF (Methane Conversion Factor)	This factor is specific each manure

Table 10: Reduced Days on Feed – Base Study Emission Reduction Calculations	
	management system and is set at 1.0% for pasture, range, and/or paddock systems or 2.0% for solid storage systems. Thus an MCF value of 1.6% for this project was derived by assuming that 40% of the manure was produced on pasture while 60% of the manure was produced in feedlot and stored in solid form.
Manure CH_4 BASELINE = [(1,000 head)*(178 days)*(2.156 kg volatile solids excreted/hd/day)*(0.19 m^3 CH_4/kg VS*(0.67 m^3/kg)*(0.02)/(1,000 head*612.5 kg live weight/head)] = **0.00159 kg CH_4/kg live cattle weight**	
Manure CH_4 PROJECT = (1,500 head)*(172.4 days)*(**Manure CH_4 BASELINE** = [(1,000 head)*(178 days)*(2.156 kg volatile solids excreted/hd/day) **Manure CH_4 PROJECT** = [(1,500 head)*(172.4 days)*(2.156 kg volatile solids excreted/hd/day)*(0.19 m^3 CH_4/kg VS*(0.67 m^3/kg)*(0.02)/(1,500 head*612.5 kg live weight/head)] = **0.00154 kg CH_4/kg live cattle weight**	
Excreted Nitrogen = NEi = DMIi * (CPi / 100%) / CFprotein * (1 – NR)	
CP (Crude Protein)	13.1%
CF (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.
Nitrogen Excreted = 10 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 for Baseline and Project**	
Manure N_20_{direct} = [Number in Production*DOF_i * NE_i * CF_{manure} * (44 / 28) /(Number Production*Live Weight Per Head)]	
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_20direct BASELINE = [(1,000 head)*(178 days)*(0.195 kg N excreted/hd/day)*(0.02 kg N_2O-N/kg N excreted)*(44/28)/((1,000 head)*(612.5 kg/head))] = **0.00178 kg N_2O/kg live cattle weight.**	
Manure N_20direct PROJECT = **[**(1,500 head)*(172.4 days)*(0.195 kg N excreted/hd/day)*(0.02 kg N_2O-N/kg N excreted)*(44/28)/((1,500 head*612.5 kg/head))] = **0.00172 kg N_2O/kg live cattle weight.**	
Manure $N_20_{direct\ storage}$ = [(Number in Production)*(DOF_i)*(NE_i)*(MS)*(EF Storage)*(44 / 28)/((Number in Production)*(Live Weight Per Head))]	
MS_α (Management System)	Default of 0.8
EF (Storage Emissions Factor)	Default of 0.007kg N2O-N/kg nitrogen excreted
Manure N_20direct storage BASELINE = [(1,000 head)*(178 days)*(0.195 kg N/hd/day)*(0.8)*(0.007 kg N2O-N/kg nitrogen excreted)*(44/28)/((1,000 head)*(612.5 kg/head))] = **0.000498 kg N_2O/kg live cattle weight.**	
Manure N_20direct storage PROJECT = [(1,500 head)*(172.4 days)*(0.195 kg N/hd/day)*(0.8)*(0.007 kg N2O-N/kg nitrogen excreted)*(44/28)/((1,500 head)*(612.5 kg/head))] = **0.000483 kg N_2O/kg live cattle weight.**	
Manure $N_20_{indirect\ volatilization}$ = [(Number in Production)*(DOF_i)*(NE_i)* (MS)*(EF Volatilization)*(44/ 28)/ ((Number in Production)*(Live Weight Per Head))]	
MS_β (Management System)	Default of 0.2 kg N2O-N/kg nitrogen excreted
EF (Storage Emissions Factor)	Default of 0.01 kg N2O-N/kg nitrogen excreted.
Manure N_20indirect volatilization BASELINE =[(1,000 head)*(178 days)*(0.195 kg N/hd/day)*(0.2 kg N20-N/kg nitrogen excreted)*(0.01 kg N2O-N/kg nitrogen excreted)*(44/28)/((1,000 head)*(612.5 kg /head))] = **0.000178 kg N_2O/ kg live weight**	
Manure N_20indirect volatilization PROJECT =[(1,500 head)*(172.4 days)*(0.195 kg N/hd/day)*(0.2 kg N20-N/kg nitrogen excreted)*(0.01 kg N2O-N/kg nitrogen excreted)*(44/28)/((1,500 heads)*(612.5 kg /head))] =	

Table 10: Reduced Days on Feed – Base Study Emission Reduction Calculations	
0.000172 kg N_2O/ kg live weight	
Manure $N_20_{indirect\ leaching}$ = [(Number in Production)* (DOF_i)*(NE_i)* (MS)*(EF Leaching)*(44 / 28)/ ((Number in Production)*(Live Weight Per Head))]	
MS_γ (Management System)	Default of 0.1 kg N2O-N/kg nitrogen excreted.
EF (Storage Emissions Factor)	Default of 0.0125 kg N2O-N/kg nitrogen excreted
Manure $N_20_{indirect\ leaching\ BASELINE}$ = [(1,000 head)*(178 days)*(0.195 kg N/hd/day)*(0.1)*(0.0125 kg N2O-N/kg nitrogen excreted)*(44/28)/((1,000 head)*(612.5 kg/head))] = **0.000111 kg N_2O/hd.**	
Manure $N_20_{indirect\ leaching\ PROJECT}$ = [(1,500 head)*(172.4 days)*(0.195 kg N/hd/day)*(0.1)*(0.0125 kg N2O-N/kg nitrogen excreted)*(44/28)/((1,500 head)*(612.5 kg/head))] = **0.000107 kg N_2O/hd.**	

Table 11: Final Example Calculations

Factor	Baseline	Project	Total kg of Beef Produced	Total Calculated emissions (Baseline – Project) * Total kgs in Production	GWP	Total Emission Reduction (kg CO_2e)
Enteric Emissions	**0.039 kg CH_4 / kg live weight**	**0.037 kg CH_4 / kg live weight**	**918,750 kg**	1,837 **kg CH_4**	21	38,587
Manure Methane Emissions	**0.00159kg CH_4/ kg live weight**	**0.00154 kg CH_4/ kg live weight**		49 **kg CH_4**	21	1,029
Direct Nitrous Oxide Emissions – Decomposition	**0.00178 kg N_2O/ kg live weight**	**0.00172 kg N_2O/ kg live weight**		**55 kg N_2O**	310	17,050
Direct Nitrous Oxide Emissions – Storage	**0.000498 kg N_2O/ kg live weight**	**0.000483 kg N_2O/ kg live weight**		13 **kg N_2O**	310	4,030
Indirect Nitrous Oxide Emissions – Volatilization	**0.000178kg N_2O/ kg live weight**	**0.000172 kg N_2O/ kg live weight**		5 **kg N_2O**	310	1,550
Indirect Nitrous Oxide Emissions - Leaching	**0.000111 kg N_2O/ kg live weight**	**0.000107 kg N_2O/ kg live weight**		3 **kg N_2O**	310	930
Total Emission Reduction for 1,500 head of cattle at 612.5 kg live weight per head (kg CO_2e)						**63, 176**

Appendix B: Statistical Sampling Method for Baseline Quantification for Reduced Days on Feed Projects

Sampling is the process by which a subset of a population is analyzed in order to make generalizations about the whole population. The values attained from measuring a sampling of pens in a feedlot, for example, is intended to be an estimation of the true value (known as the parameter) for the entire population of cattle in the yard or of a specific animal grouping (e.g. 650-750 lb fall-placed steers). We need to have some idea of how close the estimation is to the parameter and this is provided by statistics.

Sampling a subset of pens in the feedlot for greenhouse gas estimation involves taking measurements of the desired data in a number of pens. The average values of the desired data when all the pens are combined represents the larger population and we can tell how representative it is by looking at the confidence interval. A 95 per cent confidence interval is a common and appropriate measure telling us that, 95 times out of 100, the true greenhouse gas emissions lie within the interval. If the interval is small, then the estimation is more precise.

To facilitate beef project development and increase the accuracy and precision of estimating carbon reductions, it is useful to divide the cattle in the feedlot by their animal groupings or “strata” (typically they are organized in feedlot pens according to specific groupings) to form relatively homogenous sampling units. In general, stratified sampling also decreases the costs of monitoring because it typically lessens the sampling efforts necessary, while maintaining the same level of confidence due to decreased variability in the data that drive the greenhouse gas reductions in each animal grouping. The more variable the data, the more pens are needed to attain targeted precision levels.

To apply the above method then, we will need an indication of the variability of the data within the sampled strata. This is calculated quite simply using the coefficient of variation of the data in the sampled animal grouping. The following key statistics need to be calculated for each set of measured data in each animal grouping:

- Mean or Average: a measure of central tendency, calculated by

$$\bar{x} = \frac{x_1 + x_2 + \cdots + x_n}{n} = \frac{\sum_{i=1}^{n} x_i}{n}$$

- Standard deviation: a measure of dispersion, calculated by

$$s_x = \frac{\sum_{i=1}^{n} (x_i - \bar{x})^2}{n-1}$$

- Coefficient of variation (CV), calculated by:

$$CV = \frac{s_x}{\bar{x}} \times 100$$

In order to determine an appropriate size of a sample with the required precision, we need to avoid taking a sample that is too small or too large with under- or over-accuracy, respectively. Thus, we want to strike a balance by expressing the allowable error in terms of confidence limits.

- The 95 per cent confidence limits are given by:
  $\bar{x} \pm 2s_x / \sqrt{n}$.
- We let *L* be the allowable error (for GHG projects it's set at 5% of the mean) and we put:
  $L = 2s_x / \sqrt{n}$.

In other words, we are 95 per cent certain that the actual error will not exceed ±*L* or we are willing to take a 5 per cent risk that the actual error will be below –*L* or above +*L*.

Applying the Sampling Approach

Biological traits in beef cattle lend themselves well to sampling approaches because they typically follow a normal distribution. To sample the feedlot or feedlots for a statistically valid sample, the feedlot has to be sufficiently large enough to support the method. Further, the sampling method within the animal groupings described below needs to follow random selection procedures and be unbiased. This method will need to be demonstrated to the verifier.

The biostatisticians and scientists at the Department of Agriculture and Rural Development have tested this method with robust feedlot datasets[3]. The method is outlined below.

1. Determine Animal Groupings

Data are to be collected from the following pens/animal groupings if they are present in the feedlot:

- Cows
- Fall Heifer Calves
- Fall Steer Calves
- Mixed Steers and Heifers
- Winter Heifer Calves
- Winter Steer Calves
- Yearling Heifers
- Yearling Steers

2. Determine the Sampling Plan of the Data

Based on the analysis done in the Department of Agriculture and explained below in the example, the initial sample should contain 30 to 40 pens (i.e. n = 30 or 40 initially) in

[3] There are over 80,000 head of cattle in Alberta that have been used in these datasets.

each of the above animal groupings. The data to be collected include[4]:

- Number of animals per pens
- Average arrival age (days) per pen
- Average arrival weight per pen (lb or kg)
- Average daily dry matter intake per animal per pen
- Average slaughter age per pen (days)
- Average slaughter weight per pen
- Average Daily Gain per pen

Note: the sampling plan will need to be presented to the verifier of the project and demonstrate that the animal grouping/pen selection was not biased.

3. **Calculate the mean, standard deviation and coefficient of variation of the above data, by grouping.**

4. **Calculate the appropriate size of the sample for each strata/animal grouping**: Since the precision level we are setting for the sampling method dictates that we are 95 per cent certain that the actual error will not exceed ±*L* or we are willing to take a 5 per cent risk that the actual error will be below –*L* or above +*L*, the desired sample size is calculated as,

$$n = 4s_x^2/L^2 = 4CV^2/(L')^2,$$

where *L'* is the allowable error expressed as the percentage of the mean (in this case 5%).

Once the number of pens needed to reach the desired precision level is determined, these then become the sample for which the required data for the project and baseline can now be collected. See below for an example of the method being applied.

This procedure will need to be documented concisely in order to justify the method to the verifier.

Example Application:

After obtaining actual pen data for nearly 90,000 animals over a 3 year period (2006-2009), the animals were stratified according to the groupings in Step 1 above, and mean, standard deviations and coefficients of variation analyzed for the data outlined in Step 2 above.

The analysis shows that for the key trait of daily dry matter intake the coefficients of variation ranged from 4 to 32 per cent.

Next, the required sample size was calculated to find out how many pens would be

[4] The above data can be calculated as an average for the pen using the cattle inventory approach outlined in Section 4 of this document.

required to produce a mean or an average that is repeatable 95 times out of 100 or have a 5 per cent error. For all animal groupings except yearling heifers (this group tends to be less homogenous than the others), the number of pens, required or 'n' is shown in Table B1.

Table B1. Required sample 'n' within the Allowable Error (+/- 5 per cent) with a 5 per cent risk that the error will fall outside of the desired range (derived from Table 1 analysis) based on the example shown here.

Animal Grouping	**Daily Dry Matter Intake (lbs/head/day) No. of Pens**	**Slaughter Weight (lbs) No. of Pens**
Cows	34	4
Fall Heifer Calves	66	41
Fall Steer Calves	31	28
Mixed Steers/Heifers	2	0
Winter Heifer Calves	13	9
Winter Steer Calves	34	18
Yearling Heifers	167	26
Yearling Steers	48	8

A conservative starting point to recommend for initial sampling falls within 30 to 40 pens for the critical trait that drives greenhouse gas emissions from cattle operations (i.e. daily dry matter intake). Although the yearling heifers tend to be more variable in the data, the method takes care of that by requiring an increased sample size until the project developer can obtain a 5 per cent error in the estimated mean. Once this iterative process is finished, the project developer may find that less pens are required for some animal groupings as shown in the example above.

Note the project developer may need to consult with a statistician to correctly implement this methodology.