QUANTIFICATION PROTOCOL FOR SELECTION FOR LOW RESIDUAL FEED INTAKE IN BEEF CATTLE

Version: 1.0 **April 2012**

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:

Alberta Environment
Climate Change Secretariat
12th Floor, 10025 – 106 Street
Edmonton, Alberta, T5J 1G4
E-mail: **AENV.GHG@gov.ab.ca**

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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 fermentation emissions. Selective breeding of cattle using a genetic marker for low residual feed intake (RFI) can result in cattle that are more efficient in their feed utilization compared to other cattle. This increased efficiency of feed utilization results in reduced enteric fermentation emissions being released by the cattle to other cattle.

Manure storage and handling within beef cattle operations can also be a significant source of greenhouse gas emissions, namely methane and nitrous oxide (N_20) emissions. Increased feed utilization efficiency of these RFI cattle reduces the amount of manure excreted, which further reduces the greenhouse gas emissions associated with cattle operations.

1.1 Protocol Scope

Industry experts and agricultural scientists have, through the Intergovernmental Panel on Climate Change (IPCC 2006) and Canada's National Emissions Inventory (NIR 2009), developed 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 is limited to enteric fermentation emissions and associated manure greenhouse gas emissions from beef cattle using a functionally equivalent metric of emissions per kilogram of live cattle weight. The protocol allows users to quantify reductions in these emissions using established scientific estimates. Cattle operations that have incorporated a new genetic merit trait procedure known as selecting for low residual feed intake (RFI) cattle in their breeding program after January 1, 2002, and where sufficient records exist to quantify the baseline and project condition, are eligible to claim offset credits in the Alberta offset system. Emissions reductions from these activities need to be quantified according to the methodology provided in this protocol and the claim must be verified by a qualified third party verifier.

RFI is a measure of how efficiently an animal utilizes its feed and is identified by the difference between an animal's actual feed intake and its expected feed intake (i.e. baseline feed intake) based on size and growth of the animal over a specified period of time. More efficient animals have lower (negative) RFI values meaning the animals consume less feed for the same body weight gain and level of production compared to other cattle. This feed intake reduction results in less enteric fermentation and manure production by the animal resulting in fewer greenhouse gas emissions being emitted when compared to cattle in the baseline.

The project developer must be able to demonstrate that cattle included in the project condition have a low RFI value. This requires that the sires be tested by an approved testing facility that is able to establish an estimated breeding value according to a standardized process.

Note: Animals tested at facilities outside North America and imported are not eligible at this time.

The baseline condition defines what was happening in the cattle operation before intentionally selecting for low residual feed intake animals and must represent business as usual operations for the feedlot/cattle operations. The project condition defines the project activities and must meet the conditions of this protocol.

Baseline Condition for Residual Feed Intake Selection:

The baseline condition for this protocol is defined as the greenhouse gas emissions from a grouping of animals across the full life span of the animal including the cow-calf operation, backgrounding operation and feedlot operation resulting from normal dry matter intake of feed prior to the selection for low RFI animals. This assumes standard the dry matter intake of base year animals of similar weight/life stage classes on similar rations. The baseline greenhouse gas emissions are quantified based on the business as usual feed efficiency of the cattle prior to the project year start date.

The baseline is calculated using a 3-year average of feed intake and ration data for animal groupings of similar weight classes and/or life stage classes prior to implementation of the project condition. For those life stages of the animals outside of the feedlot period (e.g. wintering cows or grazing animals), feed intake can be estimated using IPCC 2006 equations[1].

The baseline quantification approach is explained further in Section 2.0.

Project Condition for Residual Feed Intake Selection:

The project condition is breeding beef cattle based on genetic merit for residual feed intake (RFI). This is done through testing of animals at a recognized testing facility to determine the estimated breeding value and resulting dry matter intake of the sires to breed for animals with low RFI (i.e. low dry matter intake per unit weight of gain). This information is used to calculate the per cent reduction in dry matter intake from the animals in the project. The reduced dry matter intake for the project in this case is a calculated number, not a measured number.

The project condition is explained further in Section 3.0 and project quantification is discussed in Section 4.0.

Table 1 provides a list of applicable greenhouse gases for this activity.

[1] Intergovernmental Panel on Climate Change (IPCC) 2006. Table 10.3. Page 10.15. An alternate source is National Research Council, 2006; or use Alberta Agriculture and Rural Development Cowbytes Program.

Table 1: Relevant Greenhouse Gases Applicable for Selecting for Residual feed intake in Beef Cattle

Specified Gas	Formula	100-year GWP	Applicable to Project
Carbon Dioxide	CO_2	1	No
Methane	CH_4	21	Yes
Nitrous Oxide	N_2O	310	Yes
Sulphur Hexafluoride	SF_6	23,900	No
Perfluorocarbons*	PFCs	Variable	No
Hydrofluorocarbons*	HFCs	Variable	No

* 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

To apply this protocol, the project developer must meet the following requirements:

1. All qualifying cattle must be registered with the Canadian Cattle Identification Agency (CCIA) or an Alberta Registry, confirmed by operational records;

2. The cattle in the project must be RFI-certified and linkages between the sire/dam and the progeny must be tracked and known, along with the certified testing facility documentation; this is best achieved through a retained ownership cattle business model, or a process verification program[2].

3. Certified low RFI breeding animals are tested at a certified facility[3]. The breeding stock/semen for sale must have certified low RFI values and accuracies as part of the sale information for the animal/semen. This information must be included in the sale and makes up part of the required documentation for animals being included in the offset project. Appendix A provides additional information on residual feed intake and estimated breeding value certified testing facilities.

4. All cattle included in the project **must** have documentation showing that at least one parent animal was certified as low RFI breeding stock. The genetic merit of offspring from a mating will be equivalent to half the genetic merit of the sire and half the genetic merit of the dam. The progeny are assigned the mean RFI value of the parents. This information will need to be collected and tracked for each animal included in the project condition;

[2] The United States Department of Agriculture's (USDA) process verified program (PVP) provides companies that supply agricultural products or services the opportunity to assure customers of their ability to provide consistent quality products or services. Companies with approved USDA PVPs are able to make marketing claims associated with their process verified points and market themselves as "USDA Process Verified" with use of the "USDA Process Verified" shield and term. Information about this program can be found at http://processverified.usda.gov/. The objective of the RFI PVP is to provide the objective foundation for measured feed efficient market claims and assurance to purchasers that a GrowSafe certified sire is feed efficient and feed efficient progeny have been sired by a GrowSafe certified sire.

[3] See Appendix A: Testing Criteria for Residual Feed Intake Markers in Beef Cattle for a listing of certified facilities in Alberta.

5. It is expected that rations fed to animals in the baseline can be demonstrated. An ability to demonstrate the content and quantity of feed is necessary in order to quantify enteric and manure-based emissions;

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

7. Reductions can be claimed for animals with low residual feed intake-estimated breeding values and their first generation progeny **only.** A project developer can claim credits for a maximum of 8-years with a possible 5-year renewal where they can demonstrate low RFI cattle being claimed to meet the requirements of this protocol; and

8. The project meets the eligibility criteria stated in section 7.0 of the *Specified Gas Emitters Regulation.*

The general data requirements for this protocol are shown in Table 2 below. Additional details are provided in Sections 4 and 5.

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

Data Requirements:	**What is needed?**	**Why do you need it?**
Animal identifier tag	CCIA, or similar Alberta Registry (Premises ID) tag	To track animals as they move through the various cattle rearing operations.
Documentation from a Certified Alberta or North American Residual Feed Intake (RFI) testing facility for cattle in the project	▪ Certified low residual feed intake-estimated breeding value documents for seedstock and progeny; ▪ Accompanying documentation from the testing facility; and ▪ Farm records of matings.	To confirm the RFI genetic merit technology to the appropriate cattle in the offset project.
Ability to demonstrate linkage of certified sire/dam to progeny and tracking of the animals in the project	▪ To ensure cattle in the project are RFI-certified according to the testing facility documentation, all sires in a breeding program would need to be RFI-certified OR ▪ The genetic linkage between sires/dam and progeny is proven through DNA testing ▪ The breeding program must be able to be defend and ensure proper tracking of relevant information.	To ensure the animals in the project have the estimated breeding values and dry matter intake values tested at the original facility, and computed by this protocol.
Characterization of the animal.grouping methods in the baseline condition	▪ Animal groupings in cow-calf, grazing and/or backgrounding operations are defined and signed off by a professional	The methods used to define an animal grouping (ie: sex, age, weight, breed, etc...)

and project years; Average number of animals per pen.	with relevant experience (e.g. D.V.M or P.Ag.); sample groupings are given in Table A2, Appendix D). ▪ Documented feedlot records for the baseline and project condition consisting of: o approximate animal age as it enters the feedlot, o animal pen entry and exit records that show average weights of the group in and out, o date of entry (by production system, quality grid program, sex, breed, and/or custom feeding lot records (if applicable); ▪ Average number of animals in each pen.	**must** be similar between project and baseline to ensure like groupings are compared for the offset calculation.
Documented proof of what was being fed to the cattle per animal grouping/pen in the feedlot including the ration composition and days on feed for each ration for the baseline.	▪ Rations for cow-calf and backgrounding operations can be derived from available tools (see Section 1.3 below) ▪ Feed purchase receipts, ▪ Delivery records for a pen; ▪ Diet ration formulations signed off by a professional with relevant experience (e.g. DVM or P.Ag.), 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: o the dry matter content, o kilograms of feed delivered to each pen per day or as monthly totals, o total digestible nutrients, o crude protein content, o number of days on rations, and o the level of concentrates in the ration.	To support calculations of the offset claim and third party verification. Note, a verifier will need evidence of the diets and total mixed rations fed to cattle groupings for the baseline and project condition.
Legal Land location of the cow-calf, backgrounding and feedlot operation and any commercial agreements	▪ Legal land description for the registration of the project, ▪ Land titles for the feedlot operation, and ▪ Any commercial agreements relating to ownership of the offset credits (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 selection for low RFI cattle. Other emission reduction opportunities may be applicable to feedlot operations in Alberta. Where sufficient records exist, one or more reduction projects may be implemented at a single site. These opportunities are summarized in Table 3 below.

Table 3: Potentially Stackable Emission Project Opportunities for Cattle Producers*

Activity:	**Protocol:**
Reducing the number of days cattle are on a finishing diet regimen.	Quantification Protocol for Reducing Days on Feed of Beef Cattle
Incorporation of Edible Oils in Beef Cattle Finishing Diets	Quantification Protocol for Including Edible Oils in Cattle Feeding Regimes
Reducing the number of days it takes to take cattle through the beef production chain (cow-calf to market).	Quantification Protocol for Reduced Age to Harvest in Beef Cattle
Use of anaerobic digesters in handling cattle manure waste at feedlots.	Quantification Protocol for the Anaerobic Decomposition of Agricultural Materials

* Project developers may apply projects under using emissions reductions opportunities under one or more protocols where the emission reductions can be clearly attributed to each activity and do not result in double counting. Note the reduced age at harvest and reduced days on feed protocols credit similar activities and **cannot** be co-implemented on the same emission reduction project.

1.3 Protocol Flexibility

1. Progeny from one RFI tested parent are eligible. In these cases, the estimated breeding value of the untested parent animal will be set at zero and the progeny will be assigned an RFI value of 50 per cent of the certified parent's RFI value.

2. Feed intake for cow-calf operations and backgrounding generally does not include crude protein or total digestable nutrients. IPCC 2006 Table 10.3; National Research Council (1996) or use Cowbytes ration formulation programs v. 4.6.8 to calculate the dry matter intake of cows (drylot, pasture) based on the animal category should be used to estimate values for these animal classes. This will require project data for animal type, number of animals in each type (e.g. lactating cow, pregnant cow, dry cow, etc), animal gain and animal weight.

3. Project developers must have measured nutrient composition for the diets of the animal groups for the feedlot stage. In cases were exact data is not available for cow-calf and backgrounding stages, default values Cowbytes default values can be used. If the default values in Appendix D are used, the results must be signed off by a professional with relevant experience (e.g. a Doctor of Veterinary Medicine (D.V.M) or a Professional Agrologist (PAg.)).

4. If the project developer does not want to back-calculate and infer the feeding regimes and dry matter intake for the animals prior to entering the feedlot, the project boundary can be condensed to applying the offset claim to the feedlot situation. However, the emission reductions possible from selecting low RFI cattle in forage based situations, which may be over 50 per cent of the life stages

of cattle, are higher than those achieved in higher concentrate rations typical of finishing diets in the feedlot.

1.4 Glossary of New Terms

Accuracy	Accuracy of estimated breeding values range from zero to 100 and is a measure of the strength of the relationship between true breeding value and the predicted breeding value for the genetic trait being assessed. For this protocol, the minimum accuracy values for residual feed intake estimated breeding values is set at 60 per cent for animals that have been measured for individual animal feed intake and growth following standard operating procedures (Arthur et al. 2001; Basarab et al. 2003; Nkrumah et al. 2006; BIF 2009)[4].
Animal Groupings (Cow-Calf/Pasture Systems)	For the purpose of this protocol, animal grouping refers to specific groupings of cattle as they move through the lifestages from cow-calf to feedlot. Suckling calves, weaned calves, weaned steer and heifers, breeding bulls and replacement heifers are considered as groups since both diets and dry matter intake will vary by group. See Appendix D for more guidance on grouping cattle on cow-calf and/or backgrounding operations.
Animal Groupings (Feedlots):	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[5].

[4] **Basarab, J.A., Price, M.A., Aalhus, J.L., Okine, E.K., Snelling W.M., and Lyle, K.L. 2003.** Residual feed intake and body composition in young growing cattle. Can. J. Anim. Sci. **83:**189-204.
Arthur, P.F., Renand, G. and Krauss, D. 2001. Genetic and phenotypic relationships among different measures of growth and feed efficiency in young Charolais bulls. Livest. Prod. Sci. **68:**131-139.
Nkrumah, D.J., Okine, E.K., Mathison, G.W., Schnid, K., Li, C., Basarab, J.A., Price, M.A., Wang, Z. and Moore, S.S. 2006. Relationships of feedlot feed efficiency, performance, and feeding behavior with metabolic rate, methane production, and energy partitioning in beef cattle. J. Anim. Sci. **84:**145-153.
Crews, D.H. Jr., Carstens, G.E., Basarab, J.A., Hill, R.A. and Nielsen, M. E. 2009. CHAPTER 7 – FEED INTAKE and EFFICIENCY. In "Beef Improvement Federation Guidelines"

[5] 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.

Days on Feed	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 group.
Concentrates:	A broad classification of feedstuffs which are high in energy and low in crude fibre (<18% 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 the animals (Ensminger and Olentine (1980).
Edible Oils[6]:	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.
Estimated breeding value:	Is a systematic way of combining available performance information on the individual animals including siblings and the progeny to predict an animal's genetic merit for a given characteristic or trait.
Expected progeny difference:	Is the difference in expected performance of future progeny of an individual compared with expected performance of future progeny of an individual based on genetic testing for the specific trait or characteristic. Estimated progeny differences make up half of the estimated breeding value for the animal.
First generation progeny	Calves resulting from the first mating of the dam and sire; i.e. sons and daughters.

[6] 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.

Progeny	Descendants or offspring from the mating of a dam and a sire.
Diet:	Is the amount of and composition for feed supplied to an animal for a definite period.
Residual Feed Intake (RFI):	Is the difference between an animal's actual feed intake and its expected feed requirements for maintenance and production. RFI values are expressed as kg of dry matter intake per day and are standardized to 10 MJ of metabolizable energy intake per kg of dry matter intake. This protocol requires RFI values be calculated for breeding animals that are post-weaning. RFI values calculated during the finishing period are not accepted at this time. See Appendix A for more information.
Seedstock producer	Provides young males/females or semen/embryos for breeding in the cattle industry; could be both purebred or cross-bred cattle.
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.

2.0 Baseline Condition

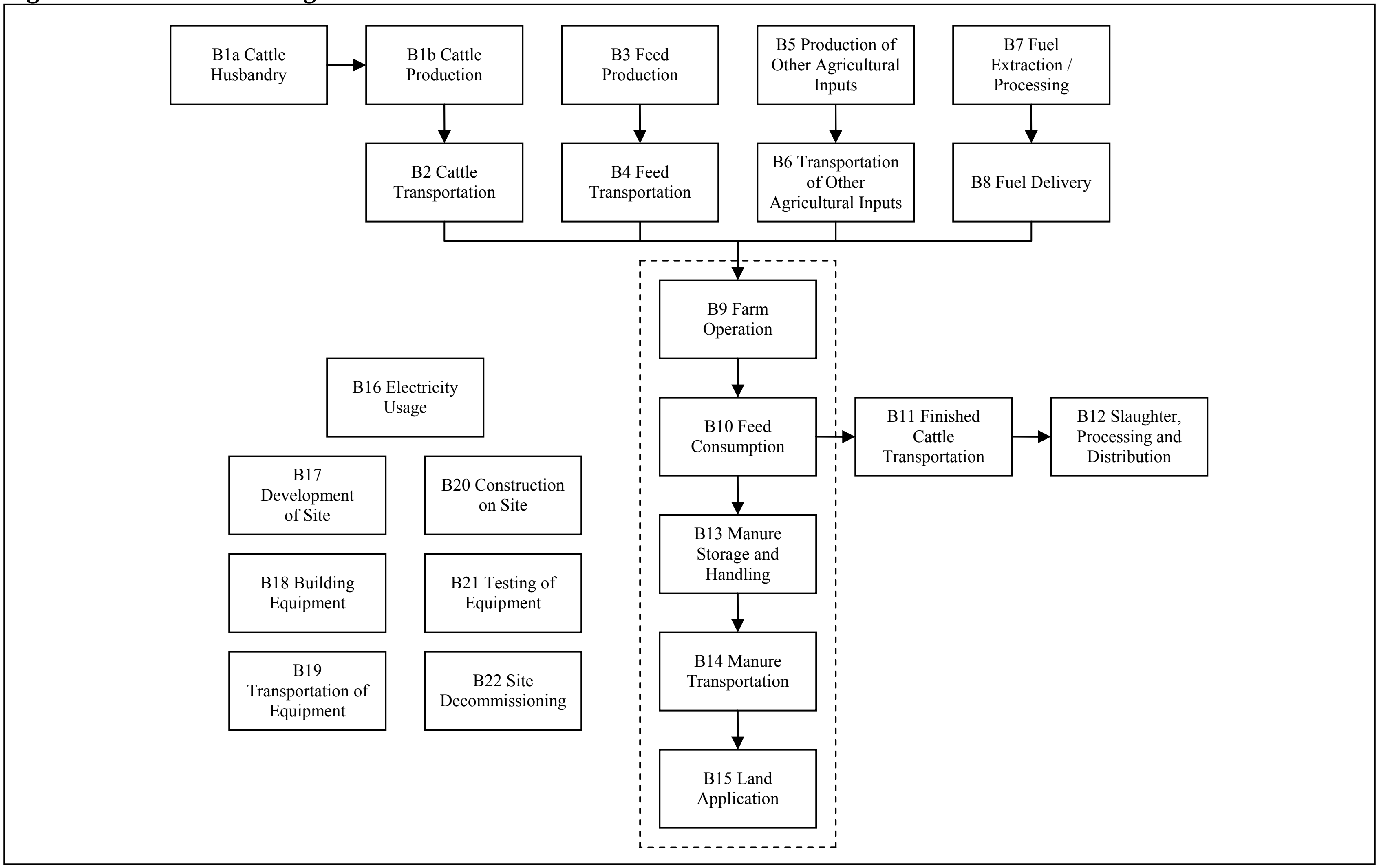
This protocol uses a **dynamic, historic benchmark** approach. The baseline condition for this protocol is defined as the greenhouse gas emissions from a grouping of animals as a result of normal dry matter intake of feed prior to the selection for low RFI (i.e. dry matter intake of base year animals of similar weight classes and similar diets). The baseline greenhouse gas emissions are quantified based on the business as usual efficiency of the cattle in the baseline year based on a common metric of average kilogram of dry matter intake per day per animal grouping per diet and is reported as emissions per kilogram of live weight animal.

The baseline condition assesses the average feed intake for specific animal groupings[7]. Various types of records may be used to develop the baseline including, but not limited to, animal category (e.g., replacement heifer on pasture; yearling steers on a finishing diet), average group weight of animals, approximate age (e.g., 6-7 month old steers calves, 11-12 month old yearling heifers), diet ingredient composition, and dry matter, energy and crude protein content of the diet.

Sources and sinks were identified for the baseline and 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 the Alberta protocol review process. This process confirmed that the sources/sinks in the process flow diagrams covered the full scope of eligible project activities under the protocol.

[7] Please refer to the protocol flexibility section 1.3 for guidance on estimating dry matter intake and nutrient composition for non-feedlot animals.

Figure 1: Process Flow Diagram for the Baseline



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 and/or sink and their classification as controlled, related or affected are provided in Table 4.

Figure 2: Baseline Condition Sources and Sinks for Selecting for Residual Feed Intake in Beef Cattle

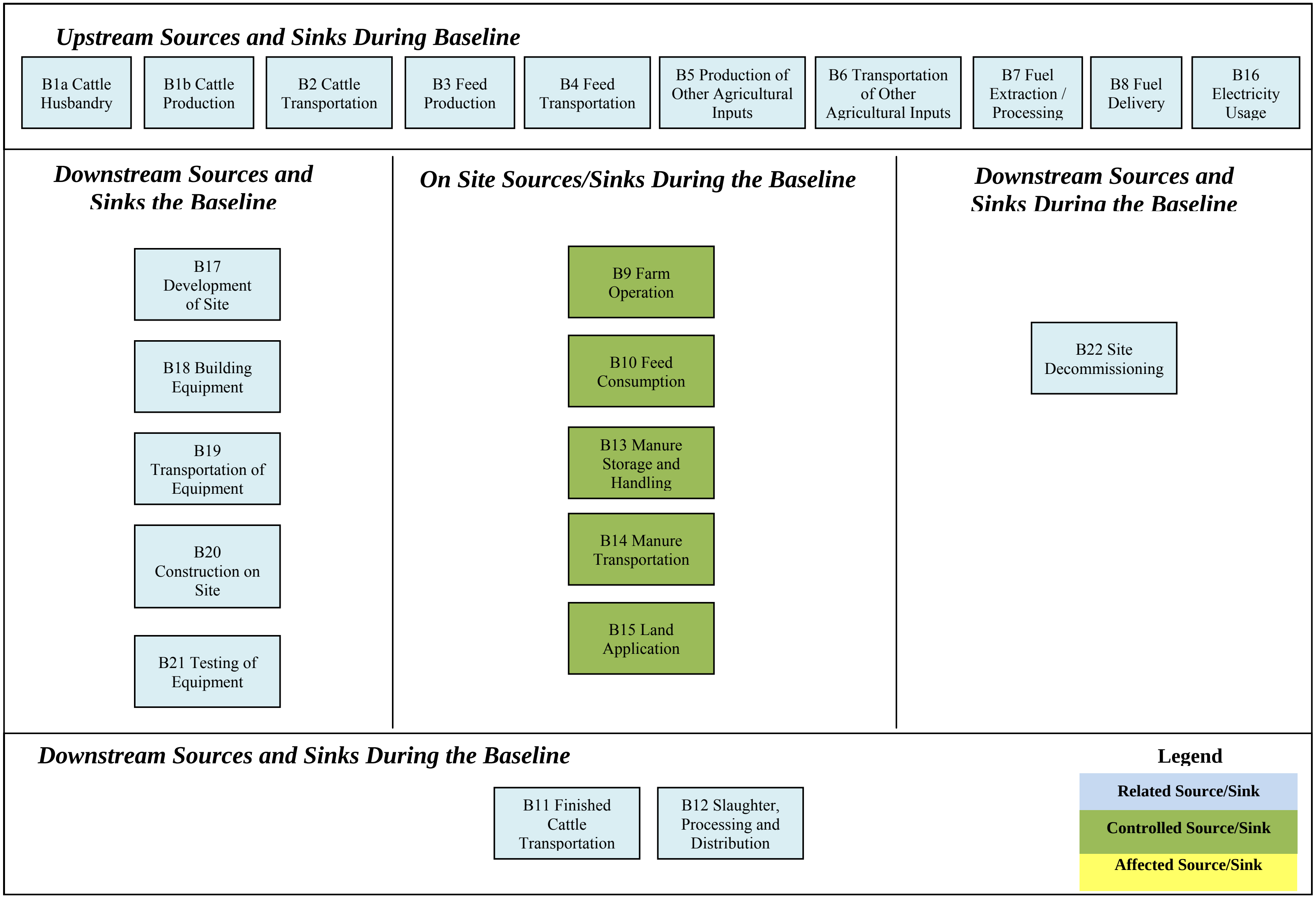


Table 4: Baseline Condition Sources and Sinks

1. Source/Sink	**2. Description**	**3. Controlled, Related or Affected**
Upstream Sources/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

Table 4: Baseline Condition Sources and Sinks

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 fuels are the important characteristics to be tracked.	Related
B8 Fuel Delivery	Each of the fuels used throughout the on-site component of the project will need to be transported to the site. This may include shipments by tanker or by pipeline, resulting in the 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

Table 4: Baseline Condition Sources and Sinks

Downstream Sources/Sinks during Baseline Operation		
B11 Finished Cattle Transportation	Finished cattle may be transported from the project site by truck, barge and/or train. The related energy inputs for fuelling this equipment are captured under this source/sink, for the 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	Related

Table 4: Baseline Condition Sources and Sinks

	electricity.	
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 the practice of selecting cattle with low RFI estimated breeding values based on testing of post-weaning cattle at certified testing facilities. The project condition encompasses pens and pastures where the cattle are raised and fed for the full lifecycle of the animal. The calculation that leads to the reduction in the quantity of feed consumed by the low RFI animals over the animals lifecycle results in a quantifiable reduction of enteric greenhouse gas emissions produced by the animal.

Reductions are also achieved in the amount of manure produced, and associated volatile solids (VS) and nitrogen (N) excreted by the certified low RFI animals. This translates into reduced manure-related greenhouse gas emissions under the project condition compared to the baseline.

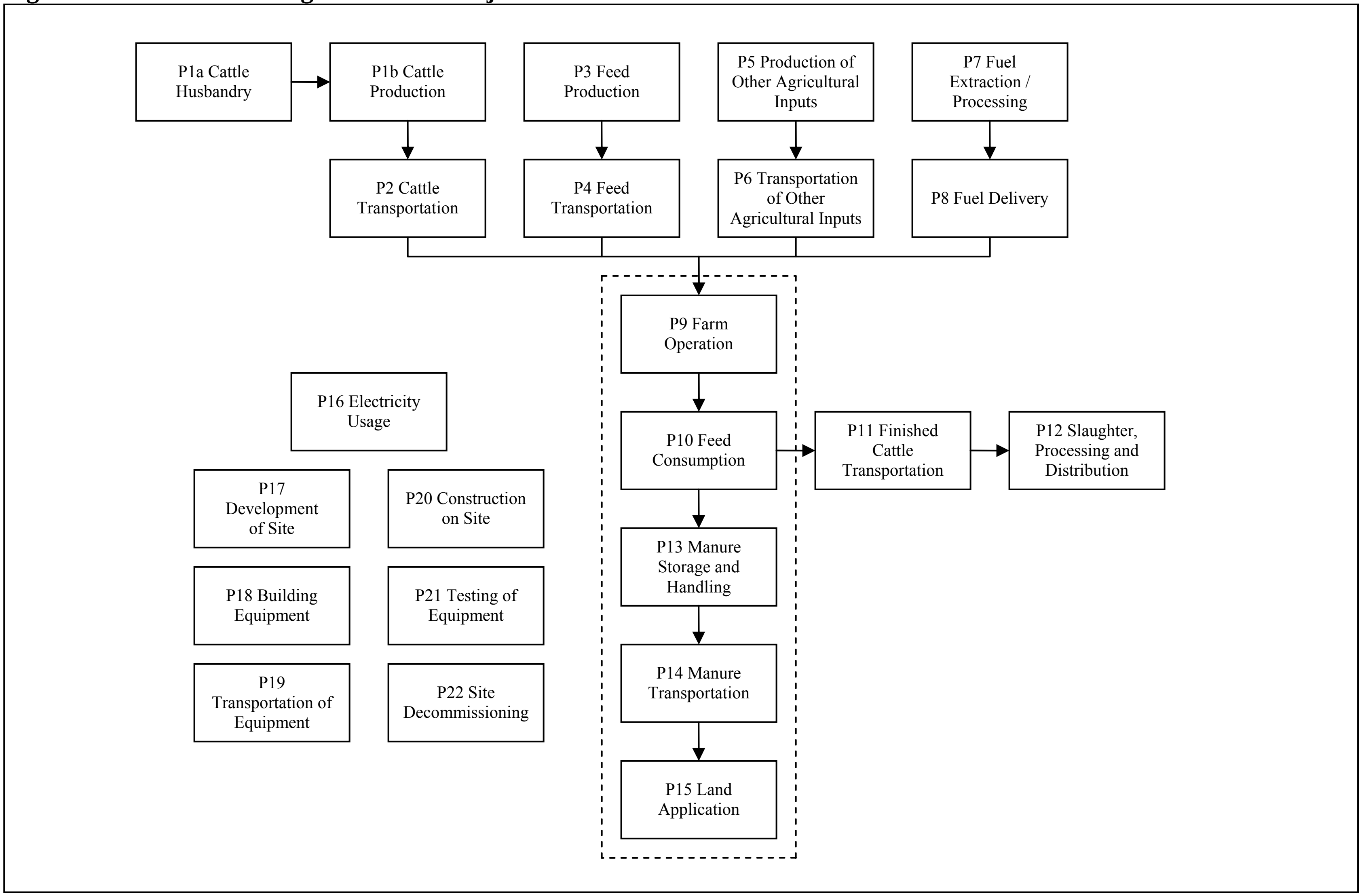
All cattle in the project condition must be registered with the Canadian Cattle Identification Agency (CCIA), or similar Alberta registry and must be supported by operational and farm records. These records, along with the Branding or Process Verification Program documentation must be available to demonstrate that the certified sire/dam and the first generation progeny are linked and enables tracking of animals in the included in the project.

Animals in the project condition have residual feed intake estimated breeding values computed using a specified year as the base year or beginning of the project. The mean estimate breeding value of a particular trait is set to zero for all the animals born in that year or earlier. This ensures that genetic improvement relative to the animals in the baseline condition can be tracked over several years. This base year can also be used in the protocol to illustrate that practice changes from that reference year have resulted in reductions in greenhouse gas emissions.

Residual feed intake requires the average feed intake (dry matter intake) of animals during the RFI test period for the base year be calculated or estimated. This value will be used to compute the per cent reduction in dry matter intake from the baseline data.

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 selecting for residual feed intake in beef cattle were identified based on a scientific review. This process confirmed that sources and sinks in the process flow diagram (Figure 3) covered the full scope of eligible project activities under this protocol.

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.

Again, 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 which must be documented in order to justify the project condition.

Figure 4: Project Condition Sources and Sinks for Selecting for Residual Reed Intake in Beef Cattle

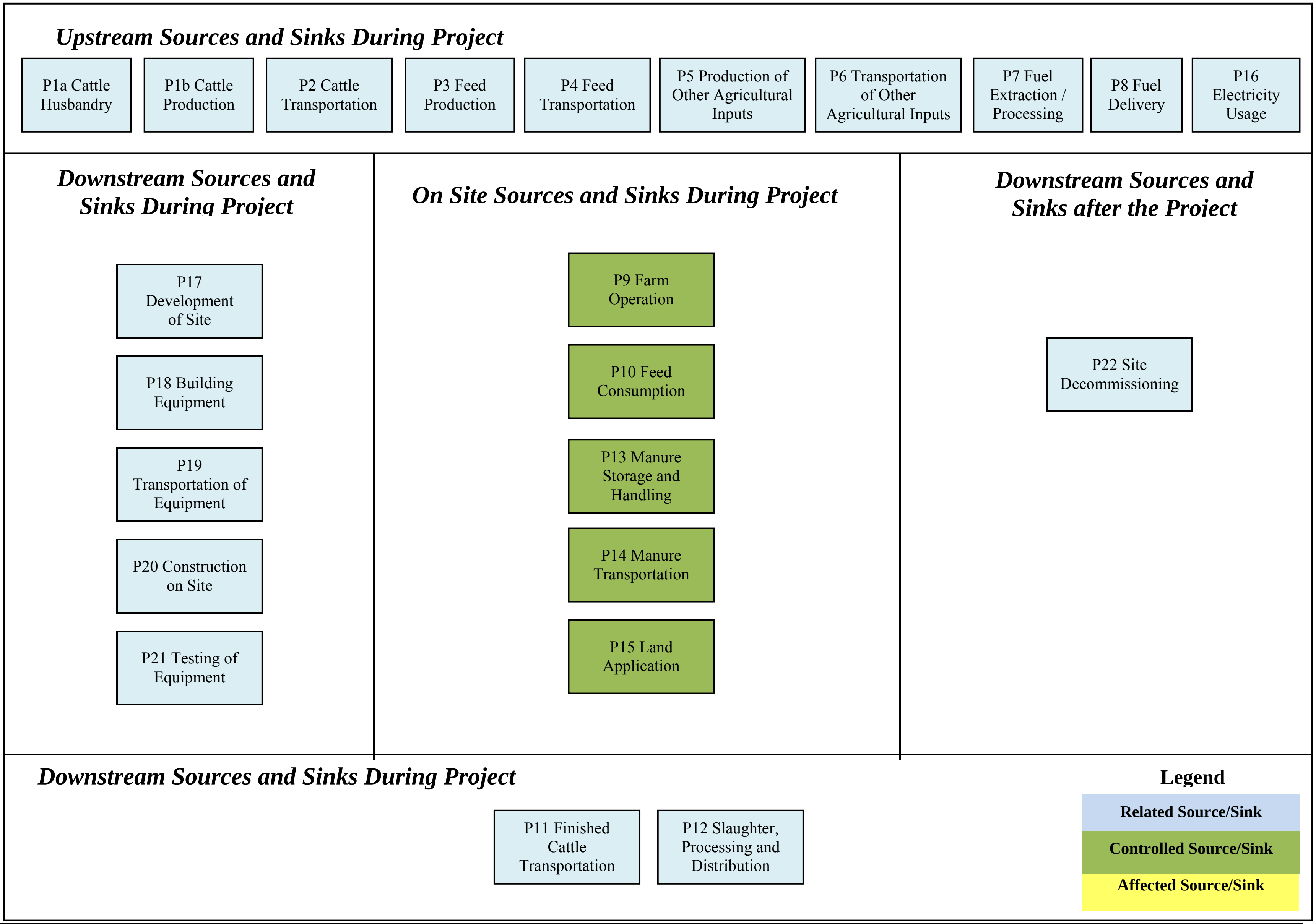


Table 5: Project Condition Sources and Sinks

1. Source/Sink	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	Related

Table 5: Project Condition Sources and Sinks

	evaluate functional equivalence with the baseline condition.	
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 SS. Volumes and types of fuels are the important characteristics to be tracked.	Related
P8 Fuel Delivery	Each of the fuels used throughout the on-site component of the project will need to be transported to the site. This may include shipments by tanker or by pipeline, resulting in the emissions of greenhouse gases. It is reasonable to exclude fuel sourced by taking equipment to an existing commercial fuelling station as the fuel used to take the equipment to the site is captured under other sources/sinks and there is no other delivery.	Related
P16 Electricity 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

Table 5: Project Condition Sources and Sinks

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
Downstream Sources/Sinks during Project Operation		
P11 Finished Cattle Transportation	Finished cattle may be transported from the project site by truck, barge and/or train. The related energy inputs for fuelling this equipment are captured under this source/sink, for the 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		
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

Table 5: Project Condition Sources and Sinks

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
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 Sources/Sinks	2. Baseline*	3. Project*	4. Include or Exclude from Quantification	5. Justification for Inclusion or Exclusion
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 upstream emissions from production of fuel inputs 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 upstream fuel delivery emissions are not impacted by the implementation of the project and as such the baseline and project conditions will be functionally equivalent.
B8 Fuel Delivery	R	N/A	Exclude	
P16 Electricity Usage	N/A	R	Exclude	Excluded as upstream emissions from production of electricity and it's use 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

Table 6: Comparison of Sources and Sinks

1. Identified Sources/Sinks	2. Baseline*	3. Project*	4. Include or Exclude from Quantification	5. Justification for Inclusion or Exclusion
B9 Farm Operation	C	N/A	Exclude	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.
P10 Feed Consumption	N/A	C	**Include**	Included because the 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 the 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, or actually less in the project condition, making it conservative to exclude these.
B14 Manure Transportation	C	N/A	Exclude	
P15 Land Application	N/A	C	**Include**	N/A
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				
P17 Development of Site	N/A	R	Exclude	Emissions from site development are not material given the long project life, and the minimal site development typically required.
B17 Development of Site	R	N/A	Exclude	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.

Table 6: Comparison of Sources and Sinks

1. Identified Sources/Sinks	2. Baseline*	3. Project*	4. Include or Exclude from Quantification	5. Justification for Inclusion or Exclusion
B18 Building Equipment	R	N/A	Exclude	Emissions from building equipment are not material for the baseline condition given the minimal building equipment typically required.
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	Emissions from transportation of equipment are not material for the baseline condition given the minimal transportation of equipment typically required.
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	Emissions from construction on site are not material for the baseline condition given the minimal construction on site typically required.
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	Emissions from testing of equipment are not material for the baseline condition given the minimal testing of equipment typically required.
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	Emissions from decommissioning are not material for the baseline condition given the minimal decommissioning typically required.

* Where A is affected, C is controlled, and R is related

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 8 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.

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

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

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

Where:

Emissions $_{\text{Baseline}}$ = sum of the emissions under the baseline condition

Emissions $_{\text{Cattle}}$ = emissions under B10 Feed Consumption
Emissions $_{\text{Manure}}$ = emissions under B13 Manure Storage and Handling and B15 land Application

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

Note: if the project developer uses the default rations for cattle in operations outside the feedlot stage, the overall emission reductions need to be decreased by 5 per cent.

<u>Cattle Inventories and Data Collection:</u>
This protocol allows cattle inventories to be collected in two ways:

1) tracking distinct groupings of animals daily based on the general animal/weight class they belong to or,
2) tracking each animal individually.

Cattle inventories must be tracked consistently between the baseline and project condition to support the quantification of emissions reductions achieved through the project. If animals are tracked based on weight groupings or other criteria, the groupings must be clearly defined (ie: Class 1 = x kgs to x kgs) in both the baseline and project. Any deaths that occur as cattle progress, or if animals are removed from an animal grouping due to sickness, should be accounted for in animal head.day calculations (see below).

The data points to be collected for cattle inventory of low residual feed intake estimated breeding value animals under the project and baseline conditions include:

- The number of head of cattle within a particular classified 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 kg of dry matter feed provided to each group per day (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 where animal head.days is the sum of the product of the number of days an individual animal is on a particular feeding regime. Many feedlots use this approach to calculate their 'yardage'. This is demonstrated in Table 7 below:

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

Pen or Lot		**No. of Days on Feed**	**No. of Head**	**Head.days**	**DMI (kg)***
A	**Diet 1**	1	119	119	1190
A		1	126	245	1260
A		1	126	371	1260
A		1	125	496	1250
A		1	125	621	1250
A		1	124	745	1250
A		1	124	869	1240
A		1	124	993	1240
A		1	124	1117	1240
A		1	124	1241	1240
A		1	124	1365	1240
A		1	124	1489	1240
A		1	124	1613	1240
A		1	124	1737	1240
Total		**14 (sum)**	**124 (average)**	**1,737 (sum)**	**17380 (sum)**

*Note-this table could be recorded in 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 (otherwise termed feeding period) is 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 period is known.

Feed is provided to cattle on an as fed basis and must be converted to a dry matter basis. This is accomplished by multiplying the feed intake by the dry matter content of the total mixed ration. The dry matter content of the ration can be obtained from a feed analysis of the total mixed ration or can be obtained from a feed analysis of the total mixed ration or can be obtained from a ration-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

Determining the change in dry matter intake from baseline to project as a result of selecting for low residual feed intake cattle:

The mechanism for emission reductions in this protocol is based on a calculated reduction in dry matter intake of the animals selected for lower residual feed intake values. This reduction in feed intake is compared to the expected feed intake of similarly grouped animals in the baseline (i.e. for the size and growth of the baseline animals). The resulting reduction in dry matter intake for the project year(s) is calculated from the dry matter intake for similar animal groupings during the baseline condition. This must be done for both the sires/dams and the progeny (for up to one generation) of the selected residual feed intake animal comparisons.

To calculate the reduction in dry matter intake for groups of animals in the project, the following equation is used:

Equation 1:

Project DMI_{group} =

average Baseline DMI_{group} x (% Change in DMI between tested project and baseline animals/100)

Where, baseline DMI is expressed in kg DM/day.

To calculate the per cent change in dry matter intake for the low residual feed intake certified sires/dams relative to baseline animals:

Equation 2:

% Change in DMI =

((Phenotypic Sire RFI test value x Phenotype Correlation factor) / baseline Sires DMI) x 100)

Where,

- the phenotypic sire residual feed intake test value is in kg DM/day, obtained from the certified facility;
- the phenotypic correlation factor is the relationship between test station feed intake performance and the feed intake performance on-farm or in the feedlot and is set at 0.75;
- the baseline sire's dry matter intake (DMI) is expressed as kg DM/day and is derived from actual measurement or Cowbytes program.

To calculate the per cent change in dry matter intake for the low residual feed intake progeny of certified sires relative to baseline animals:

Equation 3:

% Change in DMI =
(((Sire Certified RFIp EBV + Dam RFI EBV)/2) / baseline animals DMI) x 100)

Where,

- the sire-certified residual feed intake estimated breeding value (RFI_p EBV) is in kg DM/day obtained from the certified facility;
- the dam residual feed intake estimated breeding value (RFI EBV) is in kg DM/day obtained from the certified facility or is set at zero if unknown
- the baseline animals dry matter intake (DMI) expressed as kg DM/day and is derived from actual measurement or Cowbytes program.

Sample calculations are provided in Appendix C.

Statistical Sampling Approach Allowed under this Protocol

To facilitate project development under this protocol, a statistical sampling method is described in Appendix B. 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 needs to follow random selection procedures and be unbiased. This method will need to be demonstrated to the 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 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 describing 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. A 95 per cent confidence interval also supports the requirement of meeting a 5 per cent materiality threshold for verification of the project. This is explained in more detail, as well as how to apply the sampling approach, in Appendix B.

Table 8: Quantification Methodology						
1. Project/ Baseline Source/Sink	**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 feed 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 period) is known. Number in Production (head) = animal head.days/days on feed	Continuous	Direct measurement is the highest level possible.
	Days on Feed for Each Feed Regime for Cattle in Grouping i / DOF_i	Days	Estimated	Average for cattle in specific animal grouping the year 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 available farm records/ cow-calf and backgrounding can use guidance in Appendix D

Table 8: Quantification Methodology						
1. Project/ Baseline Source/Sink	**2. Parameter / Variable**	**3. Unit**	**4. Measured / Estimated**	**5. Method**	**6. Frequency**	**7. Justify measurement or estimation and frequency**
	Dry Matter Intake for Each Feed 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 period is known. Dry Matter Intake (kg/head/day) = (Total quantity of feed for a specific diet) x (dry matter content of ration) / animal head.days	Continuous	Based on actual feed delivery records to each pen/ cow-calf and backgrounding can use guidance in Appendix D
	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 Feed Regime in Grouping i / EF $_{Enteric\ i}$	%	Estimated	4 % 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).
B13 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. Project/ Baseline Source/Sink	2. Parameter / Variable	3. Unit	4. Measured / Estimated	5. Method	6. Frequency	7. Justify measurement or estimation and frequency
Storage and B15 Land Application	Daily Volatile Solid Excreted for Livestock in Grouping i and Each Feed Regime / VS_i	kg / head / day	N/A	N/A	N/A	Quantity being calculated.
	Dry Matter Intake for Each Feed 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/ cow-calf and backgrounding can use guidance in Appendix D
	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 Feed 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 ration.
	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).

Table 8: Quantification Methodology

1. Project/ Baseline Source/Sink	2. Parameter / Variable	3. Unit	4. Measured / Estimated	5. Method	6. Frequency	7. Justify measurement or estimation and frequency
	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 feed 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.
	Days on Feed for Each Feed Regime for Cattle in Grouping i / DOF_i	Days	Estimated	Average for cattle in animal grouping prior to the implementation of the project.	Annual	Based on available farm records/ cow-calf and backgrounding can use guidance in Appendix D
	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).

Table 8: Quantification Methodology						
1. Project/ Baseline Source/Sink	**2. Parameter / Variable**	**3. Unit**	**4. Measured / Estimated**	**5. Method**	**6. Frequency**	**7. Justify measurement or estimation and frequency**
	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.
	Dry Matter Intake for Each Feed 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 period is 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/ cow-calf and backgrounding can use guidance in Appendix D

Table 8: Quantification Methodology

1. Project/ Baseline Source/Sink	2. Parameter / Variable	3. Unit	4. Measured / Estimated	5. Method	6. Frequency	7. Justify measurement or estimation and frequency
	Percent Crude Protein in Diet for Each Feed 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 ration.
	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).
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 feed regime within each animal grouping / $Emissions_{Cattle}$	kg CH_4 / day / per animal grouping	N/A	N/A	N/A	Quantity being calculated.

Table 8: Quantification Methodology						
1. Project/ Baseline Source/Sink	**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. This value can also be extrapolated from animal head.days if the days on feed (otherwise termed feeding period) is known. Number in Production (head) = animal head.days/days on feed	Continuous	Direct measurement is the highest level possible.
	Days on Feed for Each Feed 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/ cow-calf and backgrounding can use guidance in Appendix D

Table 8: Quantification Methodology						
1. Project/ Baseline Source/Sink	**2. Parameter / Variable**	**3. Unit**	**4. Measured / Estimated**	**5. Method**	**6. Frequency**	**7. Justify measurement or estimation and frequency**
	Dry Matter Intake for Each Feed Regime for Cattle in Grouping i / DMI_i	kg $_{dry\ matter}$ / head / day	Estimated	Project DMI_{group} = average Baseline $DMI_{group\ (kg\ DM/head/day)}$ x (% Change in DMI between project and baseline animals/100)	Continuous	Based on actual feed delivery records to pen during the baseline condition and extrapolated for the project based on the change in DMI as a result of selecting for Low RFI cattle
	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 Feed Regime in Grouping i / $EF_{Enteric\ i}$	%	Estimated	4.0 % for diets with greater than 90 % concentrates. 6.5 % for diets with less than 90 % 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. Project/ Baseline Source/Sink	**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 Feed Regime / VS_i	kg / head / day	N/A	N/A	N/A	Quantity being calculated.
	Dry Matter Intake for Each Feed Regime for Cattle in Grouping i / DMI_i	$kg_{dry\ matter}$ / head / day	Estimated	Project DMI_{group} = average Baseline $DMI_{group\ (kg\ DM/head/day)}$ x (% Change in DMI between project and baseline animals/100)	Continuous	Based on actual feed delivery records to pen during the baseline condition and extrapolated for the project based on the change in DMI as a result of selecting for Low RFI cattle
	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 Feed 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 ration.

Table 8: Quantification Methodology

1. Project/ Baseline Source/Sink	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 Storage and Handling for each feed 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.
	Days on Feed for Each Feed Regime for Cattle in Grouping i / DOF_i	days	Measured	Direct measurement of days on each diet at the feed lot.	Continuous	Direct measurement is the highest level possible.

Table 8: Quantification Methodology						
1. Project/ Baseline Source/Sink	**2. Parameter / Variable**	**3. Unit**	**4. Measured / Estimated**	**5. Method**	**6. Frequency**	**7. Justify measurement or estimation and frequency**
	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.
	Dry Matter Intake for Each Feed Regime for Cattle in Grouping i / DMI_i	$kg_{dry\ matter}$ / head / day	Estimated	Project DMI_{group} = average Baseline $DMI_{group\ (kg\ DM/head/day)}$ x (% Change in DMI between project and baseline animals/100)	Continuous	Based on actual feed delivery records to pen during the baseline condition and extrapolated for the project based on the change in DMI as a result of selecting for Low RFI cattle

Table 8: Quantification Methodology						
1. Project/ Baseline Source/Sink	**2. Parameter / Variable**	**3. Unit**	**4. Measured / Estimated**	**5. Method**	**6. Frequency**	**7. Justify measurement or estimation and frequency**
	Percent Crude Protein in Diet for Each Feed 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 ration.
	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).
	$Emissions_{Direct\ Nitrous\ Oxide} = \Sigma (Number_{Production\ i} * DOF_i * Nitrogen_{Excreted\ I} * CF_{Manure}) * 44 / 28$					
	Direct Emissions of Nitrous Oxide from Manure for each feed 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.
	$Emissions_{Direct\ Storage} = \Sigma (Number_{Production\ i} * DOF_i * Nitrogen_{Excreted\ i} * Frac_{Storage} * EF_{Storage}) * 44 / 28$					

Table 8: Quantification Methodology						
1. Project/ Baseline Source/Sink	**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 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
	$Emissions_{Indirect\ Volatization} = \Sigma (Number_{Production\ i} * DOF_i * Nitrogen_{Excreted\ i} * Frac_{Volatization} * EF_{Volatization}) * 44 / 28$					
	Indirect Emissions of Nitrous Oxide from Volatization for each feed 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
	$Emissions_{Indirect\ Leaching} = \Sigma (Number_{Production\ i} * DOF_i * Nitrogen_{Excreted\ i} * Frac_{Leach} * EF_{Leach}) * 44 / 28$					

Table 8: Quantification Methodology

1. Project/ Baseline Source/Sink	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 Leaching in the Soil Profile for each feed 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
	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

Emission related to the baseline and project conditions are calculated in a similar manner, that is, they are calculated in two parts and summed. The first part being enteric emissions and the second related to manure.

Both baseline and project emissions must be expressed using an emission intensity of emissions per kilogram live weight basis. This is determined by dividing the total emissions for each gas in baseline and project 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.

Refer to Appendix C for a sample calculation. Further information on how to apply the this protocol is available from Alberta Agriculture and Rural Development.

In summary there are 8 key equations for determining emissions from this protocol. These equations are shown below (IPCC 2006). 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 period) =

Σ [Number Production $_i$ * DOF * DMI $_i$* GE Diet * (EF Enteric i / 100%) / EC Methane]

Equation 2: Calculating Daily Volatile Solids Excreted in Manure

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)

Manure CH_4 (kg CH_4) =

Σ [Number Production $_i$ * DOF_i * VS_i * Bo * $\rho_{Methane}$ * (MCF / 100%)]

Equation 4: Calculating Daily Nitrogen Excreted in Manure

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 Decomposition

Manure N_20_{direct} (kg N_20) =

Σ (Number Production $_I$ * DOF_i * NE_i * CF_{manure} * (44 / 28))

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

Manure $N_20_{direct\ storage}$ (kg N_20) =

Σ (Number Production $_i$* DOF_i * NE_i * MS_α * EF Storage) * 44 / 28

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

Manure $N_20_{indirect\ volatilization}$ (kg N_20) =

Σ (Number Production $_i$ * DOF_i * NE_i * MS_β * EF Volatilization) * 44 / 28

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

Manure $N_20_{indirect\ profile}$ (kg N_20) =

Σ (Number Production $_i$ * DOF_i * NE_i * MS_γ * EF Leaching) * 44 / 28

5.0 Data Management

Data quality management must be of sufficient quality to fulfill the quantification requirements and be substantiated by company records for the purpose of verification.

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 for the data, the more easily verification will be to conduct for the project.

5.1 Project Documentation

To facilitate quantification and verification of emission reductions, cattle inventory data must be tracked for cow-calf, grazing, backgrounding and feedlot stages. Cattle inventories at feedlots must be done by lots/pens. Tracking the number of head.days and the dry matter intake for each feeding period for each pen and animal grouping can facilitate the calculations and justification for verification of an assertion of emission reductions. If this approach is used, individual certified project animals must be linked to the certified sires/dams as discussed in Table 2 (i.e. all sires in a breeding program are RFI-certified, or linkages between sires and progeny are proven with DNA testing).

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 similar Alberta registry;
- Documentation from a certified testing facility in Alberta for the residual feed intake values of the seedstock. If using a testing facility located outside of Alberta, additional animal registration information will need to be collected to confirm the animal ID.;
- Records of matings of certified sires/seedstock and dams, with accompanying farm records of first generation progeny under a Brand or Process Verification style program and calculated residual feed intake-estimated breeding (RFI-EBV) values for the animals in the project;
- Proof of ownership of certified or RFI-EBV tagged progeny throughout the production chain, or the proof of being able to track the animals under a Breeding Program or Process Verification program as they move through the production system;
- Methods used to group cattle in the feedlot; must be similar for baseline and project; for cow-calf, grazing and backgrounding stages, representative groupings are given (Table D.1 for calves – fall and yearling calves as well as for other animal groupings; Appendix D), so long as a Professional with relevant experience (e.g. a D.V.M or P.Ag. signs off); for feedlot life stages, more detailed source documentation for baseline and project is required. Note: any assumptions and method applied needs to be documented in the offset project plan;
- Method applied for statistical sampling of animal groupings in the feedlot(s), if applicable;
- Entry and exit records for cattle in groupings;

- Records of the amount of feed fed to each grouping (or each animal) on a dry matter basis;
- Diet composition of the diets/total mixed ration, including any additives fed to the cattle groupings for the baseline; signed off by a professional with relevant experience;
- Records of the days on feed for each diet in the baseline;
- Legal land location of the feedlot operation(s);
- Proof of animal ownership;
- Proof of ownership confirmed through land titles and contracts; and,
- Copies of commercial agreements for offset ownership claims.

Justification for greenhouse gas assertions must be supported by evidence. Table 9 below is a summary of sources of evidence in providing adequate justification for emission reduction assertions associated with selecting for low residual feed intake cattle projects.

Table 9: Evidence Sources for Selecting for Low RFI in Beef Cattle

Data Point	**Evidence**
Animal ID Tag number	Registered with the Canadian Cattle Identification Agency or similar Alberta Registry; or if a U.S. certified residual feed intake estimated breeding value animal, from a like Registry in the U.S.; strongly recommend the estimated breeding values be registered on the specific database as well.
Methods for Grouping - feedlot	Documented methods used in the feedlot, since baseline period onwards; must show that grouping methods are similar in the project years.
Methods for Grouping - cow-calf and backgrounding	Documented methods and assumptions used to infer animal groupings/diets in for non-feedlot operations, since baseline period onwards; must show that grouping methods are applied similarily in the project years; sign off by a professional with relevant experience.
RFI-Certified Documents	Certificates of estimated breeding values from a certified testing facility in Alberta or North America (if the latter, registration of cattle will need to be collected) of residual feed intake values of the seedstock.
Guaranteed Linkage of progeny with RFI-Certified Sires/Dams	Documentation showing all sires in the breeding program were RFI-Certified OR genetic linkage demonstrated through DNA testing.
Methods for Calculating the RFI values of the sires, dams and first generation progeny	Records of matings of certified sires/seedstock and dams, with accompanying farm records of first generation progeny calculated residual feed intake estimated breeding values
Pen Entry and Exit Records	Feedlot records or third party managed data for average weights of the group in and out of the pens;

Data Point	Evidence
	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 ration should be signed off by a professional with relevant experience.
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)	Discussed in Section 5.5 below.
Commercial Arrangements/Agreements	Agreements outlining the sharing/or apportioning of offsets between those that may have a claim to the offsets.
Cattle Ownership	Cattle Brand of current owner. Sufficient paperwork to track ownership providence by CCIA tag, unique number or other identifier.

Additional information on records is available in Appendix E.

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 (feedlot operator and aggregator) must keep the information listed below and disclose all information to the verifier and/or government auditor upon request.

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.

Note: Attestations are not be considered sufficient proof that an activity took place and will not to meet verification requirements.

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

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 third party carbon data management system provider, and the project developer and/or the buyer of the offset credits, the third party data management system provider shall not and cannot pass on any regulatory liability for errors in design or implementation of their carbon data management system.

5.5 Registration and Claim to Offsets

There must be clear, legal claim of the greenhouse gas reductions or removals achieved from the project, in order to have the offsets verified and registered. Emission reductions are tracked through the Alberta Emissions Offset Registry.

Emission reductions associated with selecting for low residual feed intake can occur under either a retained ownership business model where the entities involved in initiating the breeding of low residual feed intake cattle are involved in the ownership chain so proof of certified dam/sire to progeny can be linked, **or** under a process verification program as cattle move through the cow-calf, backgrounding and feeding stages as a group for market verification purposes. More information on process verification is available in Section 1.2.

Ownership of offset credits developed under this protocol is assigned to the project developer (e.g.: feedlot operator or animal through retained ownership); however, because cattle in this protocol can span several operations (cow-calf, backgrounding, feedlot), historic ownership agreements and legal ability to include cattle in the project condition may need to be established through additional contractual obligations. See Section 1.2 for more information.

The registry relates the greenhouse gas reduction claim to a specific land location. Projects will ensure the parcel used to create the reduction (e.g.: where the animal was finished prior to harvest) is the actual parcel registered. Emission reductions are **not** be consolidated to the parcel where the business entity is legally located.

Figure 5: Example - One Feedlot, 2 Registry Parcels

Parcel 1

Parcel 2

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6.0 References

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7.0 Appendices

Appendix A:

Testing Criteria for Residual Feed Intake Markers in Beef Cattle

Applicable Alberta Testing Facilities for Certified RFI-EBVs

The residual feed intake assessment will need to be conducted on 'post-weaned animals (RFI_p)'. This involves measuring RFI on breeding cattle (bulls and replacement heifers) when they are 8 to 13 months of age. Calculating RFI requires the measurement of actual individual animal feed intake over a specific time. Animals with certified RFI-EBVs from within North America could be used as long as it can be demonstrated that the estimated breeding values (EBVs) are conducted within breed or genetic strain and the registration certificates accompany the animal to Alberta.

If RFI-EBVs have been calculated by multiplying the phenotypic RFI by the trait inheritability (e.g. 40%) then minimum accuracy values for RFI is set at 60%. If RFI EBVs have been calculated using Best Linear Unbiased Prediction (BLUP) procedures then minimum accuracy for RFI-EBV is set at 40%. The testing procedures at the certified testing facilities must adhere to these accuracy values (i.e. the verifier will need to confirm the accuracy values stated in the paperwork, meet the levels above).

The following facilities are fitted with the GrowSafe System (GrowSafe Systems Ltd., Airdrie, Alberta) for monitoring individual animal feed intake and are aware of the Standard Operating Procedures (Beef Improvement Federation 2009) for measuring individual animal feed intake and for calculating RFI. New facilities could be added to this list as the RFI and GrowSafe technologies are adopted by the beef cattle industry.

Established Alberta RFI Testing Facilities as of October, 2009:

- Morison Feedlot, Airdrie, Alberta;
- Cattleland Feedyards, Strathmore, Alberta;
- Namaka Farms, Strathmore, Alberta;
- Olds College, Olds, Alberta;
- Lacombe Research Centre, Lacombe, Alberta;
- Lethbridge Research Centre, Lethbridge, Alberta;
- Kinsella Ranch, Kinsella, Alberta.

Below is an exert from the Beef Improvement Federation's "General Minimum Guidelines for Recording Individual Feed Intake in Growing Bulls and Steer and Heifer Progeny, Chapter 7 – Feed Intake and Efficiency by D. H. Crews, Jr., G. E. Carstens, J. A. Basarab, R. A. Hill, and M. K. Nielsen available at: http://www.beefimprovement.org/library/06guidelines.pdf.

The Beef Improvement Federation website is available at: http://www.beefimprovement.org.

CHAPTER 7 – FEED INTAKE and EFFICIENCY

D. H. Crews, Jr.[1], G. E. Carstens[2], J. A. Basarab[3], R. A. Hill[4], and M. K. Nielsen[5]

[1] Department of Animal Sciences, Colorado State University, Fort Collins, CO;
[2] Department of Animal Science, Texas A&M University, College Station, TX;
[3] Alberta Agriculture and Food, Lacombe, Alberta, Canada;
[4] Department of Animal and Veterinary Science, University of Idaho, Moscow, ID; and
[5] Department of Animal Science, University of Nebraska, Lincoln, NE

Since the mid 1990's there has been a dramatic increase in the capacity for collection of individual feed intake data on group fed beef cattle, due largely to technological advances in equipment used for collecting intake records. Concurrently, research on the genetic, nutritional, physiological, and economic aspects of feed intake and efficiency has increased. Genetic evaluation programs for feed intake and efficiency are developing, recognizing the economic relevance of cost-stream input traits to genetic improvement in profitability. Amidst these advancements, the phenotypic definition of feed efficiency remains somewhat contentious, although the economic importance of intake as the largest non-fixed cost of beef production is well known. The objective of these guidelines is to recommend procedures for collection of individual feed intake records on young, growing cattle, and on alternative methods for the expression of feed efficiency.

Equipment and Facilities for Intake Measurement

Several types of equipment are currently available to measure individual feed intake. Reliable data can be obtained with the use of Calan gate systems (http://americancalan.com) as well as with newer designs that utilize electronic scales within feed bunks along with radio frequency animal identification (e.g., GrowSafe Systems, Ltd.; http://www.growsafe.com). An important distinction is that research has shown the inadequacy of feed intake data for the purposes of genetic evaluation which is derived from animals fed alone in individual confinement pens. Further, in this chapter, it is assumed that individual feed intake data are indeed measured on individual animals housed in groups, rather than from pen-feeding designs where animal is not the experimental unit for intake. Therefore, feed intake phenotypes which are computed as net feed delivered to an entire pen divided by the number of animals in the pen are not equivalent to individual feed intake records in this chapter.

The increase in capacity for collection of feed intake data has come in two forms. With the advent of electronic hardware and software systems, research facilities have been established across North America to increase their ability to conduct experiments where feed intake is of interest. At the same time, existing performance testing centers have retro-fit their facilities with feed intake measurement capabilities. Because most of the equipment mentioned above is scalable, the recommendations in this chapter have been written to accommodate both types of facilities.

Pre-Test Information

For feed intake records to be suitable for inclusion in genetic evaluation programs, pre-test information on individual animals should be recorded. Individual animal identification (e.g., registration number) should be easily compatible with other databases and unique. For example, breed and parentage (pedigree) information allows for merging feed intake records with larger pedigree and performance databases. Classification data required to assemble appropriate contemporary groups should also be recorded according to the requirements and advice of the genetic evaluation service provider. If tested animals will receive genetic evaluations independent of their larger breed population, additional data will be required. Most NCE systems utilize a minimum of a three generation ancestral pedigree (beginning with animals with data) to compute EPD. Depending on the traits included in genetic evaluation(s), birth and weaning dates and weights and age of dam information to define contemporary groups will also be required. It is recommended that test centers consult with genetic evaluation service providers for these data requirements.

Age on Test

It has been shown that feed intake is related to the age of animals when feeding tests are conducted. Animals entering a feed intake test should have actual birth date recorded so that age at the beginning of the test can be calculated. Weaning data are generally required to be collected before animals reach 260 d of age; the age at which an animal begins a feed intake test should be after weaning but not be less than 240 d. Within a feeding contemporary group, animals should have start of test ages within a 60-d range. Feed intake measurement on test should be completed before an animal reaches 390 d of age.

Pre-Conditioning Period

In order to acclimate to the testing facility, a pre-conditioning or warm-up period of at least 21 d should be incorporated into the test calendar. During this period, animals should adapt to the test facility and the final test diet. Daily individual feed intake records collected during the pre-conditioning period or when animals are consuming transitional diets cannot readily be used in the computation of daily feed intake. Transitional diets are those that differ from the test diet (bulls) or are different from the finishing diet (steers and cull heifers).

Test Period

Research has demonstrated that a minimum of a 70-d test period (following pre-conditioning) is required to accurately compute average daily gain for individual animals. Live weights are recommended to be recorded at equally spaced intervals. In research programs, live weights are often recorded at 2- and 3-week intervals. In central bull test facilities, initial and final weights are regularly estimated as the average of two live weights taken on consecutive days at the beginning and end of the test, respectively. In order to reduce measurement error, serial weighing is likely to result in the most accurate estimates of average daily gain, as long as a minimum of 5-6 weights are recorded at nearly equally spaced intervals over the test period. For a 70-d test, therefore, biweekly weight measurement is recommend, whereas for a 112-d test, recording live weight at 28-d intervals is recommended. Weigh dates must also be recorded to enable the computation of average daily gain (ADG) on test. On test ADG when serial weights are available is computed as the linear slope from the regression of live weight on test day. Linear regressions for individual animals should have R^2 values equal to or greater than 0.95.

Most studies agree that adequate estimates of daily feed intake can be obtained when individual feed intake is recorded for a minimum of 45 d. Tests will likely need to be longer than this minimum in order to accommodate feeding, equipment and computing malfunctions which vary depending on the intake data recording equipment.

The test period should be defined as the final 70 d of a 91-d or longer test. During the test period, animals must be consuming feed at *ad libitum* levels to avoid data bias due to restriction feeding. Wherever possible, daily intake records should be deleted when animals do not have *ad libitum* access to feed. Examples where feeding may be restricted include days when animals are removed from the pen due to maintenance, equipment failure, and sickness, or for collection of related data (e.g., live weights, ultrasound, etc.). Feed intake data recorded on days when animals do not have *ad libitum* access to feed due to feed delivery failures or being absent from the pen should not be used to compute average daily feed intake.

In order to compute start of test, end of test (and days on test), and related metrics, dates of the beginning and end of tests as well as when the pre-conditioning period ended should be recorded. Intake data from days where animals were absent from the pen, or intake data judged to be unusable should be set to missing, or at least corresponding dates indicated so the data can be removed prior to further analyses.

Missing feed intake data may be estimated using a regression approach as suggested by Hebart et al. (2004), however, large (> 5 d) blocks of data cannot be missing at the beginning or end of the test for any animal. If there are some missing data, and usable data includes at least 45 d of intake recording, the missing data need not be replaced or estimated.

Figure A.1: Feed intake test time line by week (Wk), day (Day), and test day (Test d) depicts a typical feed intake data recording test which conforms to the minimum numbers of days required to collect suitable data.

Figure A.1: Feed intake test time line by week (Wk), day (Day), and test day (Test d)

Wk	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Day	0	7	14	21	28	35	42	49	56	63	70	77	84	91
Test d				0	7	14	21	28	35	42	49	56	63	70
LWT[a]	R[e]			Y		Y		Y		Y		Y		Y
RTU[b]				R				R[g]		R[g]				R
PRE[c]	Y[f]	Y	Y											
DMI[d]				Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y

[a] Live weight (LWT) is often recorded in research settings every 2 wks, but could be less frequent with longer tests (minimum of 5 – 6 LWT for suitable ADG computation). LWT should be recorded on equally spaced intervals. Computation of average daily gain (ADG) as the average of LWT recorded on 2 consecutive d at the beginning and end of test is more susceptible to measurement error than from serial weights.

[b] Real time ultrasound (RTU) could be collected at the beginning and end of test, serially, or if only once, at the end of test.

[c] PRE = pre-test warm-up period of 21 d for facility and diet acclimation.
[d] Dry matter intake (DMI) data collection period of at least 70 d ensures a minimum of ~ 50 d of usable data. Archer et al. (1997) and Wang et al. (2006) showed an absolute minimum of 35 – 45 d required to obtain accurate estimates of daily dry matter intake. A minimum of 70 d is required (Archer et al., 1997) to compute accurate estimates of average daily gain.
[e] Recommended time of measurement.
[f] Required measurement.
[g] To coincide with LWT recording, RTU measurements can be taken near the midpoint of the test in test facilities where more than two scans are desired.

Test Diets

Diets utilized in feeding tests will vary quite diversely according to animal type, animal gender, environmental constraints, feed ingredient availability, cost, and management. Therefore, data collection should be implemented such that diets can be adjusted insofar as possible to a common nutritional base. All animals within one test should be fed the same test diet, and the diet should be formulated to provide essential nutrients and sufficient energy to ensure expression of animal differences for both production and intake. The ingredient composition of the diet should be recorded, and the ingredient composition of the diet maintained throughout the test period. Samples of diet ingredients or of the complete diet should be obtained during the test, and subsample(s) sent to a commercial laboratory for complete chemical analysis.

There is a growing number of reports in the scientific literature in which growing test diets are adjusted to a common energy content of 2.4 Mcal ME/(kg DM). Diets used in tests with finishing steers should contain at least 2.9 Mcal ME/(kg DM). That is, statistical adjustment to a constant energy density requires recording of enough chemical composition data on the diet(s) to derive metabolizable energy (ME) in megacalories (Mcal) on a dry matter basis. Average daily intake and functions of intake data should be reported on a dry matter basis. Expression of daily feed intake values on a dry matter basis removes variability in the moisture content across a diversity of diets, and increases the comparability across multiple tests and studies. As-fed measurement of daily feed intake can be recorded as well, but for further data analyses, sufficient information must be supplied to convert feed intake to a dry matter basis (DMI).

Pen Stocking Rates

In tests that utilize electronic feed intake recording equipment, managers should strictly adhere to the manufacturer recommendations on animal density (number of animals per feed bunk) to obtain accurate measurements of feed intake. Optimal animal density may need to be adjusted for the age of cattle, energy density of the test diet, and minimum bunk and pen space required per animal. Researchers are encouraged to consult with their local animal care and use committee for these specifications, whereas commercial testing centers should consult with animal scientists or other knowledgeable professionals to ensure that animal numbers per pen is not excessive. It is important to maintain appropriate pen density to facilitate normal feeding behavior, and accurate measurement of *ad libitum* intake.

Measurement of Body Composition

Research suggests that deposition of fat and muscle are related to feed intake (e.g., Basarab et al., 2003; Schenkel et al., 2004). A growing number of studies and testing centers in North America routinely collect body composition data on animals during feed intake testing using real time ultrasound (RTU). For these data to be valid for national cattle evaluation, ultrasound scanning must be conducted according to guidelines established by the appropriate breed association. For the purposes of calculating residual feed intake which is adjusted for body composition, RTU measurements should be taken at least once during the feed intake test, after the pre-conditioning period. If only one RTU scan will be recorded, it is recommended that this measurement be conducted at the end of the test to ensure phenotypic variability in subcutaneous fat depth. Start of test RTU measurements can be used along with end of test measurements to compute change in fat and muscle over the test period. In more intensive studies, serial RTU measurements can be used to compute deposition curves for both fat and muscle.

Data Auditing

For electronic intake data recording systems, data auditing functions monitor the quality of intake records, and are used to judge the suitability of intake data prior to further analyses. Feed delivered to animals and that recorded by the system as consumed should not differ by more than 5%. Technicians should utilize all data integrity features available on individual feed intake recording systems. Once daily dry matter intake is computed for individual animals, simple correlations among intake (DMI), growth rate (ADG), and live weight (LWT) should be computed. Correlations that are not at least moderate and positive indicate suspect data. Researchers and test managers are encouraged to consult with experts to conduct further data auditing to ensure the highest possible integrity of test data before proceeding with further analyses. Additionally, for tests where residual feed intake (RFI) or other measures of efficiency will be computed, the correlations of such measures with their components should be computed and compared to published values. Means and standard deviations of DMI, ADG, and body weight by contemporary group are also useful as low group variation in weight and(or) ADG may explain low correlations among DMI, ADG, and body weight.

Alternative Measures of Feed Efficiency

The primary objective of these guidelines is to make minimum recommendations for the collection of daily feed (dry matter) intake on individual animals. The use of feed intake to compute various alternative measures of feed efficiency depends heavily on the integrity of the intake data. The definition of alternative feed efficiency measurements and their respective utility is the subject of extensive debate among scientists as well as producers. For example, since the 1960's, more than two dozen alternative feed efficiency calculations have been proposed in the scientific literature.

Probably the most common measure in both the scientific literature and industry is feed conversion ratio. In these guidelines, feed conversion ratio (FCR), and(or) it's inverse (gross efficiency), are not considered synonymous with feed efficiency. To remove ambiguity, alternative measurements of feed efficiency will be referenced by their definition rather than with the uninformative term "feed efficiency".

Table A.1: Alternative measures of feed efficiency and their definitions.

Measurement	Definition[a]
Feed conversion ratio (FCR)	FCR = DMI / ADG
Residual feed intake 1 (RFI1)	RFI1 = DMI – ($\beta_0 + \beta_1 \times$ ADG + $\beta_2 \times$ MWT) = DMI – E(DMI)
Residual feed intake 2 (RFI2)	RFI2 = DMI – ($\beta_0 + \beta_1 \times$ ADG + $\beta_2 \times$ MWT + $\beta_3 \times$ FAT)
Residual feed intake 3 (RFI3)	RFI3 = DMI – ($\beta_0 + \beta_1 \times$ ADG + $\beta_2 \times$ MWT + $\beta_3 \times$ FAT + $\beta_4 \times$ REA)
Partial efficiency of growth (PEG)	ADG / (DMI – E(DMIm))

[a] On-test abbreviations: DMI = daily dry matter intake, ADG = average daily gain, FAT = ultrasound (RTU) subcutaneous fat depth (or RTU FAT deposition rate per d), REA = RTU longissimus muscle area (or RTU REA deposition rate per d), MWT = metabolic mid-test body size = mid-test $LWT^{0.75}$, E(DMIm) = expected daily DMI for maintenance, and E(DMI) = expected daily DMI based on requirements for growth rate and body size.

The list of alternative measures of feed efficiency listed in Table A.1: Alternative measures of feed efficiency and their definitions. is not intended to be exhaustive. Rather, the intent is to define, for reference, the more common measures utilized in both science and industry. The traditional measure defined as FCR is very common to existing bull tests and in the feedlot sector of the industry, however, FCR is undesirable with regard to national cattle evaluation. Similar to the other traits defined as ratios (PEG, KR, RGR), FCR and ratio traits in general are unsuitable for genetic evaluation (e.g., see Gunsett, 1984). In addition, FCR has been shown to have antagonistic genetic correlations with mature size and maintenance requirements. In the case of residual feed intake, several definitions are listed which supports the notion of considering “residualization” as a methodology rather than RFI as a static trait. The difference between actual and expected DMI is the universal albeit vague definition of RFI (Koch et al., 1963), however the implementation of RFI is dependent on the type of data available to compute expected DMI.

A considerable volume of research has been published which includes RFI although no constant definition (e.g., RFI1, RFI2, or RFI3 in Table A.1: Alternative measures of feed efficiency and their definitions.) is used across all studies. An important distinction to note, however, is that current RFI methodology relies on the regression approach to compute expected DMI. In older research, expected DMI was computed using published "tabular" values based on large meta-analyses such as NRC. For the purposes of these guidelines, residual feed intake exclusively refers to the residual term from the regression of DMI on its indicators measured on individual animals.

Summary

Routine collection of feed intake data has become a reality for inclusion in genetic improvement programs, and this collection of data is largely built on electronic technologies. Ample evidence exists for the presence of genetic variation available for selection to increase efficiency of beef production; increases in efficiency can result by reducing feed intake while not altering output or performance, or by increasing output while not increasing feed intake, or by some combination of these. Selection toward improved efficiency will be accomplished by a multiple-trait selection index approach that integrates feed intake with measures of output performance.

This chapter provides guidelines for feed intake testing conditions and recording of data that will be used in genetic evaluation systems. These guidelines are for measurement of young, growing animals, not mature cows. Establishment of contemporary groups, pre-test period, and the test period are outlined. The test period when body weight, gain, and feed intake are recorded has a minimum length of 70 d with valid feed intake for at least 45 d. Test diets of approximately 2.4 Mcal ME/(kg DM) are recommended for bulls, whereas test diets for steers should contain at least 2.9 Mcal ME/(kg DM). True energy values for test diets are expected to be recorded, and feed intake adjusted to a dry matter basis.

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Appendix B:

Statistical Sampling Methodology

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. A 95% confidence interval also supports the requirement of meeting a 5% materiality threshold for verification of the project.

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 (CV) 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

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

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

In other words, we are 95% certain that the actual error will not exceed ±*L* or we are willing to take a 5% 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 (ARD) have tested this method with robust feedlot datasets (over 80,000 head in Alberta). 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 ARD and explained below in the example, the initial sample should contain 30 to 40 pens (i.e. n = 30 or 40 initially) in each of the above animal groupings. The data to be collected include[8]:

- 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

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

    - 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 (CVs) 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% certain that the actual error will not exceed ±*L* or we are willing to take a 5% 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 CV's analyzed for the data outlined in Step 2 above.

The analysis shows that for the key trait of daily dry matter intake the CVs ranged from 4 to 32%.

Next, the required sample size was calculated to find out how many pens would be required to produce a mean or an average that is repeatable 95 times out of 100 or have a 5% error. For all animal groupings, with the exception of the 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%) with a 5% 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% 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: Persons using this method should consult with a statistician before implementing their project.

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Appendix C:

Sample Case Study Calculation

This case study involves an example where it was assumed that four low RFI breeding bulls (mean EBV = -0.5 kg DM/day; accuracy=63%) were purchased and mated to 100 cows. An 86% calf crop was assumed, resulting in 43 slaughter steers, 23 slaughter heifers and 20 replacement heifers. Cow fertility, calf crop weaned and cow culling rates were not affected. Cattle were harvested at 18-months of age and low RFI bulls, slaughter cattle and replacement heifers were followed for a period of three years from when the bulls were purchased.

Defining the Baseline & Project Conditions

Discussed in Section 3 and 4, there are a number of factors and data sets which are required to complete a quantification of emissions reductions. The following is a description of the baseline and project conditions defining this particular case study.

Baseline Condition:
Summarized in Table C-1 below, 43 slaughter steers, 23 slaughter heifers, and 20 replacement heifers, all the progeny of non-RFI breeding bulls and 100 non RFI selected cows progressed through nine (9) diets over a three year period, with a live weight upon completion of the dietary regime of 620.9 kgs for animals earmarked for slaughter.

Project Condition:
The same conditions apply to the project condition with the exception of the daily dry matter intake during the project decreasing as a result of the animals in question all being the progeny of 4 RFI selected breeding bulls and 100 non-RFI selected cows. See Table C-3 for an example data set.

Description of General Steps Required to Calculate Emission Reductions in this Case Study:

STEP 1: Identify categories of cattle affected by the protocol. In this case cattle categories would include slaughter steer and heifer calves, replacement heifers and feed efficient breeding bulls.

STEP 2: Identify the period over which you will be calculating greenhouse gas emissions. In this case we will track the cattle over 3 years from the time the low RFI bulls were purchased and delivered to the farm.

STEP 3: Identify the diet and days on each diet for each cattle category (e.g. Table C-1).

STEP 4: Identify the start weight and the desired rate of gain of each cattle category. This will allow calculation of mid-point weight for the feeding period and calculation of dry matter intake based on IPCC Tier 2 equations, Cowbytes or similar computer programs (e.g., NRC 2001) or from actual historic data (e.g. Table C-1**).**

STEP 5: Calculate the greenhouse gas emissions for each animal category and each diet for enteric fermentation (Table C-1) and manure handling, storage and land application (Table C-2) for the BASELINE condition.

STEP 6: Calculate the greenhouse gas emissions for each animal category and each diet for enteric fermentation (Table C-3) and manure handling, storage and land application (Table C-4) for the PROJECT condition. The dry matter intake (DMI) for the PROJECT condition is estimated from the ***expected percentage reduction in DMI*** of the animal of interest relative to that of the base year animals (% Change), as explained in Section 4.2.1 above.

For the sires measured for RFI:

<u>*Available information*</u>

Average Phenotypic RFI mean for 4 LOW RFI sires	-1.25 kg DM/day
Average Certified RFI_P EBV of 4 sires:	-0.50 kg DM/day
Base Year mean DMI for bulls tested for RFI:	10 kg DM/day (*adjusted to 10 MJ ME/kg DM*)

Percentage change in DMI of LOW RFI sires relative to his test station contemporaries.

Percentage change = (-1.25 kg DM/day x 0.75)/ 10 kg DM/day x 100 = 9.375%. The phenotype relationship between test station performance and performance on-farm or in the feedlot is estimated at 0.75. Therefore we expect this bull to consume 9.375% less feed when returned to the cow-calf ranch or if the estimated BASELINE DMI is 12 kg DM/day, the reduction in DMI for the LOW RFI bulls will be:

Reduction in DMI for Project Bulls = 12 kg DM/day (baseline bull DMI) x (9.375 / 100) = 1.125 kg DM/day

Hence PROJECT DMI for the specified period = 12 – 1.125 = 10.875 kg DM/day.

These values are calculated already and displayed in Tables 6 and 7.

For the steer or heifer progeny

<u>*Available information*</u>

Average Certified RFI_P EBV of 4 sires:	-0.50 kg DM/day
Certified RFI_P EBV of dam:	Not known and set at 0.00
Base Year for bulls tested for RFI Mean DMI:	10 kg DM/day (*adjusted to 10 MJ ME/kg DM*)

<u>*Percentage change in DMI (due to genetic selection) of the bull relative to DMI of base year:*</u>

Assigned RFI_P EBV to steer	= [(Sire RFI_P EBV) + (Dam RFI_P EBV)] / 2
	= [(-0.50) + (0)] / 2
	= -0.25 kg DM/day
Percentage change	= [(RFI_P EBV) / (Base Year mean DMI)] x 100
	= [(-0.25 kg DM/day) / (10 kg DM/day)] x 100
	= -2.5%

Therefore if the estimated BASELINE DMI is 12 kg DM/day, the reduction in DMI due to RFI selection (reduction in DMI) will be:

Reduction in DMI (progeny) = 12 kg DM/day x (2.5 / 100) = 0.3 kg DM/day.

Hence DMI for the PROJECT condition within animal category and diet = 12 – 0.3 = 11.7 kg DM/day.

STEP 7: Calculate the greenhouse gas emissions for all categories of animals and diets, sum these values for methane (CH_4) and nitrous oxide (N_2O) separately and then convert to carbon dioxide equivalents (CO_2e) by multiplying CH_4 by 21 and N_2O by 310 (IPCC global warming potentials).

STEP 8: Subtract total CO_2e for BASELINE condition from PROJECT condition for enteric fermentation and for manure handling, storage and land application.

Tables C-1 to C-4 below show the data and calculation steps. Table C-5 shows the calculated emission reductions for the Project.

Baseline Data and Calculations:

Table C- 1. Greenhouse gas emissions from ENTERIC FERMENTATION for the BASELINE condition

Diet, Location & Date	Days on feed	End Age, mo.	ADG kg/d	Start Wt, kg	End Wt, kg	Mid Wt. kg	TDN %	DMI Kg/d	EF % of GEI	Eq. 1 CH_4lost, g/hd/d	Total CH_4 lost kg/hd
1. Slaughter Steer Calves – birth to slaughter in 18 months; slaughter WT=620.9 kg; carcass WT (620.7x0.96x0.58) = 345.7 kg											
1. Pasture: May-Jul/09	91	3.0	1.07	43.0	140.4	91.7	100.0	1.29	0.00	0.00	0.00
2. Pasture:Aug-Oct/09	92	6.1	1.07	140.4	238.8	189.6	91.0	3.45	6.50	74.35	6.84
3. Pasture:Nov-Jan/10	92	9.2	0.75	238.8	307.8	273.3	63.8	6.80	6.50	146.54	13.48
4. Feedlot:Feb-May 15/10	104	12.6	1.20	307.8	432.6	370.2	70.8	9.11	6.50	196.32	20.42
5. Pasture:May16-Aug 15/10	92	15.7	0.75	432.6	501.6	467.1	63.8	10.16	6.50	218.95	20.14
6. Feedlot:Aug16-Nov 17/10	75	18.2	1.59	501.6	**620.9**	561.2	80.0	12.14	4.00	160.99	12.07
1. Pasture: May-Jul/10;Cyc 2	91	3.0	1.07	43.0	140.4	91.7	100.0	1.29	0.00	0.00	0.00
2. Pasture:Aug-Oct/10;Cyc 2	92	6.1	1.07	140.4	238.8	189.6	91.0	3.45	6.50	74.35	6.84
3. Pasture:Nov-Dec/10;Cyc 2	61	8.2	0.75	238.8	284.6	261.7	63.8	6.80	6.50	146.54	8.94
Sub-Total											88.74
2. Slaughter Heifer Calves – birth to slaughter in 18 months; slaughter WT=620.9 kg; carcass WT (620.7x0.96x0.58) = 345.7 kg											
1. Pasture: May-Jul/09	91	3.0	1.07	43.0	140.4	91.7	100.0	1.29	0.00	0.00	0.00
2. Pasture:Aug-Oct/09	92	6.1	1.07	140.4	238.8	189.6	91.0	3.45	6.50	74.35	6.84
3. Pasture:Nov-Jan/10	92	9.2	0.75	238.8	307.8	273.3	63.8	6.80	6.50	146.54	13.48
4. Feedlot:Feb-May 15/10	104	12.6	1.20	307.8	432.6	370.2	70.8	9.11	6.50	196.32	20.42
5. Pasture:May16-Aug 15/10	92	15.7	0.75	432.6	501.6	467.1	63.8	10.16	6.50	218.95	20.14
6. Feedlot:Aug16-Nov 17/10	75	18.2	1.59	501.6	**620.9**	561.2	80.0	12.14	4.00	160.99	12.07
1. Pasture: May-Jul/10;Cyc 2	91	3.0	1.07	43.0	140.4	91.7	100.0	1.29	0.00	0.00	0.00
2. Pasture:Aug-Oct/10;Cyc 2	92	6.1	1.07	140.4	238.8	189.6	91.0	3.45	6.50	74.35	6.84
3. Pasture:Nov-Dec/10;Cyc 2	61	8.2	0.75	238.8	284.6	261.7	63.8	6.80	6.50	146.54	8.94
Sub-Total											88.74
3. Replacement Heifer Calves											
1. Drylot: Apr-Jun, 09	91	3	1.07	43.0	140.4	91.7	100.0	1.29	0.00	0.00	0.00
2. Pasture: Jul-Sept, 09	92	6	1.07	140.4	238.8	189.6	91.2	3.45	6.50	74.35	6.84
3. Drylot: Oct-Apr, 09/10	212	13	0.70	238.8	387.2	313.0	64.5	7.01	6.50	151.06	32.03
4. Pasture: May-Oct, 10	184	19	0.70	387.2	516.0	451.6	63.8	10.00	6.50	215.50	39.65
5. Drylot: Nov-Dec, 10	61	21	0.50	516.0	546.5	531.2	62.6	10.30	6.50	221.96	13.54
1. Drylot:May-Jul/10;Cycle2	91	3	1.07	43.0	140.4	91.7	100.0	1.29	0.00	0.00	0.00
2. Pasture:Aug-Oct/10;Cyc 2	92	6.1	1.07	140.4	238.8	189.6	91.2	3.45	6.50	74.35	6.84
3 .Drylot:Nov-Dec/10;Cyc 2	61	8.2	0.75	238.8	284.6	261.7	63.8	6.80	6.50	146.54	8.94
Sub-Total											107.84
4. Bulls (27:1 cow to bull ratio)											
1. Drylot; Jan-Apr, 08	120	24	0.50	460	520	490	62.6	11.0	6.50	237.05	28.45

2. Pasture: May-Oct, 08	184	24	0.50	520	612	566	63.8	11.8	6.50	254.29	46.79
1. Drylot: Nov-Dec, 08	61	24	0.50	612	643	627	62.6	13.0	6.50	280.15	17.09
1. Drylot: Jan-Apr, 09	120	24	0.50	643	703	673	62.6	13.6	6.50	293.08	35.17
2. Pasture:May-Oct, 09	184	24	0.50	703	795	749	63.8	14.6	6.50	314.63	57.89
1. Drylot: Nov-Dec, 09	61	24	0.50	795	826	810	62.6	15.7	6.50	338.33	20.64
1. Drylot: Jan-Apr, 10	120	24	0.50	826	886	856	62.6	16.5	6.50	355.57	42.67
2. Pasture: May-Oct, 10	184	24	0.50	886	978	932	63.8	17.2	6.50	370.66	68.20
1. Drylot: Nov-Dec, 10	61	24	0.50	978	1009	993	62.6	18.3	6.50	394.36	24.06
Sub-Total											340.95

Total CO_2e for 4 bulls over 3 years = 4 x 340.95 x 21 = 28639.8 kg
Total CO_2e for 43 slaughter steers over 3 years = 43 x 88.74 x 21 = 80132.2 kg
Total CO_2e for 23 slaughter heifers over 3 years = 23 x 88.74 x 21 = 42861.4 kg
Total CO_2e for 20 replacement heifers over 3 years = 20 x 107.84 x 21= 45292.8 kg

Total CO_2e from enteric fermentation over 3 years for BASELINE conditions 196,926.2 kg or 196.9 t

Diets for slaughter steers and heifers in chronologic order are: 1) 100% milk; 2) 57:43% forage:milk; 3) stockpile pasture; 4) 40% barley, 35% silage, 23% hay, 1% molasses and 1% supplement; 5) pasture; 6) 84.2% barley, 10.5% silage, 3.6% feedlot supplement and 1.6% molasses.
Diets for replacement heifers are: 1) 100% milk; 2) 57:43% forage:milk; 3) 100% barley silage; 4) grass legume pasture and 5) 100% barley silage.
Diets for breeding bulls are: 1) grass hay/TM salt; 2) grass-legume pasture.

Table C- 2. Greenhouse gas emissions from manure handling, storage and land application for the BASELINE condition.

Period Location	Days on feed	Crude Protein %	TDN %	DMI kg/d	Eq. 2 Daily Volatile solids, kg/hd/day	Eq. 3 Manure handling CH_4 kg/hd	Eq. 4 Daily Nitrogen Excreted kg/hd/day	Eq. 5 Manure N_2O Direct kg/hd	Eq. 6 Manure N_2O Storage kg/hd	Eq. 7 Manure N_2O Volatil-ization kg/hd	Eq. 8 Manure N_2O Leaching kg/hd
1. Slaughter Steer Calves – birth to slaughter in 18 months; slaughter WT=620.9 kg; carcass WT (620.7x0.96x0.58) = 345.7 kg											
1. Pasture	91	26.7	100.0	1.29	0.047	0.005	0.051	0.147	0.041	0.015	0.009
2. Pasture	92	19.0	91.0	3.45	0.413	0.048	0.098	0.282	0.079	0.028	0.018
3. Pasture	92	17.1	63.8	6.80	2.515	0.295	0.173	0.500	0.140	0.050	0.031
4. Feedlot	104	11.8	70.8	9.11	2.783	0.737	0.160	0.523	0.146	0.052	0.033
5. Pasture	92	17.1	63.8	10.16	3.758	0.440	0.259	0.747	0.209	0.075	0.047
6. Feedlot	75	13.1	80.0	12.14	2.617	0.500	0.237	0.558	0.156	0.056	0.035
1. Pasture	91	26.7	100.0	1.29	0.047	0.005	0.051	0.147	0.041	0.015	0.009
2. Pasture	92	19.0	91.0	3.45	0.413	0.048	0.098	0.282	0.079	0.028	0.018
3. Pasture	61	17.1	63.8	6.80	2.515	0.195	0.173	0.332	0.093	0.033	0.021
Sub-Total						2.274		3.517	0.985	0.352	0.220
2. Slaughter Heifer Calves – birth to slaughter in 18 months; slaughter WT=620.9 kg; carcass WT (620.7x0.96x0.58) = 345.7 kg											
1. Pasture	91	26.7	100.0	1.29	0.047	0.005	0.051	0.147	0.041	0.015	0.009
2. Pasture	92	19.0	91.0	3.45	0.413	0.048	0.098	0.282	0.079	0.028	0.018

3. Pasture	92	17.1	63.8	6.80	2.515	0.295	0.173	0.500	0.140	0.050	0.031
4. Feedlot	104	11.8	70.8	9.11	2.783	0.737	0.160	0.523	0.146	0.052	0.033
5. Pasture	92	17.1	63.8	10.16	3.758	0.440	0.259	0.747	0.209	0.075	0.047
6. Feedlot	75	13.1	80.0	12.14	2.617	0.500	0.237	0.558	0.156	0.056	0.035
1. Pasture	91	26.7	100.0	1.29	0.047	0.005	0.051	0.147	0.041	0.015	0.009
2. Pasture	92	19.0	91.0	3.45	0.413	0.048	0.098	0.282	0.079	0.028	0.018
3. Pasture	61	17.1	63.8	6.80	2.515	0.195	0.173	0.332	0.093	0.033	0.021
Sub-Total						2.274		3.517	0.985	0.352	0.220
3. Replacement Heifer Calves											
1. Drylot	91	26.7	100.0	1.29	0.025	0.006	0.051	0.147	0.041	0.015	0.009
2. Pasture	92	19.0	91.0	3.45	0.372	0.087	0.098	0.282	0.079	0.028	0.018
3. Drylot	212	11.1	62.6	7.01	2.707	1.461	0.116	0.771	0.216	0.077	0.048
4. Pasture	184	17.1	63.8	10.00	3.744	1.754	0.254	1.471	0.412	0.147	0.092
5. Drylot	61	11.1	62.6	10.30	3.977	0.618	0.169	0.323	0.090	0.032	0.020
1. Drylot	91	26.7	100.0	1.29	0.025	0.006	0.051	0.147	0.041	0.015	0.009
2. Pasture	92	19.0	91.0	3.45	0.372	0.087	0.098	0.282	0.079	0.028	0.018
3 .Drylot	61	11.1	62.6	7.01	2.707	0.420	0.116	0.222	0.062	0.022	0.014
Sub-Total						4.439		3.645	1.021	0.365	0.228
4. Bulls (27:1 cow to bull ratio)											
1. Drylot	120	10.7	62.3	11.00	4.280	1.308	0.175	0.611	0.185	0.066	0.041
2. Pasture	184	17.1	63.8	11.80	4.417	2.069	0.300	1.736	0.486	0.174	0.109
1. Drylot	61	10.7	62.3	13.00	5.058	0.786	0.207	0.397	0.111	0.040	0.025
1. Drylot	120	10.7	62.3	13.60	5.291	1.617	0.217	0.817	0.229	0.082	0.051
2. Pasture	184	17.1	63.8	14.6	5.466	2.560	0.371	2.148	0.602	0.215	0.134
1. Drylot	61	10.7	62.3	15.7	6.108	0.949	0.250	0.479	0.134	0.048	0.030
1. Drylot	120	10.7	62.3	16.5	6.419	1.961	0.263	0.991	0.277	0.099	0.062
2. Pasture	184	17.1	63.8	17.2	6.439	3.016	0.438	2.531	0.709	0.253	0.158
1. Drylot	61	10.7	62.3	18.3	7.120	1.106	0.291	0.559	0.156	0.056	0.035
Sub-Total						15.372		10.318	2.889	1.032	0.645

Total CO_2e for 4 bulls over 3 years = (4 x 15.372 x 21) + (4 x ((10.318 + 2.889 + 1.032 + 0.645) x 310)) = 19747.1 kg

Total CO_2e for 43 slaughter steers over 3 years = (43 x 2.274 x 21) + (43 x ((3.517 + 0.985 + 0.352 + 0.220) x 310)) = 69686.6 kg

Total CO_2e for 23 slaughter heifers over 3 years = (23 x 2.274 x 21) + (23 x ((3.517 + 0.985 + 0.352 + 0.220) x 310)) = 37274.2 kg

Total CO_2e for 20 replacement heifers over 3 years = (20 x 4.439 x 21) + (20 x ((3.645 + 1.021 + 0.365 + 0.228) x 310)) = 34465.7 kg

Total CO_2e from manure handling, storage & land application over 3 years for BASELINE conditions 161,173.6 kg or 161.2 tonne

Table C- 3. Greenhouse gas emissions from ENTERIC FERMENTATION for the PROJECT condition.

Diet, Location & Date	Days on feed	End Age, mo.	ADG kg/d	Start Wt, kg	End Wt, kg	Mid Wt. kg	TDN %	DMI* Kg/d	EF % of GEI	Eq. 1 CH_4 lost, g/hd/d	Total CH_4 lost kg/hd
1. Slaughter Steer Calves – birth to slaughter in 18 months; slaughter WT=620.9 kg; carcass WT (620.7x0.96x0.58) = 345.7 kg											
1. Pasture: May-Jul/09	91	3.0	1.07	43.0	140.4	91.7	100.0	1.26	0.00	0.00	0.00
2. Pasture:Aug-Oct/09	92	6.1	1.07	140.4	238.8	189.6	91.0	3.36	6.50	72.49	6.67
3. Pasture:Nov-Jan/10	92	9.2	0.75	238.8	307.8	273.3	63.8	6.63	6.50	142.88	13.14
4. Feedlot:Feb-May 15/10	104	12.6	1.20	307.8	432.6	370.2	70.8	8.88	6.50	191.41	19.91
5. Pasture:May16-Aug 15/10	92	15.7	0.75	432.6	501.6	467.1	63.8	9.91	6.50	213.47	19.64
6. Feedlot:Aug16-Nov 17/10	75	18.2	1.59	501.6	**620.9**	561.2	80.0	11.84	4.00	156.97	11.77
1. Pasture: May-Jul/10;Cyc 2	91	3.0	1.07	43.0	140.4	91.7	100.0	1.26	0.00	0.00	0.00
2. Pasture:Aug-Oct/10;Cyc 2	92	6.1	1.07	140.4	238.8	189.6	91.0	3.36	6.50	72.49	6.67
3. Pasture:Nov-Dec/10;Cyc 2	61	8.2	0.75	238.8	284.6	261.7	63.8	6.63	6.50	142.88	8.72
Sub-Total											86.52
2. Slaughter Heifer Calves – birth to slaughter in 18 months; slaughter WT=620.9 kg; carcass WT (620.7x0.96x0.58) = 345.7 kg											
1. Pasture: May-Jul/09	91	3.0	1.07	43.0	140.4	91.7	100.0	1.26	0.00	0.00	0.00
2. Pasture:Aug-Oct/09	92	6.1	1.07	140.4	238.8	189.6	91.0	3.36	6.50	72.49	6.67
3. Pasture:Nov-Jan/10	92	9.2	0.75	238.8	307.8	273.3	63.8	6.63	6.50	142.88	13.14
4. Feedlot:Feb-May 15/10	104	12.6	1.20	307.8	432.6	370.2	70.8	8.88	6.50	191.41	19.91
5. Pasture:May16-Aug 15/10	92	15.7	0.75	432.6	501.6	467.1	63.8	9.91	6.50	213.47	19.64
6. Feedlot:Aug16-Nov 17/10	75	18.2	1.59	501.6	**620.9**	561.2	80.0	11.84	4.00	156.97	11.77
1. Pasture: May-Jul/10;Cyc 2	91	3.0	1.07	43.0	140.4	91.7	100.0	1.26	0.00	0.00	0.00
2. Pasture:Aug-Oct/10;Cyc 2	92	6.1	1.07	140.4	238.8	189.6	91.0	3.36	6.50	72.49	6.67
3. Pasture:Nov-Dec/10;Cyc 2	61	8.2	0.75	238.8	284.6	261.7	63.8	6.63	6.50	142.88	8.72
Sub-Total											86.52
3. Replacement Heifer Calves											
1. Drylot: Apr-Jun, 09	91	3	1.07	43.0	140.4	91.7	100.0	1.26	0.00	0.00	0.00
2. Pasture: Jul-Sept, 09	92	6	1.07	140.4	238.8	189.6	91.2	3.36	6.50	72.49	6.67
3. Drylot: Oct-Apr, 09/10	212	13	0.70	238.8	387.2	313.0	64.5	6.83	6.50	147.29	31.23
4. Pasture: May-Oct, 10	184	19	0.70	387.2	516.0	451.6	63.8	9.75	6.50	210.11	38.66
5. Drylot: Nov-Dec, 10	61	21	0.50	516.0	546.5	531.2	62.6	10.04	6.50	216.41	13.20
1. Drylot:May-Jul/10;Cycle2	91	3	1.07	43.0	140.4	91.7	100.0	1.26	0.00	0.00	0.00
2. Pasture:Aug-Oct/10;Cyc 2	92	6.1	1.07	140.4	238.8	189.6	91.2	3.36	6.50	72.49	6.67
3 .Drylot:Nov-Dec/10;Cyc 2	61	8.2	0.75	238.8	284.6	261.7	63.8	6.63	6.50	142.88	8.72
Sub-Total											105.14
4. Bulls (27:1 cow to bull ratio)											
1. Drylot; Jan-Apr, 08	120	24	0.50	460	520	490	62.6	9.97	6.50	214.83	25.78
2. Pasture: May-Oct, 08	184	24	0.50	520	612	566	63.8	10.69	6.50	230.45	42.40

1. Drylot: Nov-Dec, 08	61	24	0.50	612	643	627	62.6	11.78	6.50	253.88	15.49
1. Drylot: Jan-Apr, 09	120	24	0.50	643	703	673	62.6	12.33	6.50	265.60	31.87
2. Pasture:May-Oct, 09	184	24	0.50	703	795	749	63.8	13.23	6.50	285.13	52.46
1. Drylot: Nov-Dec, 09	61	24	0.50	795	826	810	62.6	14.23	6.50	306.61	18.70
1. Drylot: Jan-Apr, 10	120	24	0.50	826	886	856	62.6	14.95	6.50	322.24	38.67
2. Pasture: May-Oct, 10	184	24	0.50	886	978	932	63.8	15.59	6.50	335.91	61.81
1. Drylot: Nov-Dec, 10	61	24	0.50	978	1009	993	62.6	16.58	6.50	357.39	21.80
Sub-Total											308.99
Total CO_2e for 4 bulls over 3 years			= 4 x 308.88 x 21 = 25955.2 kg								
Total CO_2e for 43 slaughter steers over 3 years			= 43 x 86.52 x 21 = 78127.6 kg								
Total CO_2e for 23 slaughter heifers over 3 years			= 23 x 86.52 x 21 = 41789.2 kg								
Total CO_2e for 20 replacement heifers over 3 years			= 20 x 105.14 x 21= 44158.8 kg								
Total CO_2e from enteric fermentation over 3 years for PROJECT conditions							**190,030.7 kg or 190.0 tonnes**				

Diets for slaughter steers and heifers in chronologic order are: 1) 100% milk; 2) 57:43% forage:milk; 3) stockpile pasture; 4) 40% barley, 35% silage, 23% hay, 1% molasses and 1% supplement; 5) pasture; 6) 84.2% barley, 10.5% silage, 3.6% feedlot supplement and 1.6% molasses.
Diets for replacement heifers are: 1) 100% milk; 2) 57:43% forage:milk; 3) 100% barley silage; 4) grass legume pasture and 5) 100% barley silage.
Diets for breeding bulls are: 1) grass hay/TM salt; 2) grass-legume pasture.

***The project DMIs were calculated by taking the Baseline DMIs and adjusting them according to the following formulae:**

- **Reduction in DMI (progeny)** = $DMI_{baseline}$ kg DM/day x (2.5 %/ 100)
- **Reduction in DMI (sires)** = $DMI_{siresbaseline}$ kg DM/day x (9.375 %/ 100)

Note: The data summarized above was compiled through measurement and monitoring practices during the project and baseline condition. Alternatively, the baseline DMIs can be calculated from Cowbytes or similar computer programs, and used in the standard equations to estimate the greenhouse gas production from enteric fermentation and manure production (alternate performance standard approach to baselines).

Table C- 4. Greenhouse gas emissions from manure handling, storage and land application for the PROJECT condition.

Period Location	Days on feed	Crude Protein %	TDN %	DMI kg/d	Eq. 2 Daily Volatile solids, kg/hd/day	Eq. 3 Manure handling CH_4 kg/hd	Eq. 4 Daily Nitrogen Excreted kg/hd/day	Eq. 5 Manure N_2O Direct kg/hd	Eq. 6 Manure N_2O Storage kg/hd	Eq. 7 Manure N_2O Volatil-ization kg/hd	Eq. 8 Manure N_2O Leaching kg/hd
1. Slaughter Steer Calves – birth to slaughter in 18 months; slaughter WT=620.9 kg; carcass WT (620.7x0.96x0.58) = 345.7 kg											
1. Pasture	91	26.7	100.0	1.26	0.046	0.005	0.050	0.143	0.040	0.014	0.009
2. Pasture	92	19.0	91.0	3.36	0.402	0.047	0.095	0.275	0.077	0.027	0.017
3. Pasture	92	17.1	63.8	6.63	2.452	0.287	0.169	0.488	0.137	0.049	0.030
4. Feedlot	104	11.8	70.8	8.88	2.712	0.718	0.156	0.510	0.143	0.051	0.032
5. Pasture	92	17.1	63.8	9.91	3.665	0.429	0.252	0.727	0.204	0.073	0.046
6. Feedlot	75	13.1	80.0	11.84	2.553	0.487	0.231	0.544	0.152	0.054	0.034
1. Pasture	91	26.7	100.0	1.26	0.046	0.005	0.050	0.143	0.040	0.014	0.009
2. Pasture	92	19.0	91.0	3.36	0.402	0.047	0.095	0.275	0.077	0.027	0.017
3. Pasture	61	17.1	63.8	6.63	2.452	0.190	0.169	0.323	0.091	0.032	0.020
Sub-Total						2.217		3.430	0.960	0.343	0.214
2. Slaughter Heifer Calves – birth to slaughter in 18 months; slaughter WT=620.9 kg; carcass WT (620.7x0.96x0.58) = 345.7 kg											
1. Pasture	91	26.7	100.0	1.26	0.046	0.005	0.050	0.143	0.040	0.014	0.009
2. Pasture	92	19.0	91.0	3.36	0.402	0.047	0.095	0.275	0.077	0.027	0.017
3. Pasture	92	17.1	63.8	6.63	2.452	0.287	0.169	0.488	0.137	0.049	0.030
4. Feedlot	104	11.8	70.8	8.88	2.712	0.718	0.156	0.510	0.143	0.051	0.032
5. Pasture	92	17.1	63.8	9.91	3.665	0.429	0.252	0.727	0.204	0.073	0.046
6. Feedlot	75	13.1	80.0	11.84	2.553	0.487	0.231	0.544	0.152	0.054	0.034
1. Pasture	91	26.7	100.0	1.26	0.046	0.005	0.050	0.143	0.040	0.014	0.009
2. Pasture	92	19.0	91.0	3.36	0.402	0.047	0.095	0.275	0.077	0.027	0.017
3. Pasture	61	17.1	63.8	6.63	2.452	0.190	0.169	0.323	0.091	0.032	0.020
Sub-Total						2.217		3.430	0.960	0.343	0.214
3. Replacement Heifer Calves											
1. Drylot	91	26.7	100.0	1.26	0.025	0.006	0.050	0.143	0.040	0.014	0.009
2. Pasture	92	19.0	91.0	3.36	0.362	0.085	0.095	0.275	0.077	0.027	0.017
3. Drylot	212	11.1	62.6	6.83	2.637	1.423	0.113	0.752	0.210	0.075	0.047
4. Pasture	184	17.1	63.8	9.75	3.650	1.710	0.248	1.435	0.402	0.143	0.090
5. Drylot	61	11.1	62.6	10.04	3.877	0.602	0.164	0.315	0.088	0.032	0.020
1. Drylot	91	26.7	100.0	1.26	0.025	0.006	0.050	0.143	0.040	0.014	0.009
2. Pasture	92	19.0	91.0	3.36	0.362	0.085	0.095	0.275	0.077	0.027	0.017
3 .Drylot	61	11.1	62.6	6.63	2.637	0.410	0.113	0.216	0.061	0.022	0.014
Sub-Total						4.326		3.553	0.995	0.355	0.222

4. Bulls (27:1 cow to bull ratio)

1. Drylot	120	10.7	62.3	9.97	3.850	1.176	0.159	0.599	0.168	0.060	0.037
2. Pasture	184	17.1	63.8	10.69	4.002	1.875	0.272	1.573	0.440	0.157	0.098
1. Drylot	61	10.7	62.3	11.78	4.548	0.706	0.188	0.360	0.101	0.036	0.022
1. Drylot	120	10.7	62.3	12.33	4.761	1.455	0.196	0.740	0.207	0.074	0.046
2. Pasture	184	17.1	63.8	13.23	4.953	2.320	0.337	1.947	0.545	0.195	0.122
1. Drylot	61	10.7	62.3	14.23	5.494	0.853	0.227	0.434	0.122	0.043	0.027
1. Drylot	120	10.7	62.3	14.95	5.772	1.764	0.238	0.898	0.251	0.090	0.056
2. Pasture	184	17.1	63.8	15.59	5.836	2.734	0.397	2.294	0.642	0.229	0.143
1. Drylot	61	10.7	62.3	16.58	6.402	0.994	0.264	0.506	0.142	0.051	0.032
Sub-Total						13.877		9.350	2.618	0.935	0.584

Total CO_2e for 4 bulls over 3 years = (4 x 13.877 x 21) + (4 x ((9.350 + 2.618 + 0.935 + 0.584) x 310)) = 17890.8 kg

Total CO_2e for 43 slaughter steers over 3 years = (43 x 2.217 x 21) + (43 x ((3.430 + 0.960 + 0.343 + 0.214) x 310)) = 67948.6 kg

Total CO_2e for 23 slaughter heifers over 3 years = (23 x 2.217 x 21) + (23 x ((3.430 + 0.960 + 0.343 + 0.214) x 310)) = 36344.6 kg

Total CO_2e for 20 replacement heifers over 3 years = (20 x 4.326 x 21) + (20 x ((3.553 + 0.995 + 0.355 + 0.222) x 310)) = 33595.8 kg

Total CO_2e from manure handling, storage & land application over 3 years for PROJECT conditions 155,779.8 kg or 155.8 tonne

Final Calculation of Greenhouse Gas Reductions (Baseline – Project):

Table C- 5.	**Steers**	**Heifers**	**Replacement heifers**	**Bulls**	**Total**	**Total**	**Offsets**
<u>BASELINE</u>	**kg CO_2e/hd in 3-yr**	**kg CO_2e/hd in 3-yr**	**kg CO_2e/hd in 3-yr**	**kg CO_2e/hd in 3-yr**	**kg CO_2e in 3-yr**	**t CO_2e in 3-yr**	**t CO_2e in 3-yr**
<u>Number of animals</u>	**43**	**23**	**20**	**4**			
Enteric fermentation	1863.54	1863.54	2264.64	7159.95	196926.20	196.93	
Methane manure handling	47.75	47.75	93.22	322.81	6307.14	6.31	
N_2O manure direct	1090.27	1090.27	1129.95	3198.58	107351.14	107.35	
N_2O direct manure storage	305.35	305.35	316.51	895.59	30065.66	30.07	
N_2O volatilization	109.12	109.12	113.15	319.92	10744.60	10.74	
N_2O leaching	68.20	68.20	70.68	199.95	6714.60	6.71	
Total CO_2e in 3 years, kg	3484.23	3484.23	3988.15	12096.80	358109.38	358.11	
PROJECT							
<u>Number of animals</u>	43.00	23.00	20	4			
Enteric fermentation	1816.92	1816.92	2207.94	6488.79	190030.68	190.03	
Methane manure handling	46.56	46.56	90.85	291.42	6055.64	6.06	
N_2O manure direct	1063.30	1063.30	1101.43	2898.50	103800.40	103.80	
N_2O direct manure storage	297.60	297.60	308.45	811.58	29056.92	29.06	
N_2O volatilization	106.33	106.33	110.05	289.85	10378.18	10.38nd exampleud	

						e the	
N_2O leaching	66.34	66.34	68.82	181.04	6479.00	6.48	
Total CO_2e in 3 years, kg	3397.05	3397.05	3887.54	10961.18	345800.82	345.80	**12.31**

Appendix D:

Typical Feeding Regimes and Stages of Cattle over the Lifespan of the Cattle

The feeding regimes described below are general diet classes based on a typical range of diets fed to animal.groupings in Alberta. They have been aggregated from the various typical diet components of cattle fed in Alberta and are shown here to help the project developer in inferring days spent on each feeding regime. Table A1 and the accompanying information serves as guidance and there will be slight variations across beef cattle operations in Alberta. But, because these are typical of the majority of operations in Alberta, they are considered representative of the stages of feeding during a beef animal's lifespan.

Flexibility is given in Section 1.3 for calculating dry matter intake (e.g. crude protein, total digestible nutrients) for some animal.groupings. If this information is not available for the cow-calf stage, grazing stages or backgrounding stages of the cattle, it may be estimated using IPCC 2006 Table 10.3; National Research Council (1996) or use Cowbytes ration formulation software v. 4.6.8 to calculate the dry matter intake of cows (drylot, pasture) based on the animal category. This will require data regarding animal type (e.g. lactating cow, pregnant cow, dry cow, etc), animal gain and animal weight. The next sections give representative examples of the kinds of animals and their feeding regimes at each stage/grouping. If using the representative groupings below, and the above sources for Dry Matter Intake and diet information, the results need to be signed off by a professional with relevant experience in the area (e.g. a D.V.M or Professional Agrologist).

For fall and yearling calves, groupings and feeding regimes can be designated according to the example given in Table D.1 below. Project Developers will need to refer to Cowbytes for feed ingredients, and either Cowbytes or other models mentioned in Section 1.3 for calculating dry matter intake values for cow-calf and backgrounding animals. Beef cows, bulls and replacement heifer information is given below Table D.1.

Table D.1: Typical Feeding Regimes for Fall and Yearling Calves in Alberta

Feeding Regime [1]	Age at Harvest (months)			
	12	**14**	**18**	**21**
	Typical Duration of Days on Feed for Animals			
1. 100% Milk- baby calf suckling cow, days	91	91	91	91
2. Forage:milk – suckling calf on pasture with cow, days	31	92	92	92
3. Backgrounding on pasture and/or drylot - high roughage diet (e.g., 100% barley silage on a DM basis), days	0	0	212	212
4. Backgrounding on tame and/or native pasture, days	0	0	0	153
5. Step-up diet[2] to final finishing diet, days	31	31	0	0
6. Finishing in a feedlot (≥85% concentrate diet on a DM basis), days	212	212	153	92

[1] DM represents dry matter basis

[2] Step-up diets - typically start at a high roughage level and moves to the finishing diets over a 30-60 day period (DM basis), – where a high grain level is finally incorporated (≥85% concentrate)

Beef Cows: Typical Feeding Regimes:

1. June 1 to Oct 1 (120 days), grazing fresh forage on pasture

2. Oct 1 to Nov 30 (61 days), fall stockpile pastures; hay or swath grazing annuals or perennials if pastures limiting or snow on the ground.

3. Dec 1 to May 31 (184 days), feeding in more confined area; moderate quality hay or barley silage-straw diets; 10-20% barley grain (dry matter basis) may be added to diet during severe weather events and during the last 60 days before and after calving to meet the added nutritional requirements due to fetal growth and lactation.

Bulls: Typical Feeding Regimes:

1. June 1 to Oct 1 (120 days), grazing fresh forage on pasture

2. Oct 1 to Nov 30 (61 days), fall stockpile pastures; hay or barley/grass silage.

3. Dec 1 to May 31 (184 days), feeding in more confined area; moderate quality hay or barley silage-straw diets; 10-20% barley grain (dry matter basis) may be added to diet during severe weather events and 60-90 days before the breeding season.

Replacement Heifers: Typical Feeding Regimes:

1. June 1 to Oct 1 (120 days), grazing fresh forage on pasture

2. Oct 1 to Nov 30 (61 days), fall stockpile pastures; good quality hay or barley/grass silage.

3. Dec 1 to May 31 (184 days), feeding in more confined area; good quality hay or barley silage and 15-25% barley grain (dry matter basis).

Appendix E:

Additional Information on Project Documentation and Records

A number of records and data points are required to justify a greenhouse gas emissions assertion for the purposes of verification and registration of selecting for low residual feed intake cattle reduction projects on the Alberta Emissions Offsets Registry. Various sources of evidence have differing inherent levels of reliability. The Alberta Offset System requires a reasonable level of assurance, i.e. positive proof that supports the greenhouse gas assertion (as opposed to negative deduction at a limited level of assurance) in order for activities to be creditable. Evidence must be sufficient, reliable, relevant and useful in order for the verifier to form an opinion and support his/her findings and conclusions.

Table E.1 outlines in a generic sense, the types of evidence (Tier 1 being strongest) and some examples of the kinds of evidence that would support or not support reasonable assurance.

Table E.1: Sources of Evidence and Relative Strength in Offset Projects

Evidence Strength	Sources	Characteristics	Examples	Assurance Level
Strongest **Tier 1**	Third party documentation given by third party to the verifier.	External evidence is more reliable than internal evidence.	Google Earth accessed directly by verifier, OR Sign off by a third party professional with relevant experience (e.g. D.V.M or Agrologist).	Supports Reasonable Assurance
Tier 2	Third party documentation given by project developer to the verifier.	Written responses received directly by the verifier from third parties normally provide evidence that is more reliable than that provided by other sources.	Confirmation of harvest from the processing plant for beef cattle, OR Land title certificates OR Sign off by an internal third party professional as per above (e.g may be in employ of the Aggregator/Project Developer)	Supports Reasonable Assurance
Tier 3	Internally generated documentation by the project developer with corroborating information.	Corroborating information obtained from a source independent of the entity may increase the assurance the verifier obtains	Farm records which show farming practices **backed up** by farm inspections.	Supports Reasonable Assurance

Evidence Strength	Sources	Characteristics	Examples	Assurance Level
		from evidence that is generated internally.		
Insufficient as stand-alone (corroborating)	Internally generated documentation by the project developer without corroborating information.	Corroborating information obtained from a source independent of the entity may increase the assurance the verifier obtains from evidence that is generated internally.	Farm records which show farming practices.	**Does not s**upport Reasonable Assurance unless other corroborating information is collected.
Insufficient as stand-alone (corroborating) **Weakest**	Affirmation	Documentary evidence is more reliable than oral evidence.	Farmer affirmation on farming practices.	**Does not** support Reasonable Assurance unless other corroborating information is collected.

Justification for greenhouse gas assertions must be supported by evidence. It is recommended that **strong** evidence be collected in as many cases as possible. Other forms of evidence may support verification, however, subsequent audits initiated by Alberta Environment may require the collection and presentation of corroborating data points to justify assertions of emission reductions.

In all cases, affirmations from land owners or farmers are considered **insufficient** evidence and are not accepted by Alberta Environment and Water as evidence that an activity or practice took place.