Quantification Protocol for Emissions Reductions From Dairy Cattle

Version 2.0

February 2014

Specified Gas Emitters Regulation

Government of Alberta

Alberta

Disclaimer:
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 prevails.

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

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

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SUMMARY OF CHANGES

Below is a summary of key changes from the Quantification Protocol for Emission Reductions from Dairy Cattle (V1.0).

- This protocol has been adapted to the new Alberta Environment and Sustainable Resource Development quantification protocol format. This includes expanded evidence records and data management requirements that all project developers must adhere to. Records are discussed in Table 8, Section 5 of this protocol.
- The application of a basic and advanced approach to greenhouse gas quantification has been removed from the protocol. Instead manure based methane emissions can be quantified by two approaches, either annually or monthly depending on data availability.
- Heifers can now be excluded from the quantification, if the project developer can demonstrate that the project heifer inventory did not increase by more than 2.5% on average over the baseline numbers in any given year.
- Additional information on supporting documentation to substantiate data points required in the protocol has been added to help clarify data management.
- The quantification approach for nitrogen has been modified using IPCC factors to eliminate the need for animal weights.
- The pasture emission section has been removed as they are not expected to change from baseline to project.
- An example on ration fat inclusion has been added as an appendix (Appendix A)
- To Be Completed For Final Version

1 Offset Project Description

In Canada, emissions from dairy activities have been estimated to be approximately 0.91 kg of carbon dioxide equivalent (CO_2e) per kg of milk produced (Dyer et al., 2007). That's equal to almost 640 tonnes of CO_2e from total milk production in Alberta in 2011. Greenhouse gas (GHG) emission reductions from this sector are not regulated under the Specified Gas Emitters Regulation, providing the sector with an opportunity to generate offset credits for voluntary greenhouse gas emission reductions from a variety of activities including improved manure management practices, improved feed quality, reduced replacement herd and increased milk production (since higher milk yields generally decrease GHG emissions per kg of milk produced).

The protocol specifically quantifies GHG emission reductions from the following activities:

- An increase in annual milk productivity per cow will result in reduced GHG emissions per unit of milk produced from all sources and sinks.
- Diet is modified to reduce the proportion of gross energy intake (GEI_G) converted to methane (Ym)
- Fewer heifers are retained as replacements to reduce emissions derived from replacement animals
- Timing of manure spreading is modified to reduce methane emissions from the storage unit

These activities are meant to result in emission reductions of carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O).

This quantification protocol is written for project developers and dairy farm operators implementing dairy farm offset projects in Alberta. Familiarity with and general understanding of dairy farm practices is required.

1.1 Protocol Scope

This protocol uses a historic baseline approach to quantify GHG emission reductions resulting from changes in activities of dairy farm operations.

The scope of the protocol encompasses the animals, buildings, and land which constitute the biophysical system of a dairy farm. However, because of the complexity of the system, and because of on-going development of other GHG quantification protocols in Canada, some aspects of the animal/building/land system are simplified or excluded.

All projects are required to take place on Alberta dairy farms.

For the purpose of this protocol, a "dairy farm" is described as any farm which produces milk for eventual retail sale. For this protocol, a "dairy farm" may conduct other farming practices such as beef or veal farming, while maintaining its status as a "dairy farm" provided that it continues to produce milk for retail sale.

In all cases, the project developer (e.g. dairy farmer) must demonstrate through documentation and records and the metrics employed in this protocol that dairy farm operations in the project condition are showing a decreased carbon intensity (amount of GHG emissions/unit of fat corrected milk (FCM)) than the cattle in the baseline condition. This protocol outlines the necessary measurement and monitoring parameters needed to quantify the resulting emission reductions.

This protocol also contains a flexibility mechanism to quantify emissions reductions from dairy farm activities. More information on this flexibility mechanism is provided in Section 1.3.

Baseline Condition

A baseline condition is a reference case against which the performance of an offset project is measured. The baseline condition for this protocol defines what was happening before the dairy farm implemented improvements in manure management, diet modifications, and other management strategies; that is, the baseline represents the normal business operations of the dairy farm. This protocol requires a 3-year project-specific historic baseline (static historic approach).

This baseline is thus established at the individual farm level, based on farm data and records from the previous three (3) years before project implementation. Farm operators must be able to provide, or obtain from relevant third parties, data such as animal inventories, feed quality and quantity, milk production, and manure spreading activities to calculate their baseline emissions per unit of fat corrected milk.

More information on the baseline quantification is available in Section 4.

Project Condition for Reducing Greenhouse Gas Emissions of Dairy Farms

Generically, the project condition is defined as an action targeted at reducing, removing or storing GHG emissions at a project. Specific to this protocol, the project condition is defined as the implementation of improved feed quality, manure management, and replacement herd management. Compared to its baseline condition, these practices must be new to the dairy farm operation. A variety of project activities may be undertaken at the farm-level to reduce GHG emissions – descriptions of typical project strategies are presented in Table 1 below.

Table 1 - Detailed Description of Typical Project Activities

Description of Project Activities	
1	Annual milk productivity per cow is increased, thus reducing greenhouse gas emissions per unit of milk produced from all sources and sinks.
2	Diet is modified to reduce the proportion of gross energy converted to methane (Y_m)
3	Fewer heifers are retained as replacements to reduce emissions derived from replacement animals
4	Timing of manure spreading is modified to reduce methane emissions from the storage unit

The potential project activities are explained further in Section 3 and the project quantification is discussed in Section 4.

Table 2 provides a list of applicable Greenhouse Gases for this activity.

Table 2 - Relevant Greenhouse Gases Applicable for Dairy Farms in Alberta

Specified Gas	Formula	100-year GWP*	Applicable to Project
Carbon Dioxide	CO_2	1	Yes
Methane	CH_4	21 [25]	Yes
Nitrous Oxide	N_2O	310 [298]	Yes

*Global Warming Potential (GWP) is a measure of a greenhouse gas's relative warming effect on Earth's atmosphere compared to carbon dioxide, expressed as a 100-year average.

1.2 Protocol Applicability

This protocol is applicable to any dairy farm in Alberta where sufficient records are available to justify the emission reductions being claimed.

This protocol relies on the proper documentation of field practices and requires that data, farm records and similar direct evidence of practices are retained by the farm operators, advisors (if applicable), third parties, and project developers; and be made available to the third party verifier and government auditor upon request. See Section 5.2 for documentation requirements for dairy cattle projects.

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

1. The animal groupings/herd components on the dairy farm (lactating herd, heifer herd components, bulls, calves, dry cows, etc.) used for the quantification of emissions must be shown to be similar between the baseline and project conditions.

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

3. The calculations of GHG emission reductions of the project is based on actual measurement, monitoring and acceptable estimations as indicated by the proper application of this protocol;

4. Ownership of the offset credits are established as outlined in Section 5 of this protocol; and,

5. The project meets the eligibility criteria stated in Section 7 of the *Specified Gas Emitters Regulation*. In order to qualify, emissions reductions must:
   a. Occur in Alberta;
   b. Result from actions not otherwise required by law;
   c. Result from actions taken on or after January 1, 2002;
   d. Be real, demonstrable, and quantifiable;
   e. Have clearly established ownership including, if applicable, appropriate, documented transfers of ownership from the land owner to land lessee;
   f. Be counted once for compliance; and
   g. Be implemented according to ministerial guidelines.

In addition, a professional nutritionist is required to document feed rations provided to the herd in a verifiable manner. That is, dated and serialized feed rations for each herd relevant to the project must be available. Refer to Section 5.1 of the protocol for a more detailed description of the role of the Professional Nutritionist.

The general data requirements for this protocol are shown in Table 3. Additional details are provided in Sections 4.0 and 5.0.

Table 3 - General Overview of Data Requirements to Justify the Baseline and Project Conditions

Data Requirements:	**Type of Data Required:**	**Why the Data are Needed:**
Characterization of the average number of animals in each grouping/herd used in the quantification, and average daily dry matter intake for each animal	Documented records of: • Average number of animals in each grouping/herd; • Average date of entry and exit; and • Average daily dry matter intake of animals in each grouping/herd.	To support calculation of the offset claim and for third party verification. The verifier will need evidence of the number of animals and dry matter intake for the baseline and project conditions.
Documented proof of: • What was being fed to the cattle per animal grouping/herd; • Average days on feed for each diet; and • Diet composition feed additives,	Records include: • Feed purchase receipts or scale tickets, weights, etc.; • Feed delivery records; • Diet formulations signed off by a Doctor of Veterinary Medicine or Professional Agrologist, identifying the diet including diet ingredients;	To support calculation of the offset claim and for third party verification. The verifier will need evidence of diets and total mixed diets fed to each animal for the baseline and project conditions.

Table 3 - General Overview of Data Requirements to Justify the Baseline and Project Conditions		
Data Requirements:	**Type of Data Required:**	**Why the Data are Needed:**
management strategies or technologies employed for those groupings/herd.	• Listed diet ingredients including dry matter content, total digestible nutrients, neutral detergent fibre, crude protein content, fat content and level of concentrates in the diet; and • Proof the diet was fed to the animals as indicated by internal record keeping systems and/or third party files.	
Daily milk production, fat content and protein content of milk.	• Documented records of daily milk production and fat content from: o Provincial milk board Records	To support calculation of the offset claim and for third party verification. The verifier will need evidence of milk quantity and quality.
Manure Management: • Type of manure management system applied to each grouping/herd component quantified (i.e. liquid, solid, and/or pasture); • Amount and timing of volatile solids added to the liquid and/or solid manure storage pit; • Amount and timing of volatile solids removed from the liquid and/or solid manure storage pit; and	Farm Description of the Following: • The volume of manure in the storage unit at the beginning of the baseline; • Scale drawings of top view and cross-section of storage; indicating lines to 10% and 100% fill capacity levels; • Estimated capacity at 100% fill from the Development Permit or NRCB Approval Permit on file; and • Date stamped photos showing the amount of manure remaining in the storage facility after each emptying and spreading events.	To support calculation of the offset claim and for third party verification. The verifier will need evidence of the volume and management of manure in the baseline and project condition.

Table 3 - General Overview of Data Requirements to Justify the Baseline and Project Conditions		
Data Requirements:	**Type of Data Required:**	**Why the Data are Needed:**
• Amount and timing of manure spreading on fields if applicable.		
Legal land location of the dairy operation(s)	• Legal land description for the registration of the project.	Registration of the project on the Alberta Emissions Offset Registry.

This protocol allows for the aggregation of individual farms into one project with the following conditions:

- A description of each participating farm must be provided enabling its identification. The description should include an overview of the farm operations that defines the animal groupings/herd components included on the farm.
- Each farm included in the project must be able to provide the relevant documentation to substantiate the GHG emission reductions claimed through a third party verification.
- Calculations of GHG emission reductions must be performed on each individual farm, and then aggregated in one (1) project claim.

A complete list of data requirements is provided and defined in Section 5 of this protocol.

Other emission reduction opportunities may be applicable to dairy operations in Alberta. These opportunities are summarized in Table 4.

Table 4 - Complementary Agricultural Protocols

Activity	**Protocol**
Use of anaerobic digesters to handle cattle manure	Quantification Protocol for Anaerobic Decomposition of Agricultural Materials
Process change and retrofit of facilities to result in overall efficiencies in energy use per unit of productivity.	Quantification Protocol for Energy Efficiency Projects

A full list of approved quantification protocols available for use in the Alberta Offset System is available at http://environment.alberta.ca/02275.html.

1.3 Protocol Flexibility

1. The project developer can conservatively exclude quantifying emissions from heifer animal groupings/herd components on a given farm, if the project developer

can demonstrate that the project heifer inventory did not increase by more than 2.5% on average from the baseline numbers in any given year. Sufficient records documenting this flexibility option must be available, and signed off by a professional nutritionist, proving the monthly number of heifers on the farm for baseline and project years stayed within this variance.

2. Emissions from bulls and/or calves may be deemed negligible provided the project developer can demonstrate emissions from bulls and calves in the project and baseline conditions are less than 5% of total emissions. IPCC Tier 1 emission factors can be used to justify this exclusion (IPCC 2006).

1.4 Glossary of New Terms

Acid Detergent Fiber (ADF) The fibrous, least-digestible portion of roughage. ADF consists of the highly indigestible parts of the forage, including lignin, cellulose, silica and insoluble forms of nitrogen. Roughages high in ADF are lower in digestible energy than roughages that contain low levels of ADF. As ADF levels increase, digestible energy levels decrease.†

Animal Groupings/ Herd Component Specific groupings of animals based on age and/or feed rations. Groupings may be classified according to calf-fed, gender (heifer, steers, bulls), weight or nutritional requirements.

Concentrates A broad classification of feedstuffs which are high in energy and low in crude fiber (<18 per cent Crude Fiber). This can include grains and protein supplements, but excludes feedstuffs like hay or silage or other roughage.†

Dry Cows Cows that are not producing milk (not lactating).

Dry Matter Total weight of feed minus the weight of water in the feed, expressed as a percentage. May also be referred to as: dry, dry basis, dry result, or moisture-free basis. You can convert from As-fed basis or dry matter (DM) basis by using the following formulas: DM basis (kg) = As -fed (kg) x (DM%/100) or As-fed basis (kg) = DM (kg)/(DM %/100).

Dry Matter Intake (DMI)	All the nutrients contained in the dry portion of the feed consumed by animals.†
Edible Oils	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
Fat Corrected Milk (FCM)	Quantity of milk, normalized to a common energy basis. For this protocol, the milk quantity is corrected to 3.7 per cent fat. And, the equation is: kg 3.7% FCM = (kg milk production) * (3.7 / actual fat %).
Forage	High fiber feed, produced from grasses and legumes. Examples of forages include hay, pasture or silage. Forage is often referred to as roughages.
Gestation	The carrying of an embryo or fetus.
Gross Energy	The total energy contained in feed; measured by calorimetry.
Hay	Dried forage used for feed.
Heifer	A young, female cow that has not given birth to a calf.

Ionophores	Antimicrobial compounds fed to animals to improve feed efficiency.
Lactation/Lactating	Process of producing and/or secreting milk.
Liquid Manure	Manure with water added to it during the collection, storage, or treatment process.
Methane (CH_4)	A greenhouse gas with a global warming potential (GWP) of 25
Neutral Detergent Fiber (NDF)	Commonly called "cell walls." NDF give a close estimate of fiber constituents of feedstuffs as they measures cellulose, hemi-cellulose, lignin, silica, tannins and cutins. Neutral detergent fiber has been shown to be negatively correlated with dry matter intake. As the NDF in forages increases, animals will be able to consume less forage. NDF is used in formulas to predict the dry matter intake of cattle†
Nitrous Oxide (N_2O)	A greenhouse gas with a GWP of 298.
Professional Nutritionist	Professional nutritionists provide advice concerning the formulation of rations for dairy cows. To be considered a professional nutritionist for the purpose of the protocol, this advisor will demonstrate credentials from an accepted professional body. Specifically, they must be a member in good standing with the Alberta Veterinary Medical Association, or the Alberta Institute of Agrologists. A professional nutritionist is a professional in the area of livestock health and nutrition who has an M.Sc. or Ph.D. in the relevant discipline.

Protein	Complex compounds containing carbon, hydrogen, oxygen, nitrogen and usually sulphur - composed of one or more chains of amino acids. Proteins are essential in the diet of animals for growth, lactation and reproduction. In ruminants (for example, cattle), the rumen microbes break down about 80 per cent of the protein in the feed to ammonia, carbon dioxide, volatile fatty acids and other carbon compounds. The microbes then use the ammonia to synthesize their own body protein. As feed is passed through the rumen into the rest of the digestive tract, the micro-organisms containing about 65 per cent of the high quality protein are washed along too. The ruminant obtains most of its required protein by digesting these micro-organisms.†
Quota	The quantity of milk a dairy farmer is permitted to sell.
Replacement Heifers	Young cattle (calves, heifers, bulls) raised on a farm to replace milk cows removed from the herd.
Sign-Off Statement	This formal document, with signature of the professional nutritionist, is required in some instances in the protocol to serve as evidence concerning data quality or practice change. This dated and signed document attests to (1) to the accuracy of data regarding animal inventory, diet composition, feed quality, feed consumption, etc., or, (2) to the correctness of implementation of greenhouse gas reduction practices.
Silage	High-moisture fodder that is compressed and fermented (used as feed).
Solid Manure	Manure that has not undergone any treatment process involving the addition of water.
Total Mixed Ration (TMR)	Consists of all the feed ingredients — concentrates, forage, minerals and vitamins — mixed together to form the ration allowance for the animal†.

All definitions marked with the symbol † are from "Alberta Agriculture and Rural Development".

2 Baseline Condition

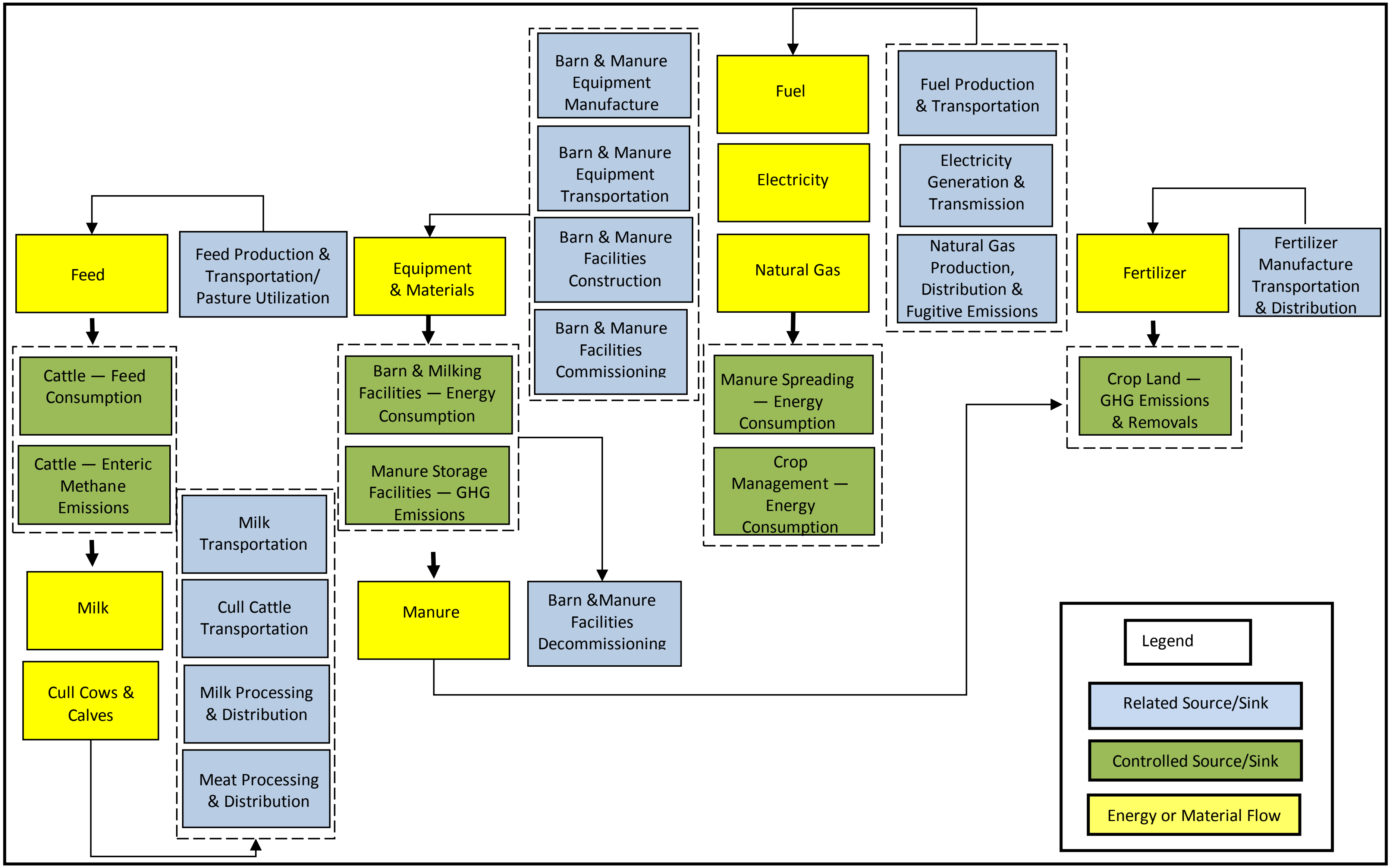
A baseline condition is a reference case against which the performance of a project is measured. This protocol uses a **static historic benchmark** baseline condition. This approach requires the calculation of a baseline for each farm participating in the project for the 3-year period prior to the project start date. Thus, each participating farm will use its own data (animal inventory, feed quality, feed quantity, milk production, manure spreading) to calculate baseline emissions per unit of milk on a fat corrected basis. The method to calculate GHG emissions per unit of milk is described in Section 4.1.

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. The full process flow diagram is presented in Figure 1

Production Equivalency

The baseline condition identified for the projects eligible under this quantification protocol may require adjustments to ensure consistency with the project. These adjustments are usually performed when the emission reductions for the project are calculated, where the milk production of the baseline is adjusted to reflect the milk production of the project. In many cases, the quantification and claims of greenhouse gas emission reductions will occur on a yearly basis, therefore these adjustments will need to be performed according to that same schedule.

Figure 1 - Process Flow Diagram for the Baseline Condition



2.1 Identification of Baseline Sources and Sinks

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

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

Based on the process flow diagram provided above, the baseline sources and/or sinks were organized into life cycle categories in Figure 2. Descriptions of each of the sources/sinks and their classification as controlled, related or affected are provided in Table 5.

Figure 2 - Baseline Condition Sources and Sinks

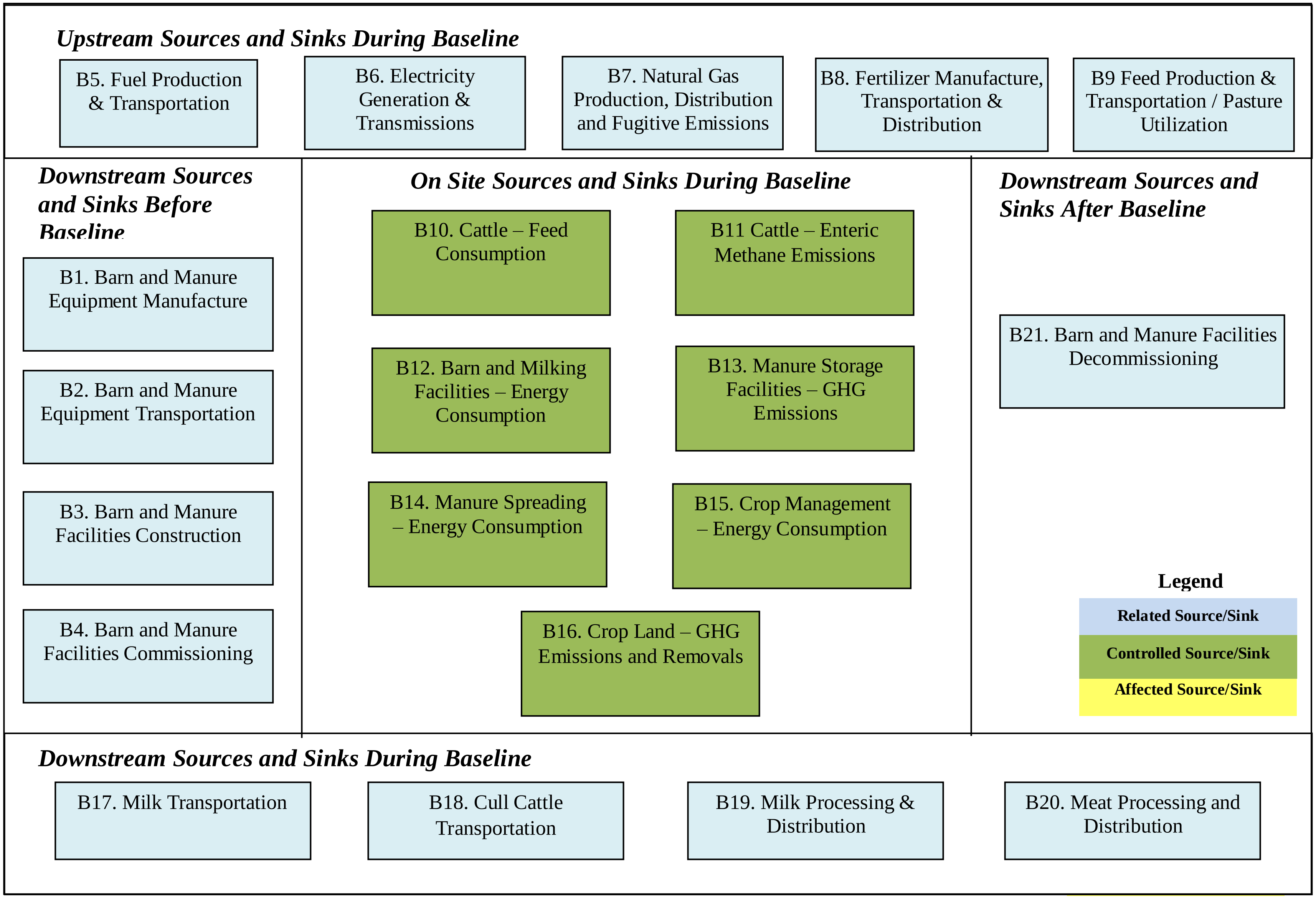


Table 5 - Baseline Condition Sources and Sinks		
1. Source/Sink	**2. Description**	**3. Controlled, Related or Affected**
Upstream Sources and Sinks During Baseline Operation		
B5. Fuel Production and Transportation	All activities (inputs of materials and energy) involved in the production and transportation of diesel fuel.	Related
B6. Electricity Generation and Transmission	All activities (inputs of materials and energy) involved in the generation of electricity.	Related
B7. Natural Gas Production, Distribution, and Fugitive Emissions	All activities (inputs of materials and energy) involved in the discovery and production of natural gas. Because natural gas is a GHG (primarily composed of CH_4), fugitive emissions during production are included in this element.	Related
B8. Fertilizer Manufacture, Transportation and Distribution	All activities (inputs of materials and energy) involved in production, transportation, and distribution of fertilizer.	Related
B9. Feed Production and Transportation / Pasture Utilization	All activities (inputs of materials and energy) involved in the production (crop growing & harvesting) and transportation of feed.	Related
Onsite Sources and Sinks During Baseline Operation		
B10. Cattle – Feed Consumption	All activities (inputs of materials and energy) involved in the use of feed. Feed or dairy farm is both raised on farm and purchased from off-farm sources.	Controlled
B11. Cattle – Enteric Methane Emissions	Emissions produced as a result of digestion of feed by cattle, released through exhalation. Also refers to practices to manage feed composition to control enteric emissions.	Controlled
B12. Barn & Milking Facilities – Energy Consumption	Fuel and electricity used to operate the barn and milking facilities, including on-farm handling of feed and bedding.	Controlled
B13. Manure Storage Facilities – GHG Emissions	Fuel and electricity used to operate the manure storage facilities. Also refers to practices to reduce emissions of GHGs from the stored manure.	Controlled

B14. Manure Spreading – Energy Consumption	All activities (inputs of materials and energy) involved in the spreading of manure, with the exception of fuel use. Also refers to practices to reduce GHGs from the spread manure.	Controlled
B15. Crop Management – Energy Consumption	Fuel used to maintain till soil, and to raise and harvest crops.	Controlled
B16. Crop Land – GHG Emissions & Removals	GHG emissions and removals associated with typical land use, including emissions from fertilizer and decomposing crop residues.	Controlled
Downstream Sources and Sinks Before Baseline Operation		
B1. Barn & Manure Equipment Manufacture	All activities (inputs of materials and energy) required to manufacture equipment used for barn and manure systems.	Related
B2. Barn & Manure Equipment Transportation	All activities (inputs of materials and energy) required to transport equipment used for barn and manure systems from the manufacturing location to the project location (farm).	Related
B3. Barn & Manure Facilities Construction	All activities (inputs of materials and energy) involved in the construction of the barn and manure systems.	Related
B4. Barn & Manure Facilities Commissioning	All activities (inputs of materials and energy) involved in the commissioning of the barn and manure systems.	Related
Downstream Sources and Sinks During Baseline Operation		
B17. Milk Transportation	All activities (inputs of materials and energy) involved in the transport of milk that is an output of the project farm.	Related
B18. Cull Cattle Transportation	All activities (inputs of materials and energy) involved in the transport of cull cattle from the project farm.	Related
B19. Milk Processing & Distribution	All activities (inputs of materials and energy) involved in processing and distributing milk from the project farm for retail sale.	Related
B20. Meat Processing & Distribution	All activities (inputs of materials and energy) involved in the processing and distribution of meat from the project farm for retail sale.	Related

3 Project Condition

A project condition is an action or actions targeted at reducing, removing or storing GHG emissions at a project. It can consist of one or more related activities developed according to a government-approved protocol.

The project condition for this protocol is defined as incremental practice changes aimed at increasing milk yield and reducing GHG emissions on the dairy farm.

Practices can be modified in order to:

- increase milk production per cow,
- reduce GHG emissions from manure storage,
- modify the herd's diet in order to reduce the proportion of gross energy converted to methane and
- limit the number of heifers retained as replacement herd.

Dairy farm operators participating in dairy cattle emission reduction projects must be able to document, at a minimum, for each year:

- legal land description;
- any additional details to assist in identifying the farm location;
- farm identifiers (i.e. Provincial Milk Board Farm ID number, Valacta ID number, etc.);
- herd inventory number per animal grouping/herd component (dry herd, lactation herd, replacement herd);
- nutritionist records including
  - average daily dry matter intake per animal grouping/herd component (level of concentrates in the diet (%), total digestible nutrients (%), forage quality indices (% NDF?), crude protein content (%), fat content (ether extract content %)
  - Incidence and inclusion of feed additives or supplements (fat sources, ionophores, Corn DDGS) as part of the project activity
- feed grown on-farm;
- manure storage volume;
- timing and amount of manure removed from the manure storage pit; and
- milk data (date, time, volume (L), butter fat).

More information on records requirements is available in Section 5.

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

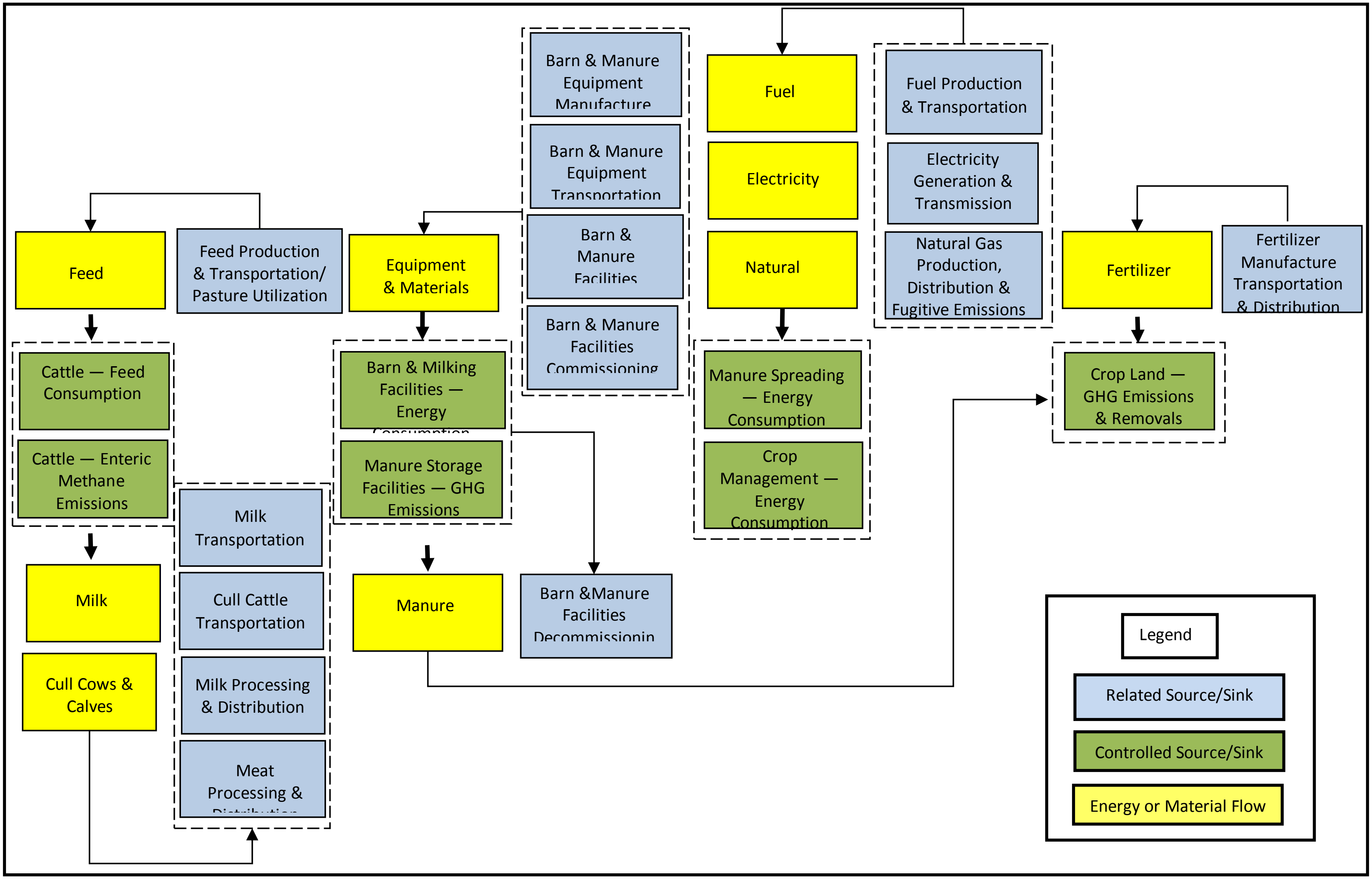


Figure 3 - Process Flow Diagram for the Project Condition

3.1 Identification of Project Sources and Sinks

Sources and sinks for the dairy protocol were identified for the project based on a scientific review. This review process confirmed that sources and sinks in the process flow diagram in Figure 3 above 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 (cf. section 2.1. for the definitions) as described in Table 6, below.

Figure 4 - Project Condition Sources and Sinks

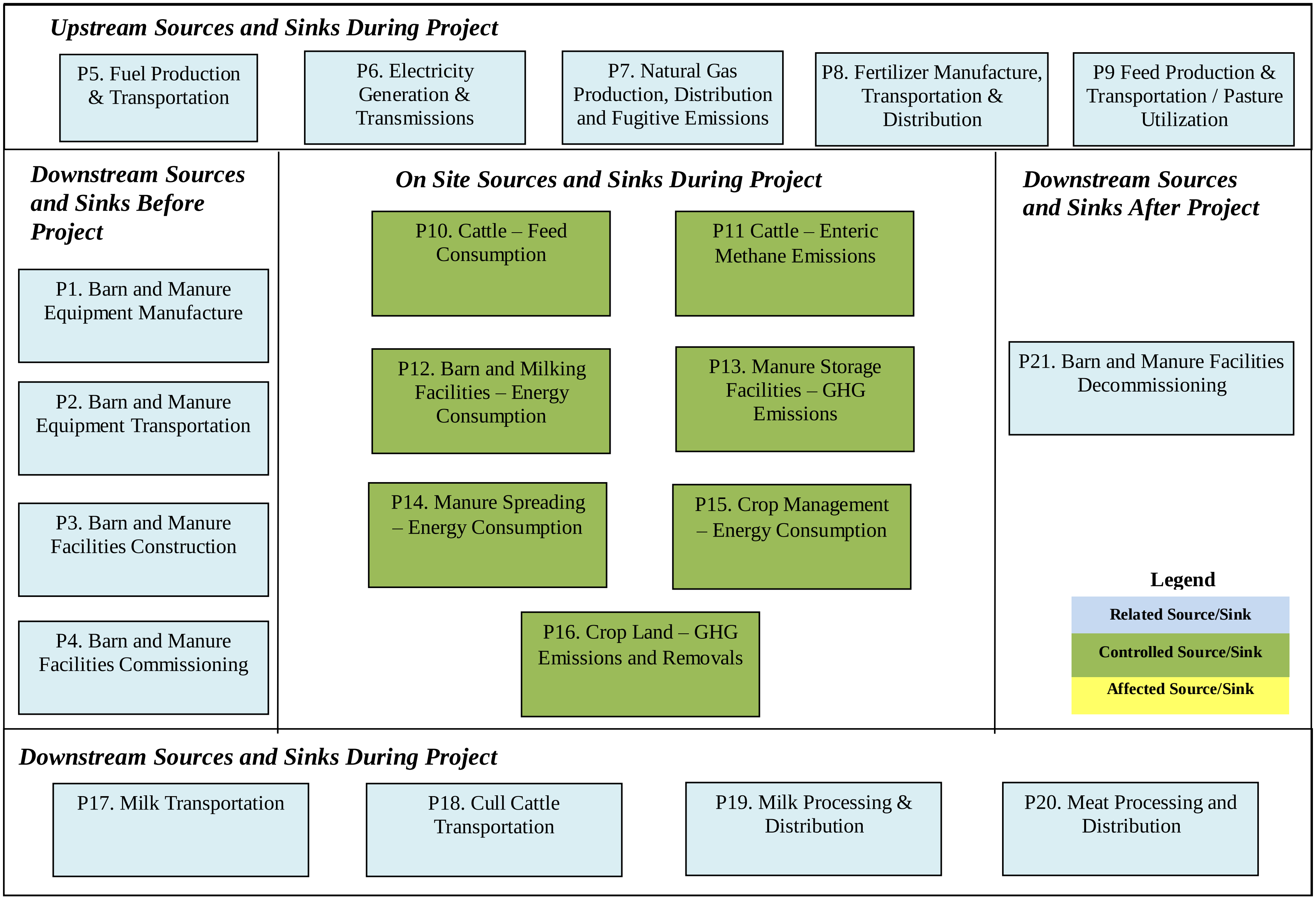


Table 6 - Project Condition Sources and Sinks

1. Source/Sink	2. Description	3. Controlled, Related or Affected
Upstream Sources and Sinks During Project Operation		
P5. Fuel Production and Transportation	All activities (inputs of materials and energy) involved in the production and transportation of diesel fuel.	Related
P6. Electricity Generation and Transmission	All activities (inputs of materials and energy) involved in the generation of electricity.	Related
P7. Natural Gas Production, Distribution, and Fugitive Emissions	All activities (inputs of materials and energy) involved in the discovery and production of natural gas. Because natural gas is a GHG (primarily composed of CH_4), fugitive emissions during production are included in this element.	Related
P8. Fertilizer Manufacture, Transportation and Distribution	All activities (inputs of materials and energy) involved in production, transportation, and distribution of fertilizer.	Related
P9. Feed Production and Transportation / Pasture Utilization	All activities (inputs of materials and energy) involved in the production (crop growing & harvesting) and transportation of feed.	Related
Onsite Sources and Sinks During Project Operation		
P10. Cattle – Feed Consumption	All activities (inputs of materials and energy) involved in the use of feed. Feed or dairy farm is both raised on farm and purchased from off-farm sources.	Controlled
P11. Cattle – Enteric Methane Emissions	Emissions produced as a result of digestion of feed by cattle, released through exhalation. Also refers to practices to manage feed composition to control enteric emissions.	Controlled
P12. Barn & Milking Facilities – Energy Consumption	Fuel and electricity used to operate the barn and milking facilities, including on-farm handling of feed and bedding.	Controlled
P13. Manure Storage Facilities – GHG Emissions	Fuel and electricity used to operate the manure storage facilities. Also refers to practices to reduce emissions of GHGs from the stored manure.	Controlled

P14. Manure Spreading – Energy Consumption	All activities (inputs of materials and energy) involved in the spreading of manure, with the exception of fuel use. Also refers to practices to reduce GHGs from the spread manure.	Controlled
P15. Crop Management – Energy Consumption	Fuel used to maintain till soil, and to raise and harvest crops.	Controlled
P16. Crop Land – GHG Emissions & Removals	GHG emissions and removals associated with typical land use, including emissions from fertilizer and decomposing crop residues.	Controlled
Downstream Sources and Sinks Before Project Operation		
P1. Barn & Manure Equipment Manufacture	All activities (inputs of materials and energy) required to manufacture equipment used for barn and manure systems.	Related
P2. Barn & Manure Equipment Transportation	All activities (inputs of materials and energy) required to transport equipment used for barn and manure systems from the manufacturing location to the project location (farm).	Related
P3. Barn & Manure Facilities Construction	All activities (inputs of materials and energy) involved in the construction of the barn and manure systems.	Related
P4. Barn & Manure Facilities Commissioning	All activities (inputs of materials and energy) involved in the commissioning of the barn and manure systems.	Related
Downstream Sources and Sinks During Project Operation		
P17. Milk Transportation	All activities (inputs of materials and energy) involved in the transport of milk that is an output of the project farm.	Related
P18. Cull Cattle Transportation	All activities (inputs of materials and energy) involved in the transport of cull cattle from the project farm.	Related
P19. Milk Processing & Distribution	All activities (inputs of materials and energy) involved in processing and distributing milk from the project farm for retail sale.	Related
P20. Meat Processing & Distribution	All activities (inputs of materials and energy) involved in the processing and distribution of meat from the project farm for retail sale.	Related

4 Quantification

Baseline and project conditions were assessed against each other to determine the scope for GHG emission 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 and baseline.

All sources and sinks identified in Table 5 and Table 6 above are listed in Table 7 below. Each source and sink is listed as included or excluded. Justification for these choices is provided.

Table 7 - Comparison of Sources and Sinks for the Dairy Cattle Protocol

Identified Sources and Sinks	Baseline (C, R, A)*	Project (C, R, A)*	Include or Exclude from Quantification	Justification for Inclusion/Exclusion
Upstream Sources/Sinks				
B5, P5. Fuel Production & Transportation	R	R	Exclude	The emissions from these elements are expected to be equal or lower in the project as compared to the baseline condition.
B6, P6. Electricity Generation & Transmission	R	R	Exclude	
B7, P7. Natural Gas Production, Distribution & Fugitive Emissions	R	R	Exclude	
B8, P8. Fertilizer Manufacture, Transportation & Distribution	R	R	Exclude	
B9, P9. Feed Production & Transportation/Pasture Utilization	R	R	**Include**	This element comprises some of the practices for greenhouse gas reduction included in the protocol. To accommodate on- and off-farm emission sources of feed production, standardized assessment of 'embedded emissions' are used to account for greenhouse gas intensity of feedstuffs.
Onsite Sources/Sinks				
B10, P10. Cattle – Feed Consumption	C	C	**Include**	These elements comprise some of the practices for greenhouse gas reduction included in the protocol.
B11, P11. Cattle – Enteric Methane Emissions	C	C	**Include**	

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

Identified Sources and Sinks	Baseline (C, R, A)*	Project (C, R, A)*	Include or Exclude from Quantification	Justification for Inclusion/Exclusion
B12, P12. Barn & Milking Facilities – Energy Consumption	C	C	Exclude	The emissions from this element are expected to be equal or lower in the project as compared to the baseline condition. Exclusion of this SS represents conservativeness concerning quantification of reductions. Also, this Protocol encourages participants to enroll in an Energy Efficiency Protocol to capture potential reductions from decreased use of energy.
B13, P12. Manure Storage Facilities – GHG Emissions	C	C	**Include**	This element comprises some of the practices for greenhouse gas reduction included in the protocol.
B14, P14. Manure Spreading – Energy Consumption	C	C	Exclude	The emissions from this element is expected to be equal or lower in the project as compared to the baseline scenario. Exclusion of this SS represents conservativeness concerning quantification of reductions.
B15, P15. Crop Management – Energy Consumption	C	C	**Include**	This element is addressed in the embodied emissions for all feedstocks.
B16, P16. Crop Land – GHG Emissions & Removals	C	C	**Include**	These emissions and removals are addressed in the standard greenhouse gas intensity of feedstuffs.
Downstream Sources/Sinks				
B1, P1 Barn & Manure Equipment Manufacture	R	R	Exclude	The emissions from these elements are expected to be equal or lower in the project as compared to the baseline scenario.

Identified Sources and Sinks	**Baseline (C, R, A)***	**Project (C, R, A)***	**Include or Exclude from Quantification**	**Justification for Inclusion/Exclusion**
B2, P2 Barn & Manure Equipment Transportation	R	R	Exclude	
B3, P3 Barn & Manure Facilities Construction	R	R	Exclude	
B4, P4. Barn & Manure Facilities Commissioning	R	R	Exclude	
B17, P17. Milk Transportation	R	R	Exclude	
B18, P18. Cull Cattle Transportation	R	R	Exclude	
B19, P19. Milk Processing & Distribution	R	R	Exclude	
B20, P20. Meat Processing & Distribution	R	R	Exclude	
B21, P21. Barn & Manure Facilities Decommissioning	R	R	Exclude	

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

4.1 Quantification Methodology

Quantification of the reductions, removals and reversals of relevant sources/sinks for each of the greenhouse gases will be completed using the methodologies in this section.. These quantification methodologies serve to complete the following three equations for calculating the annual emission reductions from the comparison of the baseline and project conditions, where:

GHG Emission Reductions = [(Emissions $_{\text{Baseline Emissions}}$ – Emissions $_{\text{Project Emissions}}$) * Annual FCM$_{\text{Project}}$] [1]

Emissions $_{\text{Baseline Emissions}}$ = [(B9 Feed Production & Transportation/Pasture Utilization $_{\text{Year1, Year 2, Year 3}}$) + B10 Feed Consumption $_{\text{Year1, Year 2, Year 3}}$ + B11 Cattle Enteric Methane Emissions $_{\text{Year1, Year 2, Year 3}}$ + B13 Manure Storage Facilities (N_2O & CH_4) $_{\text{Year 1, Year 2, Year 3}}$ + B15 Crop Management – Energy Consumption $_{\text{Year1, Year 2, Year 3}}$ + B16 Crop Land – GHG Emissions & Removals $_{\text{Year1, Year 2, Year 3}}$] /FCM$_{\text{Baseline}}$

Emissions $_{\text{Project Emissions}}$ = sum of the emissions under the project condition.

Emissions $_{\text{Project Emissions}}$ = [(P9 Feed Production & Transportation/Pasture Utilization) + P10 Feed Consumption + P11 Cattle Enteric Methane Emissions + P13 Manure Storage Facilities N_2O & CH_4 + P15 Crop Management – Energy Consumptions + P16 Crop Land – GHG Emissions & Removals]/FCM$_{\text{Project}}$

FCM$_{\text{Baseline}}$ = Average fat corrected milk produced in the baseline (kg milk produced), averaged over the three baseline years

FCM$_{\text{Project}}$= Fat corrected milk produced in the project (kg milk per year)

4.1.1 Derivation of Annual Fat Corrected Milk

Fat Corrected Milk (FCM): Quantity of milk, normalized to a common energy basis.

For this Protocol, the milk quantity is corrected to 3.7 per cent fat; the equations to calculate annual FCM are as follows:

Annual FCM (kg/year) = ∑ (Fat Corrected Milk $_{\text{Month January}}$ + Fat Corrected Milk $_{\text{Month February}}$ + Fat Corrected Milk $_{\text{Month March}}$ …. + Fat Corrected Milk $_{\text{Month December}}$) [2]

Where:

Annual FCM (kg/year) = Total fat corrected milk

Fat Corrected Milk $_{month}$ = Total fat corrected milk (kg) for each month in the year

$$\text{Fat Corrected Milk}_{Month}\ (kg/month) = (\text{kg milk production}_{month}) * (3.7 / \text{actual fat \% of milk}_{month}) \quad [3]$$

Where:

kg milk production $_{month}$ = Total monthly Milk Produced (kg) for each month in the year
actual fat % of milk $_{month}$ = Measured fat % in milk produced for the month

4.1.2 Manure Storage Facilities – GHG Emissions

4.1.2.1 Approach 1— CH_4 Emissions - Method 1: Annually

Approach 1 for calculating methane emission reductions from manure storage can be applied where the project developer does not opt to use the 4th management practice listed in Table 1, Section 1.1 – changing the timing in liquid storage emptying, or where manure data for an animal grouping/herd component are not available on a monthly basis. Methane emissions from manure storage summed across all animal groupings/herd components are calculated using Equation 4.

$$E_{SSR13,CH4} = \sum_{S,G} VS_G * N_G * 365 * 0.24 * 0.67 * MCF_S * MS_{S,G} * 21/1000 \quad \textbf{[4]}$$

Where:

$E_{SSR13,CH4}$	= Methane emissions from manure management, tonnes CO_{2e} yr^{-1}
S	= Manure management system (liquid, solid or pasture)
G	= Animal group
VS_G	= Daily volatile solids excreted by a specific animal group, kg DM $head^{-1}$ day^{-1}
N_G	= Number of animals in a specific animal group
365	= Number of days per year
0.24	= Maximum methane-producing capacity from dairy manure (m^3 CH_4 kg^{-1} of VS excreted)
0.67	= Coefficient to convert m^3 to kg for methane, kg CH_4 m^{-3} CH_4
MCF_S	= Methane conversion factor: percent of VS converted to methane for the defined manure management system (Table 8)
$MS_{S,G}$	= Fraction of animal group G's manure handled by the defined manure management system
25	= Global warming potential of methane
1000	= kg per tonne

The "average daily volatile solids excreted by a specific animal grouping/herd component", VS_G, in Equation 4 is calculated using Equation 5, below[1].

$$VS_G = (GEI_G * (1-DE_G/100) + 0.04 * GEI_G) * 0.92 / 18.45 \qquad \textbf{[5]}$$

Where:

VS_G = Average daily volatile solids excreted per day on a dry matter basis per herd component, kg DM $head^{-1}$ day^{-1}
GEI_G = Gross energy intake, MJ $head^{-1}$ day^{-1}
DE_G = Digestible energy expressed as a percentage of gross energy per herd component
0.04 = Urinary energy excretion expressed as a fraction of GEI_G
0.92 = Fraction ash-free content of manure
18.45 = Average energy content of dry matter (MJ kg^{-1} DM)

The "methane conversion factor", MCF_S, in Equation 4 is listed by manure system and region (Table 8).

Table 8 - Methane Conversion Factors (MCFS)

Manure System	Region	MCFs
Solid	All Regions	0.01
Liquid	BC	0.258
	Prairies	0.283
	Ontario	0.301
	Quebec	0.284
	Atlantic	0.294
Pasture	All Regions	0.01

4.1.2.2 Approach 2 — Manure CH_4 Emissions - Liquid Manure Management System

To account for the influence of temperature and timing of manure removal on methane emissions from liquid manure storage units, methane emissions can also be calculated monthly, following Equation 6.

$$E_{SSR13,CH4,L} = \sum_m (VS_{avail,m} * f_m) * 0.24 * 0.67 * 21/1000 \qquad \textbf{[6]}$$

Where:

$E_{SSR13,CH4,,L}$ = Methane emissions from a liquid manure storage unit, tonnes CO_{2e} yr^{-1}
$VS_{avail,m,}$ = Volatile solids available to be decomposed at end of current month (kg DM) is calculated using Equation 7;
m = Month (for a one year period)

[1] Equation 4 should be used for each specific animal grouping/herd component.

$\mathbf{f_m}$	= Fraction of available volatile solids consumed during month, Van't Hoff Arrhenius factor.
0.24	= Volume of methane emitted per kilogram of volatile solids produced ($m^3 CH_4$/kg VS)
0.67	= Conversion factor of kilograms CH_4 to m of CH_4 (kg CH_4 $m^3 CH_4^{-1}$)
25	= Global Warming Potential (Table 1)

$$VS_{avail,m} = VS_{load} + [VS_{avail,\ m-1} - VS_{converted,m-1}] \qquad \textbf{[7]}$$

Where:

$\mathbf{VS_{avail,m}}$	= Volatile solids available to be decomposed at end of current month (kg DM)
$\mathbf{VS_{load}}$	= Monthly loading of volatile solids available in the month (kg DM)
$\mathbf{VS_{avail,\ m-1}}$	= Volatile solids available to be decomposed at end of previous month (kg DM)[2]
$\mathbf{VS_{converted,m-1}}$	= Volatile solids converted to methane in the previous month (kg DM)

The "fraction of available volatile solids consumed during month" (van't Hoff Arrhenius factor), f, in Equation 6 is calculated using Equation 8, below.

$$f_m = \exp[E(T_2 - T_1)/(RT_1T_2)] \qquad \textbf{[8]}$$

Where:

E	= Activation energy constant (63,515 J mol^{-1})
$\mathbf{T_2}$	= Average monthly temperature (ºK = ºC + 273, $T_2 \geq 1$ ºC)[3]
$\mathbf{T_1}$	= 303 ºK
R	= Ideal gas constant (8.317 J K^{-1} mol^{-1})

Monthly loading of volatile solids (VS_{load}) available for each month, required for Equation 7 is calculated using Equation 9, below.

$$VS_{load} = VS_G * N_G * Days_{Month} \qquad \textbf{[9]}$$

Where:

$\mathbf{VS_{load}}$	= Monthly loading of volatile solids available in the month (kg DM)
$\mathbf{VS_G}$	= Average daily volatile solids excreted per day on a dry matter basis per herd component, kg DM $head^{-1}$ day^{-1}
$\mathbf{N_G}$	= Number of animals in a specific animal group/herd component
$\mathbf{Day_{Month}}$	= Number of days in each month

Monthly volatile solids converted to methane each month ($VS_{Converted,\ m-1}$), required for Equation 7 is calculated using Equation 10 below.

$$VS\ Converted_{m-1} = VS\ Available_{m-1} * f_m \qquad \textbf{[10]}^{4}$$

[2] Note: Volatile Solids in the manure storage pit the month prior to the project must be calculated in order to quantify emission methane emissions from manure storage in the first month of the project.

[3] Park, K.-H., Thompson, A. G., Marinier, M., Clark, K., and Wagner-Riddle, C. 2006.

Where:

VS Converted $_{m-1}$ = Monthly volatile solids converted to methane in the previous month (kg DM)

VS $_{avail\ m-1}$ = Monthly volatile solids available in the previous month (kg DM)

f_m = Fraction of available volatile solids consumed during month, van't Hoff Arrhenius factor.

4.1.3 N_2O Emissions from Manure Storage

Nitrous oxide emissions from manure storage can be calculated using Equation 11. The assessment of the protein content of the diet and the intake of feed is provided by the nutritionist formulating the rations for the dairy cows, and this professional will attest to the accuracy of the monitoring procedures used.

$$E_{SSR13N2O} = \sum_{G} (FeedN_G - MilkN_G - LWgainN_G) * 365 * N_G * E_{N2O,G} * 298/1000$$

[11]

Where:

$E_{SSR13,N2O}$ = N_2O emissions from manure storage, tonnes CO_{2e} yr^{-1}

G = Animal group

$FeedN_G$ = Feed N intake for a specific animal group, kg N $head^{-1}$ day^{-1}
= DMI * CP/100 * 0.16

Where:

DMI = daily dry matter intake, kg $head^{-1}$ day^{-1}

CP = crude protein content of diet, %

0.16 = fraction N in feed protein

$MilkN_G$ = N retained in milk N for a specific animal group, kg N $head^{-1}$ day^{-1}
= Milk * Milk protein/100 * 0.157

Where:

Milk = daily milk production, kg $head^{-1}$ day^{-1}

Milk protein = protein content of milk, % on weight basis

0.157 = fraction N in milk protein

$LWgainN_G$ = N retained in liveweight gain for a specific animal group, kg N $head^{-1}$ day^{-1} (Table 9)

365 = Number of days per year

N_G = Number of animals in a specific animal group

$E_{N2O,G}$ = g N_2O emitted per kg of N excreted for a specific animal group

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[4] The volatile solid conversion factor is based on USEPA methodology, as per Mangino J, Bartram D and Brazy A 2001 Development of a Methane Conversion Factor to Estimate Emissions from Animal Waste Lagoons Technical Report (Washington, DC: Environmental Protection Agency) p 14

$= (F_{G,S} * E_{N2O,S}) / 1000$

Where:

$F_{G,S}$ = Fraction of excreted N handled by manure management system for a specific animal group

$E_{N2O,S}$ = g N_2O emitted per kg of N excreted in a specific manure management system (Table 10), g N_2O kg^{-1} excreted N

1000 = convert g to kg

298 = Global warming potential of N_2O

Table 9 – Nitrogen Retained in Liveweight Gain for a Specific Animal Group

Livestock Group	$LWgainN_G$ (kg N $head^{-1}$ day^{-1})
Lactating Cows	0.0089
Dry Cows	0.0098
Replacement Heifers	0.0225

Wilkerson, V. A., et al., 1997.

Table 10 - Direct and Indirect N_2O Losses from Manure Storage Units for Different Manure Management Systems

$E_{N2O,S}$	Solid	Liquid	Pasture
Direct N_2O losses (g N_2O kg^{-1} excreted N)	7.9	7.9‡	0
Indirect N_2O losses†, (g N_2O kg^{-1} excreted N)	4.7	6.3	0
N_2O losses, (g N_2O kg^{-1} excreted N)	12.6	14.1	0

†Assumed no N losses due to leaching

‡Assumed liquid storage units had natural crust covers

4.1.4 Cattle – Enteric Methane Emissions

Methane emissions from enteric fermentation can be calculated using Equation 12, below. Equations for calculating enteric methane emissions from animal groups based on pasture are calculated in Section 4.1.5.2 below,

$$\mathrm{ESSR11} = \sum_{\mathrm{G}} \mathrm{GEI_G} * (Y_M/100) * \mathrm{N_G} * (365/55.65) * (21/1000)$$

[12]

Where:

E_{SSR11} = Methane emissions from enteric fermentation, tonnes CO_{2e} yr^{-1}

G = Animal group

GEI_G = Gross energy intake for a specific animal group (based on measured dry matter intake, MJ $head^{-1}$ day^{-1})
Y_M = Percent of gross energy in feed converted to methane for a specific animal group
N_G = Number of animals in a specific animal group/herd component
365 = Number of days per year
55.65 = Energy content of methane, MJ per kg methane
25 = Global warming potential of methane
1000 = kg per tonne

Dairy animals are generally grouped into milking cows (one to three groups), dry cows and replacement heifers (grouped by age). Male animals are excluded from calculations because adult bulls are rarely kept and bull calves are generally sold at a young age. Although males are excluded from quantification, it is important to note that project developers must provide the number of males on their farm during the baseline period and during the project period, to ensure that the number of males remains constant between the baseline and the project, or use the flexibility provision in Section 1.3. This will demonstrate, equivalence between project and baseline scenario and ensure that no additional GHG emissions are produced in the project due to an increase in the male population.

In cases where the number of male animals is larger or smaller in the project than in the baseline, GHG emissions created from having and maintaining the additional males, must be accounted for in the same manner as other groups (milking cows, dry cows and replacement heifers).

If replacement heifers are included in the quantification (see Section 1.3) they can be handled as one group, starting after weaning (assumed at end of two months) and extending until first calving (input variable). GHG emissions are calculated for each month. Heifer ages are assumed to be distributed uniformly over the growth period.

The Y_M value is defined as the percentage of gross energy intake by the dairy cow that is converted to methane in the rumen. The IPCC (2006) uses a Y_M of 6.5 (± 1)% for ruminants, including dairy cows. In other words, 6.5% of the gross energy consumed is converted in the rumen to methane energy. The associated uncertainty estimation of ± 1% reflects the fact that diets can alter the proportion of feed energy emitted as enteric methane.

Gross energy intake required for Equation 13 can be calculated by measuring the dry matter intake (DMI), on a daily basis using Equation 13.

$$GEI_G = DMI * 18.45 \quad \textbf{[13]}$$

Where:

DMI = Dry matter intake (kg $head^{-1}$ day^{-1})
18.45 = Average energy content of dry matter (MJ kg^{-1})

The default Y_M value from IPCC was refined by Drs. Karen Beauchemin and Ermias Kebreab to account for changes in ration formulation practices - to modify the proportion of gross energy converted to enteric CH_4 (Table 11). The Y_M values in Table 11 as a result of varying NDF contents in the diets are based on research conducted by Dr. Ermias Kebreab from the University of California, Davis[5]. The IPCC recommended value of 6.5% for diets with 30-50% NDF is used along with other categories of NDF feed content. The latter were adjusted relative to the IPCC recommendation, to obtain the suggested emission factors because the IPCC does not include dietary variables to estimate emission factors.

Thus, diets can be modified to manipulate Y_M within the range of variability of the IPCC default value. The assessment of the quality of forages is provided by the nutritionist formulating the rations for the dairy cows, and this professional must attest to the accuracy of the monitoring procedures used.

Table 11 - Estimates of the Percentage of Gross Energy Converted to Methane (Y_M) for Various Diets (Grainger and Beauchemin, 2011 and Moate et al. 2001)

Diet Description	Y_M (% of GEI)
Default (unknown diet composition)	6.5
Diet with < 25% NDF	5.5
Diet with 25-30% NDF	6.25
Diet with 30-50% NDF	6.5
Diet with >50% NDF	7.0
Situations in which adjustments apply to Y_M values above*	
Feeding fats*	
Calcium salts of palm oil (or similar bypass fats)	No reduction
Other Fat Sources*, not to exceed 80 g fat/kg DM	3.4% reduction in Y_M for each 10g increase in fat content per kg of animal feed on a dry matter basis (10g fat/kg DM_{diet})
*Corn DDGS cannot exceed 20% of dry matter of ration, and the higher protein content of the DDGS must be addressed in the ration formulation to prevent excess nitrogen excretion. The procedures to implement proper use of lipids and corn DDGS must be documented by the nutritionist An example of the GHG emission impacts of adding supplemental fat inclusion to the dairy ration is included in Appendix A.	

[5] The research involved a database that contained data from 1,111 lactating dairy cattle, 591 dry, 414 heifers and 458 steers. This data was used to estimate the percentage of gross energy converted to methane (Y_M) for various diets. The data was collected over a 40-year period at the USDA-Beltsville Research station and all observations were made under a controlled environment in a calorimetry chamber (Kebreab, unpublished data). The data were divided into four groups based on the NDF content of the feed (<25%, 25-30%, 30-50% and over 50%), and the density plots within each group were summarized to calculate the average emission and Y_M value within each category.

4.1.5 GHG Emissions from Feed Production

Emission factors applied in this protocol are expressed in CO_2 equivalent (CO_2e) and combine N_2O and CO_2 emissions. CH_4 has been excluded because emissions of this gas are not considered to be significant in Canadian cropping systems.

- Nitrous oxide sources are from N-fertilizer application (chemical or organic), crop residues, leaching and volatilization. IPCC equations adapted for Canada by Rochette *et al*. (2008) were used.
- Carbon dioxide sources are from fossil fuel use for field work, electricity, crop drying and fertilizer and machinery supply. The F4E2 model was used (Dyer and Desjardins, 2003, 2005).

Feedstuffs for cattle are divided into 9 categories, each with its own emission factor. The 9 categories are presented below while emission factors are presented in Table 12.

- Four Grains:
  - Corn grains
  - Other small grains
  - Soybeans (and other legumes)
  - Canola meal and other protein supplements
- Four Forages:
  - Legume hay/silage
  - Non-legume hay/silage
  - Corn silage
  - Small grain silage
- "Other" – including DDGS – with estimates average

4.1.5.1 Processed Feed

Emissions arising from the production of feed can be calculated using specific emission factors for various regions and types of feed. Equation 14, below, is the basic equation and is used along with data found in Table 12 to determine offsets from feed production.

$$E_{SSR9} = \sum_{G,F} FeedDM_{G,F} * FeedCO_2e_F \qquad \textbf{[14]}$$

Where:

E_{SSR9} = GHG emissions from feed production (excluding pasture[6]), tonnes CO_2e yr^{-1}
G = Animal group
F = Feed type

[6] Due to the highly variable an uncertain emissions in extensively grazed pasture situations, they are not quantified in this protocol.

$FeedDM_{G,F}$ = Amount of feed of a specific type consumed by a specific animal group, tonnes DM yr^{-1}

$FeedCO_2e_F$ = GHG emitted per tonne of feed, tonnes CO_2e $tonne^{-1}$ feed DM

Feed CO_2e were calculated for each province, combining both N_2O and CO_2 (Table 12).

The feed category “Others” in Table 12 below refers to dried distillers grains with solubles (DDGS). Calculated emissions consider only DDGS from grain corn and wheat. The calculation is as follows: assuming that 1 tonne of corn produces 309kg DDGS and 1 tonne of wheat produces 295kg DDGS, the emission factor for these two crops shall be inflated by 3.24 (i.e. 1/0.309) for corn and 3.39 (i.e. 1/0.295) for wheat.

Table 12 - Emission factors (tCO_2e / tonne of feed) for different crop category

	Crop category								
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	(tCO_2e/t.feed)								
NF	n.a.	n.a.	n.a.	n.a.	0.06	0.26	n.a.	n.a.	n.a.
PE	n.a.	0.55	0.31	n.a.	0.07	0.21	n.a.	0.24	1.73
NS	0.46	0.67	n.a.	n.a.	0.06	0.24	0.12	0.27	1.69
NB	n.a.	0.65	n.a.	n.a.	0.05	0.23	0.10	0.27	1.74
PQ	0.46	0.77	0.36	1.30	0.06	0.18	0.10	0.30	1.85
ON	0.41	0.58	0.34	1.21	0.05	0.18	0.10	0.21	1.52
MB	0.36	0.43	0.20	0.82	0.04	0.22	0.07	0.20	1.21
SK	n.a.	0.29	n.a.	0.78	0.05	0.21	n.a.	0.14	0.87
AB	0.29	0.35	n.a.	0.83	0.04	0.21	0.05	0.15	1.00
BC	n.a.	0.48	n.a.	1.30	0.05	0.22	0.05	0.18	1.49

Legend					
Legend	(1) Corn Grains	(2) Other Small Grains	(3) Soybeans	(4) Canola	(5) Legume hay/silage
	(6) Non-legume hay-silage	(7) Corn Silage	(8) Small Grain Silage	(9) “other” (DDGs – from corn & wheat)	

n.a. = not available (meaning that, according to the agricultural census, these specific crops are not cultivated in the province)

Pasture Feed Utilization

Practices and GHG emissions associated with the utilization of pasture are not expected to change from baseline to project. The uncertainty and complexity in emissions quantification for pasture preclude its inclusion in this protocol.

Feed Transportation

Practices and GHG emissions associated with the transportation of produced feed are not expected to change from baseline to project and, as a result, do not need to be quantified.

Table 13 - Quantification Procedures							
1. Baseline Sources/Sinks	**2. Parameter / Variable**	**3. Unit**	**4. Measured (M)/ Calculated (C)/ Estimated (E)**	**5. Method**	**6. Frequency**	**7. Justify measurement or estimation and frequency**	**8. Documentation Required**
Baseline & Project Sources and Sinks							
Equation 4: Approach 1 for CH_4 Manure Emissions: $E_{SSR13,CH4} = \sum_{S,G} VS_G * N_G * 365 * 0.24 * 0.67 * MCF_S * MS_{S,G} * 21/1000$							
Emissions $_{SSR13,\ CH4}$ Manure Storage	$E_{SSR13,\ CH4}$	tCO_2e / year	C	Equation 4	Yearly	Value being calculated in equation 4	
	VS_G - Daily volatile solids excreted for a specific animal group	kg DM / head / day	C	Using equation 5 of the Protocol	N/A	The value is calculated in equation 5	Application of equation 5

	N_G - Number of animals in a specific animal group	Head	M	Average number of animals for each group per year (may be calculated by averaging total number of animals per group per month for the year)	Yearly	Used in calculations performed on a yearly basis	
	365 – Number of days in the year.	Days/ year	M	-	N/A	Use in calculations performed on a yearly basis	
	0.24 - Maximum methane-producing capacity from dairy manure	m^3 CH_4/kg VS	E	Based on IPCC (2006) for dairy cattle	Once (unless IPCC updates values)	Accepted value provided by recognized source (IPCC)	
	0.67 - Coefficient to convert m^3 to kg for methane, kg CH4 m^3 CH4	kg CH_4/m^3 CH_4	C	Conversion factor	Once	Accepted value provided by recognized source (IPCC)	

	MCF_s - Methane conversion factor	%	C	Percent of VS converted to methane for the defined manure management system (see Table 8 of protocol)	Once	Accepted value provided by recognized source (Marinier et al. 2004 and Vergé et al. 2007)	
	$MS_{S,G}$ - Fraction of animal group G's manure handled by the defined manure management system	%	C	Calculate the fraction (for each group of animals) of manure handled by the defined management system.	Yearly	Needed to determine the methane emissions associated with manure management systems	
	25- Global Warming Potential of Methane	CO_2e	E	Taken from IPCC	Once – Check every year for update	Accepted value provided by recognized source (IPCC)	
	1000 – conversion factor of kg to tonne	kg / tonne	C	Conversion	Once	Conversion Factor	
Equation 5: $VS_G = (GEI_G * (1 - DE_G/100) + 0.04 * GEI_G) * 0.92 / 18.45$							

Emissions *SSR13*, CH_4 Manure Storage	VS_G - Daily volatile solids excreted per day on a dry matter basis.	kg DM / head / day	C	Equation 5	Yearly	Value being calculated according to IPCC	
	GEI_G - Gross energy intake per animal group	MJ head /day	C	Calculated based on using equation 13	Time period where feed remains constant.	The gross energy intake is based on actual diet fed to the animals.	
	DE_G - Digestible energy expressed as a percentage of gross energy	% of GEI	M	Measured value based on nutritionist records	Time period where feed remains constant. DE will change when animal diet is altered	The digestible energy is based on actual diet fed to the animals.	

	0.04 = Urinary energy excretion expressed as a fraction of GEI_G	N/A	E	IPCC Equation 10.24 - urinary energy expressed as fraction of GEI. 0.04 GEI can be considered urinary energy excretion by most ruminants.	Once	Accepted value provided by recognized source (IPCC)	
	0.92 = Fraction ash-free content of manure	N/A	E	IPCC Equation 10.24 - the ash content of manure calculated as a fraction of the dry matter feed intake (e.g., 0.08 for Cattle or 1-0.08 = 0.92).	Once	Accepted value provided by recognized source (IPCC)	

	18.45 = Average energy content of dry matter	MJ / kg DM	E	IPCC Equation 10.24 - conversion factor for dietary GEI per kg of dry matter. This value is relatively constant across a wide range of forage and grain-based feeds commonly consumed by livestock.	Once	Accepted value provided by recognized source (IPCC)	
Equation 6: Approach 2 for CH_4 emissions from manure storage: $E_{SSR13,CH4,L} = \sum_{m}(VS_{avail,m} * f_m) * 0.24 * 0.67 * 21/1000$							
Emissions $_{SSR13,\ CH4}$ Manure	$E_{SSR13,\ CH4,\ L}$	tCO_2e / year	C	Equation 4	Yearly	Value being calculated in equation 6	

Storage	$VS_{avail,m}$ - Volatile solids available to be decomposed at end of current month (tonnes)	kg DM	C	Calculated based on equation 6	Monthly	The amount of volatile solids available to decompose is necessary to quantify the GHG emissions associated with manure storage	
	f_m - Fraction of available volatile solids consumed during month, Van't Hoff-Arhenius factor.	Unitless	C	Calculated based on IPCC – Van't Hoff-Arrhenius equation relating temperature to biological activity.	Monthly	The fraction of available volatile solids consumed each month.	
	0.24	$m^3 CH_4$/ kg VS	C	Calculated based on IPCC	Once	Volume of methane emitted per kilogram of volatile solids produced	
	0.67	kg CH_4/m^3 CH_4	C	Conversion from IPCC	Once	Conversion factor to convert volume of methane into mass. i.e. m^3 CH_4 to kilograms of CH_4	

	21[25]- Global Warming Potential of Methane	CO_2e	E	Taken from IPCC	Once – Check every year for update	Accepted value provided by recognized source (IPCC)	
	1000 – conversion factor of kg to tonne	kg/tonne	C	Conversion	Once	Conversion Factor	
Equation 7: $VS_{avail,m} = VS_{load} + [VS_{avail,\ m-1} – VS_{converted,m-1}]$							
Emissions SSR13, CH4 Manure Storage	$VS_{avail\ m}$- Daily volatile solids excreted for a specific animal group	kg DM	C	Using equation 7 of the Protocol	Monthly	The value calculated in equation 7	Application of equation 7
	VS_{load} – Monthly loading of volatile solids available in the month	kg DM	C	Using Equation 9 in the protocol	Monthly	The value is calculated in equation 9	Application of equation 9

	$VS_{avail\ m-1}$ – Volatile solids available to be decomposed at the end of the previous month	kg DM	C	Calculated from the previous month's VS load (last month of baseline)	Monthly	The value is calculated in equation 7	Application of equation 7
	$VS_{converted,m-1}$= Volatile solids converted to methane in the previous month	kg DM	C	Using Equation 10	Monthly	The value is calculated in equation 10	Application of equation 10
Equation 8: van't Hoff-Arrhenius factor. $f = \exp[E(T_2-T_1)/(RT_1T_2)]$							
Emissions SSR13, CH4 Manure Storage	f – Van Hoff-Arrhenius factor	Unitless	C	Using equation 8 of the Protocol	N/A	The value is calculated in equation 8	
	E - Activation energy constant (63,515)	J / mol	C	Constant used in equation 7	Monthly	Accepted value provided by recognized source (IPCC)	

	T_2 - Average monthly temperature	ºK (Kelvin)	M and C	Average monthly temperature in Celsius converted to Kelvin with the following equation: ºK = ºC + 273,	Monthly	Required to calculate f	Records from the closest meteorological station to the farm (typically from 30 month normals)
	T_1 - 303	ºK (Kelvin)	C	Constant	Monthly	Required to calculate f	
	R - Ideal gas constant (8.317)	J / K / mol	C	Constant	Monthly	Required to calculate f	
Equation 9: $VS_{load} = VS_G * N_G * Days_{Month}$							
Emissions SSR13, CH4 Manure Storage	VS_{load} – Monthly loading of volatile solids available in the month	kg DM	C	Using equation 9 of the Protocol	N/A	The value is calculated in equation 9	

	VS_G – Average daily volatile solids excreted per day on a dry matter basis per herd component	kg DM / Head / day	C	Equation 5	Yearly	Value calculated according to IPCC in Equation 5	
	N_G - Number of animals in a specific animal group/herd component	Head	M	Average number of animals for each group (may be calculated by averaging total number of animals per group per month for the year)	Yearly	Used in calculations performed on a yearly basis	
	$Days_{Month}$- Number of days in each month	Days	M	-	Monthly	Used in calculations performed on a monthly basis	
Equation 10: $\textbf{VS Converted}_{\mathbf{m-1}} = \text{VS Avail}_{m-1} * f_m$							

Emissions SSR13, CH4 Manure Storage	$VS_{converted,m-1}$= Volatile solids converted to methane in the previous month	kg DM	C	Using Equation 10	Monthly	The value is calculated in equation 10	Application of equation 10
	$VS_{avail\ m-1}$ - Monthly volatile solids available in the previous month	kg DM	C	Using equation 7 of the Protocol	N/A	The value is calculated in equation 7	Application of equation 7
	f_m - Fraction of available volatile solids consumed during month, Van't Hoff-Arhenius factor.	Unitless	C	Calculated based on IPCC – Van't Hoff-Arrhenius equation relating temperature to biological activity.	Monthly	The fraction of available volatile solids consumed each month.	f_m - Fraction of available volatile solids consumed during month, Van't Hoff-Arhenius factor.
Equation 11: N_2O Emissions from Manure Storage $E_{SSR13,N2O} = \sum_G (FeedN_G - MilkN_G - LWgainN_G) * 365 * N_G * E_{N2O,G} * 310 / 1000$							
Emissions SSR13, N2O - Manure Storage	$E_{SSR13,N2O}$ - N_2O emissions from manure storage	tCO_2e / year	C	Calculated based on equation 11	Monthly	Derived from the accompanying document in Appendix A	

	G - Animal group	Lactation, dry, heifer, bull, calves	M	Measured by counting animals in each group in each month	Monthly	Required to calculate $E_{SSR13,N2O}$	
	$FeedN_G$ - Feed N intake for a specific animal group,	Kg N / head /day	C	Calculated based on the following formula: DMI * CP/100 * 0.16 Where: DMI = Daily dry matter intake, (kg head^{-1} day^{-1}) CP = Crude protein content of diet, (%) 0.16 = fraction N in feed protein	Monthly	Derived from the accompanying document in Appendix A	

	$MilkN_G$ - N retained in milk N for a specific animal group	kg N / head / day	C	Calculated based on the following formula: Milk * Milk protein/100 * 0.157 Where, Milk = daily milk production, (kg $head^{-1}$ day^{-1}) Milk protein = protein content of milk, (% on weight basis) 0.157 = fraction N in milk protein	Monthly	Derived from the accompanying document in Appendix A	
	$LWgainN_G$ - N retained in liveweight gain for a specific animal group	Kg N / head / day	C	Default factor derived from Table 9 – Nitrogen Retained in Liveweight Gain for a Specific Animal Group	Monthly	Derived from Wilkerson, V. A., et al., 1997.	

	365 - Number of days per year	days/year	M	Days per year of project period	Monthly	Derived from the accompanying document in Appendix A	
	N_G - Number of animals in a specific animal group	Head / year	M	Average number of animals for each group per year (may be calculated by averaging total number of animals per group per month for the year)	Yearly	Used in calculations performed on a yearly basis	

	$E_{N2O,G}$ - N_2O emitted per kg of N excreted for a specific animal group	kg N_2O / kg excreted N	C	Calculated based on the following formula: $(F_{G,S} * E_{N2O,S})/1000$ Where, $F_{G,S}$ = Fraction of excreted N handled by manure management system for a specific animal group $E_{N2O,S}$ = N_2O emitted per kg of N excreted in a specific manure management system (g N_2O kg^{-1} excreted N) (see Table 10 in protocol)	Monthly		

	298 - Global warming potential of N_2O	CO_2e	E	From IPCC	Once	From recognized origin (IPCC)	
	1000 – conversion factor from kg to tonne	kg/tonne	M	Conversion factor	Once	Conversion factor	
Equation 12: Cattle – Enteric CH_4 Emissions $ESSR11 = \sum_{G} GEI_G * (Y_{mG}/100) * N_G * (365/55.65) * (21/1000)$							
Emissions $_{SSR11}$ – Cattle enteric methane emissions	E_{SSR11} = Methane emissions from enteric fermentation	tCO_2e / year	C	Calculated based on equation 12	Monthly	A calculated value.	
	G = Animal group	Lactation, dry, heifer, bull, calves	M	Measured by counting animals in each group in each month	Monthly	Required to calculate $E_{SSR11,CH4}$	

	GEI_G = Gross energy intake for a specific animal group	MJ / head / day	C	Calculated using equation 13	Time period where feed remains constant. The GEI_G will change when animal diet is altered.	The gross energy intake is based on actual diet fed to the animals.	
	Y_M = Percent of gross energy in feed converted to methane for a specific animal group (Table 11)	%	E	Estimated based on IPCC values with revision to account for changes in ration formulation practices.)	Time period where feed remains constant.	The methane conversion factor to estimate the extent to which feed energy is converted to CH_4.	

	N_G - Number of animals in a specific animal group	Head / year	M	Average number of animals for each group per year (may be calculated by averaging total number of animals per group per month for the year)	Yearly	Used in calculations performed on a yearly basis	
	365 - Number of days per year	Days / year	M	Days per year of project period	Monthly		
	55.65 = Energy content of methane, MJ per kg methane	MJ / kg CH_4	M	Energy content of methane	Once	Accepted value provided by recognized source (IPCC)	
	21[28]- Global Warming Potential of Methane	CO_2e	E	Taken from IPCC	Once – Check every year for update	Accepted value provided by recognized source (IPCC)	
	1000 – conversion factor from kg to tonne	kg / tonne	M	Conversion factor	Once	Conversion factor	

Equation 13 – Gross Energy Intake $GEI_G = DMI*18.45$							
GEI_G - Gross energy intake for a specific animal group	GEI_G - Gross energy intake for a specific animal group	MJ / head / day	C	Calculated based on measured Daily Dry Matter Intake (DMI)	Daily	A calculated value.	
	DMI - Dry matter intake	kg / head / day	M	The DMI value is calculated as the sum of all ration ingredients, but monitoring of individual ration ingredients is needed in the Advanced approach to determine the Y_M value	Daily	Necessary to calculate in order to determine amount of volatile solids produced	
	18.45 – Average energy content of dry matter	MJ / kgDM	E	Energy content of dry matter	Once	Required to calculate gross energy intake	

Emissions $_{SSR9}$ – Emissions from Processed Feed	**Equation 14 – Emissions from Processed Feed** E_{SSR9} $E_{SSR9} = \sum_{G,F} FeedDM_{G,F} * FeedCO_2e_F$						
	E_{SSR9} – GHG emissions from feed production (excluding pasture)	tCO_2e / year	C	Calculated based on equation 14	Annually	A calculated value	
	G = Animal group	Lactation, dry, heifer, bull, calves	M	Measured by counting animals in each group in each month	Monthly	Required to calculate E_{SSR9}	

	$FeedDM_{G,F}$= Amount of feed of a specific type consumed by a specific animal group	tonnes DM / year	M	Measured by daily or monthly records which may include: • feed purchase receipts or scale tickets, weights, etc. and/or; feed delivery records; and diet, and proof the diet was fed to the animals as indicated by internal record keeping systems and/or third party files.	Daily or Monthly	Necessary to calculate in order to determine annual volume of each feed consumed	

	FeedCO2eF = GHG emitted per tonne of feed	(tonne CO_2e/ tonne DM feed)	C	Accepted emission factors based on scientific consensus from Desjardins, R., Dyer J., Vergé X. and Worth D (Table 12)	Annual	Required to calculate E_{SSR9}	

5 Data Management

Data management systems must be of sufficient quality to support quantification requirements of greenhouse gas emissions and reductions. **In all cases, greenhouse gas emission reductions must be substantiated with records and must meet minimum requirements specified in Table 15 Alberta Environment and Sustainable Resource Development cannot accept offset credits for compliance purposes that are not supported by records.**

In general, data quality management must include sufficient data capture such that the mass and energy balances may be easily performed with the need for minimal assumptions and use of contingency procedures. The data must be of sufficient quality to fulfill the quantification requirements and be substantiated by company records for the purpose of verification.

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

Third party verifiers are required to assess the data management system, the internal procedures manual, quantification and project records as part of the third party verification. Incomplete adherence to any protocol terms are considered a contravention and will **not be accepted by Alberta Environment and Sustainable Resource Development.**

5.1 Project Documentation

Minimum data management requirements and examples of acceptable records needed to support emission reductions from dairy cattle are outlined in Table 15 below. The project developer is required to obtain and retain copies of records for each field converted for each year of the project in their data management system and must disclose records to a third party verifier and government auditor upon request. Farm operators must retain records for their files and may be asked to produce records during a site visit conducted by a third party verifier or government auditor.

Alberta Environment and Sustainable Resource Development will not accept offset credits as a compliance option under the Specified Gas Emitters Regulation that do not have sufficient evidence to support the greenhouse gas reductions being claimed. Records are needed to support each type of data requirement listed for each field farmed for each project year. These documents may be requested to support verification or government audit.

Table 14 - Evidence Required for Emissions Reductions from Dairy Cattle

Data Requirement	Examples of Records	Why it is Required
Animal Inventory		
Number of head – averaged monthly for each grouping/herd component	▪ Daily or monthly dairy animal inventories either tracked through farm records or third party agency records, including number of animals moving in and out of each class[7] AND ▪ Records of any deaths and receipts for dairy cattle purchased or sold for the operation.	To ensure an accurate average number of head for animals in each dairy class for offset calculation purposes
Feeding Management		
Processed Feed	▪ Farm records or third party managed data showing both monthly-purchased complete feed and manufactured complete feed delivered to each grouping (where applicable): AND • Sign-Off by a P.Ag. or D.V.M who reviewed and collected supporting farm records that specific feed ingredients for each animal grouping	Needed for calculating greenhouse gas emissions from feed production (excluding pasture)
Daily dry Matter Intake averaged monthly per grouping (Dry Matter Basis) Feed Content	▪ Farm records or third party managed data for the amount of dry matter grouping consumes on average, on a daily basis, including: • Total digestible nutrients (%DE or digestible energy) • Forage quality indices (% Neutral detergent fibres (NDF) • Crude protein content (%) • Fat content (Ether extract content %) • Incidence and inclusion of feed additives or supplements (fat sources, ionophores, Corn DDGS) as part of the project activity	Needed for calculating greenhouse gas emissions from feed production (excluding pasture), manure emissions (VS and N excretion for advanced approach) and methane emissions from enteric fermentation

[7] Note - for lactating and dry cow classes, milk recording agencies such as CanwestDHI (Western Canada) and /or Valacta (Eastern Canada) collect and track monthly or near monthly inventories.

Data Requirement	Examples of Records	Why it is Required
	AND, if dairy farm records only (i.e. no third party managed data): • Sign off by a P.Ag. or D.V.M. confirming the average daily dry matter intake/diet contents for each dairy grouping	
Manure Management		
Manure Storage Description/ Volume	Farm Description of the Following: ▪ Scale drawings of top view and cross-section of storage; indicating lines to 10% and 100% fill capacity levels; ▪ Estimated capacity at 100% fill from the Development Permit or NRCB Approval Permit on file; ▪ Date stamped photos showing the agitation equipment used, and the amount of manure remaining in the storage facility after the each spreading event.	To justify the manure storage fits the requirements of the protocol, and to document emptying dates and proportion of storage emptied
Manure Storage System	• Farm records estimating the proportion of manure handled under a specific management system for animal groupings	To determine the amount of volatile solids deposited in each manure system

Manure Managed According to the Agriculture Operation Practices Act (AOPA)	• Dairy operation documentation to show that a permit from the NRCB is in place and no major changes in manure management have occurred since the baseline period (for those operations built or expanded after 2002), including:
	  • Manure Handling Plans or Nutrient Management Plans and record keeping systems for those operations that exceed the land base requirements;
	  • Manure Storage and Collection Areas
	  • Application guidelines
	
	OR
	
	Sign-Off by a P.Ag. who reviewed and collected supporting farm records that confirm the manure management conforms to AOPA requirements and that no major changes in manure management have occurred since the baseline period.
		Needed to demonstrate that no major changes in how manure is managed have occurred since the baseline period. Major changes include:
		• switching storage types
		• instituting a composting system
		• installing an anaerobic digester
		The intent is to verify that a permit is in place and is current and no major changes in manure handling have occurred.
		
		A major change is a signal to contact Alberta Environment and Sustainable Resource Development for more clarification on how to

Data Requirement	Examples of Records	Why it is Required
		proceed
Milk Production		
Amount of milk shipped (kg/head/day), averaged monthly or measured daily	▪ Farm records of milk production shipped from the dairy operation; AND ▪ Alberta Milk shipment records, recorded daily for each dairy operation	Required for calculating N retained in milk for specific animal class, functional equivalence between baseline and project; N_20 emissions from manure storage
Fat and protein content of milk (% by weight), averaged monthly or measured daily	▪ Milk tests conducted and data collected by CanWest DHI and/or Valacta milk recording companies, signed off by an authorized representative of the company	Required for determining N retention in animals; functional equivalence between baseline and project
Legal Claim to the Offsets		
Location of Operation	▪ Legal land Description for the land parcel(s) upon which the dairy operation(s) are located AND ▪ Records showing appropriate Ecodistrict where farm resides[8] AND ▪ Records showing appropriate nearest weather station from Environment Canada[9];	To support registration and title to the offset claim and for 3rd party verification; to obtain monthly long term average temperature data for calculations (advanced approach)

Copies of records must be retained by the dairy operator, the Professional Agrologist /D.V.M. (if applicable), and the project developer for **7 years after** the end of the credit duration period.

Table 16 below provides clarity on the roles and responsibilities of each party.

Table 15. Responsibilities for Data Collection and Retention.

Entity	Data Collection and Retention Responsibilities
Dairy Operator	Provides copies of farm records and documentation to the project

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[8] For on-line interactive map to determine ecodistricts: http://atlas.agr.gc.ca/agmaf/index_eng.html

[9] To obtain monthly long term average temperatures http://climate.weatheroffice.gc.ca/climate_normals/index_e.html

	developer. The farm operator must retain original records for their files.
Project Developer	The project developer has primary responsibility for record keeping and record coordination to support project implementation and due diligence, and will be the primary information source for third party verification. The project developer is required to collect and manage copies of farm records and supporting documentation – guidance provided in Table 2 above.
Professional Agrologist/D.V.M.	The Professional Agrologist/D.V.M. provides a confirmation of the diet components of the project based on project records. Records must be collected and maintained consistent with this protocol
Milk Recording Companies	Canwest DHI and/or Valacta can provide a source of third party collected data, through trained technicians who visit dairy operations on a near monthly basis.
Alberta Milk	Alberta Milk's shipment record system can provide a corroborating source data for milk shipping volumes and milk quality ingredients.

5.2 Record Keeping

Alberta Environment and Sustainable Resource Development 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 dairy operator and the project developer must both maintain sufficient records to support the offset project. The project developer must keep the information listed below and disclose all information to the verifier and/or government auditor upon request. For more information, see Technical Guidance for Offset Project Developers available at: http://environment.gov.ab.ca/info/library/7915.pdf

Record Keeping Requirements:

- Records, like those suggested in Table 15 above, for all applicable years in which offset credits are being claimed;
- A record of all adjustments made to the project data with justifications;
- List of equipment included and any changes that occurred during the crediting period;
- Common practices relating to possible greenhouse gas reduction scenarios discussed in this protocol (dairy operation practices);
- All calculations applying the greenhouse gas assertion and emission factors listed in this protocol; and
- Initial and annual verification records and audit results.

In order to support the third party verification and 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 has ended;
- Project developers must maintain electronic records; while dairy operators must maintain original records, which may include hardcopy records; and
- Copies of records should be stored in two locations to prevent loss of data.

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

5.3 Quality Assurance and Quality Control Considerations

Project developers are required to ensure sufficient and appropriate quality assurance/quality control procedures are implemented to support the project implementation. 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:

- Outlining the process related to data management and record keeping for offset credits, including:
    - Data process flow charts for each dairy operation describing - data collection systems and input systems for dairy animal class, ration/nutrient tracking systems; validation points in the data flow (data oversight; second party checks; supervisor sign-off);
    - Data process flow charts for the milk recording agencies and Alberta Milk, if being used;
    - Data process flow charts for the overall project - describing how data collected from each pork operation is being input into the data management systems, with same data flow and controls as in above;
- Restriction of user access to offset claim calculations and data;
- Filtering procedures on animal class inventory, weights, and feed management data – descriptions of techniques used to scrub the raw data to remove erroneous values/outliers
- Ensuring that the changes to operational procedures (including manure management, etc.) continue to function as planned and achieve greenhouse gas reductions;
- Ensuring that the measurement and calculation system and greenhouse gas reduction reporting remains in place and accurate;
- Checking the validity of all data before it is processed, including emission factors, static factors, and acquired data;
- Exception reports for identification of duplicate records, incorrect emission factors, or records with values outside of expected ranges;
- Performing recalculations of quantification procedures to reduce the possibility of mathematical errors;

- Storing the data in its raw form so it can be retrieved for verification;
- Protecting records of data and documentation by keeping both a hard and soft copy of all documents;
- Recording and explaining any adjustment made to raw data in the associated report and files;
- A contingency plan for potential data loss; and
- Management review and approval of agreements, records, completeness of dairy operation activity information, consistency with underlying data, as well as linkage between base data and claims.

5.4 Liability and Risk

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

Notwithstanding any agreement between a project developer (aggregator) and the land owner / farmer, the project developer shall not and ***cannot*** pass on any regulatory liability for errors in design and/or errors in the project developer’s data management ***system.***

5.5 Registration and Claim to Offsets

Project developers must complete and submit a spatial locator template to the Alberta Emission Offsets Registry as part of the required documentation needed for project registration. This template is provided as part of the project registration package and may be requested directly from the registry.

6 References

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APPENDIX A
Ration Fat Inclusion Example

The following scenarios for ration fat inclusion are presented as an example of the Y_M effect, and resulting GHG reductions that could be expected with the deployment of a ration fat inclusion project.

The baseline ration data is taken from an operating dairy farm milking 48-holstein cows on average. Tallow is the non-bypass fat product assumed for inclusion in the ration as outlined in the scenarios below.

GHG output, and reductions associated with the various inclusion rates of tallow is presented for a 48-lactation cow dairy, and scaled up for a 500- lactation cow dairy. The inclusion of 500 g/cow/day of tallow is recognized as an upper limit for inclusion in lactation rations, based on feedback from industry practitioners. This level of inclusion may still result in a net decrease in butterfat production on a per cow basis, which would impact the farms overall production efficiency and likely override any GHG reduction benefit realized from the inclusion of fat in the diet.

A total ration fat content of 6% is a reasonable target for commercial dairy production, which would equate to an inclusion rate of 250 grams per cow per day in this particular scenario resulting in a total ration fat content of 5.96%. On 500-cow and 48-cow dairies, this would theoretically result in reductions of 67.22 and 6.45 Tonnes CO_2e $Year^{-1}$, respectively.

Tables 18 and 19 outline the GHG calculation results of the baseline and project scenarios for the 500-cow and 48-cow dairies.

Table 17 Ration Fat Inclusion Scenarios

Scenarios	Inclusion Rate - As Fed		Total DMI	Fat Inclusion Rate - Dry Matter Basis			Ration Fat Content
	(g/cow/day)	DM (%)	(kg DM/cow/day)	(g/cow/day)	(g/cow/day/kg DM)	(% of DMI)	
Baseline	0	98.00%	23.00	0.00	0.00	0.00%	4.89%
Project - 125 g/cow/day	125.00	98.00%	23.12	122.50	5.30	0.53%	5.42%
Project - 250 g/cow/day	250.00	98.00%	23.25	245.00	10.54	1.05%	5.96%
Project - 375 g/cow/day	375.00	98.00%	23.37	367.50	15.73	1.57%	6.49%
Project - 500 g/cow/day	500.00	98.00%	23.49	490.00	20.86	2.09%	7.02%

Table 18 GHG Impact of Fat Inclusion Scenarios: 500-Lactation Cow Dairy

	Ym	CH4 Emissions (Tonnes CO_2e $Year^{-1}$)	Reduction (Tonnes CO_2e $Year^{-1}$)	% Reduction
Baseline	6.50	1899.57		
Project - 125 g/cow/day	6.38	1864.50	35.07	1.85%
Project - 250 g/cow/day	6.27	1832.35	67.22	3.54%
Project - 375 g/cow/day	6.15	1797.28	102.29	5.38%
Project - 500 g/cow/day	6.04	1765.14	134.43	7.08%

Table 19 GHG Impact of Fat Inclusion Scenarios: 48-Lactation Cow Dairy

	Ym	CH4 Emissions (Tonnes CO_2e $Year^{-1}$)	Reduction (Tonnes CO_2e $Year^{-1}$)	% Reduction
Baseline	6.50	182.36		
Project - 125 g/cow/day	6.38	178.99	3.37	1.85%
Project - 250 g/cow/day	6.27	175.91	6.45	3.54%
Project - 375 g/cow/day	6.15	172.54	9.82	5.38%
Project - 500 g/cow/day	6.04	169.45	12.91	7.08%