For the Certification of a Greenhouse Gas Protocol and Calculator for the Canadian Dairy Industry

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1.0 PROJECT AND METHODOLOGY SCOPE AND DESCRIPTION

1.1 Protocol Scope and Description

This quantification Protocol has been developed with the purpose of quantifying greenhouse gas (GHG) emissions and emission reductions from Dairy Farms in Canada. GHG emissions are to be normalized to unit of "GHG emissions per unit of fat corrected milk (FCM) produced".

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

FIGURE 1.1 offers a typical process flow diagram for a typical project.

This protocol is intended to quantify emissions and emission reductions of carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) for dairy farms in Canada. The main sources of GHG emissions from dairy farms include CH_4 emissions from enteric fermentation and manure, N_2O emissions from manure, and CO_2 and N_2O emissions from feed production. Although the type of GHG emissions reduced under this protocol will be dependent on the specific project(s) undertaken, the majority of projects will result in emission reductions of CO_2, CH_4, and N_2O.

All projects are required to take place on Canadian 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.

A variety of project scenarios may be undertaken at the farm-level to reduce GHG emissions – a detailed description of typical project scenarios is described in **TABLE 1.1**.

Protocol Flexibility

Other protocols relating to specific aspects of diary farm operation are currently available or under development. This Protocol is designed to link and complement relevant protocols to provide additional flexibility and opportunity to mitigate GHG emissions and create GHG reduction credits.

This Protocol provides flexibility for the user by introducing Basic and Advanced approaches to GHG emission quantification for specific sources. The basic approach for quantification will use accepted emission factors or default assessments of feed quality/GHG emissions, while the Advanced approach will require on-site measurement (with proper calibrations and QA/QC procedures). Basic and Advanced approaches are not available in all quantifications; wherever flexibility is an option, the requirements and result of each approach will be stated.

Protocol participants using the Basic approach will use a discount factor to decrease the number of GHG reductions created. To be eligible for "Advanced approach" benefits, participants in the Protocol must follow the Advanced approach for all quantification calculations which offer such flexibility (no Basic approaches may be followed). The discount factor scheme is outlined in **TABLE 1.2**. **FIGURE 1.2** outlines a process flow diagram for a typical baseline configuration.

TABLE 1.1 – Detailed Description of Typical Project Scenarios

Potential Scenarios	Description
1	Annual milk productivity per cow is increased, thus reducing GHG emissions per unit of milk produced from all SSRs.
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	Pasture use is increased to reduce GHG emissions from manure storage and feed production
5	Timing of manure spreading is modified to reduce methane emissions from storage unit

TABLE 1.2 - Discount Factors for Basic and Advanced Approaches

Advanced Approaches Only Used in Dairy Protocol	Simple Approaches Used in Dairy Protocol	% of GHG Credits to be Received under this Protocol
YES	NO	100
NO	YES	80

FIGURE 1.1 - Process Flow Diagram for Project Condition

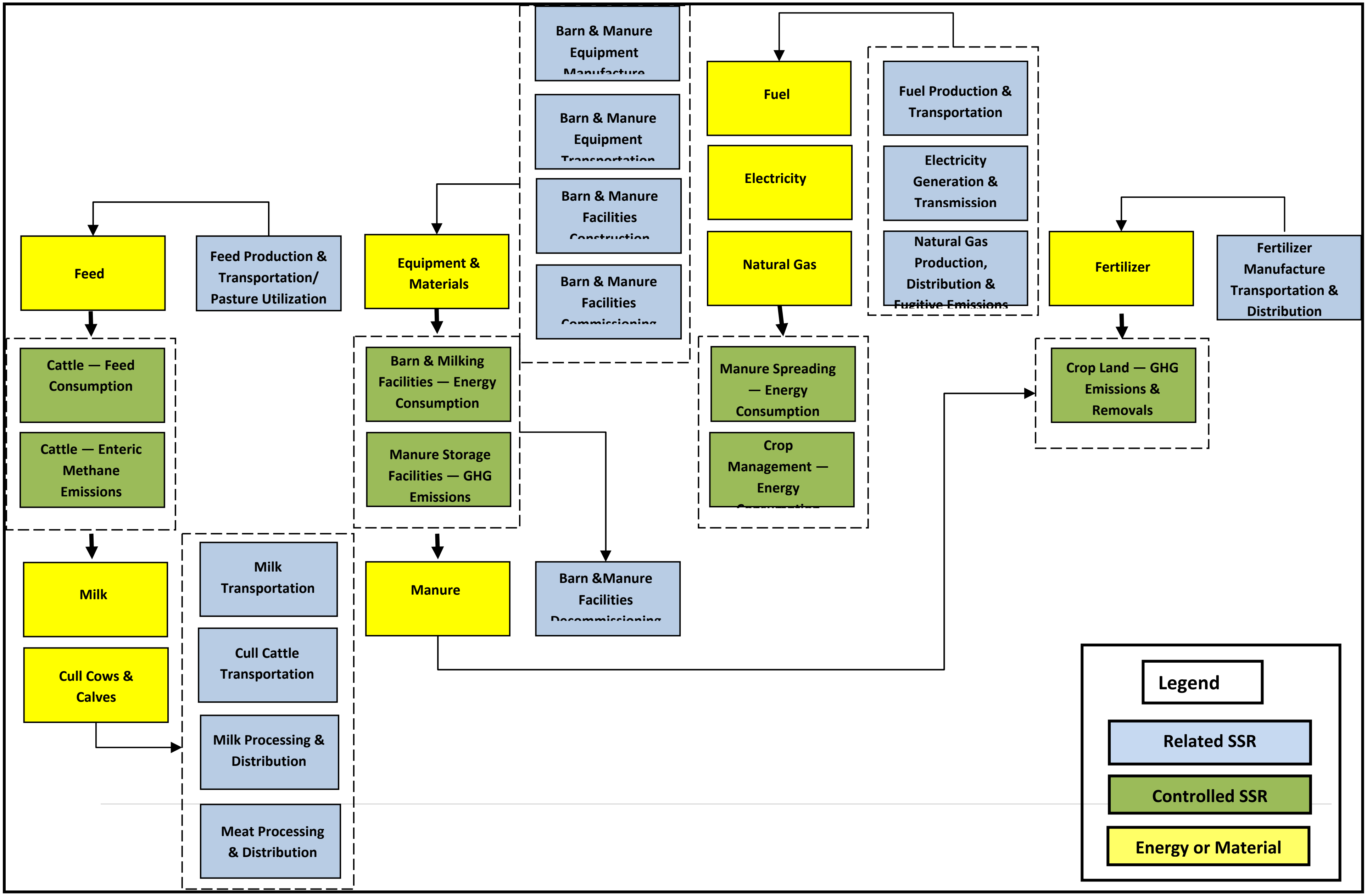
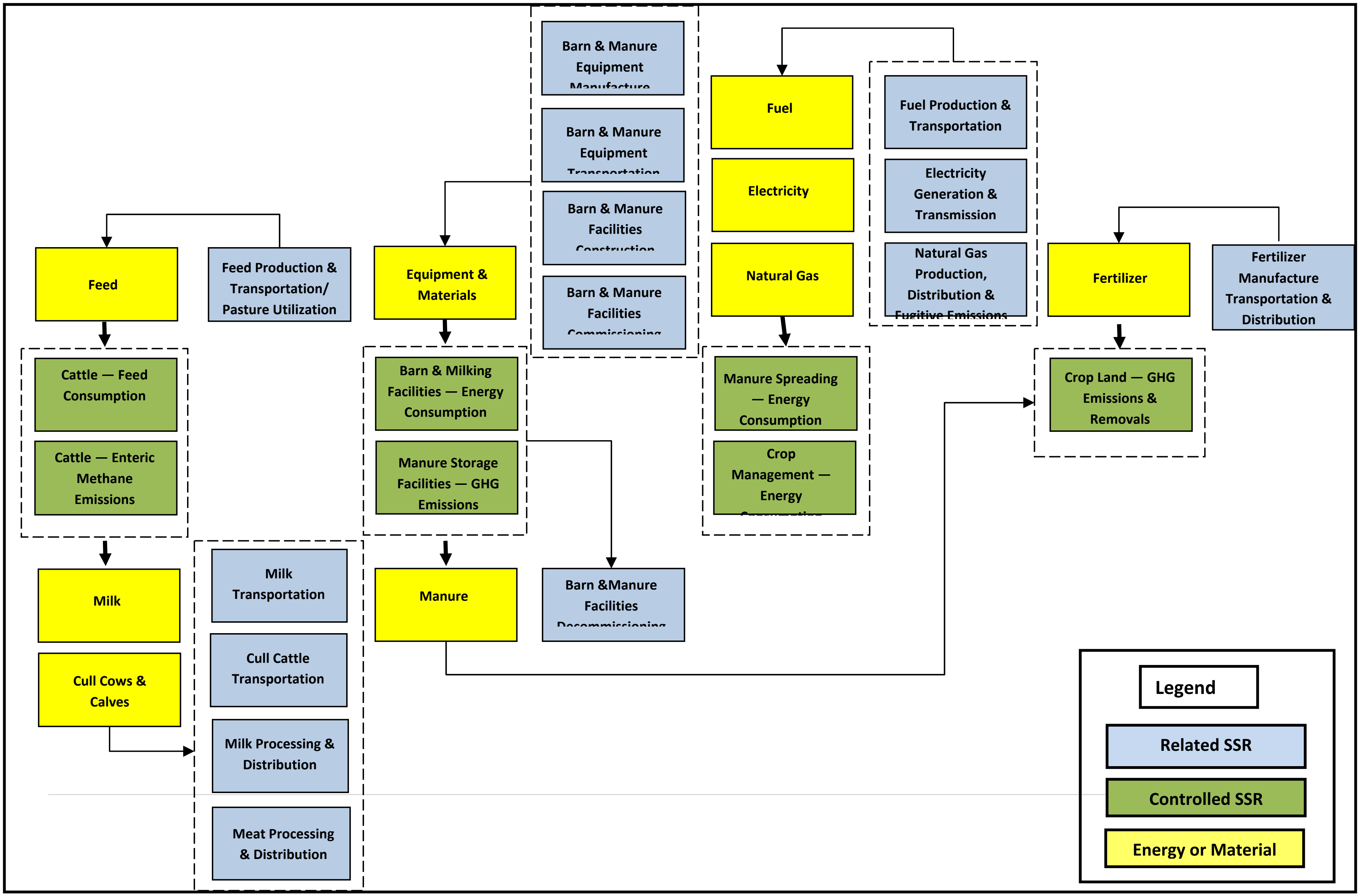


FIGURE 1.2 - Process Flow Diagram for Baseline Condition



1.2 Glossary of New Terms

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

Acid Detergent Fibre (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.†

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

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 basis by using the following formulas: DM basis = As-fed basis x (Dry Matter %/100) or As-fed basis = DM basis x (Dry Matter %/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% content in the diet. †

Enteric Methane Emission - Methane (CH_4) released by cattle (or other ruminants) as part of the normal digestive process.

Fat Corrected Milk (FCM) – Quantity of milk, normalized to a common energy basis. FCM is used in the scientific literature to mean 4 % percent fat corrected milk. The equation for calculating it is given as:

- kg FCM = 0.4 x kg milk + {(15 x % fat/100)} x kg milk
- Alternatively, the milk quantity can be corrected to other fat levels. For example, at 3.5 % fat the equation is:
    - kg 3.5% FCM = (0.4255 x kg milk) + {16.425 x (% fat/ 100)} x kg milk

Source: Dairy Reference Manual (3rd Edition). Penn State University.

Forage – High fibre 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 21.

Neutral Detergent Fibre (NDF) - commonly called "cell walls." NDF give a close estimate of fibre constituents of feedstuffs as they measures cellulose, hemi-cellulose, lignin, silica, tannins and cutins. Neutral detergent fibre 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 310.

Pasture - Land with vegetation used for grazing of cows and other livestock.

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 Cattle – Young cattle (calves, heifers, bulls) raised on a farm to replace milk cows removed from the herd.

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.†

2.0 QUANTIFICATION DEVELOPMENT AND JUSTIFICATION

2.1 Identification of Sources and Sinks (SS's) for the Project

SS's were identified for the project by reviewing the seed protocol document and relevant process flow diagram. This process confirmed that SS's in the process flow diagrams covered the full scope of eligible project activities under the protocol.

Based on the process flow diagram provided in **FIGURE 1.1**, the project SS's were organized into life cycle categories in **FIGURE 2.1**. Descriptions of each of the SS's and their classification as controlled, related, or affected are provided in **TABLE 2.1**.

Procedures used for the identification of relevant SSRs:

- Aggregation or disaggregation of identified SSRs. The number of SSRs defined and the degree of detail presented is determined in large part by data availability and required level of accuracy.

- Review system of SSRs identified for the project by confirming that:
    - all relevant SSRs are identified;
    - each SSR is classified appropriately as controlled & owned, related or affected;
    - all GHG inputs and outputs for each element are identified; and
    - that the sequence of SSRs for the system is correct.
    - Repeat previous steps as necessary

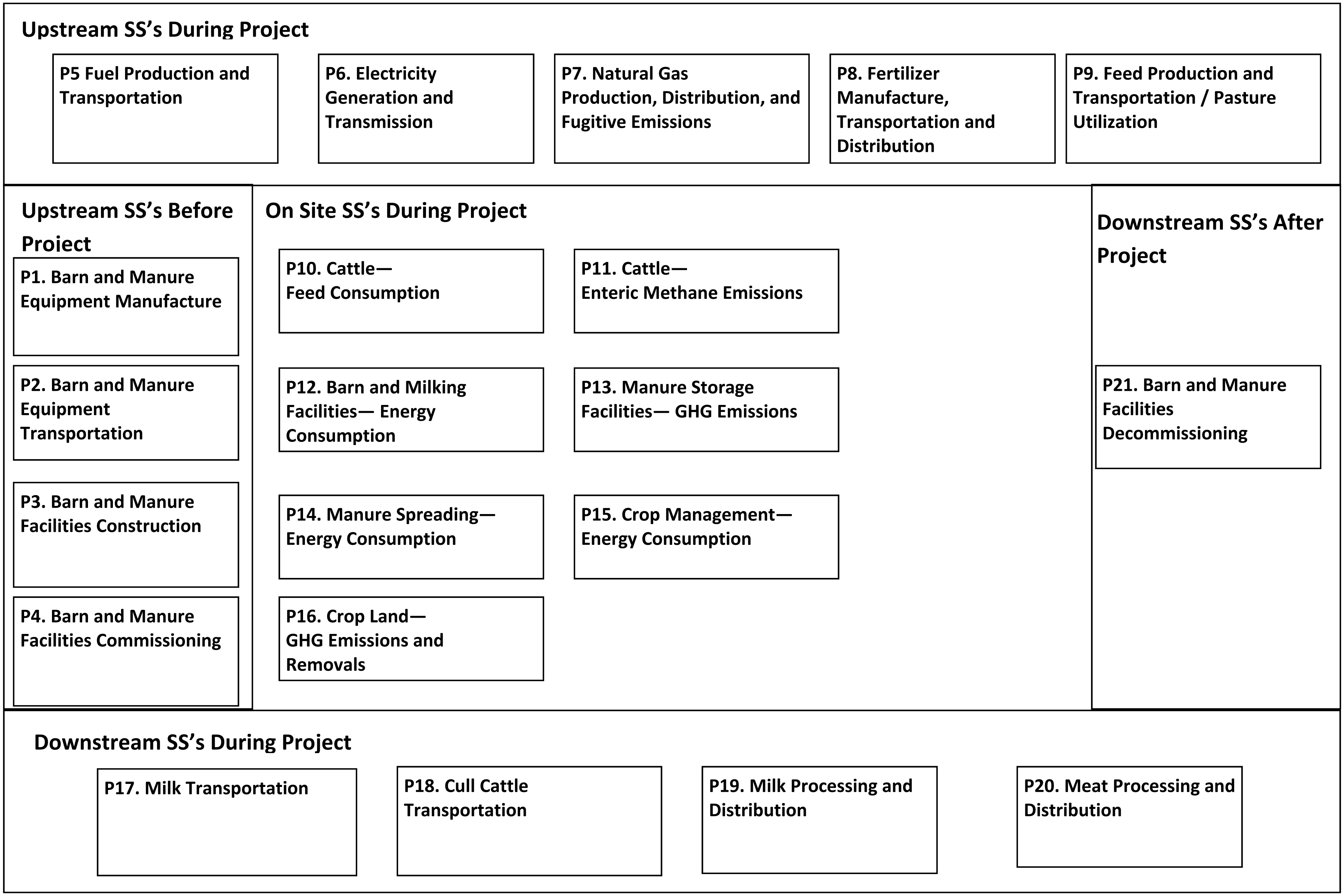
- Identification of all SSRs physically *related* to the primary project activities, by tracing products, materials and energy inputs/outputs upstream to origins in natural resources and downstream along their life-cycles. For example electricity production, fossil fuel production, etc...

- For each identified SSR the parameters required to estimate or measure the greenhouse gases are determined including materials and energy inputs/outputs, and information on activities, products and services.

- Determination of the function[1] provided by the system of SSRs in order to assist in assessing equivalence of service between the project and the baseline scenario.

[1] The function is the products, goods and/or services provided by the SSRs identified for the project scenario.

FIGURE 2.1 – Project Element Life Cycle Chart



1 **TABLE 2.1** –Project SS's

SSR	Description	Controlled, Affected, Related
Upstream SSRs Before Project		
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
Upstream SSRs During Project		
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 SSRs During Project		
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	Controlled

	manage feed composition to control enteric emissions.	
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 SSRs During Project		
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
Downstream SSRs After Project		
P21. Barn & Manure Facilities Decommissioning	All activities (inputs of materials and energy) required to shut down the barn(s) and manure storage facility.	Related

2.2 Identification of Baseline

The baseline scenario is the most appropriate and best estimate of GHG emissions and removals that would have occurred in the absence of any project(s). With respect to developing the baseline scenario for the Protocol and Calculator, two sets of circumstances must be considered to determine a baseline scenario. First, dairy farms across Canada can vary widely in their GHG emissions per kg of milk produced. Second, according to Canada Census data, the number of dairy cows and dairy farms steadily is declining, but total milk production continues to increase to meet the demand of increasing population. These same data, however, also point out that the rate of decline in GHG emissions per unit milk production has slowed such that further decrease in emissions will require incremental practice change.

The approach to quantifying the baseline will be primarily a Project-Specific Historic Benchmarks. This approach requires individual farms to calculate a baseline for each farm in the project for the 3-year period prior to project registration. 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 3.7% fat corrected basis. The method is described in Section 2.5 to calculate GHG emissions per unit milk, with data needed outlined in Table 2.5.

Baseline Scenario Adjustments

The baseline scenario identified for the projects eligible under this quantification protocol may require adjustments to ensure functional equivalence with the project. These adjustments are usually performed when the energy savings are quantified. In many cases, the quantification and claims of GHG emission reductions will occur on a yearly basis, therefore these adjustments will need to be performed according to that same schedule.

2.3 Identification of SS's for the Baseline

Based on the process flow diagrams provided in **FIGURE 1.2**, the project SS's were organized into life cycle categories in **FIGURE 2.2**. Descriptions of each of the SS's and their classification as either 'controlled', 'related', or 'affected' is provided in **TABLE 2.2**.

Historical Benchmark and Performance Standard

All SSRs relevant to the baseline scenario selected must be identified. In addition to on-site SSRs, SSRs upstream and downstream of the facility must also be identified.

FIGURE 2.2 – Baseline Element Life Cycle Chart

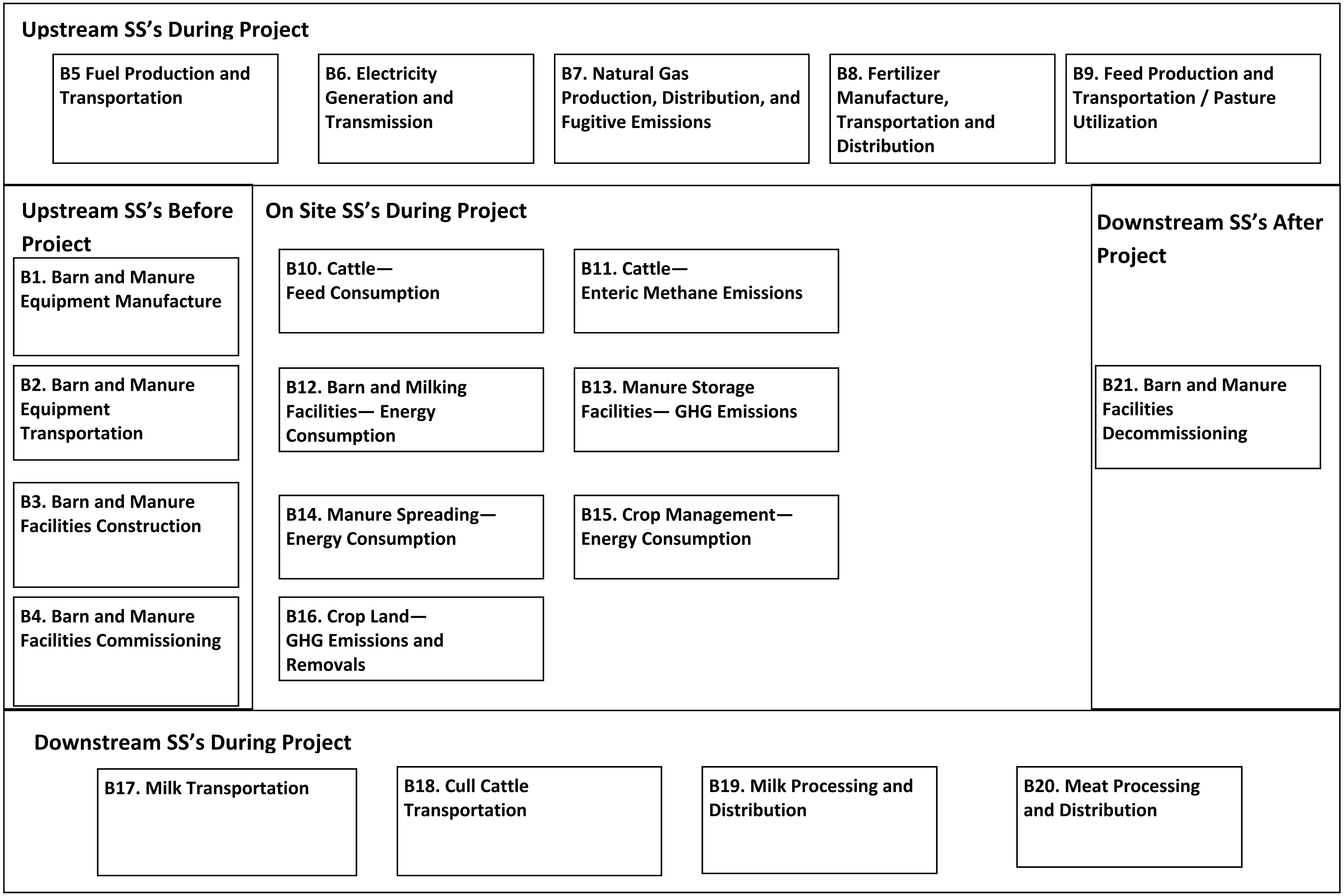


TABLE 2.2 – Baseline SS's

SSR	Description	Controlled, Affected, Related
Upstream SSRs Before Project		
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
Upstream SSRs During Project		
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 SSRs During Project		
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	Controlled

	manage feed composition to control enteric emissions.	
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 SSRs During Project		
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
Downstream SSRs After Project		
B21. Barn & Manure Facilities Decommissioning	All activities (inputs of materials and energy) required to shut down the barn(s) and manure storage facility.	Related

2.4 Selection of Relevant Project and Baseline SS's

Each of the SS's from the project and baseline condition were compared and evaluated as to their relevancy and to determine if it is necessary to quantify the GHG emission by direct monitoring or estimation. This procedure was adapted form Canada's Offset System for Greenhouse Gases – Guide for Protocol Developers (August 2008-Draft version). The justification for the exclusion or conditions on which SS's may be excluded is provided in **TABLE 2.3**. All other SS's listed previously are included.

TABLE 2.3 – Comparison of SS's

Identified SSRs	Baseline (C, R, A)	Project (C, R, A)	Include or Exclude from Quantification	Justification for Exclusion
Upstream SSRs				
B1/P1. Barn & Manure Equipment Manufacture	Related	Related	Exclude	The emissions from this element are expected to be equal or lower in the project as compared to the baseline scenario.
B2/P2. Barn & Manure Equipment Transportation	Related	Related	Exclude	The emissions from this element are expected to be equal or lower in the project as compared to the baseline scenario.
B3/P3. Barn & Manure Facilities Construction	Related	Related	Exclude	The emissions from this element are expected to be equal or lower in the project as compared to the baseline scenario.
B4/P4. Barn & Manure Facilities Commissioning	Related	Related	Exclude	The emissions from this element are expected to be equal or lower in the project as compared to the baseline scenario.
B5/P5. Fuel Production and Transportation	Related	Related	Exclude	The emissions from this element are expected to be equal or lower in the project as compared to the baseline scenario.
B6/P6. Electricity Generation and Transmission	Related	Related	Exclude	The emissions from this element are expected to be equal or lower in the project as compared to the baseline scenario.
B7/P7. Natural Gas Production, Distribution, and Fugitive Emissions	Related	Related	Exclude	The emissions from this element are expected to be equal or lower in the project as compared to the baseline scenario.
B8/P8. Fertilizer Manufacture,	Related	Related	Exclude	The emissions from this element are expected to

Transportation and Distribution				be equal or lower in the project as compared to the baseline scenario.
B9/P9. Feed Production and Transportation / Pasture Utilization	Related	Related	Include	This element comprises some of the practices for GHG reduction included in the protocol. To accommodate on- and off-farm sources of feed, standardized assessment of 'embedded emissions' are used to account for GHG intensity of feedstuffs.
Onsite SSRs				
B10/P10. Cattle – Feed Consumption	Controlled	Controlled	Include	This element comprises some of the practices for GHG reduction included in the protocol.
B11/P11. Cattle – Enteric Methane Emissions	Controlled	Controlled	Include	This element comprises some of the practices for GHG reduction included in the protocol.
B12/P12. Barn & Milking Facilities – Energy Consumption	Controlled	Controlled	Exclude	The emissions from this element are expected to be equal or lower in the project as compared to the baseline scenario. Exclusion of this SSR represents conservativeness concerning quantification of reductions. Also, this Protocol encourages participants to enrol in an Energy Efficiency Protocol to capture potential reductions from decrease use of energy.
B13/P13. Manure Storage Facilities – GHG Emissions	Controlled	Controlled	Include	This element comprises some of the practices for GHG reduction included in the protocol.
B14/P14. Manure Spreading – Energy	Controlled	Controlled	Exclude	The emissions from this element are expected to

Consumption				be equal or lower in the project as compared to the baseline scenario. Exclusion of this SSR represents conservativeness concerning quantification of reductions.
B15/P15. Crop Management – Energy Consumption	Controlled	Controlled	Exclude	The emissions from this element are expected to be equal or lower in the project as compared to the baseline scenario. Exclusion of this SSR represents conservativeness concerning quantification of reductions.
B16/P16. Crop Land – GHG Emissions & Removals	Controlled	Controlled	Exclude/Include	For the most part, these emissions and removals are addressed in part in the standard GHG intensity of feedstuffs. The emissions from this element are expected to be equal or lower in the project condition as compared to the baseline scenario.
Downstream SSRs				
B17/P17. Milk Transportation	Related	Related	Exclude	The emissions from this element are expected to be equal or lower in the project as compared to the baseline scenario.
B18/P18. Cull Cattle Transportation	Related	Related	Exclude	The emissions from this element are expected to be equal or lower in the project as compared to the baseline scenario.
B19/P19. Milk Processing & Distribution	Related	Related	Exclude	The emissions from this element are expected to be equal or lower in the

				project as compared to the baseline scenario.
B20/P20. Meat Processing & Distribution	Related	Related	Exclude	The emissions from this element are expected to be equal or lower in the project as compared to the baseline scenario.
B21/P21. Barn & Manure Facilities Decommissioning	Related	Related	Exclude	The emissions from this element are expected to be equal or lower in the project as compared to the baseline scenario.

1

2.5 Quantification of Reductions, Removals and Reversals of Relevant SS's

2.5.1 Quantification Approaches

Quantification of the reductions, removals, and reversals of relevant SS's for each of the greenhouse gases will be completed using the methodologies outlined in **TABLE 2.5**. These calculation methodologies serve to complete the following equations for calculating the emission reductions from the comparison of the baseline and project conditions.

GHG emission reductions are calculated using Equation 1, below.

$$\textbf{GHG Emission Reductions} = (\textbf{Baseline Emissions} - \textbf{Project Emissions}) * \textbf{Milk} \qquad [1]$$

Where:

Baseline GHG Emissions and **Project GHG Emissions** are the GHG emissions quantified per kg FCM for the baseline and project scenarios, respectively; and

Milk is the total milk production in the Project.

GHG emissions for both the project and baseline scenario are calculated using Equation 2. Various multiplication factors are used for the quantification of each SSR and are described in their respective sections of this protocol.

$$\textbf{GHG Emissions} = \textbf{Activity Level} \times \textbf{Multiplication Factors} \qquad [2]$$

Where:

Activity Level represents the "quantity" of a particular input, dependant on SSR

Multiplication Factors represents the various factors used to convert the activity level to an appropriate unit of GHGs

Activity levels will be either measured or estimated, depending on the SSR while multiplication factors will be acquired from current published documentation.

Application of Discount Factor

Once all GHG emission reductions have been properly calculated, the appropriate discount factor must be applied. The discount factor used to determine eligible GHG reductions is dependent on the quantification approach used to determine GHG emissions and reductions.

The discount factor is to be applied by multiplying the total GHG emissions from all SSRs by the discount factor, yielding total eligible GHG emission reductions.

Manure Storage Facilities – GHG Emissions

Basic Approach — CH_4 Emissions - Method 1: Annually

Methane emissions from manure storage are calculated using Equation 3.

$$E_{SSR13,\,CH4} = \sum_{S,G} VS_G * N_G * 365 * 0.24 * 0.67 * MCF_S * MS_{S,G} * 21 / 1000 \quad \textbf{[3]}$$

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

$MS_{S,G}$ = Fraction of animal group G's manure handled by the defined manure management system

21 = Global warming potential of methane

1000 = kg per tonne

The "daily volatile solids excreted by a specific animal group", VS_G, in Equation 3 is calculated using Equation 4, below.

$$VS = (GE * (1-DE/100) + 0.04 * GE) * 0.92 / 18.45 \quad \textbf{[4]}$$

Where:

VS = Daily volatile solids excreted per day on a dry matter basis, kg $head^{-1}$ day^{-1}

GE = Gross energy intake, MJ head day^{-1}

DE = Digestible energy expressed as a percentage of gross energy

0.04 = Urinary energy excretion expressed as a fraction of GE

0.92 = Fraction ash-free content of manure

18.45 = Average energy content of dry matter (MJ kg^{-1})

The "methane conversion factor", MCF_S, in Equation 3 is listed by manure system and region (**Table 2.4.1**).

Table 2.4.1 - Methane Conversion Factors (MCF_S)

Manure System	Region	MCF (%)†
Solid	All regions	1.0
Liquid	BC	25.8
	Prairies	28.3
	ON	30.1
	PQ	28.4
	Atlantic	29.4
Pasture	All regions	1.0

†Based on Marinier et al. 2004 and Vergé et al. 2007

Advanced Approach — CH_4 Emissions - Method 2: Monthly

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 5.

$$E_{SSR13,CH4,L} = \sum_{m} (VS_{avail,m} * f_m) * 0.24 * 0.67 * 21/1000 \quad \textbf{[5]}$$

Where:

$\mathbf{E_{SSR13,CH4,,L}}$ = Methane emissions from a liquid manure storage unit, kilogram CO_{2e} yr^{-1}

m = Month (for a one year period)

$\mathbf{VS_{prod,m}}$ = Volatile solids added to manure storage unit during month (tonnes) (calculated for all animal groups contributing to unit)

$\mathbf{VS_{avail,m-1}}$ = Volatile solids in the storage unit at the end of the previous month available to be consumed by decomposer microorganisms

$\mathbf{f_m}$ = Fraction of available volatile solids consumed during month, Vant Hoff Arhenius factor.

$\mathbf{VS_{avail,m-1}}$, above, is calculated using Equation 6;

$$VS_{avail,m} = VS_{avail,\,m-1} + VS_{prod,m} - VS_{consumed,m-1} - VS_{stabilized,m} - VS_{removed} \quad \textbf{[6]}$$

Where:

$VS_{avail,m}$ = Volatile solids available to be decomposed at end of current month (tonnes)

$VS_{avail,\,m-1}$ = Volatile solids available to be decomposed at end of previous month (tonnes)

$VS_{prod,m}$ = Volatile solids added to manure storage unit during month (tonnes)

$VS_{consumed\ m}$ = Volatile solids consumed during month (tonnes)

= $VS_{avail,m} * f_m$

$VS_{stabilized}$ = Volatile solids stabilized into non-available forms (tonnes)

= $VS_{prod,m} * 0.55$

$VS_{removed}$ = Volatile solids removed from manure storage during month (tonnes)

The "fraction of available volatile solids consumed during month", f, in Equation 5 is calculated using Equation 7, below.

$$f = \exp[E(T_2-T_1)/(RT_1T_2)] \quad \textbf{[7]}$$

Where:

E = activation energy constant (63,515 J mol^{-1})

T_2 = average monthly temperature (ºK = ºC + 273, $T_2 \geq 5$ ºC)

T_1 = 303 ºK

R = ideal gas constant (8.317 J K^{-1} mol^{-1})

N_2O Emissions from Manure Storage

Nitrous oxide emissions from manure storage can be calculated using Equation 8. 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.

$$E_{SSR13,N2O} = \sum_G (FeedN_G - MilkN_G - LWgainN_G) * 365 * N_G * E_{N2O,G} * 310/1000 \quad \textbf{[8]}$$

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 day^{-1}

CP = crude protein content of diet, % of DMI

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 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}

= LWgain * 0.027

Where:

LWgain = daily liveweight gain, kg head day^{-1}

0.027 = fraction N in liveweight gain

365 = Number of days per year

N_G = Number of animals in a specific animal group

$E_{N2O,G}$ = N_2O emitted per kg of N excreted for a specific animal group, g N_2O kg^{-1} excreted N

= $F_{G,S}$ * $E_{N2O,S}$

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 (**Table 2.4.2**), g N_2O kg^{-1} excreted N

310 = Global warming potential of N_2O

1000 = kg per tone

Table 2.4.2 - Direct and Indirect N_2O Losses from Manure Storage Units for Different Manure Management Systems

Variable	Solid	Liquid	Pasture
Direct N_2O losses, g N kg^{-1} excreted N	7.9	7.9‡	0
Indirect N_2O losses†, g N kg^{-1} excreted N	4.7	6.3	0
N_2O losses, g N kg^{-1} excreted N	12.6	14.1	0

†Assumed no N losses due to leaching

‡Assumed liquid storage units had natural crust covers

Cattle – Enteric Methane Emissions

Methane emissions from enteric fermentation can be calculated using Equation 9, below.

$$E_{SSR11} = \sum_{G} GE_G * (Y_{mG} / 100) * N_G * 365 / 55.65 * 21 / 1000 \quad [9$$

Where:

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

G = Animal group

GE_G = Gross energy intake for a specific animal group (based on measured dry matter intake, MJ head day^{-1}

Y_{mG} = Percent of gross energy in feed converted to methane for a specific animal group

N_G = Number of animals in a specific animal group

365 = Number of days per year

55.65 = Energy content of methane, MJ per kg methane

21 = 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.

Replacement heifers are handled as one group, starting after weaning (assumed at end of two months) and extending until first calving (input variable). Weight gain is assumed to be constant over the growth period. GHG emissions are calculated for each month, based on calculated weights. Heifer ages are assumed to be distributed uniformly over the growth period. Pasture use and manure handling systems can be set differently for older heifers and younger heifers.

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 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.

Basic Approach

"Gross energy intake", GE_G, in Equation 9 may be estimated using the energy required for a representative animal in each group using the approach outlined by IPPC (2006) (**Table2.4.3**).

Table 2.4.3 - Calculations of Net Energy Requirements Using IPCC Equations

$NE_m = Cf_l * LW^{0.75}$ Where: NE_m = Net energy for maintenance, MJ head^{-1} day^{-1} Cf_l = Maintenance energy coefficient, MJ day^{-1} kg^{-1} (0.386 for cows in lactation, 0.322 for heifers and dry cows) LW = Average liveweight (kg)
$NE_a = 0.17 * F_{pstr} * NE_m$ Where: NE_a = Net energy for activity, MJ head^{-1} day^{-1} 0.17 = Coefficient for animals on pasture with sufficient forage for modest energy expense of feed acquisition F_{pstr} = Fraction of time spent on pasture
$NE_p = 0.1 * F_{preg} * NE_m$ Where: NEp = Net energy for pregnancy, MJ head^{-1} day^{-1} F_{preg} = Fraction of animal group that are pregnant
$NE_l = Milk * (1.47 + 0.40 * Fat)$ Where: NE_l = Net energy for lactation, MJ head^{-1} day^{-1} Milk = Amount of milk produced, kg head^{-1} day^{-1} Fat = Fat content of milk, % by weight
$NE_g = 22.02 * (BW/0.8/MW)^{0.75} * WG^{1.097}$ Where: NE_g = Net energy for growth, MJ head^{-1} day^{-1} BW = Average live body weight for animals in group, kg MW = Mature live body weight of an adult cow, kg WG = Average daily weight gain, kg day^{-1}
$REM = 1.123 – 0.004092*DE + 0.00001126*DE^2 – 25.4/DE$ Where: REM = Ratio of net energy available for maintenance to digestible energy consumed DE = Digestible energy expressed as a percentage of gross energy
$REG = 1.164 – 0.005160*DE + 0.00001308*DE^2 – 37.4/DE$ Where: REM = Ratio of net energy available for growth to digestible energy consumed

DE = Digestible energy expressed as a percentage of gross energy
$GE = [(NE_m + NE_a + NE_l + NE_p)/REM + NE_g/REG]/(DE/100)$ Where: GE = Gross energy, MJ $head^{-1}$ day^{-1}

Advanced Approach

Methane emissions from enteric fermentation may also be calculated more accurately by measuring the dry matter intake, DMI, on a daily basis using Equation 10.

$$GE_G = DMI/18.45 \qquad \textbf{[10]}$$

Where:

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

18.45 = Average energy content of dry matter (MJ kg^{-1})

The DMI value will be determined 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.

The default Y_M value of IPCC was refined by Karen Beauchemin and Alan Fredeen to account for changes in ration formulation practices - to modify the proportion of gross energy converted to enteric CH_4 (**Table 2.4.4**). Thus, the Advanced approach of the Dairy Protocol allows farmers to modify diets to manipulate Y_M within the range of variability of the IPPC 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. This protocol will use the following rules for the Y_M for dairy cows:

Table 2.4.4 - Estimates of the Percentage of Gross Energy Converted to Methane (Y_M) for Various Diets

Diet Description	**Concentrate kg/ kg milk (as is basis)**	**Y_M (% of GE)**
Default (unknown diet composition)		6.5
Feeding forages of known quality with grain		
Low quality grass or legume forages including hay, silage and pasture (> 50% NDF; 25% ADF) with low grain); excludes small grain silage and corn silage	< 0.25	7.5
Low quality grass or legume forages including hay, silage and pasture (> 50% NDF; 25% ADF) with low grain supplement	< 0.25	7.0
Moderate forage quality (40-50% NDF; 20- 30% ADF) and low grain supplement	< 0.25	7.0
Moderate forage quality (40-50% NDF; 20- 30% ADF) and high grain supplement	> 0.25	6.5
High forage quality (including cereal silages, corn silage) and low grain supplement	< 0.25	6.5
High forage quality (including cereal silages, corn silage) and high grain supplement	>0.25	6.0

Situations in which adjustments apply to Ym values above		
1. Use of monensin ionophores either as CRC bolus or in feed		10% reduction of Ym
2. Feeding fats*		
Calcium salts of palm oil (or similar bypass fats)		No reduction
Oilseeds		5% reduction for every 1% added fat on DM basis
3. Corn distillers dried grain with solubles (DDGS) fed		0.5% reduction applied to Ym for every 1.0% DDGS in diet DM
* Feeding fats, DDGS and ionophores together are additive		

NOTE:

Dietary manipulation to reduce enteric methane production is an important strategy in whole farm reduction of greenhouse gas emission. Short-term effects of certain inhibitory compounds are well known. Because of microbial adaptation, the effect of dietary modifications over the long term is less certain. Efficacy of feeding an ionophore can be short-lived, producing a reduction in Y_M that applies for only about 4 to 6 weeks. To capture the benefit of ionophores for reduced enteric emissions in the Dairy Protocol, the dairy farm must implement and document ionophore treatments lasting no longer than 6 weeks, with at least 4 weeks between treatments. Other dietary manipulations have a sustained effect. This includes lipids. To be effective, oilseeds must be crushed before feeding, and levels in the diet must not exceed the recommended levels of 4 to 6% on a dry matter basis. Again, the procedures to implement proper use of lipids must be documented.

GHG Emissions from Feed Production

Emission factors applied in this protocol are expressed in CO_2 equivalents (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 10 categories, each with its own emission factor. The 10 categories are presented below while emission factors are presented in Table 2.4.5:

- 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

- Pasture
- "Other" – including DDGS – with estimates averaged

Processed Feed

Emissions arising from the production of feed can be calculated using specific emission factors for various regions and types of feed. Equation 11, below, is the basic equation and is used along with data found in Table to determine offsets from feed production.

$$E_{SSR9} = \sum_{G,F} FeedDM_{G,F} * FeedCO_2e_F \qquad \textbf{[11]}$$

Where:

E_{SSR9} = GHG emissions from feed production (excluding pasture), tonnes CO_2e yr^{-1}

G = Animal group

F = Feed type

$FeedDM_{G,F}$ = 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

The feed category "Others" refers to dried distillers grains with solubles (DDGS). Calculated emissions consider only DDGS from grain corn and wheat. The calculations is as follows: assuming that 1t corn produces 309kg DDGS and 1t 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 2.4.5 - Emission factors (tCO_2e / tonne of feed) for different crop category

	Crop category									
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	(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	**See Table 13**	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

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

(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) Unimproved Pasture

(10) "Other" (DDGs – from corn and wheat)

Pasture Feed

For pasture, the ninth category, results are given per animal and per year because animal weight varies. Hence, Emission factors are presented for an equivalent of 1000kg of live weight (LW) per year (kgCO_2e./(tLW.yr)). As an example, for a cow which weights 600kg the emission factor must be multiplied by 0.6.

In this protocol pasture refers to "unimproved pasture". As a result, N_2O emissions are only due to deposited manure. Direct N_2O emissions from manure decomposition and indirect emissions such as volatilization and leaching are included, but N_2O from N-chemical fertilizers and crop residues is excluded, as is CO_2 from fossil energy. Methane emissions from enteric fermentation and manure are not included for the following reasons:

1) Enteric fermentation emissions do not apply to crops;

2) CH_4 emissions from manure deposited on pasture are considered negligible.

GHG emissions from pasture feed can be calculated using Equation 12:

$$E_{SSR9,\ pstr} = \sum_{G} PstrCO_2e_G * LW_G * F_{pstr,G} * N_G \qquad \textbf{[12]}$$

Where:

$E_{SSR9,pstr}$ = GHG emissions from pasture feed utilization, tonnes CO_2e yr^{-1} (**Table 2.4.6**)

G = Animal group

$PstrCO_2e_G$ = GHG emissions from unimproved pasture per tonne liveweight per year for a specific animal group, tonnes CO_2e $tonne^{-1}$ LW yr^{-1}

LW_G = Average liveweight for a specific animal group, tonne

$F_{pstr,G}$ = Fraction of annual dry matter intake obtained from pasture

N_G = Number of animals

Table 2.4.6 - Emission Factors for Unimproved Pasture Feed Utilization by Different Animal Groups

	Dairy Cows	Heifers (>1yr)	Calves
		Tonnes CO_2e LW^{-1} yr^{-1}	
Atl Prov.	1.90	1.34	1.16
PQ	1.90	1.34	1.16
ON	1.90	1.34	1.16
MB	1.87	1.32	1.15
SK	1.83	1.29	1.12
AB	1.80	1.27	1.10
BC	1.81	1.28	1.11

LW: Liveweight (tonnes)

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 2.5 – Quantification Procedures

ID number (SSR)	Data type	Data variable	Data unit	Measured (m) calculated (c) estimated (e)	Recording Frequency	Proportion of data monitored	How will data be archived? (electronic paper)	For how long is archived data kept?	Comments
Enteric Fermentation									
Enteric Methane - 1	Gross energy intake for a specific animal group	GEG	MJ head-1 day -1	m (advanced) e (basic)	Daily (advanced) Monthly (simple)	100%	Electronic	Minimum of two years after last issuance of carbon credit	
Enteric Methane – 2	Percent of gross energy in feed converted to methane for a specific animal group	Y_{mG}	%	e	Monthly	100%	Electronic	Minimum of two years after last issuance of carbon credit	
Enteric Methane – 3	Number of animals in a specific animal group	N_G	Head/year	c	Monthly	100%	Electronic	Minimum of two years after last issuance of carbon credit	
Enteric Methane – 4 (Basic)	Net energy for maintenance	NE_m	MJ head^{-1} day $^{-1}$	e	Monthly	100%	Electronic	Minimum of two years after last issuance of carbon credit	
Enteric Methane – 5 (Basic)	Maintenance energy coefficient	Cf_1	MJ head^{-1} kg $^{-1}$	e	Monthly	100%	Electronic	Minimum of two years after last issuance of carbon credit	
Enteric Methane – 6 (Basic)	Average live weight of cows	LW	kg	e	Monthly	100%	Electronic	Minimum of two years after last issuance of carbon credit	

Enteric Methane – 7 (Basic)	Net enegy for activity	NE_a	MJ $head^{-1}$ day^{-1}	e	Monthly	100%	Electronic	Minimum of two years after last issuance of carbon credit	
Enteric Methane – 8 (Basic)	Fraction of time spent on pasture	F_{pstr}	%	e	Monthly	100%	Electronic	Minimum of two years after last issuance of carbon credit	
Enteric Methane – 9 (Basic)	Net energy for pregnancy	NEp	MJ head-1 day -1	e	Monthly	100%	Electronic	Minimum of two years after last issuance of carbon credit	
Enteric Methane – 10 (Basic)	Fraction of animal group that are pregnant	Fpregp	%	e	Monthly	100%	Electronic	Minimum of two years after last issuance of carbon credit	
Enteric Methane – 11 (Basic)	Net energy for lactation	NEl	MJ head-1 day -1	e	Monthly	100%	Electronic	Minimum of two years after last issuance of carbon credit	
Enteric Methane – 12 (Basic)	Amount of milk produced	Milk	Kg head-1 day-1	m	Daily	100%	Electronic	Minimum of two years after last issuance of carbon credit	
Enteric Methane – 13 (Basic)	Fat content of milk	Fat	% by weight	m	Daily	100%	Electronic	Minimum of two years after last issuance of carbon credit	
Enteric Methane – 14 (Basic)	Net energy for growth	NEg	MJ head-1 day -1	e	Monthly	100%	Electronic	Minimum of two years after last issuance of carbon credit	
Enteric Methane – 15 (Basic)	Average live body weight for animals in group	BW	kg	e	Monthly	100%	Electronic	Minimum of two years after last issuance of carbon credit	
Enteric Methane – 16 (Basic)	Mature live body weight for an adult kow	MW	kg	e	Monthly	100%	Electronic	Minimum of two years after last issuance of carbon credit	
Enteric Methane – 17 (Basic)	Average daily weight gain	WG	Kg/day	e	Daily	100%	Electronic	Minimum of two years after last issuance of carbon credit	
Enteric Methane – 18 (Basic)	Ratio of net energy available for maintenance	REM		c	Monthly	100%	Electronic	Minimum of two years after last issuance of carbon credit	

	to digestible energy consumed								
Enteric Methane – 19 (Basic)	Digestible energy expressed as a percentage of gross energy	DE	% of gross energy (GE)	e	Monthly	100%	Electronic	Minimum of two years after last issuance of carbon credit	
Enteric Methane – 20 (Basic)	Ratio of net energy available for growth to digestible energy consumed	REG		c	Monthly	100%	Electronic	Minimum of two years after last issuance of carbon credit	
Enteric Methane – 21 (Advanced)	Dry matter intake for each ration ingredient (including edible oils, ionophores, etc.)	DMI	Kg head-1 day-1	m	Daily	100%	Electronic	Minimum of two years after last issuance of carbon credit	
Enteric Methane – 22 (Advanced)	Measure of quality of forage (NDF)	NDF		m	Monthly	100	Electronic	Minimum of two years after last issuance of carbon credit	This data could be provided by nutritionist judgment for diet formulation.
Manure Storage									
Manure Storage – 1 (Basic)	Daily volatile solids excreted by a specific animal group	VSG	kg DM head-1 day-1	m	Daily	100%	Electronic	Minimum of two years after last issuance of carbon credit	
Manure Storage – 2 (Basic)	Number of animals in a specific animal group	NG	Head/year	m	Monthly	100%	Electronic	Minimum of two years after last issuance of carbon credit	
Manure Storage – 3	Methane conversion factor	MCFS	%	e	Monthly	100%	Electronic	Minimum of two years after last issuance of	

(Basic)								carbon credit	
Manure Storage – 4 (Basic)	Fraction of animal group G's manure handled by the defined manure management system	MSS,G	%	e	Monthly	100%	Electronic	Minimum of two years after last issuance of carbon credit	
Manure Storage – 5 (Basic)	Daily volatile solids excreted per day on a dry matter basis	VS	kg head-1 day-1	e	Daily	100%	Electronic	Minimum of two years after last issuance of carbon credit	
Manure Storage – 6 (Basic)	Gross energy intake	GE	MJ head-1 day-1	e	Daily	100%	Electronic	Minimum of two years after last issuance of carbon credit	
Manure Storage – 7 (Basic)	Digestible energy	DE	%	e	Monthly	100%	Electronic	Minimum of two years after last issuance of carbon credit	
Manure Storage – 8 (Advanced)	Volatile solids added to manure storage unit during month for all animal groups contributing to unit	VSprod, m	tonnes	m	Monthly	100%	Electronic	Minimum of two years after last issuance of carbon credit	
Manure Storage – 9 (Advanced)	Volatile solids in the storage unit at the end of the previous month available to be	VSavail, m-1	tonnes	m	Monthly	100%	Electronic	Minimum of two years after last issuance of carbon credit	
Manure Storage – 10 (Advanced)	Fraction of available volatile solids consumed during month	f		c	Monthly	100%	Electronic	Minimum of two years after last issuance of carbon credit	
Manure Storage – 11 (Advanced)	Volatile solids available to be decomposed at	VSavail, m	tonnes	m	Monthly	100%	Electronic	Minimum of two years after last issuance of carbon credit	

	end of current month								
Manure Storage – 12 (Advanced)	Volatile solids available to be decomposed at end of previous month	VSavail, m-1	tonnes	m	Monthly	100%	Electronic	Minimum of two years after last issuance of carbon credit	
Manure Storage – 13 (Advanced)	Volatile solids added to manure storage unit during month	VSprod, m	tonnes	m	Monthly	100%	Electronic	Minimum of two years after last issuance of carbon credit	
Manure Storage – 14 (Advanced)	Volatile solids consumed during month	VSconsu med	tonnes	m	Monthly	100%	Electronic	Minimum of two years after last issuance of carbon credit	
Manure Storage – 15 (Advanced)	Volatile solids stabilized into non-available forms	VSstabiliz ed	tonnes	m	Monthly	100%	Electronic	Minimum of two years after last issuance of carbon credit	
Manure Storage – 16 (Advanced)	Volatile solids removed from manure storage during month	VSremov ed	tonnes	m	Monthly	100%	Electronic	Minimum of two years after last issuance of carbon credit	
Manure Storage – 17 (Advanced)	Average monthly temperature	T2	°C	m	Monthly	100%	Electronic	Minimum of two years after last issuance of carbon credit	
N_2O Emissions									
N2O Emissions - 1	Feed N intake for a specific animal group	FeedNG	Kg N head-1 day-1	m	Daily	100%	Electronic	Minimum of two years after last issuance of carbon credit	
N2O Emissions - 2	Dry matter intake	DMI	Kg head-1 day-1	e	Monthly	100%	Electronic	Minimum of two years after last issuance of carbon credit	
N2O Emissions - 3	Crude protein content of diet	CP	% of DMI	e	Monthly	100%	Electronic	Minimum of two years after last issuance of carbon credit	

N2O Emissions - 4	Nitrogen retained in milk for a specific animal group	MilkNG	Kg N head-1 day-1	e	Monthly	100%	Electronic	Minimum of two years after last issuance of carbon credit	
N2O Emissions – 5	Daily milk production	Milk	Kg head-1 day-1	m	Daily	100%	Electronic	Minimum of two years after last issuance of carbon credit	
N2O Emissions - 6	Protein content of milk	Milk protein	% on weight basis	e	Monthly	100%	Electronic	Minimum of two years after last issuance of carbon credit	
N2O Emissions - 7	Nitrogen retained in liveweight gain for a specific animal group	LWgainNG	Kg N head-1 day-1	e	Monthly	100%	Electronic	Minimum of two years after last issuance of carbon credit	
N2O Emissions - 8	Daily liveweight gain	LWgain	Kg head-1 day-1	e	Monthly	100%	Electronic	Minimum of two years after last issuance of carbon credit	
N2O Emissions - 9	Number of animals in a specific animal group	NG	Head/year	m	Monthly	100%	Electronic	Minimum of two years after last issuance of carbon credit	
N2O Emissions - 10	N2O emitted per kgof N excreted for a specific animal group	EN2O,G	kg N2O kg-1 excreted N	e	Monthly	100%	Electronic	Minimum of two years after last issuance of carbon credit	
N2O Emissions - 11	Fraction of excreted N handled by manure management system for a specific animal group	FG,S	%	e	Monthly	100%	Electronic	Minimum of two years after last issuance of carbon credit	
N2O Emissions - 12	N2O emitted per kg of N excreted in a specific	EN2O,S	Kg N2O kg excreted N-1	e	Monthly	100%	Electronic	Minimum of two years after last issuance of carbon credit	

	manure management system								
Feed									
Processed Feed - 1	Amount of feed of a specific type consumed by a specific animal group	FeedDM G,F	tonnes DM yr-1	m	Monthly	100%	Electronic	Minimum of two years after last issuance of carbon credit	
Processed Feed - 2	GHG emitted per tonne of feed	FeedCO2 eF	Tonne CO2e tonne-1 feed DM	e	Monthly	100%	Electronic	Minimum of two years after last issuance of carbon credit	
Pasture Feed – 1	GHG emissions from unimproved pasture per tonne liveweight per year for a specific animal group	PstrCO2e G	tonnes CO2e tonne-1 LW yr-1	c	Monthly	100%	Electronic	Minimum of two years after last issuance of carbon credit	
Pasture Feed – 2	Average liveweight for a specific animal group	LWG	tonne	e	Monthly	100%	Electronic	Minimum of two years after last issuance of carbon credit	
Pasture Feed - 3	Fraction of annual dry matter intake obtained from pasture	Fpstr,G	%	e	Monthly	100%	Electronic	Minimum of two years after last Pasture Feed - 4issuance of carbon credit	
Pasture Feed - 4	Number of animals in a specific group	NG	Head/year	m	Monthly	100%	Electronic	Minimum of two years after last issuance of carbon credit	

2.5.2 Contingent Data Approaches

Not applicable in this Protocol.

2.6 Management of Data Quality

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

The project proponent shall establish and apply quality management procedures to manage data and information. Written procedures should be established for each measurement task outlining responsibility, timing and record location requirements. The greater the rigour of the management system for the data, the more easily an audit will be to conduct for the project.

2.6.1 Record Keeping

The project proponent shall keep the information listed below for the time period stated **TABLE 2.6**. All information must be available to the verifier upon request.

TABLE 2.6 – Record Keeping Requirements

Kept for Duration of Project's GHG Credit-Production
Raw baseline period energy, feed, milk production, livestock, and manure management data, independent variable data, and static factors within the measurement boundary
A record of all adjustments made to raw baseline data with justifications
All analysis of baseline data used to create mathematical model(s)
All data and analysis used to support estimates and factors used for quantification
Expected end of life date of equipment removed or renovated under the project
Common practices relating to possible GHG reduction scenarios discussed in this protocol (such as manure management practices)
Metering equipment specifications (model number, serial number, manufacturer's calibration procedures)

Kept for 2 Years After Generation
Raw reporting period energy, feed, milk production, livestock, and manure management data, independent variables, and static factors within the measurement boundary
A record of changes in static factors along with all calculations for non-routine adjustments
All calculations of GHG emissions/reductions and emission factors
Measurement equipment maintenance activity logs
Measurement equipment calibration records
Initial and annual verification records and audit results

The project proponent 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 should be maintained in an orderly manner;
- All documents must be retained for the life of the project;
- Electronic and paper documentation are both satisfactory; and
- Copies of records should be stored in two locations to prevent loss of data.

2.6.2 Quality Assurance/Quality Control (QA/QC)

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

a Ensuring that the changes to operational procedures (including feed intake, manure management, etc.) continue to function as planned and achieve GHG reductions
b Ensuring that the measurement and calculation system and GHG reduction reporting remains in place and accurate
c Checking the validity of all data before it is processed, including emission factors, static factors, and acquired data
d Performing recalculations of quantification procedures to reduce the possibility of mathematical errors
e Storing the data in its raw form so it can be retrieved for verification
f Protecting records of data and documentation by keeping both a hard and soft copy of all documents
g Recording and explaining any adjustment made to raw data in the associated report and files.
h A contingency plan for potential data loss.

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