White Paper

Understanding the current state of carbon measurement and reporting landscape

Version 2.0

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Disclaimer: Measurement and reporting of GHG emissions and carbon sequestration is a moving topic. As new research is developed, techniques in measurement but also as standards and protocols evolve. While this report is to the best of our knowledge at time of writing. Please note that this is a field that is quickly changing.

This paper is not comprehensive and excludes many topics that have been discussed at the CRSB in the past (such as the plethora of goals made by governments and corporations, pressures on reducing long-lived vs. short-lived gases, metrics such as GWP100 vs. GWP*).

Version Number	**Publication Date**	**Description**
1.0	April 8, 2024	Initial publication available to CRSB members only.
2.0	August 28, 2024	Addition of sections on ISO standards (4.2), Global Reporting Initiative (4.5), and tools for banks to achieve net-zero requirements (6.1.1) and updated content in the following sections: introduction, 2.2, 4.3.1, 4.6, 5.1.2, 6.1.

1 INTRODUCTION

Significant progress has been made in reducing emissions from the Canadian beef industry. From 1981 to 2011, emissions intensity dropped 15% or 0.5% per year (Legesse et al. 2015). The Canadian Roundtable for Sustainable Beef (CRSB) was established in 2014 to advance, measure and communicate continuous improvement in sustainability of the Canadian beef value chain. This has been successful with the National Beef Sustainability Assessment (NBSA) showing a 15% reduction in emissions intensity between 2014 and 2021 or 2.1% per year (Aboagye et al. 2024). This puts the Canadian beef industry on-track to reach the goal of reducing emissions intensity by 33% by 2030.[1] Communication and collaboration are still needed.

As the countdown to 2030 goals quickly approaches, the move towards "environmental impact reporting is *fast* (with many initiatives already underway) and *furious* (with a sometimes confusing landscape of organizations, approaches, proposals and methodologies competing for attention)." (Deconinck et al. 2023). The urgency to figure things out is high as baselines are needed against which to measure progress. However, the current state of knowledge from the research and standards communities continues to be a frustration and barrier; creating risk exposure for companies that made climate goals between 2018 and 2020 and are anxious to have baselines that capture progress since then.

The desire to include carbon sequestration in models and standards is high, with the intent of recognizing the positive contribution that primary producers can make. However, uncertainty intervals remain wide, requiring direct measurement with expensive soil samples.

Currently, most impacts are estimated or modelled by applying emission factors or by using complex empirical or biophysical models. However, different methods put forward by various standards can give different results, leading to questions about the most appropriate method and the reliability and comparability of claims generated. As the media puts a spotlight on companies for greenwashing (whether it is present or not), risk-aversion increases resulting in a push for direct measures (despite the costs associated with it).

Caution is needed in the push from modelled to measured approaches in emissions tracking. While it could strengthen industry's position and its claims regarding emission mitigation. It comes at a high cost of reporting burden to primary producers. This high bar for reporting, annual monitoring and verification has the potential to create captive supplies to supply chains with only certain types of producers able to participate. Creating a real disadvantage for producers without the time, resources or patience to deal with research-level requirements on a commercial operation.

Multiple agricultural companies have committed to following international reporting guidelines including the GHG Protocol. This somewhat addresses the concern about countries and companies adopting different methodologies and reporting requirements, which would lead to high transaction costs and confusion. The lack of clarity on "Land Sector Removals" (WRI and WBCSD 2022) raises questions on if mass balance approaches will be accepted or if identity preservation will be required – making it largely

[1] https://beefstrategy.com/pdf/2020/GHG_Goal_Fact_Sheet%20Sept%203.pdf

unfeasible for many agricultural commodities such as dairy and beef. Also, for Scope 3 the inventory boundary requires emissions at land level and not at regional or jurisdictional scale. This poses a challenge for companies providing financial assistance to producers delivering GHG reductions through improved land management, restoration, or forest conservation, which could be at the sourcing region or jurisdictional scale. Such activities may not be traceable to a farm and thus cannot be included in Scope 3. Furthermore, land management units in the land sector removal guidance consist of forest lands, grasslands, and land set aside for conservation, however, it does not specify community pastures, which are managed communally or by organizations. The guidance also excludes lands with other protective status, which may play an important role in carbon removals. E.g., peatland conservation can provide multiple ecosystems functions including carbon storage.

As companies establish benchmarks (by the end of 2024) and turn to focus on strategies to meet their 2030 climate goals (gives five years of activity from 2025-29). Questions about the best (most robust and risk adverse) way to achieve those goals are being discussed. Companies that have tried the carbon credit market and been burnt with 'junk' credits that did not have robust protocols are hesitant to go that road again. Even when there are extremely robust protocols now available, being able to discern between a robust protocol developed with scientific rigour and one that is not requires technical expertise to understand the science and modelling behind them. Consequently, some companies have turned to projects that give them control and oversight of the measurement and direct connections with primary producers.

Regardless of whether a company is using carbon credits or a project, they are looking for a tool that allows producers to baseline and monitor change for the whole farm (covering multiple commodities grown). Understanding the underlying model strengths, weaknesses and appropriate purpose is challenging with over 40 known tools related to beef production alone to choose from. A comparison of five farm-level greenhouse gas calculators on seven beef production system datasets was conducted by Skyes et al. (2017) finding considerable variation. Differences in scope along with allocation between enterprises explained a large amount of the variation. Again, this requires technical expertise to understand the science and modelling behind each tool and to choose one that is appropriate for companies utilizing them for scope 3 reporting purposes.

The ability to make meaningful impacts is blunted with aggregation but is also a feasible starting point without burdensome reporting for producers. The concern is that more stringent requirements in one market might lead to a 'reshuffling' of trade flows, where low-impact products are sent to the most stringent markets; while high-impact products are sent to less stringent markets, with only limited improvements in global environmental impacts (Deconinck et al. 2023). Identifying pathways that generate meaningful change is critical for companies as they transparently report against their goals. However, there is a danger that the drive for perfection delays progress and critical learning to get started on the road to mitigation efforts.

The objectives of this paper are:

- to provide a current state of knowledge on research around livestock emissions and carbon sequestration. Many research projects are underway across Canada, but results are not expected until after 2028. This means that 2030 goals need to be reached with the current state of knowledge.
- to provide a common understanding of carbon reporting, standards, verification, and incentive options for CRSB members. CRSB members may choose to pursue a variety of options for incentives which include carbon credits, insets, and the Certified Sustainable Beef Framework.
- communicate how the various international standards interact with each other.
- identify pain points that need to be addressed to fill gaps leading up to 2030.

It should be recognized that progress has been made over the last five years. International standards build on each other and are complimentary, not contradictory. However, the fragmentation in the current landscape needs to be addressed to clear a path for future efforts.

2 CURRENT STATE OF KNOWLEDGE ON CLIMATE

The average weather conditions over a minimum of three decades are termed as climate, while deviations from the expected climate are called climate change (Imran et al. 2023). Climate change comprises water scarcity, uneven rainfall distribution, floods, rising temperatures, drought, decreased crop yield, and overall threatens the existence of life (Imran et al. 2023). Intergovernmental Panel on Climate Change (2022) reports the impact of climate change on different systems (Table 1).

Table 1. Global Impacts of Climate Change

Category	Impacts of climate change
Ecosystem and biodiversity	• Loss of flora and fauna, change in geographic ranges and altered timing of seasonal events (e.g., change in geographic ranges, mostly to high altitudes and earlier spring events), increases in disease and mortality of plants and animals, wildfire over wide areas and decline in ecosystem services • The shift in geographical ranges to high altitudes results in the introduction of new diseases into mountain regions and high Arctic • Biodiversity is reduced in the warmest regions as adaptation limits are exceeded • Introduced species reduce or replace native species, consequently increasing vulnerability • Ecosystem services – limits CO_2 fertilization, changing ecosystems from carbon sinks to sources • Coastal blue carbon is negatively altered
Food systems, food security and forestry	• Negative impacts on livestock production, and crop and grassland yield and quality • Variability in grazing systems negatively affected animal fertility, herd recovery rates and mortality • Decreased sustainable yields of wild-caught fish • Altered distribution of cultivated and wild terrestrial, marine and freshwater species • High temperatures and humidity increase toxigenic fungi on many food crops
Water systems and water security	• Water scarcity and increasing frequency of extreme water events such as floods and droughts • Highest global glacier mass loss rate in the last two decades • Loss and degradation of terrestrial and freshwater species and ecosystems in the Arctic, mountain regions and other biodiversity hotspots
Health and well-being	• Mortality from heatwaves, flooding, drought, and storms • Trauma associated with extreme weather, loss of livelihoods and culture • Higher temperatures combined with land use/land cover change make more areas suitable for the transmission of vector-borne diseases
Human migration and displacement	• Drought and tropical storms and hurricanes, heavy rains and floods directly cause involuntary migration and displacement and indirectly through deteriorating climate-sensitive livelihoods
Cities, settlements, and infrastructure	• Cities and settlements damaged due to sea level rise, changes in runoff, floods, wildfires and permafrost thaw, causing disruptions in key infrastructure and services such as energy supply, transmission, communications, food and water supply systems
Economic sectors	• Large cost through property damage, infrastructure and supply chain disruptions • Impacts on inputs and crop yields • Reduced economic growth

2.1 Livestock and Emissions

Methane (CH_4) and nitrous oxide (N_2O) are the two major greenhouse gases (GHG) from livestock farming (Gerber et al. 2013; IPCC 2006), accounting for 60% or 3.7 Gt CO_2eq (carbon dioxide equivalent) of the total emission from the sector (FAO 2023a). Methane originates from rumen fermentation and manure storage, and N_2O arises from manure storage and the application of manure or fertilizers on land (Gerber et al. 3013). Land use change, fertilizer and pesticide manufacturing, feed processing, and feed transport also contribute to emissions in livestock farming (Gerber et al. 2013), amounting to 2.6 Gt CO_2eq (FAO 2023a). UNEP and CCAC (2021) reported 3.4 Gt CO_2eq (enteric and manure CH_4) and 0.9 Gt CO_2eq (N_2O from manure and feed production), estimated globally for the year 2015. For the corresponding year, respectively emissions from enteric CH_4 and manure management were 24 and 7.7 Mt CO_2eq (ECCC 2022). Methane and N_2O are more potent with a 100-year global warming potential of 28 and 265 than CO_2, respectively (Myhre et al. 2013). Following CO_2, CH_4 is the second GHG driving climate change globally (Myhre et al. 2013).

A rapid increase in atmospheric CH_4 has been reported in the past decade and strategies to mitigate CH_4, in addition to CO_2, could provide the greatest lever in global warming reduction in the short term as CH_4 has a relatively short atmospheric lifetime (UNEP and CCAC 2021).

2.2 Current enteric methane measurement techniques

Hill et al. (2016), Bekele et al. (2022), and FAO (2023b) provide a list of methane measurement techniques. All of these have trade-offs in accuracy (therefore confidence intervals), feasibility in confinement versus on grass, and cost. Highly accurate enteric methane measurements on grass are still a limitation of current measurement techniques. Accurate measurement is foundational for effective mitigation and being able to verify that reductions have taken place.

Respiratory chambers: are considered the gold standard for measuring CH_4 from the rumen and hindgut. The chambers and enclosures are designed to measure the air at the inlet and outlet for CH_4 and other GHGs. It provides individual animal data, and measurements from this system are highly accurate. However, chambers are expensive to build and maintain, they may alter the natural behaviour of animals, and are not feasible for grazing animals.

SF_6 tracer technique: canisters are attached to animals to capture animal respiration and belches. Permeating tubes containing SF_6 are deposited in the rumen. The advantage of this system is that it can be used for grazing animals. This system has a moderate cost. The limitation is that CH_4 collection equipment is attached to the animal and this may disrupt normal animal behaviour. Also, all the traces may not be captured.

GreenFeed system: consists of a head-chamber system combined with a portable feeding station for spot sampling of CH_4 emissions and gaseous exchange. It measures enteric CH_4 production from the breath of animals while on pasture or in confinement. It is portable and less expensive than the chamber system. The cost could be moderate to high.

Gas sensor capsules: concurrently measure concentrations of CH_4, CO_2, and H_2 in the rumen and breath.

In vitro techniques: rumen fermentation is simulated in a laboratory by incubating feed under gas-tight culture bottles using rumen fluid and buffer solution under anaerobic environment. This technique is used in research and commercial settings. The advantage of this technique is that it can be used to evaluate feeds and rumen microbial environments. However, *in vitro* (laboratory-based, outside the animal) results may not reflect *in vivo* (within the animal) results.

Open-path laser: measures enteric CH_4 from herds of animals by using lasers and wireless sensor networks that send beams of light from the herds of animals and analyzes CH_4 by infrared-absorption spectroscopy. Global positioning devices are fitted on cattle to track their movements and wind speed, and allows for individual measurements. It is used to obtain a short-term measurement of CH_4 from a grazing herd.

Satellite and drone imagery: have been used to track and count animals and there is a potential for adapting these technologies to assess livestock-related CH_4 emissions on farms.

Eddy covariance: allows continuous instantaneous covariance measurements of drafts of air and the concentration of gasses such as CH_4. This method was successfully used to measure CH_4 emissions from grazing cattle.

Blood CH_4 concentration tracer: is a future technology based on the quantification of CH_4 from a blood sample from the jugular vein.

Computer models: Mathematical modeling employs equations to describe or simulate processes assuming it reasonably represents the behaviour of the system. Empirical and dynamic mechanistic models are mainly used to estimate enteric CH_4 emissions. Empirical models estimate emissions using measured animal and feed data, while mechanistic models predict emissions using mathematical description of rumen's fermentation biochemistry.

2.3 Methane Mitigation Strategies

Several CH_4 mitigation strategies are possible (Table 2) and broadly categorized as animal breeding and management, feed management, diet formulation and precision feeding, forage quality, and rumen manipulation. The adoption and applicability of these strategies depend on the production system and local conditions. Ideally, the best mitigation strategy decouples emission reduction from animal productivity. How this plays out cannot be isolated to individual countries. Trade has the potential for more stringent requirements in one market leading to a 'reshuffling' of trade flows, where low-impact products are sent to the most stringent markets; while high-impact products are sent to less stringent markets, with only limited improvements in global environmental impacts (Deconinck et al. 2023).

The efficacy of a mitigation strategy should be calculated by multiple metrics, in terms of decreasing absolute emissions (grams of CH_4/animal/day) or emissions yield (grams of CH_4 per kg dry matter intake) or decreased emissions intensity (grams of CH_4 per kg of meat or milk produced) or energy loss as a proportion of gross energy intake (Y_m) (Beauchemin et al. 2020, 2022; FAO 2023b).

To report reductions in emissions measurements are needed. National assessments such as the CRSB NBSA is a starting point. But significant variation from farm to farm represents both opportunity and the potential to overwhelm producers. The ability to make meaningful impacts is blunted with aggregation but is also a feasible starting point without burdensome reporting for producers. This begs the question: Is individual farm reporting truly necessary if progress continues to be made through other means? Such as national assessments and industry communications on strategies (as outlined in Table 2) that producers can adopt as appropriate to their operation, when considering the economic cost benefit.

Table 2. Methane Mitigation Strategies (Alemu et al. 2017, 2023; Basarab et al. 2013; BCRC 2024; Beauchemin et al. 2007, 2011, 2022; FAO 2023b; Legesse et al. 2016; Mengistu et al. 2022)

Strategy	Limitations	Application/research status, and known gaps across Canada's beef sector
Animal breeding and management		
Improved management and increasing animal productivity through improved feeding (both quantity and quality of feed), health, reproductive performance, and selection and breeding for high productivity. Increased productivity is accompanied by increased feed intake and absolute CH_4 emissions. However, since maintenance requirements remain low with increased nutrient intake, emissions per unit of product (emissions intensity) are low in high-producing animals.	• Higher mitigation potential with low input systems	• Improved production (increases in reproductive efficiency, average daily gain, slaughter weight and crop yield) contributed to decreased emission intensity in Canadian beef cattle production • However, the association between improved productivity and the cost of inputs for intensification needs to be examined
Breeding for low CH_4 production through selecting animals with lower feed requirement, increased feed efficiency and feed digestibility, and microbial activity and fermentation pattern towards lower CH_4 production.	• Requires robust CH_4 measurement • Negative consequences on productivity and health are largely unknown	
Breeding for low residual feed intake (RFI). This is related to feed efficiency and RFI refers to the difference between actual and expected feed intake based on the animal's size and growth.	• The RFI method is based on accurate feed intake measurement, but its application is limited under pasture conditions	• Improved feed efficiency and reduced enteric CH_4 have been reported
Feed management and forage quality		
Lipids. Supplementation of lipids modifies fermentation patterns in the rumen by causing toxicity against methanogens and protozoa, serving as a hydrogen sink (biohydrogenation of unsaturated fatty acids into saturated fatty acids), and shifting towards the production of propionate.	• Limited applicability to grazing animals • May not be cost-effective	• Research demonstrated the potential to reduce absolute emissions and intensities in experiments and modelling
Concentrates. Feeding high-starch diets such as cereal grains results in the production of propionate in the rumen. Production of propionate utilizes hydrogen, competing with methanogenesis, thereby lowering CH_4 production.	• Limited impact on grain-fed systems. It could be expensive for forage-based systems	• Modelling demonstrated a decrease in emissions intensity

	• It disregards the role of ruminants in converting fibrous non-edible forages to high-quality protein • It may result in feed-food competition, which is expected to escalate with climate change with negatively affected crop production	
Increase forage quality. This improves feed digestibility (lower feed retention in the rumen) and thereby productivity.	• May result in increased N_2O emission	• Modelling demonstrated a decrease in emissions intensity
Pasture and grazing management. Incorporating legumes in grass pastures may improve fibre digestibility. Furthermore, legumes contain plant secondary metabolites such as tannins with anti-methanogenic activity and lowered fibrolytic bacteria activity. Grazing management improves pasture quality and quantity which contributes to lowered emissions intensity.	• Region specific research/data is required	• A study compared the effects of grazing management under Canadian conditions
Precision feeding is based on meeting the nutrient requirement of individual animals and thus decreasing feed input per product output.	• Little research on beef cattle	
Rumen manipulation		
Ionophores are compounds that target hydrogen producing bacteria in the rumen.	• Due to concerns about antimicrobial resistance, their use might be limited in the future	• Currently used in beef cattle diets
Bovaer (3-Nitrooxypropanol) is a molecule that inhibits CH_4 production in the rumen.	• Requires approval by regulatory bodies • Availability of supply • Cost	• Efficacy demonstrated in feedlots and forage-based diets Approved in December 2023 for use in Canada
Vaccine serves as anti-methanogenic by stimulating the immune system of animals to produce antibodies against methanogens.	• At the experiment level but limited publications • Inconsistent results and effects are small or nonexistent	

Macroalgae (Seaweeds) have anti-methanogenic properties and have resulted in reduced CH_4 production.	• Variability in efficacy depends on seaweed species, time of collection and growth environment, as well as animal dietary composition feeding period • Requires approval by regulatory bodies • May be a challenge to implement in grazing systems	
Alternative electron acceptors (e.g., calcium nitrate) supplementation draw electrons away from CH_4 formation.	• Although nitrate supplementation decreases CH_4, it can be partially converted to N_2O, contributing to emissions • Its use in nitrogen sufficient diets can result in the excretion of more N, consequently contaminating groundwater • Due to the risk of toxicity, nitrate supplementation is applicable to production systems where intake can be monitored • Requires approval by regulatory bodies	
Essential oils exert antimicrobial activities on various rumen microbes.	• Decrease CH_4 production *in vitro* but results from *in vivo* studies are inconsistent	• Research is needed to identify essential oils with consistent composition that selectively inhibit rumen methanogenesis, without adverse effects on feed intake and animal productivity
Tannins and Saponins are known to inhibit methanogens and protozoal populations associated with methanogens.	• Efficacy depends on the source and tannin composition (hydrolysable and condensed)	• Sainfoin is used in Western Canada grazing systems. • Research focus on agronomic characteristics and the role of tannins in N

		utilization and bloat-reducing characteristics • Research required to evaluate Sainfoin for CH_4 reducing characteristics
Direct-fed microbials are live microorganisms added to diets to modify rumen fermentation and improve fiber digestion.	• Limited research where direct-fed microbials affect CH_4	
Early life intervention (modifying and programing post-weaning and adult rumen microbiota in a way that decreases CH_4)	• Efficacy depends on dose, mode, and duration of administration, etc.	• Further understanding of early-life rumen microbial ecology and the mechanism of CH_4 mitigation is required
Phage and Lytic enzymes (breakdown pseudomurein, the principal cell wall component of rumen methanogens)	• No published studies	
Elimination of protozoa (defaunation). Rumen protozoa supply hydrogen to methanogens and defaunation could be achieved through, for example, tannins, saponins, or ionophores.	• Not practical under commercial conditions because of re-inoculation by cross-contamination	
Biochar enhances biofilm formation in the rumen	• Effect is non-existent in many reported studies	• *In vitro* and *in vivo* studies demonstrated no CH_4 mitigation potential
CH_4-oxidizing device (for dairy cattle by ZELP)	• Needs verification by independent studies	

2.4 Grassland Carbon Sequestration

Grasslands account for 40.5% of the Earth's land area and store one-third of the terrestrial carbon stocks. Globally the achievable soil organic carbon (SOC) sequestration potential of grasslands is 2.3-7.3 billion tons, 148-699 megatons, and 147 megatons of CO_2e per year respectively from biodiversity restoration, improved grazing management, and sown legumes in pasturelands. In grasslands, the belowground is where approximately 60% of the net primary productivity is allocated and where approximately 90% of their carbon is stored, therefore playing a vital role in carbon sequestration (Gao et al. 2016; Bai and Cotrufo 2022; Liang et al. 2023).

The desire to include carbon sequestration in models and standards is high, with the intent of recognizing the positive contribution that primary producers can make. However, uncertainty intervals remain wide, requiring direct measurement with expensive soil samples. This uncertainty is driven by the multiple factors at play in soil dynamics, vegetative species, temperature, and precipitation.

Soil organic carbon is classified into particulate organic matter (POM) and mineral associated organic matter (MAOM), which differ in physical and chemical properties, residence time and formation. POM is formed from plant and microbial residues and characterized by light weight; while MAOM is formed from molecules that are leached from plant residues or exuded from plant roots, which is associated with minerals (Gao et al. 2016; Bai and Cotrufo 2022; Liang et al. 2023).

Climate (temperature and precipitation) is the primary driver of POM formation, while soil properties (e.g., clay, silt content), cation-exchange capacity, and microbial nitrogen availability determine the accumulation of MAOM, and therefore the MAOM pool may saturate due to a finite sorption capacity of the soil mineral matrix. Across crops, grasses and trees more than 50% of root exudates and tissues are transformed into MAOM suggesting plants such as grasses, which allocate larger amounts of carbon belowground, contribute more to soil carbon sequestration. Climate regulates microbial activity and thus the microbial necromass and SOC storage. Climate induced precipitation anomalies, in the future, will affect plant community composition, productivity, carbon allocation, and microbial process (Gao et al. 2016; Bai and Cotrufo 2022; Liang et al. 2023).

In addition, increased fire frequency can substantially modify long-term SOC storage in grasslands. Globally, cold, moist soils promote the accumulation of microbial necromass and preserving these areas contributes to SOC stock. However, there is limited knowledge on how the contribution of above- and below-ground inputs to SOC accumulation is affected by grassland types, climate and soil properties. SOC losses are shown to vary between soil types when native grassland was converted to agricultural land in the Canadian Prairies, and the order of losses was medium-textured soils > coarse-textured soils > fine-textured soils (Gao et al. 2016; Bai and Cotrufo 2022; Liang et al. 2023). This suggests GHG mitigation interventions in reducing grassland conversion play a significant role.

The ability to measure changes in soil carbon stocks is a major barrier and needs refinement before being affordable at a large scale. This accurate measurement is foundational for effective mitigation or incentive payments, making this the biggest hurdle to address before further discussion on sequestration can take place. The risk of proceeding without solid science is the creation of 'junk' credits that disillusion producers and make companies risk-averse to participating in the market.

Even once current barriers are addressed, native and tame pastures are most suitable for different program options.

Table 3. Suitability of Carbon Credits, Ecosystem Goods and Services (EGS) and Conservation Easement

	Carbon Credits	EGS – Outcome-based biodiversity index	Conservation Easement
Targeted Land base	Suitable for tame pasture, degraded soil, higher annual rainfall, with a higher probability of sequestering carbon	Suitable for native pasture at equilibrium, unlikely to be sequestering carbon	Suitable for native pasture at equilibrium, unlikely to be sequestering carbon
Pros	Measurable and saleable Contributes to reduced net emissions reporting	Discourages carbon from being plowed by providing a financial incentive	Prevents carbon from being plowed with easement on the land title and provides financial payment
Limitations	Needs a Canadian protocol (ECCC underway, see Section 5.2.1) Protocols that require soil testing, will need ways of reducing the cost of verification	More challenging to have marketing claims associated with, but possible	More challenging to have marketing claims associated with, but possible

3 GHG EMISSION MEASUREMENT

Global concerns about rising temperatures and approaching tipping points have escalated the pressure to take measures to mitigate GHG emissions and increase carbon sequestration. The IPCC report by Rogelj et al. (2018) showed that long-lived gases (CO_2 and N_2O) were already so high that the only way to prevent global average temperatures from surpassing the 1.5 °C target was through a dramatic reduction in short-lived (CH_4) gas emissions.

Over the last several years, governments and private corporations have made commitments and begun taking action in their supply chain to reduce emissions. This has necessitated the ability to both benchmark and monitor emissions at multiple levels and through supply chains to ensure that emissions are not simply being moved from one sector to another.

3.1 Life Cycle Assessments (LCA)

Life cycle assessment is a modelling tool to quantitatively assess the environmental impacts of a product during its entire life cycle – from extraction of raw materials to end of life (ISO 2006). The two types of LCA are attributional and consequential (Table 4). Attributional LCAs assess the environmental impact of a product during its life cycle (Finnveden et al. 2009; Ekvall 2019; Vries and Boer 2010) and serve as a tool to compare emissions from material flows in the production (and consumption and disposal) of a product. Consequential LCAs assess how environmentally relevant flows change in response to possible decisions (Finnveden et al. 2009; Vries and Boer 2010) and therefore take into account the direct and indirect effects of the decisions. The pros and cons of the two LCA methods are presented below.

Table 4. The Pros and Cons of Attributional and Consequential LCA

	Attributional LCA	Consequential LCA
Pros	• Well-established guidelines are available (Ekvall 2019) • Provide clear guidelines for carbon sources and sinks, and allocate 'responsibility' or 'ownership', which can be used for accounting and establishing quotas • Uses a simple estimation approach • Scalable to large product portfolios (Brander 2021)	• Describes the consequence of a decision, and helps to make decisions to reduce negative environmental impacts (Ekvall 2019) • Takes into account the changes in environmental burden with a product, and considers market-mediated effects (Ekvall 2019; Russel 2019)
Cons	• May ignore indirect effects outside the boundaries, and market-mediated effects (Ekvall 2019; Russell 2019) • Decisions made based on LCA outcome may be wrong as this does not investigate consequences outside the boundary (Ekvall 2019; Brander 2021)	Requires more data on more processes, and data and emissions factors may be lacking. This makes it laborious and expensive (Ekvall 2019; Russell 2019) • Does not define scope and therefore can be sensitive to the choice of system boundary (Ekvall 2019; Brander 2021)

An example illustrating attributional and consequential LCA is given in Figure 1.

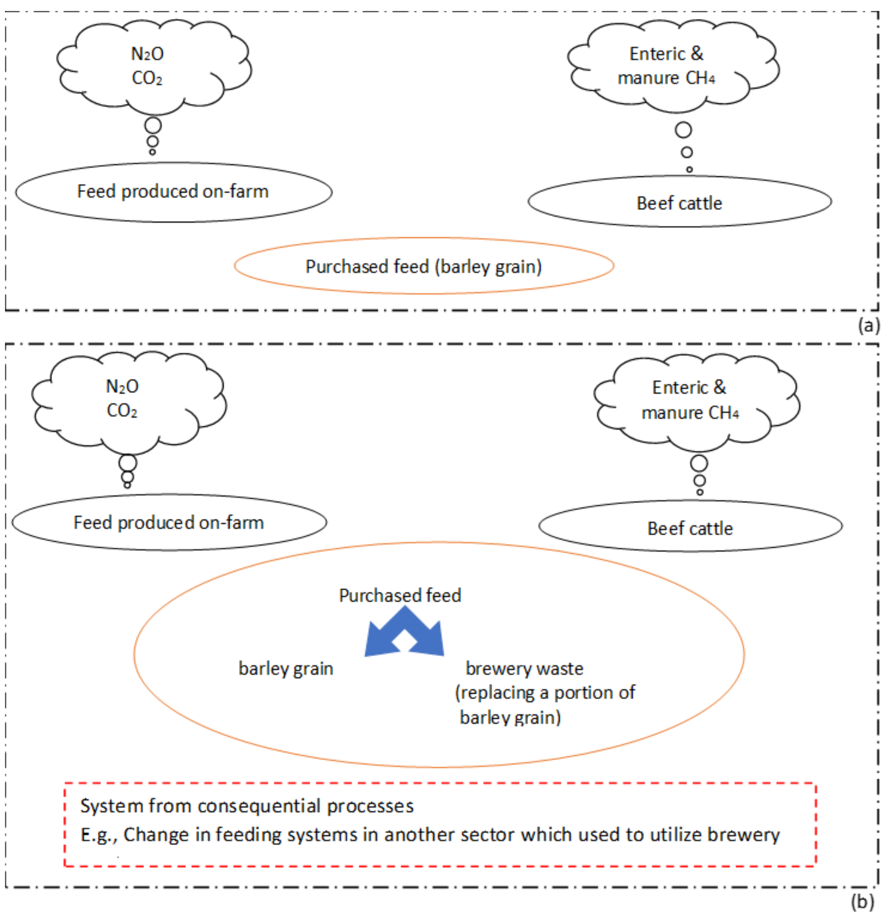

Figure 1. A simplified example of a beef system demonstrating attributional LCA (a) and consequential LCA (b)

The FAO LEAP Guidelines and Global Roundtable for Sustainable Beef (GRSB) Beef Carbon Footprint Guidelines are presented using Attributional LCA methodology. Therefore, despite rising pressure for a shift within the LCA community to utilize Consequential LCA (which captures changes in environmental burden) to drive mitigation decision-making (see Table 4), the majority of measuring and monitoring continues to use the Attributional approach (due to fewer data points needed and consistency with historical reporting).

The IPCC provides guidelines for estimating national inventories of anthropogenic emissions and removals of GHGs and employs Tier 1, 2, and 3 methodologies, which differ in complexity and accuracy (IPCC 2006).

- **Tier 1** is the basic method and relies on default emission factors from literature or calculated using Tier 2 methodology. For example, enteric emission factors for dairy and beef cattle are 128 and 53 kg CH_4/head/year, respectively.
- **Tier 2** is a more complex approach that requires detailed country-specific data. For example, data on gross energy (the total amount of feed energy) intake and CH_4 conversion factors for specific livestock categories.
- **Tier 3** incorporates additional country-specific information in estimates. For example, a model may consider detailed diet composition, concentration of products from enteric fermentation, and feed quality and seasonal availability. These estimates would be derived from direct experimental measurements. However, the Tier 3 method should be subjected to a wide degree of international peer review to ensure the accuracy and/or precision of estimates.

The Canadian Roundtable for Sustainable Beef (CRSB)'s National Beef Sustainability Assessment (NBSA) utilizes diet composition based on a variety of data sources specific to each region, along with regional information for slaughter, carcass weight and feed efficiency (based on literature). This aligns with the Tier 2. While project level reporting aims to utilize Tier 3 with individual farm data.

3.2 Inventory versus Intervention Accounting

Table 5 compares inventory and intervention accounting methods. Inventory accounting methods measure GHG emissions and removals within a defined system boundary over time relative to a historical baseline. The NBSA is an inventory accounting utilizing attributional LCA methodology.

In contrast, intervention accounting quantifies changes in GHG emissions and removals by focusing on the associated inputs and outputs for a specific intervention. This means that a full LCA is not done. Many regulated carbon market protocols are based on intervention accounting, which is supported by strong research with replicated emission factors and known impacts throughout the life cycle.

The combined use of both inventory and intervention accounting methods is recommended for decision-making. Particularly, for less researched interventions with uncertain impacts through the life cycle.

Table 5. The Pros and Cons of Inventory and Intervention Emission Accounting Methods

	Inventory	Intervention
Pros	• A well-established accounting method used to meet various objectives: accounting emissions and removals within a defined boundary, setting and tracking progress, and identifying leverage points for GHG emission reduction	• Reduced data needs as change is focused on a single intervention and associated changes (e.g. feed protocol impact on feed processing, consumption and manure)
Cons	• Has larger data requirements to cover the entire LCA compared to an intervention protocol. • Labour can be a barrier to data collection. This could be in particular a challenge with the cow-calf sector, with smaller herd size, on average 69 beef cows for Canada, where most of the emissions arise • It does not capture the impacts outside its boundary. • It does not quantify the change in emissions caused by the company's decisions as quantification. This makes it difficult to identify hotspots to reduce emissions	• Protocols must be robustly defined to capture unintended consequences where reductions in one place are captured elsewhere in the system. Weak protocols have damaged the quality of carbon credit produced (e.g. junk credits) • Because comparison is before and after an intervention is implemented, a robust baseline is needed. This may require 3-5 years of historical data, which can be a limitation to utilizing this approach

Emission factors are representative coefficients that quantify the GHG emissions or removals per unit of an activity. One of the advantages of the CRSB National Beef Sustainability Assessment, which is an inventory accounting of beef, is that it provides representative emission factors for stakeholders to use in corporate social responsibility reporting.

3.3 Modelled versus measured: When is sampling needed?

Carbon credits are based on physical measurement (measuring) or using a model to predict the amount of carbon emissions mitigated or sequestered (Duncan 2023). The choice between modelling or measuring is driven by the purchaser's need for accuracy and reliability or practicality and cost.

Modelling requires data (i.e. emission factors) on interventions to calculate carbon change. While it is cheaper and scalable there is greater uncertainty and wider confidence intervals. Particularly, if local emission factors are not available. Since farmers are paid based on predicted carbon credits (when using modelling) and this value could be lower than the actual carbon credits because of model limitations, physical measurement is currently preferred to improve accuracy. Table 6 summarises the pros and cons of the two methods. Verification requirements are different for modelled versus measured approaches but apply to both.

Table 6. The Pros and Cons of Modelling versus Measuring

	Modelled	Measured
Pros	• Modelling based on limited data points collected is cost-effective and scalable to test multiple scenarios quickly facilitating learning	• Physical measurement gives accuracy and higher levels of confidence
Cons	• Requires detailed data on the impact of specific interventions to calculate change • Due to uncertainty impact from local conditions has larger uncertainty and wider confidence intervals	• Expensive • Labour intensive • Time consuming – delays learning by limiting the number of scenarios examined at one time

Caution is needed in the push from modelled to measured approaches in emissions tracking. While it could strengthen industries position and its claims regarding emission mitigation. It comes at a high cost of reporting burden to primary producers. This high bar for reporting, annual monitoring and verification has the potential to create captive supplies to supply chains with only certain types of producers able to participate. Creating a real disadvantage for producers without the time, resources or patience to deal with research-level requirements on a commercial operation.

4 INTERNATIONAL STANDARDS

Multi-national companies that have made GHG reduction goals have also committed to following specific international standards and guidelines in measuring and reporting against their goals. This has created a multitude of standards addressing the four levels (product, project, firm and country) of reporting (Deconinck et al. 2023). Each level of reporting serves a purpose, see Table 7.

Table 7. Four Levels of Measurement

Level	Measurement	Purpose
Product	Life Cycle Assessments (LCA)	Communicate environmental impacts to consumers
Project	Frequently used at the whole farm level to capture change in carbon from multiple commodities	Generation of carbon credits for sale or reporting to the GHG Protocol
Firm	GHG protocol-a Corporate Accounting and Reporting Standard	Scope 1 and 2 reporting to the GHG Protocol, Carbon Disclosure project (CDP) for accountability against goals
Country	National Inventory Reports	Focused on impacts from domestic production and reporting against the Kyoto Protocol

Source: Deconinck et al. 2023

Figure 2 shows how these standards build from the most general at the firm level (bottom left corner) to more specific product-level standards at the top. These product-level standards, such as the Global Roundtable for Sustainable Beef (GRSB) Beef Carbon Footprint Guideline, build upon and are aligned with the more general standards such as ISO, IPCC, and FAO LEAP Guidelines for agriculture.

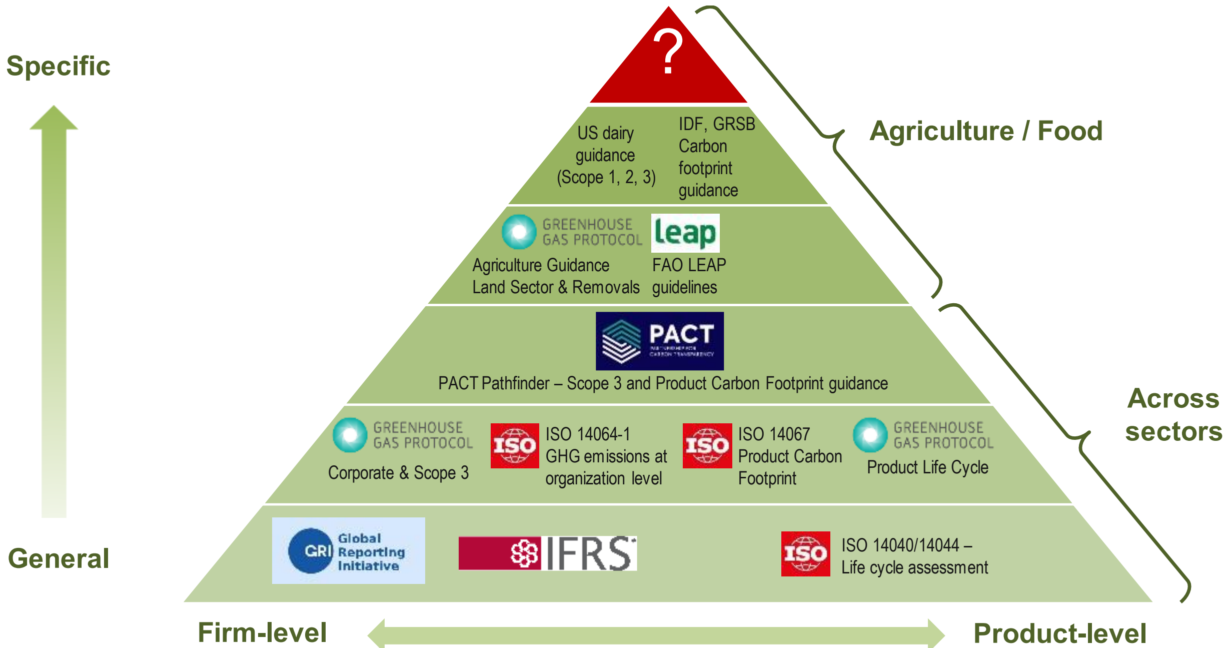

Figure 2. Landscape of reporting standards and guidelines for carbon footprints of food products (Deconinck et al. 2023)

Deconinck et al. (2023) raised concerns that with the growing number of standards instead of fostering collaboration, fragmentation is occurring instead. This has the potential to lead to captive supplies based on data reporting relationships. The OECD is convening policy makers and experts to work together to avoid fragmentation.[2] They have asked what it would take to have a smooth and reliable system of carbon footprints in food supply chains, and are proposing seven building blocks:

1. Reporting standards and guidelines,
2. Farm-level calculation tools,
3. Databases with secondary data,
4. A way of communicating carbon footprint data along the supply chain,
5. A way to ensure the integrity and quality of the data,
6. A way to scale up carbon footprint calculations while keeping costs low, and
7. A way to update these elements as new insights and technologies emerge.

4.1 GHG Protocol

The **GHG protocol** ([Homepage | GHG Protocol]) develops accounting and reporting standards through multi-stakeholder development that enables companies, cities and countries to measure, manage and report GHG emissions from their operation and value chains. Started in 1998, it is a collaboration of the World Resources Institute (WRI) and the World Business Council for Sustainable Development (WBCSD) with over 10,000 entities utilizing their standards.

[2] Meetings were held in April 2023 (Carbon footprints for food systems) and June 2023 (measuring environmental impacts of food products).

It categorized emissions into Scope 1, Scope 2 and Scope 3 (Figure 3), separating emissions to avoid double counting (see section 4.1.2). Brander (2021) commented, however, that accounting using the three scopes does not give a complete picture of emissions.

- Scope 1: accounts for all direct emissions from sources owned by a company or corporation. The company or corporation can have an influence in reducing emissions.
- Scope 2: indirect emissions from purchased electricity and energy. Can be controlled by the company and emissions reduction could be through buying renewable energy credits.
- Scope 3: emissions in the value chain (upstream and downstream).

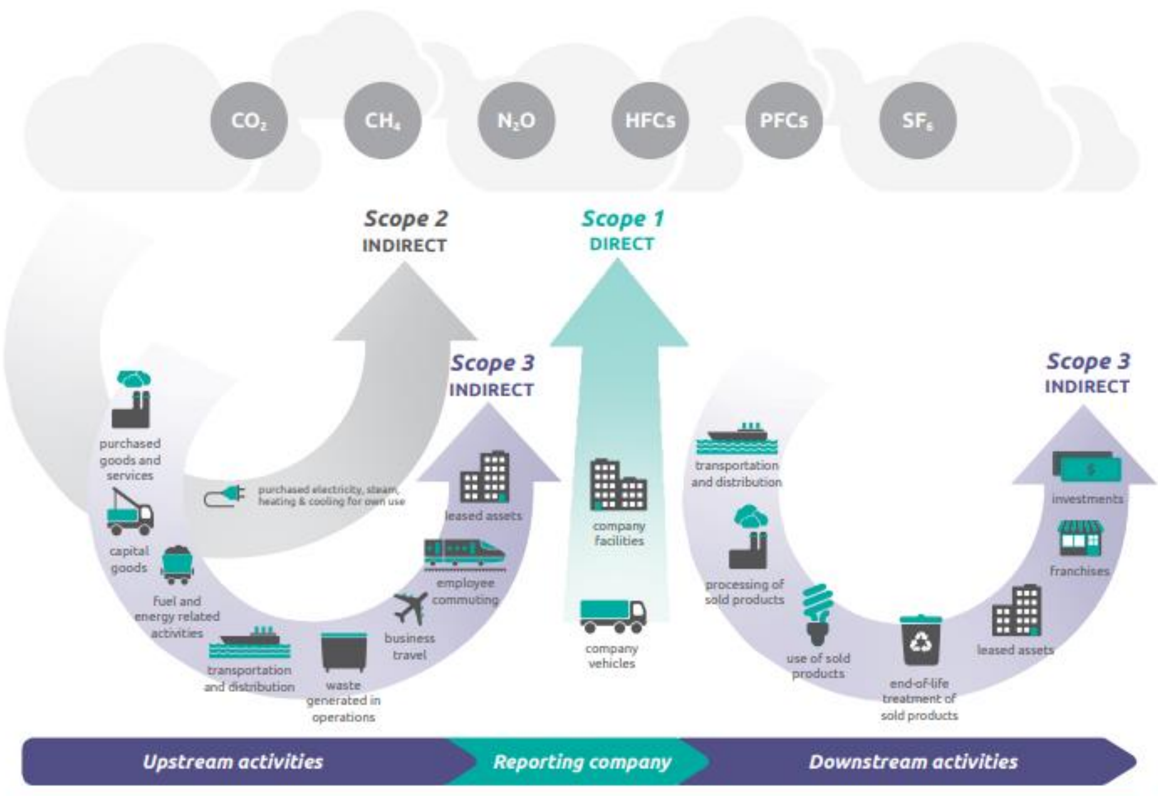

Figure 3. The GHG protocol scopes (WRI 2011)

The GHG Protocol currently has four areas of work. In 2023, Technical Working Groups are focusing on the following areas:

1. **Corporate Standard**: Development of updates and/or additional guidance related to the GHG Protocol Corporate Standard. Topics for this workstream include those outlined in the **Corporate Standard Webinar**.
2. **Scope 2**: Development of updates and/or additional guidance related to the GHG Protocol Scope 2 Guidance. Topics for this workstream include those outlined in the **Scope 2 Survey Summary**.
3. **Scope 3**: Development of updates and/or additional guidance related to the GHG Protocol Scope 3 Standard and Scope 3 Technical Guidance. Topics for this workstream include those outlined in the **Scope 3 Webinar**.

4. **Mitigation impacts / market-based mechanisms**: Development of guidance on options for accounting and reporting for GHG impacts/mitigation outcomes resulting from the organization's activities using inventory accounting and/or project-based accounting methods. Topics for this workstream include those outlined in the **Market-based Accounting Webinar**.

The GHG Protocol Secretariat in consultation with the Independent Standards Board will finalize the design and structure of the Technical Working Group to best address the areas of focus listed here. Additional information on these workstreams, including links to all survey summary webinars and presentations, as well as available survey summary reports can be found **here**. In 2022, a draft of the Land Sector Removals guidelines was published and will be finalized in 2024.

4.1.1 Measurement, Reporting and Verification (MRV)

MRV is a transparency framework that helps countries identify emissions sources and sinks, design effective mitigation strategies as part of their nationally determined contributions (NDCs), assess the impacts of interventions, track progress towards climate goals, enhance credibility and enable meeting international reporting obligations (Singh et al. 2016). There are three levels of MRV (Singh et al. 2016; Figure 4):

- GHG emissions: refer to estimating, reporting and verifying actual emissions over a defined period of time. This includes national emissions such as the NBSA, corporate and supply chain reports (there is interpretation in what level of rigour is needed at each level).
- Mitigation actions: related to assessing the impacts of GHG emissions reduction actions and monitoring their progress and implementation, such as individual projects.
- Support: refers to monitoring the provision of technical knowledge, capacity building and financial resources. For example, support is provided towards larger action – such as a CRSB membership.

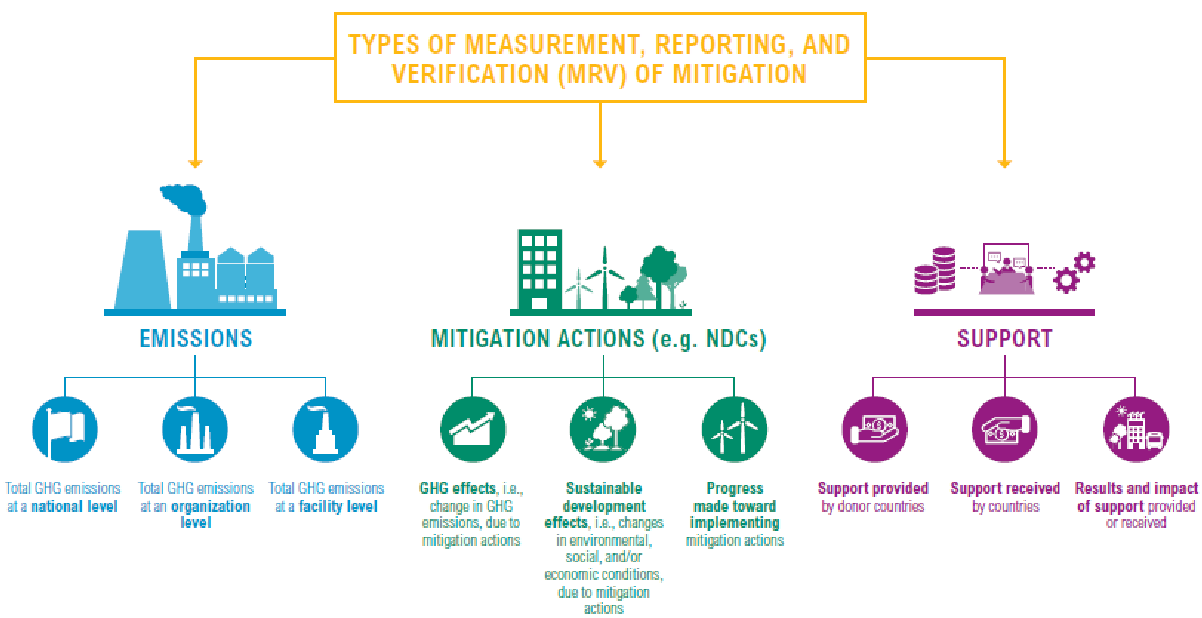

Figure 4. Various Types of Mitigation related MRV (Source: World Resource Institute)

A mitigation **goal** is a commitment by an entity to reduce, limit the increase of, or enhance the removal of GHG emissions, or to reduce GHG emissions intensity by a specified quantity, to be achieved by a future date. A mitigation **project** refers to a specific activity or set of activities intended to reduce GHG emissions, increase the storage of carbon, or enhance GHG removals from the atmosphere. MRV of mitigation actions involves an assessment of the effects and implementation progress associated with mitigation actions, which may involve direct measurement depending on what it is going to be used for.

Identifying the type of MRV needed can be done using the following questions (Singh et al. 2016):

- **Why carry out MRV?** This helps to describe objectives to ensure the MRV is designed to serve specific local goals while fulfilling international obligations. *What is it going to be used for?*
- **How will Measurement, Reporting and Verification be carried out?** This involves putting in place methodological and technical guidelines and processes to carry out MRV. The choice of methods depends on what is assessed and at what level. For example, a variety of methods may be available for individual projects but for national inventories, IPCC guidelines are used.
- **When will MRV be performed?** This involves defining a timeframe to undertake measurement, monitoring and verification. For example, MRV could be done at the end of an intervention, but it is also an ongoing process and how often it is done needs to be determined.
- **Who will carry out MRV?** This refers to identifying the human resources, institutional capacity, technical capacity and financial resources.

More information on types of MRV and the GHG protocol can be found at: MRV_101_0.pdf (wri.org).

4.1.2 Double Counting

Scope 1, scope 2, and scope 3 are mutually exclusive and ensure there is no double counting of emissions within one company's inventory. In other words, a company's scope 3 inventory does not include any emissions already accounted for as scope 1 or scope 2 by the same company. Combined, a company's scope 1, scope 2, and scope 3 emissions represent the total GHG emissions related to company activities. Furthermore, the GHG Protocol defines scope 1 and scope 2 to ensure that two or more companies do not account for the same emissions within scope 1 or scope 2. By properly accounting for emissions in scope 1, scope 2, and scope 3, companies avoid double counting within scope 1 and scope 2.[3]

In certain cases, two or more companies may account for the same emission within scope 3. For example, the scope 1 emissions of a cow-calf are the scope 2 emissions of a feedlot, which are in turn the scope 3 emissions of both the packing plant and foodservice/retailer. Each of these four sectors has different and often mutually exclusive opportunities to reduce emissions. The cow-calf can producer calves using lower-carbon sources. The feedlot can use feed more efficiently. The packing plant can increase the efficiency of the beef it produces, and the foodservice/retailer can offer more energy-efficient beef product choices.

[3] https://ghgprotocol.org/sites/default/files/standards_supporting/Scope%203%20Detailed%20FAQ.pdf

Because of this type of double counting, scope 3 emissions should not be aggregated across companies to determine total emissions in a given region. Note that while a single emission may be accounted for by more than one company as scope 3, in certain cases the emission is accounted for by each company in a different scope 3 category.

By allowing for GHG accounting of direct and indirect emissions by multiple companies in a value chain, scope 1, scope 2, and scope 3 accounting facilitates the simultaneous action of multiple entities to reduce emissions throughout society.

Double counting within scope 3 occurs when two entities in the same value chain account for the scope 3 emissions from a single emissions source. This type of double counting is an inherent part of scope 3 accounting. Each entity in the value chain has some degree of influence over emissions and reductions. Scope 3 accounting facilitates the simultaneous action of multiple entities to reduce emissions throughout society.

Companies may find *double counting within scope 3 to be acceptable* for purposes of reporting scope 3 emissions to stakeholders, driving reductions in value chain emissions, and tracking progress toward a scope 3 reduction target. To ensure transparency and avoid misinterpretation of data, companies should acknowledge any potential double counting of reductions or credits when making claims about scope 3 reductions. For example, a company may claim that it is working jointly with partners to reduce emissions, rather than taking exclusive credit for scope 3 reductions.

Double counting is a problem when it comes to offset credits or other market instruments that convey unique claims to GHG reductions or removals. If GHG reductions or removals take on a monetary value or receive credit in a GHG reduction program, it is necessary to avoid double counting of credits from such reductions or removals. To avoid double crediting, companies should for example specify exclusive ownership of reductions through contractual agreements.

Reductions within a supply chain can be counted by only one player at each stage of the supply chain. For example, a dairy supply chain where on-farm reductions occur is counted and reported by the producer (production stage), processor, and retailer. However, if there are multiple retailers utilizing the product chain of custody must be proven to ensure that two retailers are not both counting the same reduction (i.e. double-claiming).

4.2 ISO standards

Data quality and verification, and reporting and verification can be enhanced in the beef value chain by leveraging ISO standards (Figure 5). This can be done at the organizational (ISO 14064-1), project (ISO 14064-2), and product (ISO 14067) level. Guidance for verification and validation of GHG statements are available in ISO 14064-3. The ISO 14068 presents principles, requirement and guidance for achieving and demonstrating carbon neutrality through the quantification, reduction and offsetting of the carbon footprint.

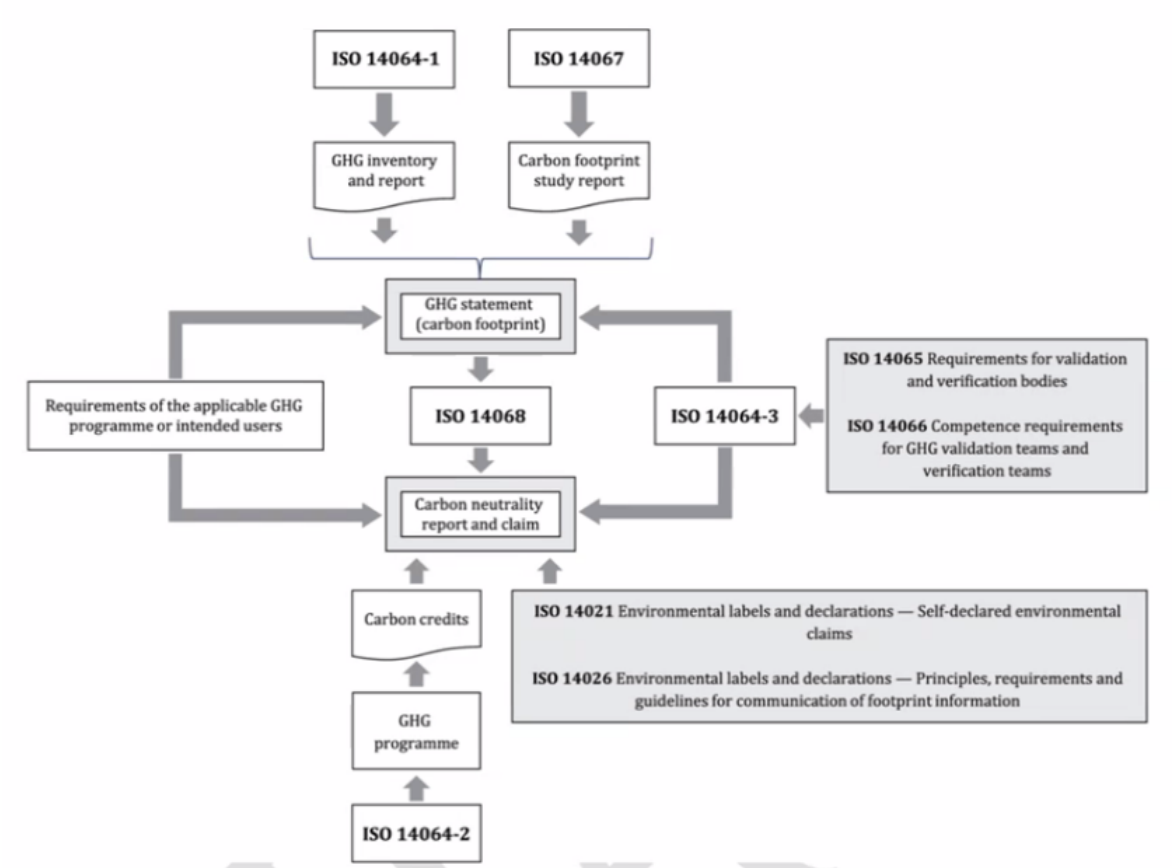

Figure 5. Relationship between GHG inventory and reporting in the beef value chain and ISO standards (Wilton Consulting Group 2024)

The use of environmental data in decision making by individuals and organizations has been increasingly immense and users are interested in the accuracy and reliability of such data (ISO 2020). The ISO 17029 provides guidance on validation and verification as a conformity assessment of the reliability of information declared in claims (ISO 2019). Validation and verification are applied to claims regarding an intended future use and results that have already been obtained, respectively (ISO 2019). However, this guideline is generic and specific programs specifying principles, rules and processes are required for the validation and verification of processes as well as for the competence of validators/verifiers for a specific sector. Therefore, ISO 14065 is the application of ISO 17029, ensuring the evaluation is conducted with less risk and more robust results. The main purposes of the ISO 14065 are listed below (Andrea Russi, person. comm.).

- Ensuring data quality
- Validating environmental data quantification procedures
- Verify the tools used for quantification
- Determine the required level of assurance for emission categories
- Specify the allowable materiality for each emission category
- Identify which emissions to include in a balance
- Deciding when an emission can be excluded
- Managing biogenic emissions
- Establishing verification periods
- Indicating control requirements for data registrations

4.3 Science Based Targets initiative (SBTi)

The Science Based Targets initiative (SBTi) aims to support companies to set GHG emission reduction and net zero targets in line with climate science and Paris Agreement goals. The Science Based Targets initiative (SBTi) is a partnership between the CDP, the United Nations Global Compact, the World Resources Institute (WRI) and the World Wide Fund for Nature (WWF).

The GHG protocol provides a detailed guideline for emissions accounting. The SBTi guidance provides a framework for companies to set meaningful science-based targets to reduce emissions in line with NDCs. "Targets are considered science-based if they are in line with what the latest climate science deems necessary to meet the goals of the Paris Agreement-limiting global warming to 1.5°C above pre-industrial levels" (Science Based Targets ND). The SBTi currently validates targets aligned with 1.5°C for scopes 1 and 2 and targets aligned with well below 2°C or with 1.5°C for scope 3 (Science Based Targets ND).

Eligible science-based target methods (Pineda et al. 2021).

- The Absolute Contraction Approach – setting targets delivering **absolute emissions reductions** in line with global decarbonization pathways. It is considered a one-size-fits-all method.
- The Sectoral Decarbonization Approach – allows **carbon-intensity metrics and targets** to be derived from global mitigation pathways for some of the most carbon-intensive activities. This approach distinguishes the pace at which decarbonization occurs in different sectors.

Netto et al. (2020), reviewed an array of definitions for greenwashing and described greenwashing as simultaneously retaining the disclosure of negative information and exposing only the positive information related to a company's environmental performance.

Just as the adoption of Beneficial Management Practices (BMPs) will vary from region to region and by production system on what makes economic sense, the goals for each commodity will vary depending on land base location and emissions profile (CH_4, CO_2, N_2O). This recognition of the complexity of the agriculture sector is key in managing expectations. The IPCC proposal to achieve climate neutral outcomes for methane includes a 30% reduction by 2030 and a 50% reduction by 2050 (from 2005 levels) and for nitrous oxide, a 20% reduction by 2050. These are deemed equivalent to Net Zero. The Canadian beef industry's goal to reduce emissions intensity by 33% by 2030 is aligned with this intent under the Global Methane Pledge.

Recently a guidance for land-intensive sectors – '**Forest, Land and Agriculture Science Based Target Setting Guidance (FLAG)'** – was introduced (Science Based Targets 2023a). Agriculture food production is one of the land-intensive activities for which FLAG is required. The boundary for agriculture-related emissions and removals is the farm gate. Accounting for land-based removals is based on the GHG protocol (Land Sector and Removals Guidance) and is under development. For companies already in SBTi, the land-based emissions must be separated. Current concerns about the Land Sector and Removals Guidance (identified by the Global Dairy Platform) are the *requirements for identity preservation* and a lack of recognition of mass balance as an entry point for agricultural commodities.

4.3.1 Why Net Zero goal is not feasible for Agriculture

Prioritizing GHG emissions reduction in the agriculture sector is driven by factors such as best management practices (BMPs) motivated by environmental stewardship and/or increasing return on investment, policies and funding programs, and requirements for public disclosure of GHG emissions (CAPI 2024). For the livestock sector, improved efficiency (through feed quality and genetic improvement) and nature-based carbon sequestration (through improved grazing management, fertilization to increase production, and reduction of N_2O emissions from soil), manure management, adoption of reduced or no-tillage, and reducing food loss and waste are suggested practices potentially leading to net zero emissions (Costa et al. 2022). However, agriculture inherently involves the conversion of carbon into food, with the resultant GHG (mainly CH_4 and N_2O) emissions, requiring perpetual carbon removal. Furthermore, the projected increase in beef demand (driven by a growing population and incomes) will be accompanied by an associated increase in GHG emissions. Even with aggressive and continual improvements, for example, in beef cattle management, carbon emissions are expected to outpace removals.

Carbon sequestration rates diminish over time, and carbon input/loss reaches a steady state based on the potential of the soil type. While grasslands store carbon primarily underground in their root systems, making them less exposed to carbon loss due to fire (e.g. tree burn). Tillage, erosion (from wind and water) and drought may still reverse carbon storage in grasslands (BCRC 2024).

A meta-analysis (Cusack et al. 2021) of 292 beef cattle life cycle assessment studies indicated that improved management practices in many of these studies resulted in significant net beef GHG emissions reductions over conventional practices. However, only 2% of the studies showed the potential for net zero or negative emissions (i.e., through carbon sequestration).[4] It should be acknowledged that in a scenario where herd size remains constant and efficiency increases, the biogenic cycle can continuously absorb atmospheric carbon, reducing the burden (Liu et al. 2021).

The most economical carbon capture is still through plants (photosynthesis). Recent carbon capture technologies (e.g., enhanced mineralization) are costly. Strategies known to reduce enteric emissions (e.g., the use of vegetable oils and high-quality feeds) have limited adoption for economic reasons. Widespread adoption of practices that reduce emissions in the beef sector depends on the cost:benefit for individual operations that vary based on production practices and the environment (i.e., soil type, rainfall).

The IPCC is currently (2023) debating if Net Zero is possible (feasible or credible) for agriculture. Maintaining high levels of ambition is possible, while also adjusting to new scientific information becoming available and avoiding greenwashing. This is the balance required by companies who have committed to the SBTi.

4.3.2 GHG Protocol and SBTi

Assumptions have been made that the GHG Protocol, which provides guidance for emissions accounting, is 100% aligned with SBTi for reporting against GHG goals. Many companies are aligned with both and have committed to following both guidelines. However, conversations with LCA practitioners reveal some

[4] Net GHG sinks were reported for grass-finished beef production systems in the Midwestern United States attributable to grazing management (multi-paddock and pasture forage diversification) (Rowntree et al. 2016; Stanley et al. 2018), and cow-calf farms in southern Great Plain United States when grazing management changed from heavy continuous to light continuous or multi-paddock (Wang et al. 2015).

confusion. It appears that how the two work together is open to interpretation. LCA practitioners are currently following a "be consistent" in whatever approach is chosen as multiple ways could be acceptable. This creates risk for the companies following both guidelines as they are unsure what exposure they have, in any one particular action.

4.4 Sustainability Standards Board(s)

The International Sustainability Standards Board (ISSB) leans on the GHG protocol for emissions accounting. Therefore, efforts to ensure that the GHG Protocol Standards are feasible for agriculture is a key priority.

The Canadian Sustainability Standards Board (CSSB) is in the process of creating its standards. CSSB's role is to take the ISSB's standards and adapt them to the Canadian context. The standards are intended to provide consistency in environmental, social and governance disclosures for publicly traded companies. The use of existing assessments (or estimates), such as the National Beef Sustainability Assessment, would be acceptable. If sourcing regionally, the east and west GHG emission factors are available. For companies that have specialized production systems (e.g. hormone-free), a supply-chain assessment would be needed. Companies can voluntarily complete assessments if they believe they have a lower emissions intensity that could lead to a marketing claim, but this is not required. The reporting burden on the supply chain must be considered in these situations.

4.5 Global Reporting Initiative (GRI)

"The GRI Standards enable any organization (large or small, private or public) to understand and report on their impacts on the economy, environment and people in a comparable and credible way, thereby increasing transparency on their contribution to sustainable development. In addition to companies, the Standards are highly relevant to many stakeholders – including investors, policymakers, capital markets, and civil society" (GRI 2024). The Standards are a modular system of three standards: the GRI Universal standards, the GRI Sector standards, and the GRI Topic standards (Figure 6).

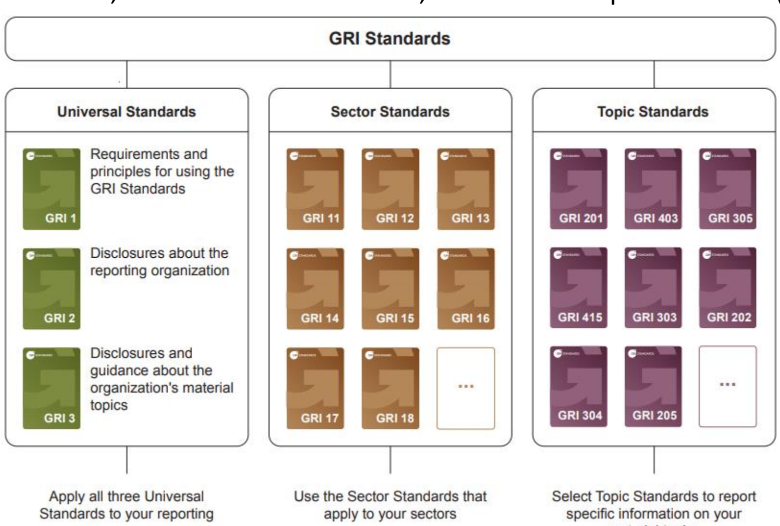

Figure 6. Global Reporting Initiative standards (GRI n.d.)

4.6 Other International Standards

There are several other international standards, that can be used for a variety of purposes.

- **Taskforce on Nature-related Financial Disclosures (TNFD)** - “The TNFD developed a set of disclosure recommendations and guidance that encourage and enable business and finance to assess, report and act on their nature-related dependencies, impact, risks and opportunities” (TNFD 2024).
- **Taskforce on Climate-related Financial Disclosures (TCFD) -** The TCFD develops voluntary, consistent, climate-related financial risk disclosures useful to investors, lenders, and insurance underwriters in understanding material risks (TCFD 2017).
- **Accountability Framework Initiative (AFi) -** “The AFi provides a consensus-based roadmap for companies to set goals, take action, and report on progress towards addressing deforestation, ecosystem conversion, and human rights in their supply chains” (AFi 2024).
- **Kunming-Montreal Global Biodiversity Framework -** “The Kumming-Montreal Global Biodiversity Framework aims to catalyze, enable and galvanize urgent and transformative action by Governments, and subnational and local authorities, with the involvement of all of society, to halt and reverse biodiversity loss, to achieve the outcomes it sets out in its Vision, Mission, Goals and Targets, and thereby contribute to the three objectives of the Convention on Biological Diversity and to those of its Protocols” (UNEP 2022).
- **ISEAL -** “ISEAL works to support and strengthen market-based tools to deliver measurable impacts at a global scale on critical sustainability issues, including climate, biodiversity, human rights, decent work and livelihoods” (ISEAL 2023).
- **World Resources Institute Aqueduct Tool -** “Aqueduct’s tools map water risks such as floods, droughts, and stress, using open-source, peer reviewed data. Beyond the tools, the Aqueduct team works one-on-one with companies, governments, and research partners to help advance best practice in water resources management and enable sustainable growth in a water-constrained world” (The World Bank Group 2024).
- **Carbon Disclosure Project -** CDP provides an environmental, water and forest impact disclosure system used by private and public sector (CDP 2024).
- **WWF Ag water challenge -** “The AgWater Challenge aims to engage leading food and beverage companies with significant agricultural supply chains on water stewardship. Specifically, it spurs companies to make stronger, more transparent, time-bound and measurable commitments that better protect our limited freshwater resources” (WWF 2024a).
- **WWF Water Risk Filter -** The “Water risk filter is a screening tool to help companies and investors to prioritise action on what and where it matters the most to address water risks for enhancing business resilience and contributing to a sustainable future” (WWF 2024b).
- **Global Food Safety Initiative (GFSI) -** The GFSI focuses on benchmarking and harmonisation, capability building and public-private partnerships (GFSI 2021).
- **GlobalG.A.P -** “GlobalG.A.P is a brand of smart farm assurance solutions built on a portfolio of standards for safe and responsible production processes in agriculture, aquaculture, and floriculture” (GlobalG.A.P 2024).
- **National Sanitation Foundation (NSF)-** “NSF engages in the rigorous testing, auditing, and certification of an array of products and services” (NSF 2024).

5 CARBON MARKETS

“A carbon market refers to the buying and selling of credits that represent GHG emissions, reduction or removals. Organizations or individuals buy tradeable units in a carbon market to meet a GHG emissions limit or objective” (ECCC ND). “Carbon markets are an essential driving force in helping us stay within the bounds of our global carbon budget, by effectively putting a price on pollution" (Archer and Panya 2023). There is a growing number of countries planning to participate in the carbon markets to meet their Nationally Determined Contributions (NDCs) set out in the Paris Agreement (World bank 2022).

The carbon market is one tool to drive change and it should be used where appropriate. Businesses should prioritize executing a transparently disclosed, science-based strategy to reduce Scope 1, 2 and 3 emissions over the purchase of carbon credits. Carbon credits should be made only in addition to such a strategy. Hierarchy of decarbonization measures:

- Science based strategy to reduce Scope 1 and 2 emissions
- Science based strategy to reduce Scope 3 emissions
- Purchase of high-quality carbon credits
    - For businesses where few technologically viable direct abatement opportunities presently exist, carbon credit purchases could be framed as temporary, bridging steps toward longer-term decarbonization.
- Businesses can purchase carbon credits as part of a complementary or supplementary commitment to finance emissions reductions outside of the company's operations and value chain.
- Businesses purchasing carbon credits should not subtract those purchases from their Scope 1, 2 and 3 emissions inventories.
- Purchased carbon credits should meet robust quality criteria

Governments around the world have utilized two approaches to reach their NDC set out in the Paris Agreement. "These could be achieved by either a carbon tax or a cap-and-trade scheme, shifting economic incentives by making it more expensive to pollute" (Archer and Panya 2023). A carbon tax is straightforward, paid by all who use a product that has a higher rate of pollution. The price of carbon is set with a carbon tax, providing clarity on the value of carbon. In Canada, discussions are ongoing about exemptions for on-farm fuel, heating of barns, grain drying, and other activities that have the potential to increase the cost of food production, squeeze producer margins and ultimately reduce production and a country's self-sufficiency in cases where imports are needed.

Of greater interest to agriculture is the cap-and-trade scheme where large polluters are capped at a certain level and required to buy carbon credits for any emissions above that level.[5] This creates a carbon market, where agriculture can generate carbon credits through avoided emissions or enhanced carbon sequestration. For governments using a cap-and-trade scheme, "it is not easy to determine the appropriate level at which to set the cap, an over allocation could prove to be ineffective in reducing GHG, whilst a stringent allocation could have severe economic costs" (Archer and Panya 2023). Finding this balance is critical to reaching climate goals.

5.1.1 Carbon credits – the players and rules

Carbon credits are generated by following a recognized protocol that results in known avoided emissions or enhanced carbon sequestration. In Canada, governments set and approve the protocols for offsets and

[5]The cap-and-trade scheme is also categorized under a compliance market in the literature.

issue credits through provincial registries. It is through these registries that large polluters can go to purchase verified carbon credits. The voluntary market also has protocols and private registries.

Figure 7 shows the carbon credit and protocols landscape, which includes:

- Accreditation bodies and guidance setters – this is where protocols are created
- Certificate issuance and retirement, trading, settlements and custody – this traceability ensures credits are counted only once (see section 4.1.2) and occurs at multiple levels
- Project development – working with producers and aggregating data this includes validation and verification bodies
- Demand creation – buyers either through the compliance or voluntary markets can operate directly on the market or through middle-men

Some organizations are involved at multiple levels. See Appendix A for a listing.

Figure 7. Landscape of carbon markets and GHG emissions reporting protocols (Source: Viresco Solutions)

The generation of carbon credits and use of offsets are commonly subject to rules and environmental integrity criteria intended to ensure that offsets achieve their stated mitigation outcome. Relevant criteria include additionality, the avoidance of double counting (see Section 4.1.2), double-claiming and leakage, the use of appropriate baselines, and permanence or measures to address impermanence. For any regulated or voluntary carbon market, the creation of carbon credits depends upon protocols that work for producers.

Permanence in carbon credit schemes refers to measures applied to manage the risk of reversal of carbon dioxide removals, such as requirements to maintain sequestered carbon in vegetation or soil pools for one hundred years. This has been a hurdle for creating scientifically robust protocols for carbon sequestration.

Aggregators provide a service to producers by taking their farm data and putting it through the protocol to calculate how much carbon has changed. Frequently, the numbers are small and aggregated across multiple producers into a "project". The aggregator packages offset credits from producers and posts them on a registry where they can be purchased by companies who want to offset their carbon emissions. However, differences in production systems and record types may be a challenge to get data together. Radicle,[6] in collaboration with Telus Agriculture is the largest carbon credit aggregator in Canada.[7] Currently, the benefit to producers is small as the cost of an aggregator represents a large portion of the benefit.

The aggregator cost could be a flat fee, where the percentage will decrease as the price of carbon increases, leaving a larger benefit to producers over time, or a percentage of the total value, acting as a variable cost. At this point, it sounds like most agricultural and non-agricultural aggregators in Canada are opting for a percentage fee.

Identifying emissions sources, measurement, and regular monitoring are required for effective GHG mitigation as well as ensuring credible reporting. For this, the MRV (measurement, reporting and verification) has been introduced (Figure 8). See section 4.1.1 for more information.

[6]https://decisivefarming.com/radicle/#:~:text=Radicle%20is%20recognized%20as%20a%20world%20leader%20in, and%20the%20largest%20independent%20offsets%20aggregator%20in%20Canada.
[7]https://www.newswire.ca/news-releases/radicle-announces-investment-by-telus-ventures-to-accelerate-growth-854611540.html

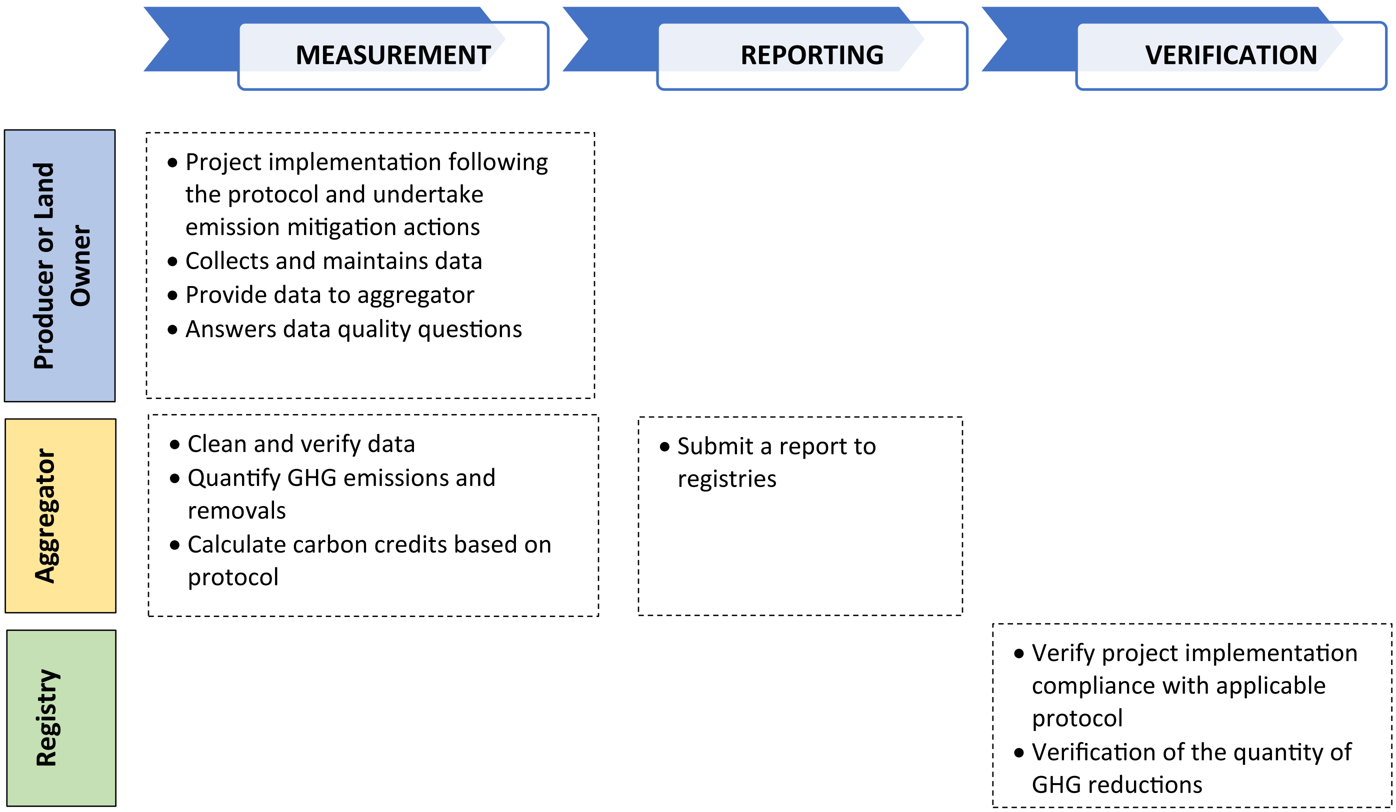

Figure 8. Framework for measurement, monitoring, reporting and verification in carbon markets in Canada.

5.1.2 Offsets versus Insets

An offset is a reduction, avoidance or removal of a unit of greenhouse gas (GHG) emissions by one entity, used by another entity to counterbalance a unit of GHG emissions by that other entity. Offsets are usually represented by a carbon credit that has been retired or cancelled in a register by or on behalf of the entity to counterbalance its residual GHG emissions. Such as when a large polluter purchases carbon credits from either a regulated or voluntary market and those credits come from a different supply chain or commodity. For example, an oil and gas company purchasing dairy carbon credits.

Insets are when a company purchases carbon credits from either a regulated or voluntary market and those credits are from the same supply chain or commodity, such as beef. For example, a retailer or packer purchasing beef carbon credits. For an inset market to function there needs to be traceability to ensure that the credits are purchased and sold within the same supply chain or commodity. The advantage of insets is that the commodity continues to claim the carbon reductions and they are not “lost” to the supply chain. The disadvantage is that the credits remain within the farm or company and thus it reduces the number of buyers and potentially reduces the price paid to those selling the carbon credits. Insetting is also related to the reduction of Scope 3 emissions by applying sustainable practices and mitigating emissions.

However, for companies reporting Scope 3 emissions and also purchasing or retiring inset credits, the overlap and double counting between the two remain an intrinsic challenge. Therefore, it is indicated that companies should use the inventory accounting approach rather than the crediting approach for Scope 3 emissions and removals. "Within an inventory accounting approach, companies that work with value chain partners to achieve GHG reductions or removal can choose to purchase and retire inset credits from suppliers or other value chain partners or enter into other contractual agreements to ensure that unique claims to the GHG reduction or removals from activities in the value chain will not be sold/transferred to third parties via credits. Inset credits cannot therefore be used to adjust Scope 3 emissions or removals (e.g., by subtracting credits from reported emissions), but can be used as a tool for ensuring that actions in the value chain are properly accounted for in the Scope 3 inventory using an inventory accounting approach" (WRI and WBCSD 2022). Partnership for Carbon Transparency devised a principle (cradle-to-gate product carbon footprint) as basis for Scope 3 reporting. Suppliers in the value chain would report emissions data to the company/farm where own emission (Scope 1) and emissions from supplies would then be shared with customers (GRSB 2024).

Table 8. The Pros and Cons of Insets versus Offset from a Producer or Land Manager Perspective

	Insets	Offsets
Pros	• Because insets stay within the beef industry, they can be used to reduce net emissions when reporting against a climate neutral or Net Zero Carbon goal. • Efforts by industry are recognized in reporting frameworks	• Gives access to a larger pool of buyers, including large emitters who need to purchase and may be willing to pay a higher price
Cons	• There is a smaller pool of buyers with an inset market, potentially resulting in a lower carbon price than if utilizing an offset market	• Once sold outside the beef supply chain, they cannot be used by the beef industry. This results in agriculture not benefiting from the reductions being made in some reporting frameworks

5.1.3 Voluntary vs. Regulated

In voluntary carbon markets, the buying and selling of credits is on a voluntary basis, while the regulatory markets are created as a result of regulatory requirements. Because voluntary markets are not regulated, different schemes can be followed for measuring, reporting, verification and price setting. In regulated markets, credits are sold based on a set price and because companies are mandated, this type of market contributes to meeting local goals and international obligations in reducing GHG emissions.

Challenges related to the voluntary carbon market include price transparency and variability in rules, criteria, and methodology (Archer and Panya 2023). Direct trades and private registries mean that producers are unable to see how prices on the voluntary market compare with other platforms.

In theory, protocols for voluntary markets could be less stringent than regulated markets, reducing their cost. However, as noted above, verification requirements for measurement vs. modelling and protocol rigour of inventory vs. intervention are dependent upon what the buyer will accept.

Table 9. Pros and Cons of the Regulated and Voluntary Carbon Market

	Regulated Carbon Market	Voluntary Carbon Market
Definition	• Demand for carbon credits is created as a result of regulatory requirements	• Demand for carbon credits is created from company climate goals and commitment to reductions and reporting
Pros	• Price Transparency, on a provincial or federal registry • Stringent protocols that meet government standards and have the confidence to stand the test of time	• For the buyer, carbon prices tend to be lower on the voluntary market, running at a discount to the regulated market • International registries can provide access to a wider pool of participants
Cons	• For the buyer, carbon prices tend to be higher than the voluntary market, particularly since Canada has a federal carbon price	• Registries used can be private and lack price transparency for outsiders to compare with alternatives • Greater diligence is needed in confirming protocols are robust

5.2 Carbon markets in Canada

Canada passed a carbon tax legislation in 2018 at a federal level, which came into effect in 2019. Seven Canadian provinces currently use the federal carbon tax, while three (Table 10) have their own carbon tax legislation (World population review 2023). Alberta pioneered in setting up a compliance (aka cap-and-trade) carbon market which has operated for more than a decade (Henderson 2022).

Table 10. Carbon Tax Regulations in Three Canadian Provinces

Province	Program	Description	Requirement
Ontario	Emission Performance Standards (Regulated)	Determine emissions limits for greenhouse gasses (GHG) emitting industrial facilities	• A facility reported GHG emissions of ≥ 50,000 tonnes or more of carbon dioxide equivalent (t CO_2e) for any year since 2014[a]; and, • A facility engaged in activities listed in paragraphs 1038 of Schedule 2 of the EPS Regulation
	Emission Performance Standards (Voluntary)		• A facility reported GHG emissions of ≥ 10,000 tonnes or more of carbon dioxide equivalent (t CO_2e) for any year since 2014[a]; and, • A facility engaged in activities listed in paragraphs 1038 of Schedule 2 of the EPS Regulation
Alberta	Technology Innovation and Emissions Reduction (TIER) (Regulated)	Implements Alberta's industrial carbon pricing and emissions	• Facilities emit ≥ 100,000 t CO_2e per year in 2016, or any subsequent year • Facilities import more than 10,000 tonnes of hydrogen annually
	Voluntary		• Facilities emit < 100,000 t CO_2e per year

Quebec	Cap-and-trade system	Impose an overall annual cap on GHG emissions	• Facilities emit ≥ 25,000 t CO_2e since 2013
	Voluntary		• ≥ 10,000 and < 25, 000 t CO_2e

[a]reporting to the ministry of the Environment, Conservation and Parks (MECP)
[b]EPS: 190241_e.doc (live.com). The list consists of industries *(not specific to agriculture)*

5.2.1 Federal protocols

Any proponents seeking to generate offset credits in Canada's GHG Offset Credit system would have to register a project with Environment and Climate Change Canada's (ECCC's) Credits and Tracking System (i.e. registry). Offset credits can be sold to facilities covered by the federal Output-Based Pricing System to use as compensation for excess emissions. The facility seeking to purchase the credits does not have to be from the same province as the project. There are no restrictions on who can use federal offset credits. Additional demand for federal offset credits may come from other sources such as governments or businesses wanting to meet Carbon Neutral or Net Zero commitments or other voluntary GHG reduction goals.

Canada's GHG Offset Credit System is national in scope, but it is designed to complement and not compete with offset systems in provinces or territories. *A federal offset protocol does not apply in a jurisdiction that has a provincial offset system with an active protocol for the same project activities*. For example, the Reduction of Enteric Methane Emissions (REME) protocol will be applicable across Canada, except in Alberta due to a protocol within Alberta's Provincial Offset system that incentivizes reductions in enteric CH_4 emissions from many of the same project activities. ECCC encourages producers in Alberta to explore using Alberta's Quantification protocol for reducing greenhouse gas emissions from fed cattle – Version 3.0 in Alberta's Provincial Offset System.

Recognized units process. Based on the Output-Based Pricing System (OBPS) Regulations, a provincial offset credit might be recognized as a valid compliance unit if it meets the eligibility requirements in section 78 of the Regulations. The credit must be issued under a GHG offset program and protocol that appears on the List of Recognized Offset Programs and Protocols for the Federal OBPS. Currently, the List of Recognized Offset Programs and Protocols for the Federal OBPS includes Alberta Emissions Offset System and British Columbia Greenhouse Gas Emission Offset System which can be found at: List of Recognized Offset Programs and Protocols for the Federal OBPS - Canada.ca. Alberta's fed cattle protocol appears on this list.

Federal protocols under development include:

- Improved forest management or Private Land
- Reducing Enteric Methane Emissions from Beef Cattle (comment period to February 6, 2024)
- Direct Air Carbon Dioxide Capture and Sequestration
- Enhanced Soil Organic Carbon
- Avoidance of Manure Methane Emissions through Anaerobic Digestion and Other Treatments

5.3 Carbon markets for the beef industry

Carbon markets are designed to incentivize producer adoption of practices that benefit the environment. In agriculture, the benefits are mainly in the form of carbon sequestration and avoided emissions from change of practices. Short-term economic feasibility in terms of increased production or profitability is the driver of BMP adoption, over programs providing only ecological services (Piñeiro et al. 2020). A similar observation was reported for a group of organic and inorganic crop/crop-livestock farmers in carbon markets (Barbato and Strong 2023). Long-term, maintaining healthy soils and crops, and overall environmental benefits are the motivations to adopt BMPs, even though these are not direct payments (Piñeiro et al. 2020; Barbato and Strong 2023). In beef production, most of the emission is associated with on-farm sources. Based on a life cycle study in Canada, 83% of the GHG emissions occur at the primary production stage (CRSB 2024). This suggests the huge potential for emission reduction interventions where actors in the value chain could participate (Schulte and Jordahl 2022), creating opportunities for farmers to participate not only in offsets but also in insets (Nolet 2022).

In Canada, grasslands are the primary reserves for soil carbon stocks, and avoiding their conversion, through market mechanism (Haugen-Kozyra 2021) provides the largest opportunity to sequester carbon in 2030 with 2.2 to 41.3 Tg CO_2e/year (Drever et al. 2021). This is based on preventing the conversion of 2.5 Mha of native grassland and managed pasture to cropland between the years 2021 and 2030, mainly in the Prairie regions (Dever et al. 2021). Combined with beneficial practices (e.g., improved grazing management, improved pasture quality) the carbon stored in grasslands could result in carbon credits (see Table 3 for program options suitable for different types of grassland in Section 2.4).

5.3.1 Questions for Producers to Ask

The choice of a carbon program depends on the landowner's eligibility, farm goals, the time and effort the producer wants to invest (e.g., reporting burden, direct measurement requirement), the length of contracts which may depend on whether a land is owned or rented, and carbon credit prices – which may fluctuate (AgWeb 2023; AHDB 2023).

Questions for producers to ask about a carbon credit market (regulated or voluntary):

- Does my operation meet the criteria outlined in the protocol?
- Do I have the data? What is the reporting burden?
- Is measurement required (e.g. soil samples)? What is the cost? Who pays it?
- Is there an aggregator?
- What portion of the final payment makes it through to the producer?

Contract terms will vary depending on the platform. Producers should be clear up-front on these terms:

- Additionality, permanence, no double counting
- Can be more complex than government programs
- Time frame – 1-10 years
- Measurement – may be required pre and post
- Modelling – assumptions vary

- Who pays for what?
- Timing – when does verification and payments occur, what is the time lag from starting the process to first and last payment
- Data transparency

Questions for producers to ask about GHG feed additives in a carbon credit market (regulated or voluntary) or protocol:

- Is there a performance benefit?
- Can this be stacked with other products I am already using? E.g. mode of action
- What is the cost:benefit analysis?
- How is the GHG reduction recognized?
    - Do I need to apply for a carbon credit?

6 PROGRAM OPTIONS TO INCENTIVIZE GHG MITIGATION

There are multiple program choices to incentivize GHG mitigation. Current programs are focused on providing a financial incentive for meeting a specific environmental or animal welfare standard (e.g. Certified Sustainable Beef Framework). The CRSB Certified program can serve as a catalyst in establishing such collaboration and to decarbonize the beef value chain. However, that does not exclude utilizing other means that can be stacked such as ecosystem goods and services or carbon credits.

Table 11. Program Options to Incentivize GHG Mitigation

Program	Pros	Cons
Certifications Programs (e.g. CRSB Certified)	• Verified through on-farm audits • Chain of Custody utilizing mass balance for initial uptake • Outcome-based not prescriptive • Meets legal requirements for marketing claims • Potential for use of a tiered system to enhance data	• Data quality and standardization gap • Challenge to balance producer reporting burden with demand • Slow build of supply as producers question the return on investment with high audit costs
Ecosystem Service Payments (e.g. ALUS, Cows & Fish, FRISP)	• Outcome-based, work in the local context with support for producers	• Local programs are difficult to scale • Not audited • Questions on what can be said about biodiversity claims
Carbon Credit System (e.g. Offsets/Insets)	• Protocols based on intervention inventory accounting provide high standard meeting requirements for data rigour, additionality, permanence, • Use of registries gives transparency	• Aggregators take a large cut reducing the benefit received by a producer • Data reporting requirements are high

		• Do not yet have a tiered voluntary system with varying levels of data rigour that meet buyer requirements

6.1 On-Farm GHG measurement tools

Tools to estimate on-farm GHG emissions are grouped into three categories with differing complexity and purpose (CAPI 2024).

1. **Indicative tools** are simple and accessible and provide farmers with basic understanding of emissions.
2. **Educational tools** might involve simplified models and are used to raise farmers' awareness and knowledge about emissions and its mitigation.
3. **Compliance tools** are designed to meet reporting requirements or revenue generation and require a deeper engagement and a more sophisticated understanding.

Ensuring that the right tool is selected for the stated objective and purpose is critical to balancing the reporting burden with the outcome the data will be used for. Tools used by Canadian farmers to estimate emissions at the farm level (crop and livestock) include: Holos, AgriSuite, CropTrak, AgriTask, Cool Farm Tool, and Manitoba Environmental Farm Plan GHG tool (CAPI 2024).

As companies establish benchmarks (by the end of 2024) and turn to focus on strategies to meet their 2030 climate goals (gives five years of activity from 2025-29). Questions about the best (most robust and risk adverse) way to achieve those goals are being discussed. Companies that have tried the carbon credit market and been burnt with 'junk' credits that did not have robust protocols are hesitant to go that road again. Even when there are extremely robust protocols now available, being able to discern between a robust protocol developed with scientific rigour and one that is not requires technical expertise to understand the science and modelling behind them. Consequently, some companies have turned to projects that give them control and oversight of the measurement and direct connections with primary producers. Regardless of whether a company is using carbon credits or a project, they are looking for a tool that allows producers to baseline and monitor change for the whole farm (covering multiple commodities grown).

Multiple countries have created on-farm GHG calculators to get producers to benchmark their farms and then monitor reductions. However, the value of these calculators frequently comes down to how accurate they are. To make them producer-friendly, the number of data points is reduced and replaced by national averages or proxies. This greatly reduces the benefit received. Even more important is understanding that a producer can do nothing and the on-farm GHG emissions will vary each year based on environmental conditions (i.e. rainfall, temperature, and soil type) all of which are outside of the producers influence or control. In addition, a proper baseline takes 3-5 years of data to get an understanding of those external fluctuations before a change in management can be measured. This is why current confidence intervals are so wide, making it difficult to say that a change in carbon has actually occurred.

No tool will be perfect, but they can be useful. How accurate, science-based and rigorous a tool is depends on its intended purpose and the theory of change driving it. There are four main purposes that tools are being developed for:

1. Producer Information
2. Scope 3 reporting
3. Informing policy
4. Carbon credits

The purpose determines what is 'good enough'. The end use needs to be clearly understood by all involved. In addition, tools must be sufficiently dynamic to account for weather, soil and regionality. Therefore, tools will not be globally relevant for the beef sector.

In addition, most intervention on-farm calculators are a first step before starting the process of meeting an intervention protocol that would allow a producer to sell carbon credits. This discourages producers from continuing with an on-farm calculator for the number of years needed to get any meaningful information. It is also why protocols are based on intervention protocols and not whole farm inventory accounting, as they require less data.

When requiring an on-farm calculator for Scope 3 project participants, the purpose needs to be clear. What is it being used for? And what is the benefit to the producer? Managing producer expectations is key for long-term engagement. If they are doing all the data reporting to meet Scope 3 reporting for a project, with no expectations that it directs on-farm decision making that is very different than if a producer expects to make decisions based on a limited number of years of data which could be influenced more by weather.

A comparison of five farm-level greenhouse gas calculators on seven beef production system datasets was conducted by Skyes et al. (2017) finding considerable variation. Differences in scope along with allocation between enterprises explained a large amount of the variation. This requires technical expertise to understand the science and modelling behind each tool and to choose one that is appropriate for companies utilizing them for scope 3 reporting purposes. This highlights the importance of understanding the methodology, assumptions and modeling that goes into each tools with its designed purpose and limitations. The GRSB undertook a survey of tools (March 2024) to identify alignment with the GRSB Beef Carbon Footprint Guideline and GHG Protocol; but also to assist members in identifying tools suitable for their specific needs.

While quantification of farm-level emissions is not straightforward, it is considered a crucial step. However, it should be asked - what does it provide? Analysis paralysis is real and having more detailed data does not necessarily provide a producer with meaningful information for decision making. In fact, information overload can stagnate progress when the next step is unclear.

Table 12. Pros and Cons of On-Farm Calculators

Pros	Cons	To be Addressed
• Can cover multiple commodities, providing a single	• Tools still require validation and verification of data	• Differences in underlying methodology and assumptions

tool for primary producers to focus on • Indicates progress over time, for an operation specific to their production system and environment • Provides companies with a direct connection to primary producers via data collection	sources used and potentially on-farm measurement • Project aggregation from multiple operations is only possible at the level of tonnes of carbon mitigated or avoided	leave companies utilizing tools for projects or carbon credits exposed to risk. Understanding the science behind each tool requires technical expertise • Raises questions about data ownership, rights and traceability

Tools being used for Scope 3 and carbon credits will need to have farm activity data verified, which can be a time-consuming process. Also, being clear about data ownership for these uses is critical and should be included in any contracts (see Section 5.3.1)

6.1.1 Tools for banks to achieve net-zero requirements

There is a general understanding on the urgency of addressing climate change among Canada's banks and that the financial sector plays a key role in the transition to a low-carbon economy, mitigating the impacts of humans on the environment and ensuring the continued national financial system (Canadian Bankers Association 2024). Canada's banks pledged to implement climate action plans to meet the goal of a net-zero economy by 2050 by the Paris Agreement. One of the plans is to finance and support low-carbon businesses and work with existing business customers in higher-carbon sectors to finance their transition efforts (Canadian Bankers Association 2024). For banks to help their clients in the low-carbon journey, clear and reliable benchmark pathways should be in place to be used as planning tools and to measure progress. Furthermore, availability of farm-level emissions data and accessibility of the same data is a challenge. Consequently, banks largely rely on proxy indicators from national average emissions or other sources. With the growing number of reporting standards, banks are also faced with the associated challenges of dealing with variations in reporting/data presentation formats. This calls for standardized GHG measuring tools and reporting guidelines.

Current limitations to the adoption of tools are: (Wilton Consulting Group 2024)

- Lack of regionally specific data
- Tool complexity and accessibility
- Whole farm considerations
- Lack of interoperability and transparency
- Science takes time
- Economic and incentive alignment
- Data privacy and security concerns

Gauthier (2024) proposed that GHG data and methodology gaps can be addressed through a collaborative effort between banks, experts, regulators, public agencies, and agri-food companies, and by supporting farm-level GHG emissions data gathering through special loan programs. The choice of farm level GHG estimation tools depends on the objective (see section 6.1). **Compliance tools** intended for reporting requirements or revenue generation could provide more relevant data, but they involve deeper engagement and sophisticated understanding (CAPI 2024). While **educational tools** aiming at raising awareness and knowledge among farmers on GHG reduction strategies (CAPI 2024) would be more practical. Tools currently used in the Canadian beef cattle industry landscape (see section 6.1) are largely the educational type and require standardizing, continuously refining to reflect local production systems, and linking to market-oriented reporting ultimately benefiting producers, financial institutions and other stakeholders. The GRSB survey, mentioned in earlier sections, indicated that the majority of available GHG tools did not have financial institutions as target audience suggesting a need to fill in this gap.

6.2 What is an appropriate benchmark?

When examining ways to incentivize change, identifying an appropriate benchmark can result in low-hanging fruit to be identified and pursued. Many organizations have created benchmarks (from birth to processor/fork), such as the CRSB's National Beef Sustainability Assessment (NBSA). However, some of the options for comparing an individual farm that is only cow-calf, backgrounding or finishing would need to be compared to a benchmark for that specific sector. This is a greater issue in countries where specialization is more present compared to countries with retained ownership from birth to slaughter. While a specialized beef farm and whole supply chain benchmarks could be done using the GRSB Carbon Footprint Guideline; the boundaries for each sector (e.g. cow-calf, finishing) would be different. This is why tools that encourage producers to enter data to get their farm emissions are focused on comparing self to self over time. If there was an interest, sector-level types of benchmarks would need to be developed.

Types of benchmark comparisons *(self = farm or supply chain)*

1. Comparing self to self over time. Used by many carbon markets, both regulated and voluntary, to see incremental change on a farm or supply chain. Often needs a 3-5 year control to ensure that change is not simply a reflection of change in feed rations and are actual changes in animal performance via management or adoption of practices/products.
2. Comparing self to a regional/national/global average (used to evaluate competitive comparison). This identifies low emission production systems within a country, but also between countries.
3. Comparing self to production system average. This shows what is possible within a small, local region to encourage adoption and change as producers strive to meet something that has been shown is possible.

What is happening in Canada?

The Alberta AgriSystem Living Lab (AALL) is creating whole farm benchmarks utilizing HOLOS and data from the Canadian Cow-Calf Cost of Production Network. This provides over 60 benchmarks for mixed cow-calf operations with different production systems with representation from every province from British Columbia to Prince Edward Island.

Beneficial Management Practices (BMPs) are by definition beneficial for the environment, they say nothing about the cost-benefit to producers. Therefore, the AALL is running scenarios on the economic and environmental impact of adopting BMPs to identify drivers of which production systems have an economic and environmental win-win from adoption.

APPENDIX A: CARBON MARKET PLAYERS

As noted in Figure 7, there are multiple players within the carbon market space. This includes protocol developers, carbon trading platforms, aggregators and data platforms. For producers considering selling carbon credits, evaluating the contract terms is critical to understanding what they are committed to and the implications for their operation.

Groups that develop **protocols** to be used in carbon markets including:

- California Air Resources Board (trucking and refrigeration)
- Climate Action Reserve (protocols and voluntary offset program)
    - Canada Grassland Protocol Version 1.0 approved October 2019
- The Gold Standard (global goal setting including land use activities and nature-based solutions)
    - Safeguarding principles: All Gold Standard certified projects must assess their potential environmental and social impacts and implement mitigation measures where necessary. Specifically, for land use activities this means following safeguarding principles that protect water resources, soil erosion and degradation, access to food, livestock wellbeing and areas with a high conservation value.
    - Scope 3 guidance for supply sheds and accounting
- Verra – a voluntary GHG crediting platform
    - Covering blue carbon, carbon capture and storage, agriculture, forestry and other land use, and energy transition.
    - Utilize peer-reviewed emissions reduction formulas for quantifying GHG benefits, verified by a third party, and posted in a publicly available registry system.
- Ecosystem Services market Consortium (voluntary platform in the US)
    - Protocol was updated in August 2023 to add soil carbon, reduction in net greenhouse gas emissions, and increases in water quality and quantity.
    - Eco-Harvest sells impact units for soil carbon and net greenhouse gas impact units generated through a scientifically rigorous, standards-based, and cost-effective framework that meets corporate sustainability and reporting standards.

Carbon Trading Platforms can be separate from the protocol body but must function on credible protocols. These include:

- Agoro: Carbon Alliance – focused on carbon sequestration by US farmers
- Athian – industry-led platform for the livestock value chain
    - build software to aggregate, certify, and fund greenhouse gas reductions
    - First transaction of verified carbon credits in January 2024
    - Partnered with Elanco, California Dairies Inc., NewTrient, DSM-firmenich, and Tyson as seed investors
- Carbon by Indigo – registry issues agricultural carbon credits

    - Practice change supported by agronomists, soil samples and on-farm data are collected and results are shared for verification and credit issuance. Indigo facilitates the payout process delivering at least 75% of the average credit price directly to the farmer.
- NORI
    - Credibly compensate for emissions with Nori Net Zero Tonnes™ — carbon removal credits that pair regenerative (soil carbon sequestration) and permanent carbon removal (direct air capture, biomass carbon, enhanced rock weathering) for impact that's both immediate and lasting.
    - Tiered program allowing for fast (past) and slow (future) carbon storage over ten years of carbon storage (e.g. 2019 to 2027), that become permanent.
- Nutrien Carbon Program – goal to be operational by 2030, generating high quality carbon assets that are verified based on industry best practices
    - Pilot acres in 3 provinces of Canada and the US (20 states)
- Soil and Water Outcomes Fund – financial incentives for soil and water stewardship (US based)
    - Meet regulatory and voluntary sustainability goals such as scope 3 GHG emission insets
    - 50% of payment once measured and verified, typically in the spring.
- TruTerra (US based)
- Yara Institute: Knowledge grows

Aggregators
Radicle, in collaboration with Telus Agriculture (including Feedlot Health Management Services) is the largest carbon credit aggregator in Canada.

Data Platforms that help facilitate participation in carbon markets include:
- Bayer Carbon Program powered by Fieldview
    - a digital farming platform that turns field data into insights, by getting it all in one place.
    - Data privacy keeps the producer in the driver's seat
    - Multinational – have users in Canada
    - In 2024, collaboration with Precision Planting's Panorama platform
- Farmers Business Network
    - Grain marketing services with a data service

Voluntary and regulated markets internationally
The following summarizes the regulated markets that exist internationally for the European Union, United Kingdom, United States and China as outlined by Archer and Panya (2023).

The **European Union** Emissions Trading System (EU ETS)
- World's first major carbon market established in 2005

- Regulates around 11,000 installations across different sectors
- Works on the cap-and-trade principle. I.e., the total amount of GHG emissions if limited or caped which is further reduced over time with the eventual fall in total emissions

United Kingdom

- United Kingdom Emissions Trading System (UK ETS)

United States

- Does not have a federal carbon tax
- State-level carbon tax systems exist for California, Oregon, Wahington, Hawaii, Pennsylvania and Massachusetts, with more states expected to join in the future.
- Voluntary standards are available through multiple groups

China

- Has Emissions Trading Scheme (ETS), launched in July 2021
- Based on a cap-and-trade, initially involving coal- and gas-fired energy plants with plans to add heavy and manufacturing industries

Australia

- Australia Carbon Credit System at the national level

Verra's certification programs include the Verified Carbon Standard (VCS) Program[8] and its Jurisdictional and Nested REDD+ (JNR) framework, the Climate, Community & Biodiversity Standards (CCBS) Program, the Sustainable Development Verified Impact Standard (SD VISta) Program, and the Plastic Waste Reduction Program. They work with governments, businesses, and civil society to advance the use of these standards, including through the development of international voluntary markets (see Section 5.3).

[8] The Verified Carbon Standard (VCS) Program is the world's most widely used greenhouse gas (GHG) crediting program.

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