Climate Disclosure and Target Setting in the Agriculture Sector

Lessons from the Canadian Market

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Disclaimer

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About RMI

RMI is an independent nonprofit, founded in 1982 as Rocky Mountain Institute, that transforms global energy systems through market-driven solutions to align with a 1.5°C future and secure a clean, prosperous, zero-carbon future for all. We work in the world's most critical geographies and engage businesses, policymakers, communities, and NGOs to identify and scale energy system interventions that will cut climate pollution at least 50 percent by 2030. RMI has offices in Basalt and Boulder, Colorado; New York City; Oakland, California; Washington, D.C.; Abuja, Nigeria; and Beijing.

Contents

1. Introduction

The purpose of this paper is to provide an analysis of the key components, opportunities, and challenges for disclosure and target setting in the agriculture sector, specifically the Canadian agriculture sector.

Financial institutions can play an important role in supporting and facilitating the agriculture sector's transition to net zero. However, there is a recognized need for the development of more comprehensive guidance on how these institutions can effectively establish baselines for their emissions, set targets, and transparently disclose the emissions attributable to their agriculture portfolios.

This paper does not provide a step-by-step guide for setting targets for financial institutions active in the Canadian agriculture sector; rather, it is designed to lay a foundational framework. It analyzes and builds on existing frameworks and standards for emissions accounting and net-zero target setting, consolidating ways financial institutions can manage and disclose emissions within their agriculture portfolios and approach the setting of targets.

Input for this paper was solicited from a group of Canadian financial institutions, among which were several Canadian Bankers Association banks and Farm Credit Canada, a federal Crown corporation, ensuring that it is reflective of industry perspectives and practices. RMI would like to thank the representatives from these banks for their contribution. The scope of the input from the banks included analysis of pathways for farming, focusing on the on-farm, or farm gate, section of the value chain, in alignment with the World Business Council for Sustainable Development's Banking for Impact on Climate in Agriculture (B4ICA) recommendations. The commodity focus was beef, dairy, and crops (specifically oilseeds).

Although crafted with a focus on the Canadian agriculture sector, the principles and recommendations outlined are broadly applicable to other countries and sectors.

This paper was developed in response to the evolving landscape of climate-related regulatory disclosure requirements and the establishment of target-setting deadlines by entities such as the Net-Zero Banking Alliance (NZBA).

1.1. Net-Zero Banking Alliance

NZBA is a bank-specific commitment platform that brings together banks from diverse regions, representing more than 40% of global banking assets. NZBA members commit to transitioning the operational and attributable greenhouse gas (GHG) emissions from their lending and investment portfolios in line with 1.5°C-aligned pathways by 2050 or sooner. The Guidelines for Climate Target Setting for Banks outline key principles to underpin the setting of credible, robust, impactful, and ambitious targets in line with achieving net zero by 2050 GHG emissions goals, including these four overarching principles:

- Banks shall individually and independently set and publicly disclose long-term and intermediate targets to support meeting a net zero by 2050 GHG emissions goal.
- Banks shall establish an emissions baseline and annually measure and report the emissions profile of their lending, investment, and capital markets activities.
- Banks shall use widely accepted science-based decarbonization scenarios to set both long-term and intermediate targets that are aligned with a net zero by 2050 goal.
- Banks shall regularly review targets to ensure consistency with current climate science.

Specific guidance on targets includes:

- Targets must include Scope 1, 2, and 3 emissions where significant and where data allows.
- Targets must be based on absolute emissions or an emissions intensity measure.
- Targets must be based on no- or low-overshoot scenarios aligned with 1.5°C.
- Targets must cover lending and capital markets activities; coverage of investment activities is strongly recommended (effective November 2025).
- Banks must report on targets annually.

NZBA signatory banks report their progress in line with these guidelines, adhering to the comply-or-explain principle. If targets cannot be fully met or certain information is omitted or disclaimers provided, signatory banks must explain any deviations. This approach encourages progress while allowing for reasonable adjustments.

The analytical process underpinning this paper was conducted with the aim to align with NZBA guidelines; however, the findings are intended to serve as a reference tool for any financial institution seeking guidance on disclosure and target setting.

This paper seeks to foster collaboration and advance the collective approach to target setting in the agriculture sector, addressing critical sustainability challenges in this crucial industry.

1.2. Complexities of Decarbonizing Agriculture

Decarbonizing agriculture presents a multifaceted, complex set of challenges, based on the sector's inherent characteristics and socioeconomic importance.

The diversity of agricultural practices and the variability of agricultural ecosystems pose significant obstacles. Agricultural practices vary widely across different regions, influenced by local climate, soil types, water availability, and socioeconomic conditions. This heterogeneity makes it challenging to develop and implement standardized decarbonization strategies that are effective across all contexts.

Furthermore, the economic implications for farmers and rural communities must be carefully managed. Many farmers operate with slim profit margins and have limited financial resources to invest in new technologies or practices. Transitioning to low-carbon agricultural methods often requires significant up-front investments in equipment, training, and infrastructure, which can be prohibitive for smallholder farmers.

Farm animals in many agricultural systems present a specific challenge. Livestock, especially ruminants like cattle, are significant sources of methane (CH_4), a potent GHG. Reducing emissions from livestock farming necessitates changes in animal husbandry practices, dietary adjustments, and potentially reduced herd sizes, all of which can be contentious and disruptive to livelihoods. Additionally, given the necessity to reduce emissions related to the use of chemical fertilizers, there is corresponding need to increase the utilization of animal waste-based fertilizers.

The need for food security further complicates the decarbonization agenda. As the global population continues to grow, the demand for food is increasing, placing pressure on agricultural systems to enhance productivity. Resilience in domestic food production can improve food security by reducing the impact of global economic and political shocks. Balancing the dual objectives of reducing emissions and increasing food production requires innovative approaches that can improve yield efficiency while minimizing environmental impact.

Technological and infrastructural constraints also play a critical role. Many low-carbon agricultural technologies are still in developmental stages or are not widely accessible. Scaling these technologies requires investment in research and development, as well as in the creation of supportive infrastructures.

Policy and regulatory frameworks would also need to evolve to support the transition to low-carbon agriculture. Effective policies must incentivize sustainable agriculture practices, provide financial and technical assistance to farmers, and ensure that the benefits and burdens of decarbonization are equitably distributed.

Further, any climate or decarbonization initiative and target setting must consider the intricate balance of ecosystems and strive for a nature-based solution. This means not only mitigating harm but also enhancing and restoring natural habitats, thereby supporting biodiversity and ensuring sustainable agriculture practices that coexist harmoniously with the environment.

Decarbonizing agriculture is a complex endeavor that requires coordinated efforts across multiple dimensions, including technological innovation, economic support, policy reform, and (international) cooperation. An important step for financial institutions to support this transition is to gain insights into their portfolio emissions and then conduct constructive conversations with their clients to gain understanding of how the financial sector and its clients can collectively work toward a sustainable and equitable transition.

1.3. Canada's Progress on Decarbonizing Agriculture

Canada has already made significant strides in the decarbonization of its agricultural sector, including the development of technological innovations, policy initiatives, and collaborative programs designed to transform agricultural practices and mitigate environmental impacts. This is shown in numerous life-cycle assessments (LCAs) of Canadian agricultural commodities, which indicate that the emissions intensity of some agricultural commodities is decreasing. In their LCA, Dairy Farmers of Canada documented a decrease from 1.03 kg CO_2 per liter of milk in 2011 to 0.94 kg CO_2 per liter of milk in 2016.[1] For Canadian beef, a decrease in emissions intensity was found during a 2021 LCA, falling from 12.6 kg CO_2 per kg of live weight in 2013 to 10.4 kg CO_2 per kg of live weight in 2021.[2] One key reason for this was the reduction in time taken to raise calves from birth to finish (market weight), which reduces the amount of CH_4 a single cow produces over its lifetime. The Global Institute for Food Security also found, in numerous LCAs conducted in 2022, that Canadian canola, wheat, lentils, and peas are less carbon-intensive than the same crop grown in France, Germany, or the United States.[3]

These efforts reflect a comprehensive approach to reducing GHG emissions while maintaining agricultural productivity and resilience. Continued commitment to innovation, investment, and collaboration will be essential, and financial institutions could play an important role.

2. Canadian Agriculture

2.1. Subsectors and Market Structure

The agriculture industry of Canada is important both domestically and internationally.

Internationally, Canada is a leading exporter of agricultural products, ranking among the top five global exporters of commodities like wheat and canola. In 2022, Canada's agri-food exports reached a record high of $82 billion, reflecting its critical role in the global food supply chain. In 2022, the whole agriculture and agri-food system employed 2.3 million people (one in nine jobs in Canada) and generated $143.8 billion (around 7.0%) of Canada's gross domestic product (GDP).[4] Canada produces a wide variety of crops and livestock, but only a handful of these varieties are responsible for a large amount of the farm cash receipts in these subsectors. For example, for crops, the top five contribute to 62% of the total, as can be seen in Exhibit 1.

Exhibit 1 Farm receipts for selected Canadian crop categories

Crops	2023 cash receipts (millions of dollars)	% of total crop receipts
Canola	13,663	25%
Wheat (except durum wheat)	10,255	19%
Soybeans	3,941	7%
Corn for grain	3,399	6%
Cannabis	2,818	5%
Total	**34,076**	**62%**

RMI Graphic. Source: Statistics Canada

The same picture emerges for the livestock subsector, with the top three contributing 75% of the total for livestock, as seen in Exhibit 2.

Exhibit 2 Farm receipts for selected Canadian livestock categories

Livestock	2023 cash receipts (millions of dollars)	% of total livestock receipts
Cattle	13,525	36%
Unprocessed milk	8,555	23%
Hogs	5,855	16%
Total	**27,935**	**75%**

RMI Graphic. Source: Statistics Canada

Despite the high concentration of specific crops and livestock accounting for the majority of farm receipts, the ownership structure within the sector is extremely fragmented. Most farms operate under sole proprietorships, or partnerships, or are family-owned corporations (see Exhibit 3).

Exhibit 3 Farm ownership structure

Operating arrangement	Number of farms in 2021
Sole proprietorship	96,702
Partnership	45,059
Family corporation	43,233
Other	4,880
Total number of farms	**189,874**

RMI Graphic. Source: Statistics Canada

This presents a significant challenge from an emissions accounting perspective because it is easier to account for emissions when they originate from a limited number of actors within a sector. Despite the large number of farms and ranches, production is somewhat concentrated within key agriculture subsectors in Canada. For instance, in the beef sector, only 1% of farms have more than 500 cattle, yet they are responsible for 13% of the Canadian herd.[5] A similar situation exists for dairy, where approximately 1% of farms are responsible for 10% of the dairy herd.[6]

Key takeaways

There are just under 200,000 farm operators in Canadian agriculture — making it unrealistic to directly engage all on emissions. However, the Canadian agriculture industry can be characterized by a high degree of concentration of farm receipts in certain crops and livestock subsectors. Due to the concentrated nature of the sector, there is an opportunity to focus on materiality by better understanding the emissions of the largest producers. Regardless of size, there are also tools available at the farm level that can assist farmers in measuring their emissions, especially if they have good digital farm records. These tools will be discussed in subsequent sections.

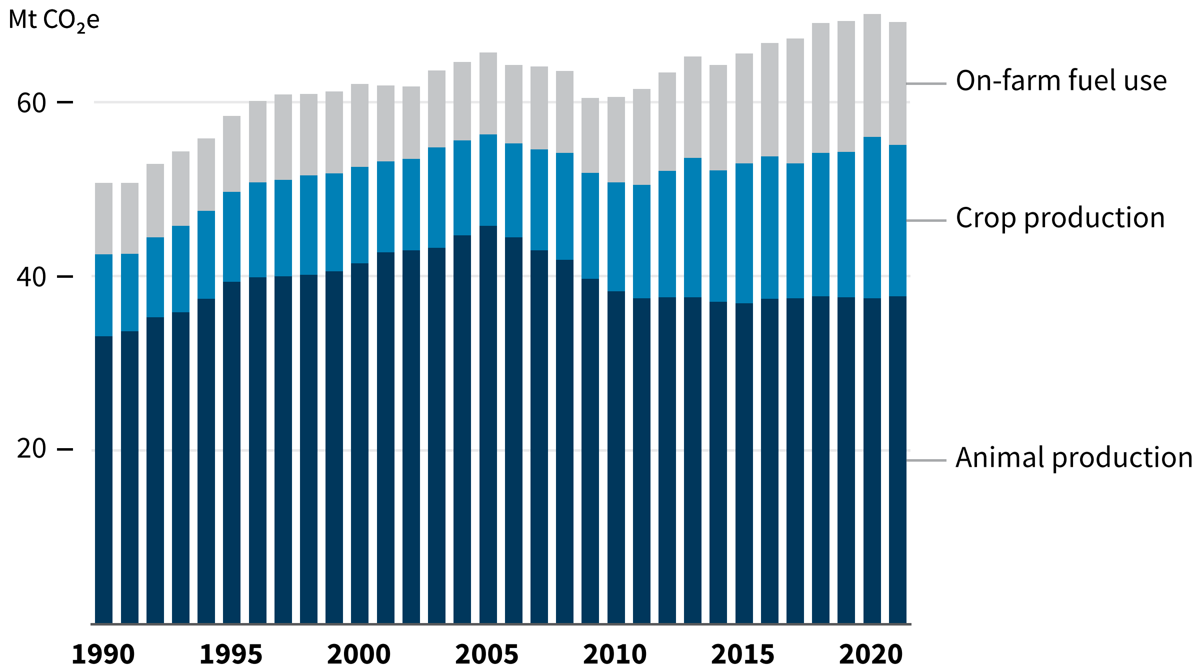
2.2. On-Farm Agriculture Emissions

In Canada's *National Inventory Report 1990–2021* (NIR), the agriculture sector was reported as the fifth largest source of GHG emissions, accounting for 10% of the total national emissions with approximately 69 megatons of carbon dioxide equivalent (Mt CO_2e) emitted in 2021.[7] However, the NIR outlines two methods of allocating emissions from the sector. The first follows the Intergovernmental Panel on Climate Change (IPCC) categories as defined by *2006 Guidelines for National Greenhouse Gas Inventories*.[8] The second uses Canadian economic sector categories.

For the purposes of analyzing economic trends and policies, it is useful to reallocate emissions to the economic subsector from which they originate. This reallocation simply recategorizes emissions under different headings and does not change the total magnitude of Canadian emissions estimates. The 69 Mt CO_2e figure originates from using the economic sector allocation approach. The three economic subsectors of agriculture are animal production, crop production, and on-farm fuel use. Emissions from these three economic subsectors are depicted in Exhibit 4. Between 1990 and 2021, emissions increased 35%, from 51 Mt CO_2e to 69 Mt CO_2e. This increase is primarily attributable to the doubling of crop production emissions: since 2005, the proportion of emissions from crop production has risen from 16% of sector emissions to 25% in 2021. Emissions from animal production have consistently contributed at least half of the total agriculture GHG emissions. This shift in sectoral emissions can be attributed to smaller cattle populations combined with a continued increase of crop production and fertilizer use.

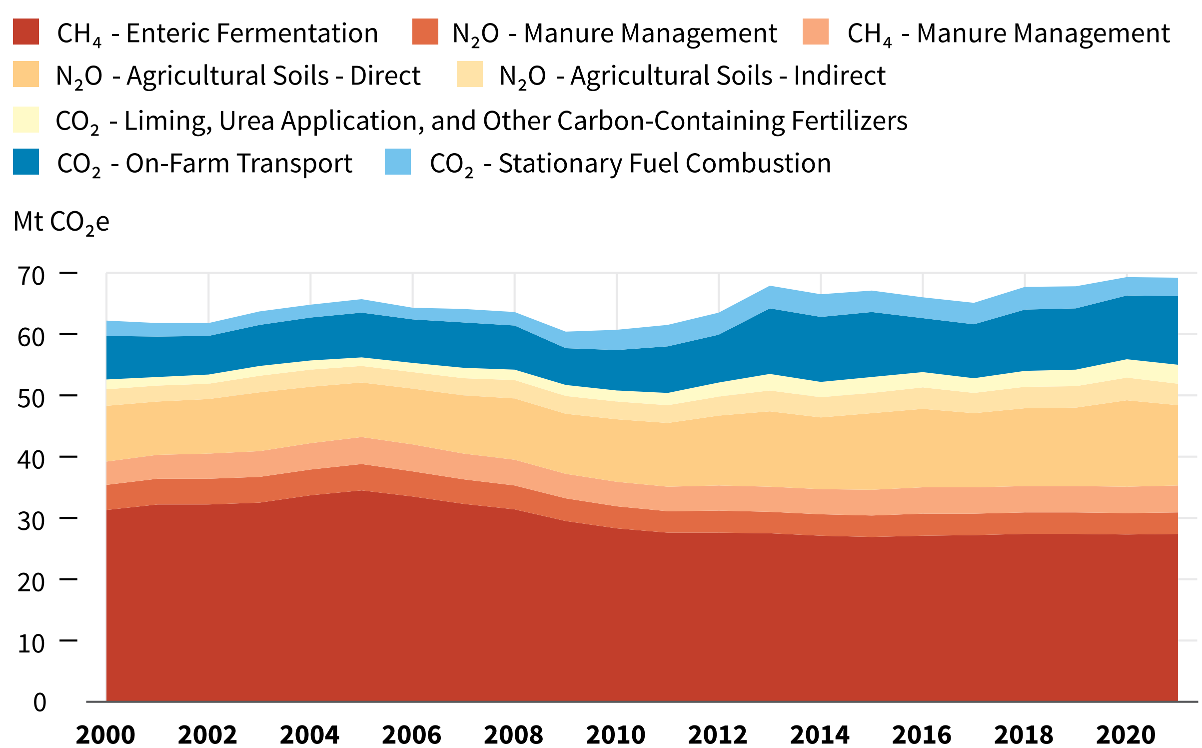
It is not sufficient to analyze emissions solely from the perspective of these economic sectors because, unlike other industries, agricultural emissions are primarily from CH_4 and nitrous oxide (N_2O). In 2021, CH_4 emissions constituted 41% of the Canadian agriculture sector's emissions, N_2O contributed 33%, and carbon dioxide (CO_2) accounted for 26%. The breakdown of emissions based on GHG type and activity is illustrated in Exhibit 5.It is helpful to explore in detail the specific activities responsible for these emissions, as well as identify the cropping or livestock activity primarily contributing to them to understand how they contribute to the overall emissions profile of the Canadian agriculture sector.

Exhibit 4 **Emissions from Canadian agricultural economic sectors, 1990–2021**



RMI Graphic. Source: Environment and Climate Change Canada

Exhibit 5 **Source of emissions from Canadian agriculture by GHG type and activity, 2000–21**



RMI Graphic. Source: Canada's *National Inventory Report*

Enteric Fermentation

Enteric fermentation occurs when the microbes present in an animal's digestive system ferment the feed consumed by the animal, producing CH_4 as a by-product. This CH_4 is then eructated, or exhaled by the animal.[9] This phenomenon is specific to ruminant animals, which possess a forestomach (called a rumen) that essentially functions as a large fermentation vat. Cattle, buffalo, sheep, and goats are all ruminant animals. As indicated in Exhibit 2, beef and dairy are significant subsectors within the Canadian agriculture economy. Emissions from enteric fermentation in Canada originate almost entirely (96%) from cattle production in Canada. Beef cattle are the main contributor to these emissions (81%), followed by dairy cattle (15%) and other species (5%).[10] In addition, CH_4 is a potent GHG, with 27–30 times the global warming potential as CO_2.[11]

Manure Management

Livestock manure is primarily composed of organic material and water. Under anaerobic conditions, where oxygen is absent, the organic material is decomposed by bacteria. The end products of this decomposition are CH_4, CO_2, and residual organic material. Manure storage results in production of CH_4 and N_2O. N_2O is produced from nitrification and denitrification processes acting on the nitrogen in manure. The management of cattle and poultry manure produces predominantly N_2O, whereas pork manure produces predominantly CH_4. This difference arises because ruminants are inefficient nitrogen converters, with only 5%–30% of ingested nitrogen being assimilated by the animal, while the remaining 70%–95% is excreted via feces and urine. Consequently, ruminants create manure that is disproportionally nitrogen heavy.[12]

Agricultural Soils

Direct emissions from agricultural soils arise from the application of nitrogen fertilizers to annual and perennial cropland. The processes of nitrification and denitrification are the two main ways that microbes produce N_2O.[13] Nitrification occurs when ammonia (the foundational compound in nitrogen-based fertilizers) is oxidized by microbes in the soil and is turned into nitrate, with a small fraction of nitrogen released as N_2O. This process occurs in oxygen-rich soils and is believed to occur more often than denitrification. Denitrification is the process that converts nitrate into nitrogen gas, with N_2O emitted as an intermediary gas.[14] Denitrification occurs in anaerobic environments, typically wet soils. Another source of direct N_2O emissions from soils is the decomposition of crop residue, which increases nitrogen availability after crop residue is incorporated into the soil.[15]

The indirect emissions from agricultural soils are defined as emissions from volatilization. Volatilization is the loss of nitrogen applied to the atmosphere as ammonia gas soon after application, which is subsequently redeposited on nearby soil, providing the necessary substance for nitrification or denitrification.[16] Another way soils indirectly emit N_2O is through nitrogen leaching, where nitrogen is being carried away from the soil by water after the application of animal manure, biosolid nitrogen, or inorganic nitrogen fertilizer. N_2O is released during leaching because nitrate-rich soils become saturated with moisture, initiating the denitrification process.

There are significant uncertainties in measuring emissions from fertilizer use because they can vary depending on factors such as application rate, time of fertilizer placement, formulation, soil type, and more. Although it is well established that fertilizer-related emissions are among the highest in agriculture, this uncertainty poses a significant challenge for accurately measuring emissions in the sector.

Liming, Urea, and Other Carbon-Containing Fertilizer

Limestone is often added to soil to reduce soil acidification. When limestone comes in contact with strong acid sources such as nitric acid in the soil, a chemical reaction is triggered, resulting in the degradation of limestone, releasing CO_2 emissions.[17] Similarly, when urea, or urea-based nitrogen fertilizer, is applied to soil to assist in crop production, it is broken down by water molecules in the soil, releasing CO_2.

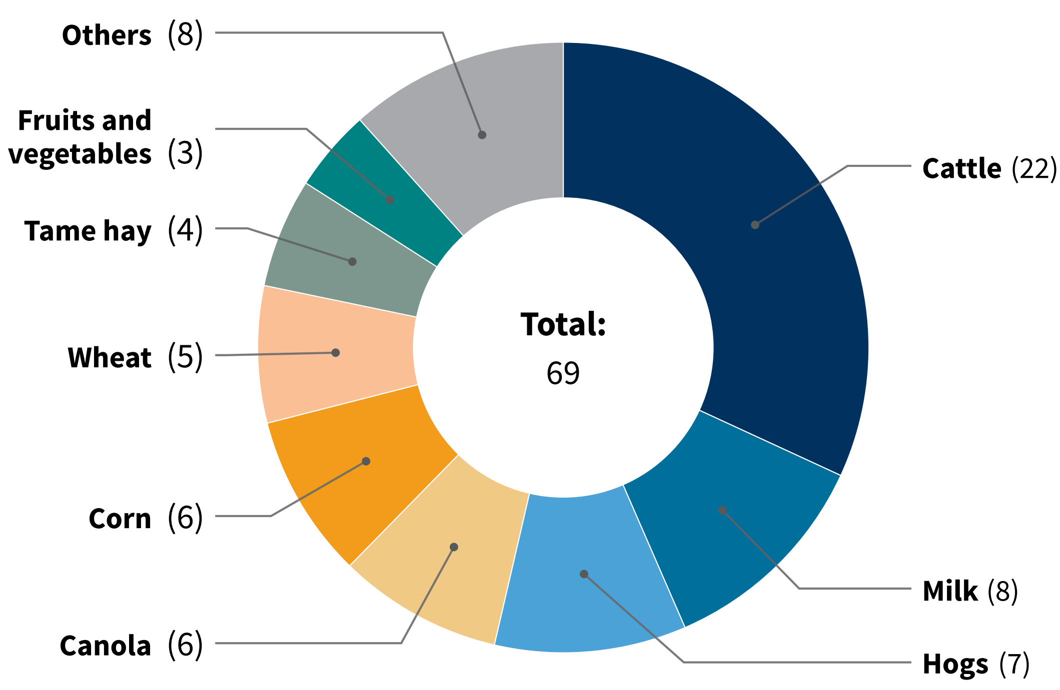
Transport and Stationary Fuel Combustion

These emissions categories are less complex than the previous, and simply refer to the CO_2 emissions generated from on-site combustion of fuel, as well as those associated with on-site transport.

2.3 Emissions Based on Commodity

It is beneficial to break down emissions from on-farm agriculture by economic sector and source. Additionally, breaking down emissions by individual commodity proves advantageous. Although sources can be deduced, such as the majority of enteric fermentation emissions originating from cattle, distinguishing the contributions from beef cattle versus dairy cattle from this dataset remains challenging. In the paper *Greenhouse Gas Emissions from Canadian Agriculture: Estimates and Measurements*, emissions from each commodity were estimated by multiplying academically sourced emissions factors for commodities by production values.[18] The result can be seen in Exhibit 6.

Exhibit 6 **Emissions from Canadian agricultural commodities, 2016 (Mt)**



RMI Graphic. Source: *Greenhouse Gas Emissions from Canadian Agriculture: Estimates and Measurements*

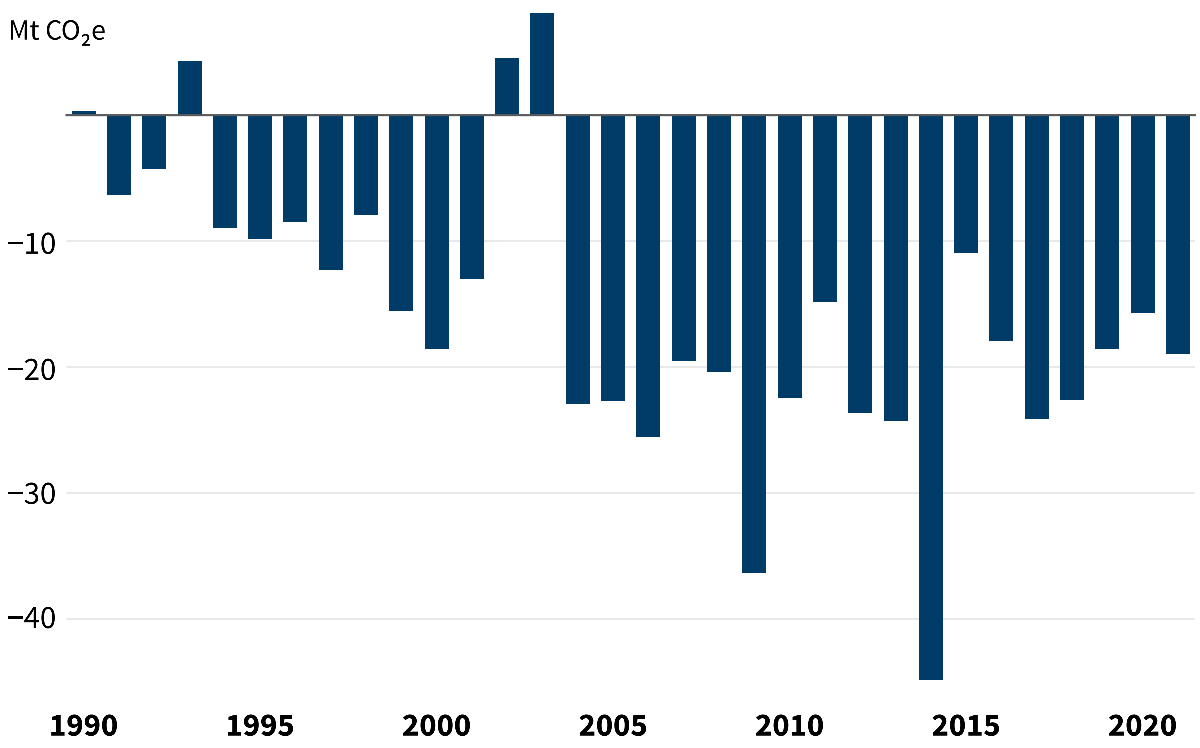
2.4 Land Use, Land Use Change, and Forestry

The land use, land use change, and forestry (LULUCF) sector includes the emissions and removals of GHGs that occur because of human activities related to LULUCF. Carbon is sequestered by forestry (and to a lesser extent cropland), while carbon emissions occur when existing forestry or cropland is converted to a form of land use that sequesters carbon less, such as forestry to cropland conversion, or cropland to settlement conversion. Cropland in the NIR includes field crops, summer fallow, hayfields, and tame or seeded pastures. These figures are not included in Exhibit 5 because they are reported separately in the NIR.

Because the focus of this paper is agriculture, the focus is on emissions and/or removals of the land use category cropland remaining cropland, as well as emissions and/or removals from the land use change (LUC) category land converted to cropland. Generally speaking, cropland remaining cropland has been a net remover of emissions since 1990 and was a net remover of approximately 19 Mt CO_2e in 2021.[19] However, the amount per year varies significantly and can sometimes be a net emissions source. The largest driver of carbon sequestration is organic carbon input into soil from residual crops, while the largest driver of emissions is the conversion of perennial to annual crops.[20]

Exhibit 7

Emissions and removals from land use and LUC from cropland in Canada



RMI Graphic. Source: Environment and Climate Change Canada

Regarding land converted to cropland, 99% of which is originally forestland, immediate emissions totaled 1.4 Mt in 2021, while residual emissions from events that occurred in the between 2000 and 2020 totaled 2.0 Mt.[21] Although these reported emissions are small in comparison to other sources of emissions from agriculture, forests in Canada are vital areas of biodiversity.[22] Increasing agricultural production while ensuring the sustainability of Canadian forests remains a challenge for the sector.

Key takeaways

The emissions from the agriculture sector in Canada predominantly consist of CH_4 and N_2O. CH_4 emissions primarily arise from enteric fermentation from cattle, while N_2O emissions are mainly due to the application of fertilizer. CO_2 emissions also contribute significantly, primarily resulting from on-site transport and fuel combustion. The following sections discuss the decarbonization levers that address these sources of emissions.

2.5 The 2030 Emissions Reduction Plan: Canada's Next Steps for Clean Air and a Strong Economy

On March 29, 2022, the Canadian government announced its 2030 emissions reduction plan.[23] This plan adopts a sector-by-sector approach, with a target of reducing absolute emissions by 40% below 2005 levels by 2030. The plan includes $9.1 billion in new investments and sets various emissions targets across different sectors and subsectors.

For the agriculture sector, the plan sets out a commitment to reduce absolute emissions by 1% compared with 2005 levels (a target of 71 Mt compared with 72 Mt CO_2e emitted). It should be noted that due to methodological updates and improvements, historical emissions from this sector have been revised downward. For instance, 2005 emissions figures from agriculture used in the 2030 emissions reduction plan have been revised downward from 72 Mt to 66 Mt. Recalculations were primarily driven by revisions to the emissions factors used to estimate direct N_2O emissions from agricultural soils. It is unclear whether the Canadian government has updated its target to reflect this downward revision. If it is assumed that the target will be updated to be below 2005 levels, then Canadian agriculture faces the difficult task of decarbonizing as food production increases, as is projected.[24] To support this transition, several new funds were made available to Canadian farmers.[25]

- $470 million for Agricultural Climate Solutions: This fund is available to help farmers adopt sustainable practices such as cover crops, rotational grazing, and fertilizer management.
- An additional $330 million for the Agricultural Clean Technology Program: This supports the development and acquisition of more energy-efficient equipment for farmers.
- An investment of $100 million in transformative agricultural science: This includes fundamental and applied research, knowledge transfer, and the development of metrics.

The intake periods have all now closed; however, there are still some provincial programs available, such as the Sustainable Canadian Agricultural Partnership in Alberta. Additionally, the government of Canada committed to launching a Sustainable Agriculture Strategy (due to be released in late 2024) for the nation, a long-term strategy to ensure the environmental and economic sustainability of the sector.

Key takeaways

When engaging with clients in the agriculture sector, financial institutions should inform them of the available funding options at their disposal to adopt more sustainable practices.

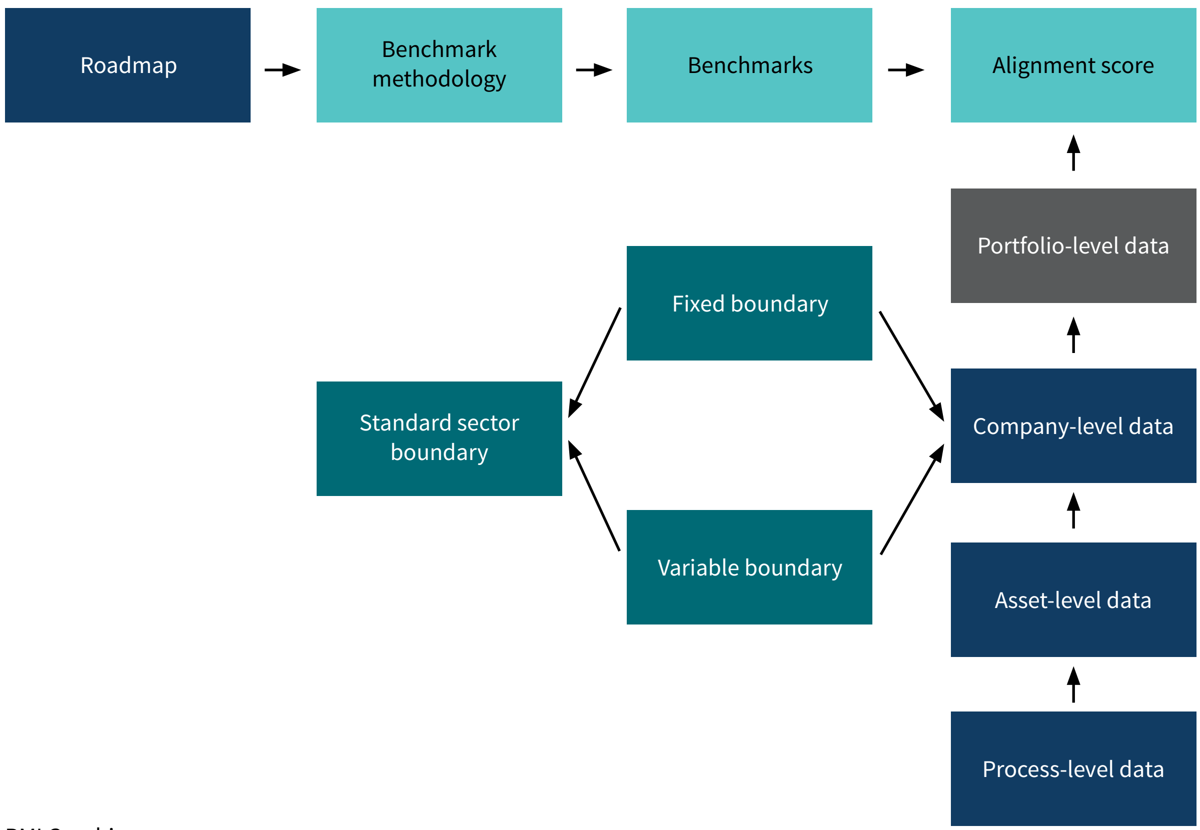
3. Target-Setting Building Blocks

The following section will first provide a more theoretical explanation of what elements comprise target setting, the so-called target setting building blocks (Exhibit 8). The subsequent sections will analyze these building blocks in an agriculture setting.

Exhibit 8

Target-setting building blocks

The target-setting building blocks are comprised of boundary, methodology, roadmap, and data source components.



RMI Graphic.

3.1. Boundary

The emissions boundary delineates the activities that will be included in the scope of emissions measurement. The primary objective of setting an emissions boundary around specific activities is to create a system of reported emissions that is both extensive in coverage, and also as simplistic as possible to ease reporting requirements. When defining the scope of the boundary, it should be clear which emissions are included and which are excluded.

3.2. Methodology

An emissions accounting methodology outlines the process for distinguishing and benchmarking relevant subsectors and identifying the appropriate metrics for measuring client and portfolio emissions. The primary objective of an emissions accounting methodology is to define a boundary for measurement and to determine which activities within that boundary are in scope for emissions measurement. An emissions accounting methodology can be considered robust if it accounts for the significant emissions sources within a supply chain, without imposing excessive reporting burdens on the entity.

The objective of an emissions target-setting methodology is to prescribe an emissions target for a future date (often 2030 or 2050) based on the necessary reductions outlined in decarbonization scenarios. Each entity follows a unique decarbonization pathway, and the degree to which an entity adheres to this pathway is referred to as alignment. For financial institutions, this process is aggregated at the portfolio level, enabling the determination of the alignment of the entire portfolio.

3.3. Roadmaps

Once an emissions boundary and accounting methodology have been selected, a roadmap needs to be chosen. A roadmap is an emissions trajectory from now until 2050 or 2100, and its objective in this context is to provide a benchmark against which the emissions performance of an entity will be measured. When calculating portfolio alignment, portfolios are compared with this benchmark. From this benchmarking exercise, it is possible to determine whether an entity is on track or not to meet emissions reduction targets.

3.4. Data

Access to robust, standardized data is necessary for the implementation of the agreed methodology. Data could be self-reported by clients, estimated by institutions for clients, or acquired through a third party.

4. Selecting a Boundary

4.1 The Agriculture Value Chain

When determining the boundary, the materiality of emissions from each part of the agriculture value chain — upstream, preproduction-linked emissions (pre-farm), farm gate emissions (on-farm), and postproduction-linked emissions (post-farm) — should be considered. This paper previously outlined emissions from within the farm gate (on-farm) and emissions from land use and LUC in section 2; upstream and downstream emissions will be the focus of this section.

4.2 Upstream Emissions

Upstream (pre-farm) emissions from agriculture vary based on production activity. However, this paper focuses on three areas: fertilizer manufacturing, machinery manufacturing, and pesticide manufacturing. This is mainly due to the availability of existing research on the emissions associated with these inputs. Data for fertilizer manufacturing and machinery manufacturing has been obtained from *Agricultural Greenhouse Gas Emissions in Canada: A New, Comprehensive Assessment*, third edition,[26] and pesticide manufacturing emissions have been obtained from the Food and Agriculture Organization Corporate Statistical Database (FAOSTAT).[27] Data from unavailable years has been interpolated.

4.3 Downstream Emissions

In addressing downstream (post-farm) emissions, there are a few key areas to be examined. Food transport, food retail, and household consumption are the most emissions-intensive subcategories. Additionally, emissions from processing, packaging, and waste contribute substantially. Below is a concise description of each category, with the exception of household consumption, whose relevance to target setting within an agriculture or agri-services lending book remains unclear. The data source for Canadian postproduction activities is FAOSTAT.[28] When considering the entire agri-food value chain (on-farm, post-farm, pre-farm), the emissions total in 2021 was approximately 134 Mt CO_2e.

Fertilizer Manufacturing

Fertilizer manufacturing is a highly emissions-intensive process. This is because natural gas and coal are the primary energy sources for the manufacturing of fertilizer.[29] In 2021, the emissions from the manufacturing of sulfate, phosphate, and nitrogen fertilizer in Canada were 10.3 Mt CO_2e, contributing to about 8% of the agriculture value chain emissions, with nitrogen fertilizer making up the vast majority at 7.5 Mt.

Machinery Manufacturing

The energy consumed due to the manufacturing of machinery is comparable to the fuel energy consumed during farm field work but has been falling due to the increased amounts of recycled steel being used in machinery manufacturing.[30] In this analysis of farm machinery manufacturing, the focus is the manufacturing of tractors, not only because they provide the power for most on-field operations, but also because they require more energy during manufacturing than most other farm equipment. Machinery manufacturing in Canada contributed 2.6 Mt CO_2e in 2021.

Pesticide Manufacturing

Pesticide manufacturing contributes the least amount of emissions to Canadian agriculture compared with the other pre-farm inputs, but still requires a significant amount of energy. Inherent energy is used to manufacture the chemical and is retained in the chemical structure of the pesticide's active ingredient, with additional process energy used in the manufacturing process (such as for heating, cooling, and pressurizing), and the energy used for the formulation of pesticide mixtures.[31] Pesticide manufacturing in Canada contributed 2.0 Mt CO_2e in 2021.

Food Transport

Post-farm gate, the proper distribution of food requires safe transportation of the food from farm or processor to the consumer. Studies have shown that emissions from food transport contribute approximately 4.8% of global food system emissions.[32] However, more recent studies (which factor in the entire food value chain including transportation of fertilizer and feed) have determined this figure to be around 19%.[33] In Canada, food transport contributed 17.8 Mt CO_2e in 2021, amounting to approximately 13% of the total agri-food value chain emissions. Many food items are highly perishable and rely on a refrigerated distribution system (known as the cold chain) to reach the consumer with a reasonably stable shelf life. As such, some food items that have a particularly short shelf life must be distributed via the most emissions-intensive forms of travel, such as air freight.

Food Retail

GHG emissions from food retail consist of CO_2 generated by energy consumption in food retail facilities, as well as fluorinated gases (F-gases) generated from refrigerant leakage. Food retailers and supermarkets consume high amounts of energy due to their refrigeration needs, and they typically have one of the highest specific energy consumptions (energy consumption per total area) among commercial buildings in the United States,[34] as well as in Western European economies.[35]

Food Processing

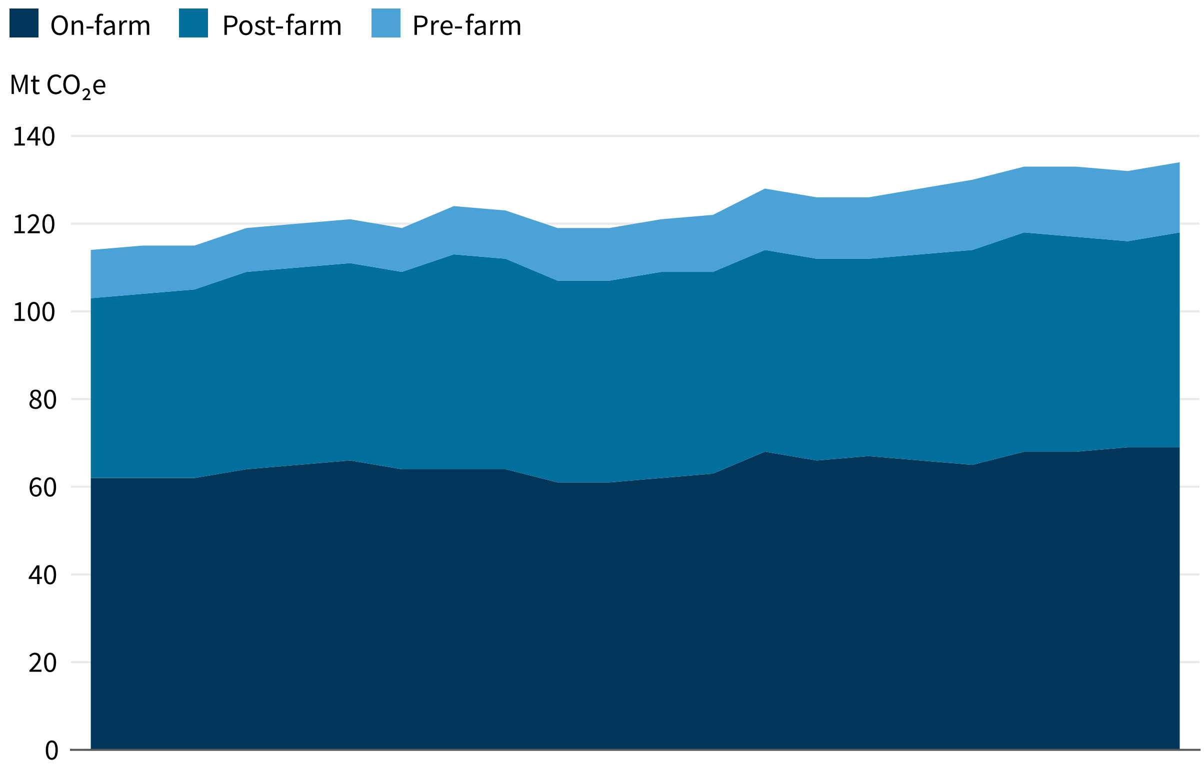
Food processing includes all intermediary operations needed to transform raw agricultural commodities into food products for consumption. Thermal processes, such as refrigeration and heating, account for most of the energy use in food processing, with process heating generally being the most demanding.[36] An important exception is meat and milk processing, where most energy is used for cooling and refrigeration.

Food Waste

Food systems waste, including solid food waste and domestic and industrial wastewater, can generate significant amounts of GHG emissions depending on how they are managed. In Canada, between 2000 and 2020, emissions from solid food waste accounted for 77% on average of the total of these waste categories. Solid food waste can be disposed of in several ways, including incineration, composting, or utilization as an input to biogas production. In most countries, however, most of the solid food waste ends up in landfills and open dumps where the anaerobic decomposition of organic material releases CH_4 gas. Additionally, studies have shown that 58% of food produced in Canada is lost or wasted, the vast majority of which ends up in landfill.[37]

Exhibit 9 shows how impactful upstream and downstream emissions are to the top-line emissions figure when these two classes of emissions are introduced into the source of emissions diagram.

Exhibit 9 **Source of emissions (pre- and postproduction included) from the Canadian agriculture sector**



RMI Graphic. Source: National Farmers Union (NFU), Canada's *National Inventory Report*, FAOSTAT

Key takeaways

There are significant volumes of emissions throughout the agriculture value chain. As a result, boundary selection is a complex task. For exposure to on-farm emissions, Scope 1 and 2 and upstream Scope 3 emissions could be considered. Downstream Scope 3 emissions could also be included in farm-level targets but are currently difficult to measure and influence at the farm level. This aligns with recommendations set out in other initiatives, such as B4ICA guidance and the Science Based Targets Initiative Forestry, Land, and Agriculture (SBTi FLAG), both of which are explored in the following section.

5. Target-Setting Methodology

5.1. Existing Methodologies for the Agriculture Sector

The only methodology that has been fully developed by civil society and applied by financial institutions is the SBTi FLAG target-setting methodology. Consequently, it is the only methodology that is extensively covered in this paper.

Rabobank and Nordea are among the financial institutions that have set targets using SBTi FLAG. The B4ICA initiative identified SBTi FLAG in its paper *An Introductory Guide for Net Zero Target Setting for Farm-Based Agricultural Emissions — Overview of Best Practices to Operationalize Banks' Net Zero Commitments in the Food System* and noted that SBTi FLAG represents "a useful starting point for exploring and selecting a scenario and setting pathways" especially for banks that have high subsector concentration and those that wish to have subsector breakdown in scenarios.[38] However, in that same paper, B4ICA stated that the pathways in SBTi FLAG are not customized for banks and not necessarily suitable as given for bank target-setting purposes and called for additional guidance for financial institutions to support banks in applying the SBTi FLAG pathways.

5.2. SBTi FLAG

SBTi is a collaborative effort between CDP (formerly Carbon Disclosure Project), the United Nations Global Compact, the World Resources Institute, and the World Wide Fund for Nature. It aims to drive ambitious climate action in the private sector by enabling companies to set science-based emissions reduction targets. These targets are aligned with the level of decarbonization required to keep global temperature increases below 1.5°C or well below 2°C, in accordance with the goals of the Paris Agreement. SBTi provides a framework for companies to develop, validate, and publicly commit to their emissions reduction targets, thereby promoting transparency, accountability, and a standardized approach to corporate climate action. All information here can be found in the FLAG target setting guidance document and tool.[39]

5.3. FLAG Target-Setting Options

SBTi FLAG has two approaches.

- FLAG sector approach/pathway: This approach is for companies with diversified emissions across FLAG emissions sources. It follows a percentage reduction against a baseline model, with the near-term absolute target set as −3.03%/year linear reduction as opposed to the −4.2%/year (and −90% long term) for energy and industrial targets. The lower ambition reflects the challenges in reducing N_2O and CH_4 emissions from agriculture.
- FLAG commodity approach/pathway: This is an alternative option for nine agricultural commodities (beef, dairy, chicken, pork, maize, wheat, soy, palm oil, rice) where the emissions associated with any one commodity exceed 10% of total FLAG emissions. The SBTi commodity pathways are modeled by the SBTi Sectoral Decarbonization Approach (SDA).

5.4 FLAG Emissions

The following three categories are considered relevant for FLAG emissions accounting: LUC and non-LUC, which are emissions sources, and carbon removals and storage, which are accounted for as removals.

Land Use Change

- CO_2 emissions from LUC associated with deforestation and forest degradation, including conversion of natural forest to plantation following GHG Protocol definitions
- CO_2 emissions from LUC associated with conversion of coastal wetlands; conversion, draining, and burning of peatlands; and conversion of savannas and natural grasslands (sector pathway only)

Non-Land Use Change [or Land Management]

- CH_4 emissions from manure management
- Enteric CH_4 emissions (sector pathway and, where relevant, commodity pathways)
- CH_4 emissions from flooded soil (for lowland rice)
- Direct and indirect N_2O emissions from manure management
- Direct N_2O emissions from soil due to fertilizer application
- Indirect N_2O emissions from leaching, runoff, and volatilization
- N_2O emissions from crop residue
- CH_4 and N_2O emissions from agricultural waste burning
- CO_2 emissions from machinery used on-farm (commodity pathways only)
- CO_2 emissions from transport of biomass (commodity pathways only)
- CO_2 and N_2O emissions from fertilizer production

Carbon Removals and Storage

- Forest restoration that occurs on working lands only (e.g., silvopasture) (sector pathway only)
- Improved forest management (e.g., optimizing rotation lengths and biomass stocks, reduced-impact logging, improved plantations, forest fire management) (sector pathway and timber and wood fiber commodity pathway)
- Agroforestry: Carbon sequestration from integration of agroforestry into agricultural and grazing lands (sector pathway only)
- Enhancing soil organic carbon: Shifting from current management to activities such as erosion control, use of larger root plants, reduced tillage, cover cropping, restoration of degraded soils (e.g., implementing integrated crop–livestock systems), and biochar amendments

Who Should Set FLAG Targets?

SBTi requires companies that meet either of the following two criteria to set a FLAG target:

- Companies from the following FLAG-designated sectors:
    - Forest and paper products: forestry, timber, pulp and paper, rubber
    - Food production: agricultural production
    - Food production: animal source
    - Food and beverage processing
    - Food and staples retailing
    - Tobacco
- Companies with FLAG-related emissions that total 20% or more of overall emissions across scopes

It is recommended that companies with FLAG-related emissions that fall below the 20% threshold nonetheless set a FLAG target. The FLAG target must cover at least 95% of FLAG-related Scope 1 and 2 emissions, and 67% of FLAG-related Scope 3 emissions.

The Sectoral Decarbonization Approach

SBTi developed the SDA to support sector-specific target-setting for companies. One key aspect is the convergence approach, which normalizes a sector decarbonization trajectory to the baseline of a specific company to set targets relevant to that company. It is called the convergence approach because all company pathways converge to the intensity of the sector pathway in 2050. Targets are determined by market share and initial emissions intensities. Companies with higher initial emissions intensities and increasing market share have a steeper pathway.

The SDA convergence approach (hereafter referred to as the SDA) is implemented using the following equations. It should be noted that over the course of preparing this paper the market share parameter was kept out of consideration, mainly due to the difficulty of predicting production volumes for small farms in the target year.

- The starting emissions intensity performance of the company in the baseline year is determined by how far it is from the 2050 sector intensity.

$$d = CI_b - SI_{2050}$$

d = Initial performance in base year relative to 2050 sector target
CI_b = Company emissions intensity in base year
SI_{2050} = Sector emissions intensity in 2050 as per roadmap

- The decarbonization index determines how much progress a company should have made from the baseline to the 2050 intensity by the target year.

$$p_y = \frac{SI_y - SI_{2050}}{SI_b - SI_{2050}}$$

p_y = Decarbonization index of the sector in target year
SI_y = Sector emissions intensity in target year y
SI_{2050} = Sector emissions intensity in 2050 as per roadmap
SI_b = Sector emissions intensity in base year

- All these parameters are combined into a company intensity for the target year. This company intensity can be determined for all years from the base year to 2050 to establish a company trajectory.

$$CI_y = d \times p_y + SI_{2050}$$

How the SBTi FLAG Commodity SDA Differs from the Traditional SDA

The main differentiations between the SDA used in FLAG compared with other industries is the breakout of non-LUC and LUC.

$$d_{\text{non-LUC}} = CI_{b\,(\text{non-LUC})} - SI_{2050\,(\text{non-LUC})}$$

$d_{\text{non-LUC}}$ = Initial performance in base year relative to 2050 sector target for non–LUC
$CI_{b(\text{non-LUC})}$ = Company emissions intensity in base year for non–LUC
$SI_{2050(\text{non-LUC})}$ = Sector emissions intensity in 2050 as per roadmap for non–LUC

$$d_{\text{LUC}} = CI_{b\,(\text{LUC})} - SI_{2050\,(\text{LUC})}$$

d_{LUC} = Initial performance in base year relative to 2050 sector target for LUC
$CI_{b(\text{LUC})}$ = Company emissions intensity in base year for LUC
$SI_{2050(\text{LUC})}$ = Sector emissions intensity in 2050 as per roadmap for LUC

Because emissions intensity is equal to the absolute emissions divided by production of the unit, the above equations are equal to the following:

$$d_{\text{non–LUC}} = \frac{E_{\text{non–LUC}}}{CP_b} - SI_{2050(\text{non-LUC})}$$

$$d_{\text{LUC}} = \frac{E_{\text{LUC}}}{CP_b} - SI_{2050(\text{LUC})}$$

CP_b = Production activity of the company in the base year
$E_{\text{non–LUC}}$ = Emissions from non–LUC
E_{LUC} = Emissions from LUC

Although the user has the option of inputting separate non-LUC and LUC emissions, this is often hard to obtain, especially for smaller organizations with fewer resources to conduct more granular emissions accounting. However, the SBTi FLAG tool allows the user to simply input total emissions in the base year, which is then multiplied by a scale factor that is determined by data from the scenario, as seen in the following equation:

$$E_{\text{non–LUC}} = TE_B * \frac{\text{Scenario}_{\text{non–LUC–intensity}*CP_b}}{(\text{Scenario}_{\text{non–LUC–intensity}*CP_b}) + (\text{Scenario}_{\text{LUC–intensity}*CP_b})}$$

TE_B = Total emissions in base year
$\text{Scenario}_{\text{non–LUC–intensity}*CP_b}$ = Emissions intensity for non–LUC emissions as given by the scenario
$\text{Scenario}_{\text{LUC–intensity}*CP_b}$ = Emissions intensity for LUC emissions as given by the scenario

The same is done for LUC emissions. Using this information, target year emissions intensities can be calculated for non-LUC and LUC, as can be seen below.

$$CI_{y\,(\text{non–LUC})} = d_{\text{non–LUC}} \times p_y + SI_{2050\,(\text{non-LUC})}$$

$$CI_{y\,(\text{LUC})} = d_{\text{LUC}} \times p_y + SI_{2050\,(\text{LUC})}$$

How Are Removals Calculated?

Removals may be included in FLAG targets only when the appropriate requirements are met, in accordance with the GHG Protocol Land Sector and Removals Guidance.[40] Reforestation and forest or woody vegetation restoration occurring on working lands are included in the FLAG sector target, whereas those occurring outside working lands are excluded because they are outside the scope of an organization's immediate influence. The following removal sources are covered by SBTi FLAG:

- Forest restoration that occurs on working lands only (e.g., silvopasture) (sector pathway only)
- Improved forest management (e.g., optimizing rotation lengths and biomass stocks, reduced-impact logging, improved plantations, forest fire management) (sector pathway and timber and wood fiber commodity pathway)
- Carbon sequestration from integration of agroforestry into agricultural and grazing lands (sector pathway only)
- Shifting from current management to activities such as erosion control, use of larger root plants, reduced tillage, cover cropping, restoration of degraded soils (e.g., implementing integrated crop–livestock systems), and biochar amendments

Removals are determined for three different classes in the FLAG methodology: the sectoral approach, the commodities approach for livestock and arable crops, and the commodities approach for timber and wood pulp.

For the sectoral approach, emissions reductions without removals are calculated (using the nonremovals levers outlined in the scenario, which are LUC, improved agriculture management, shifting diets, and reducing food losses and waste). These are the required emissions reductions through abatement. The removal calculations are then done by summing the emissions reductions needed per year outlined by the scenario (restore forests, improve sustainable forest management and agroforestry, enhance soil carbon sequestration in agriculture and application of biochar, deploy bioenergy with carbon capture and storage) and adding this required removal to the yearly reduction figure. Without removals, the yearly reduction figure is 1.9%. With removals, it is 3.03%.

For cropping and livestock, a linear pathway is followed that starts at the removals input by the user, which then progresses along a curve dictated by the following equation:

$$\text{Removals intensity} = \frac{\text{removals per hectare}}{\text{yield per hectare}} = \frac{\frac{\text{yearly removals}}{\text{hectare of cropping land}}}{\text{yield per hectare}}$$

The pathway remains essentially unchanged, no matter what the starting removals input.

6. Roadmaps

6.1. Key Criteria for Assessing Roadmaps

The selected roadmap will need to be ambitious, robust, and credible, and financial institutions will need to be able to communicate the rationale for this selection to various stakeholders, including clients, to ensure buy-in. Furthermore, if seeking NZBA compliance, the NZBA guidelines require that financial institutions set targets against roadmaps that are 1.5°C aligned with no to low overshoot. Because members of NZBA constitute >40% of global banking assets,[41] selecting a benchmark that is compliant with NZBA guidance creates the best opportunity to maximize adoption across the sector.

The following criteria can guide assessment and selection of a roadmap and help communicate the rationale behind its selection:

- Climate alignment: Does the model reach net-zero emissions by 2050 and is it no to low overshoot of 1.5°C?
- Legitimate: Has the roadmap gone through a process of validation from key stakeholders?
- Standardization: Is the model being used by other voluntary or mandatory initiatives?
- Granularity: Does the model include granular data for the sector, such as yearly data on emissions reductions through 2050, as well as geographical granularity?
- Robustness: Does the roadmap make sensible and reasoned assumptions for the sector?
- Openness: Is information regarding the roadmap available to the public stakeholders?

6.2. Existing Roadmaps for the Agriculture Sector

There are numerous roadmaps available for the agriculture sector. This section outlines the key components of each and determines their suitability based on the criteria listed above. For agriculture, roadmaps are often generated via integrated assessment models (IAMs). IAMs are top-down models that seek to analyze and project the interactions between human and natural systems, incorporating multiple sectors such as energy, transport, agriculture, and land use, and outputting a wide range of information such as GHG emissions, temperature change, food production volumes, and more. These models are driven by socioeconomic parameters such as projected population change, technology development, and policy intervention, and thus provide a valuable tool to analyze the results of different sets of assumptions.

One group of parameters that are often used in IAMs are the Shared Socioeconomic Pathways (SSPs). SSPs are narratives that describe global changes up to 2100, including the elements mentioned above. The impact of these socioeconomic changes can then be quantified using IAMs. The SSP scenarios are:

- SSP1: Sustainability (Taking the Green Road)
- SSP2: Middle of the Road
- SSP3: Regional Rivalry (A Rocky Road)
- SSP4: Inequality (A Road Divided)
- SSP5: Fossil-Fueled Development (Taking the Highway)

Integrated Model to Assess the Global Environment

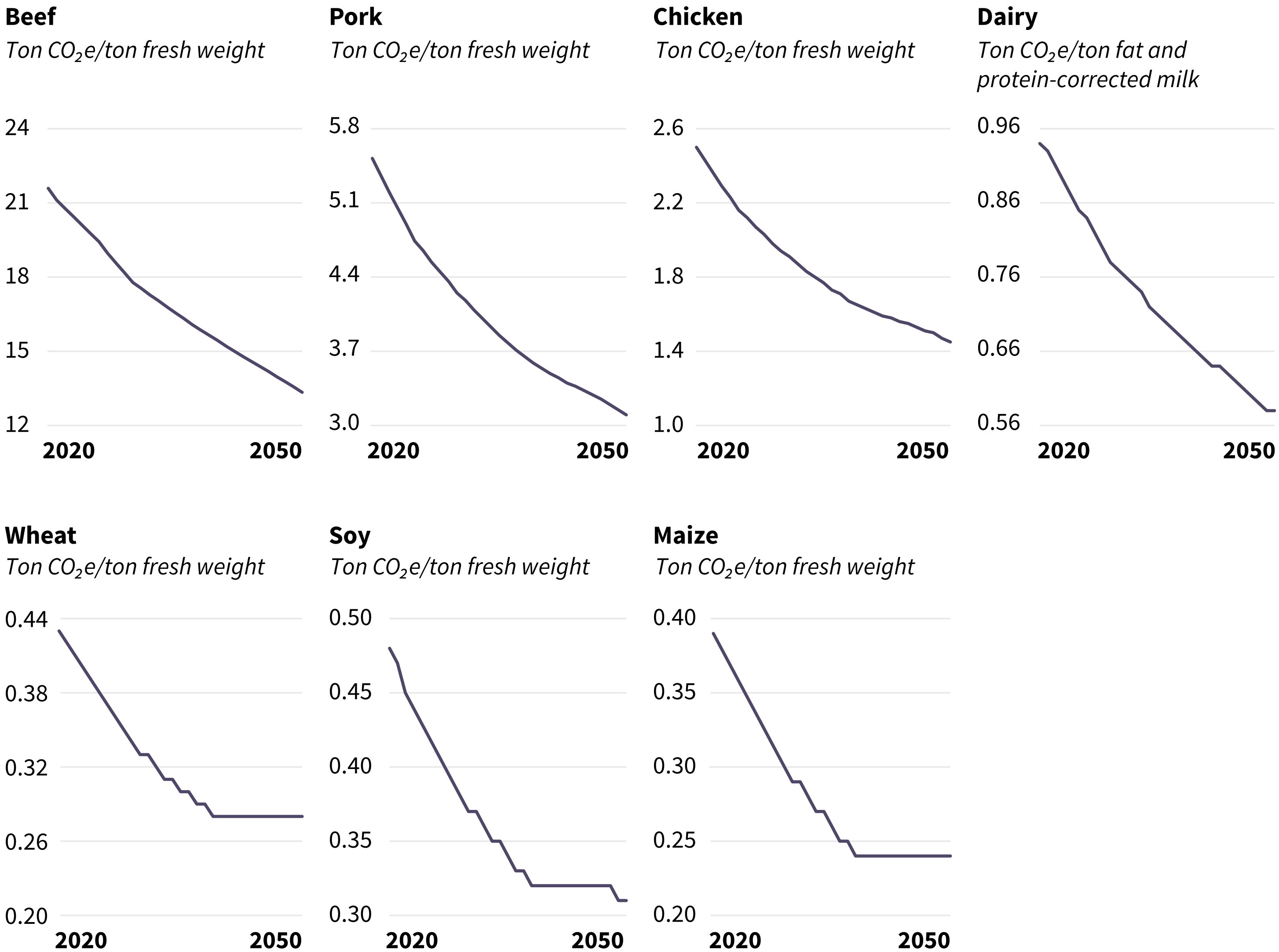
The Integrated Model to Assess the Global Environment (IMAGE) is an integrated assessment model developed by the Netherlands Environmental Assessment Agency (PBL). The first iteration was developed in 1990. The latest version, IMAGE 3.2, was released in 2020. The model, driven by inputs and assumptions given by the user, projects future trends in various sectors such as energy, industry, agriculture, and LUC, as well as the resulting GHG emissions. The method of how emissions from agriculture are projected in IMAGE can be found in *Appendix B*.

IMAGE, the PBL Science-Based Targets Tool, and SBTi FLAG

In 2016, University of Aberdeen, PBL Netherlands, and Ecofys developed a tool to set science-based targets. This was done using data from the IMAGE model (using SSP2 as the input scenario) and derived average emissions intensity pathways from 2010 to 2050 per agricultural commodity across the 26 IMAGE regions. The difference between these intensity pathways from the data originally in IMAGE is the inclusion of cradle-to-farm-gate emissions such as those associated with upstream production of fertilizers, on-field application of fertilizers, on-farm machinery use, manure management, and other relevant on-farm activities. This tool served as the foundation on which SBTi FLAG was built for non-LUC emissions pathways. A variety of Canadian-specific commodity pathways are presented below. LUC emissions pathways (to ensure compatibility between sector and commodity approaches) were derived using FAO for forest and forest loss, Global Livestock Environmental Assessment Model for livestock feed baskets associated with LUC, and the World Food LCA Database for regionally specific crop type and land management parameters.

Exhibit 10 shows seven Canadian commodity pathways as given by SBTi FLAG. It should be noted these are not projections of what will definitely happen, but rather projections of emissions intensity reductions occurring under a scenario. Unfortunately, it is not clear what specific mitigation levers contribute to these emissions intensity reductions.

Exhibit 10 Canadian commodity pathways in SBTi FLAG



RMI Graphic. Source: SBTi

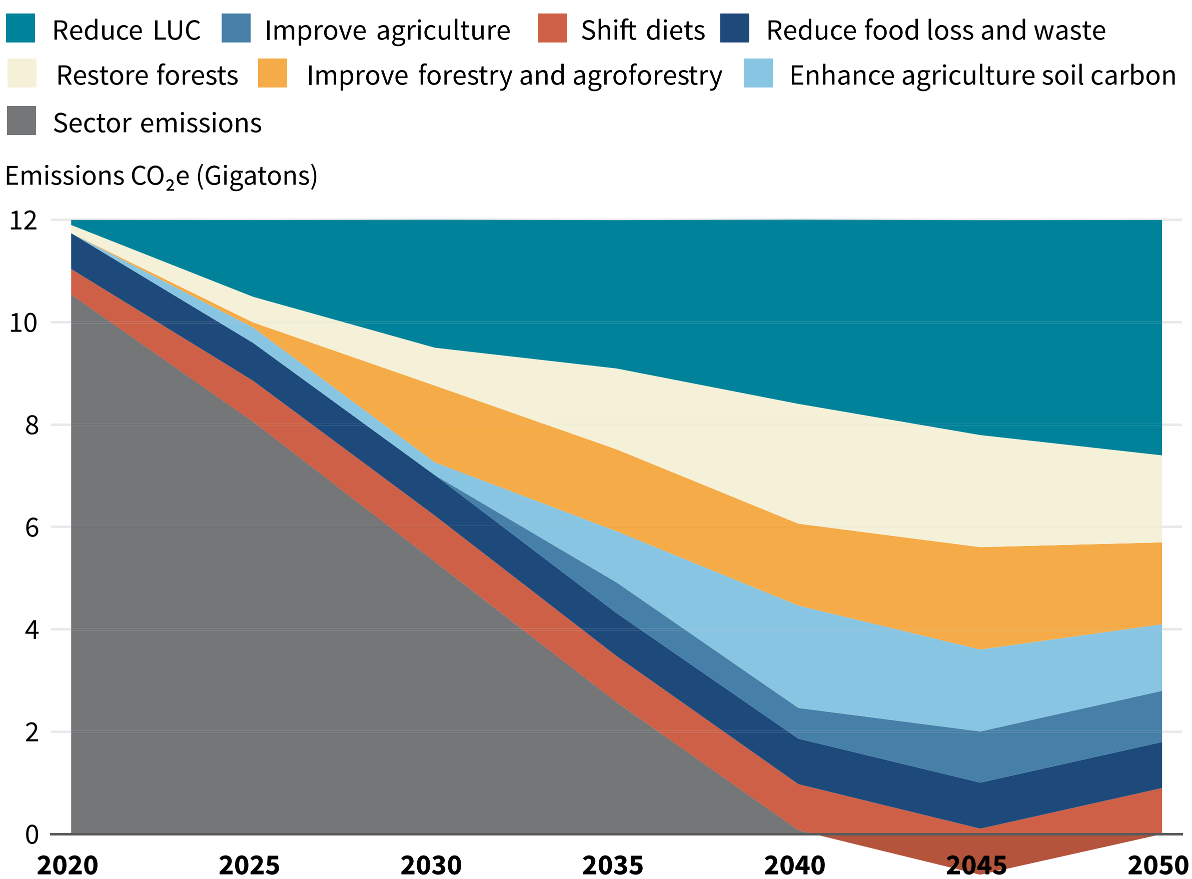
Relevance and Use Case for Agriculture

For agriculture, IMAGE can project future crop and livestock production volumes, as well as the emissions from the agriculture sector. Furthermore, the model can do so with regional granularity, outputting information for 26 different regions and countries, including Canada. In addition, due to the work conducted by the PBL Netherlands team, emissions intensity pathways for the IMAGE commodities have already been generated. However, because IMAGE is a global IAM, a certain degree of nuance is lost because it cannot model every region with complete accuracy, in contrast to a more bottom-up model that uses provincial and national data and policies to construct a scenario.

“Contribution of the Land Sector to a 1.5°C World,” by Roe et al. and SBTi FLAG

The other roadmap used by the SBTi FLAG sectoral pathway has been developed from the paper “Contribution of the Land Sector to a 1.5°C World,” by Roe et al.[42] This paper assembled relevant 1.5°C scenarios from the SSP and Integrated Assessment Modeling Consortium databases as well as relevant bottom-up peer-reviewed studies to craft a decarbonization roadmap for the agriculture and land use sectors. SBTi used this roadmap for the sectoral approach because it is best suited to companies that have diversified exposure across multiple subsectors and geographies, and although the focus in this paper is on specific commodities and the geography of Canada, it is still useful to analyze this roadmap because it is one of the few that have defined mitigation levers, shown in Exhibit 11.

Exhibit 11 Roe et al. sectoral pathway



RMI Graphic. Source: SBTi

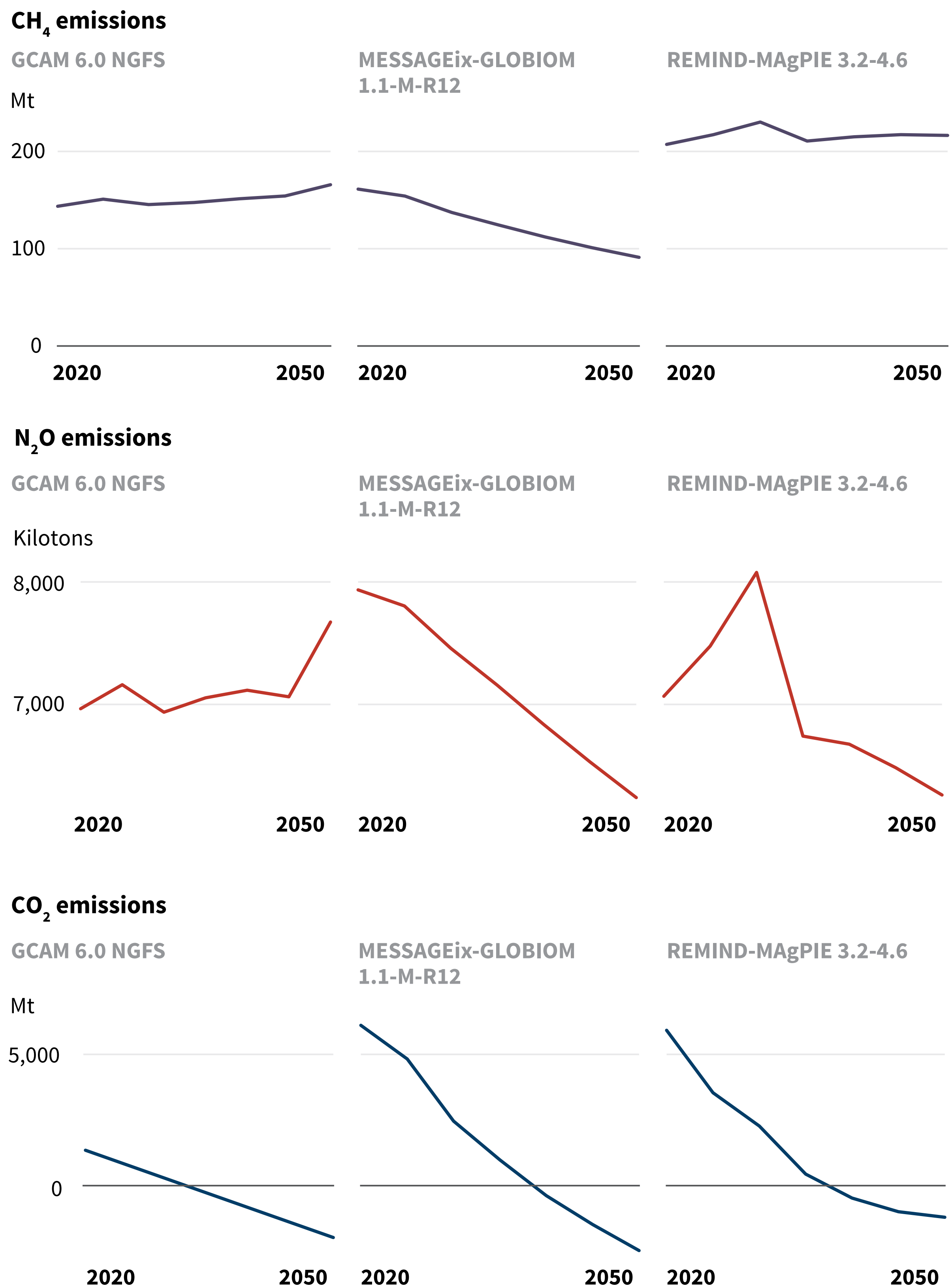
Network for Greening the Financial System Net Zero 2050

The Network for Greening the Financial System (NGFS) is a coalition of central banks and financial supervisors with the goal of contributing to the development of climate-related risk management in the financial sector, as well as mobilizing mainstream finance to support the transition toward a sustainable economy.

As part of this effort, NGFS designed six scenarios to cover a broad range of physical and transition risks so that users can explore possible futures, as well as understand the course of action that leads to each. One of those scenarios is the Net Zero by 2050 scenario. This scenario is one that projects global temperature rise of no more than 1.5°C and is characterized by stringent regulation as well as technological innovation. The six NGFS scenarios have been generated by three different IAMs, namely Global Change Analysis Model (GCAM), Model for Energy Supply Strategy Alternatives and their General Environmental Impact–Global Biosphere Management Model (MESSAGEix-GLOBIOM), and REgional Model of Investment and Development–Model of Agricultural Production and its Impact on the Environment (REMIND-MAgPIE).

The three models share a similar structure. Like IMAGE they combine macroeconomic, agriculture and land use, energy, water, and climate systems into a common numerical framework that enables the analysis of the complex interaction between these components. However, due to variations in model structure, each IAM produces different results, as can be seen in Exhibit 12.[43] The way each IAM calculates the emissions from each agricultural activity varies; this detail can be found in *Appendix D*.

Exhibit 12 NGFS IAMs, emissions from agriculture, forestry, and other land use



RMI Graphic. Source: NGFS

Relevance and Use Case for Agriculture

The NGFS Net Zero 2050 scenario utilizes three robust and well-used IAMs to produce information regarding emissions from the agriculture, forestry, and other land use (AFOLOU) sector. However, an existing dataset of emissions intensity projections per commodity per region is not available yet from NGFS. Second, using an AFOLOU roadmap for benchmarking an agriculture lending book with no significant amount of forestry lending could lead to a misalignment of emissions scope. Additionally, only one IAM (GCAM) models Canada specifically in the NGFS scenarios.

One Earth Climate Model

Commissioned by the Net-Zero Asset Owner Alliance and the European Climate Foundation, the One Earth Climate Model (OECM) is a roadmap for limiting global average temperature rise to 1.5°C. This research, titled *Achieving the Paris Climate Agreement Goals* and released in 2019, was supported by the nonprofit organization One Earth, which worked with scientists at the University of Technology Sydney, the German Aerospace Center, and the University of Melbourne's Climate and Energy College.[44]

The OECM projects both energy- and non-energy-related emissions from agriculture. This includes CO_2 emissions associated with LUC, CH_4 emissions arising from the enteric fermentation of livestock, N_2O emissions from crop residue, organic and inorganic fertilizers, and manure management. Projections of the future energy demand for the agriculture and food processing sector are based on GDP development projections, and GDP projections are based on the World Bank and International Energy Agency data.

Non-energy-related carbon emissions are calculated with the Generalized Equal Quantile Walk method, the land-based sequestration design method, and the carbon cycle and climate Model for the Assessment of Greenhouse Gas Induced Climate Change. OECM has a global pathway, but also models for G20 nations (Canada included) and the 27 nations in the European Union.

Relevance and Use Case for Agriculture

The OECM roadmap for agriculture, while being robust in encompassing the three main GHG emissions from agriculture, is less readily applicable as a roadmap for target setting. Although OECM has high regional granularity, it unfortunately does not model specific commodities, which would make it more suitable for application.

6.3. Subsector Roadmaps Specific to Canadian Agriculture

Dairy Farming Forward to 2050: Dairy Farmers of Canada's Net-Zero Strategy

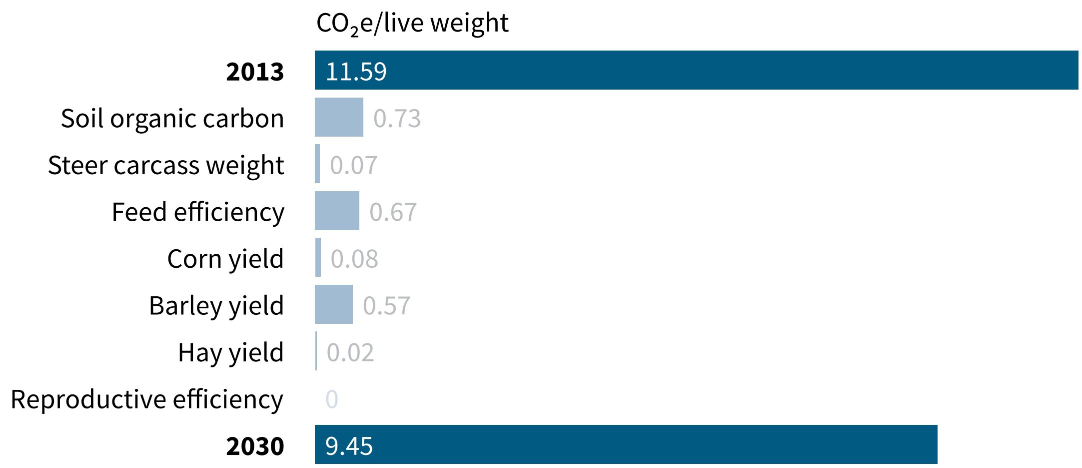
In February 2022, the Dairy Farmers of Canada (DFC) announced a decarbonization roadmap with the goal of reaching net-zero GHG emissions from farm-level dairy production by the year 2050. The subsector reaches its goal via a combination of emissions reductions and emissions removals. Approximately a year later, DFC announced its *Net Zero by 2050 Best Management Practices Guide to Mitigate Emissions on Dairy Farms*, which aims to provide dairy farmers with a list of actions to reduce their carbon emissions.[45] This includes improved livestock management, feed production, manure management, energy, and land management techniques. This guide also states the percentage of Canadian dairy farms currently using each optimal management practice and sets percentage goals for 2030 and 2050. As an example, 6% of Canadian dairy farms in 2022 were producing solar energy, but the target for 2030 (and 2050) is 8%.

Canadian Beef Advisors — Industry Goals to 2030

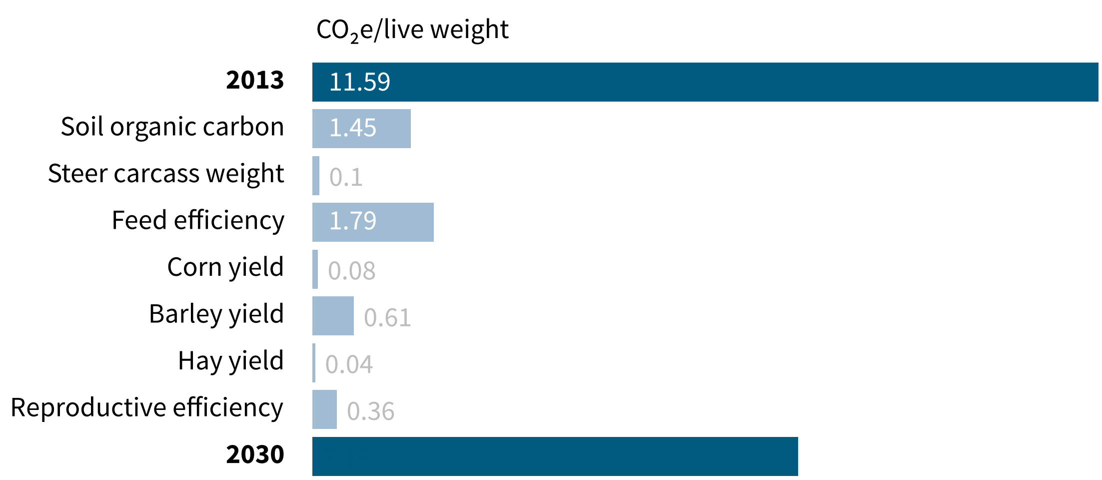
Canadian Beef Advisors is a group of seven Canadian beef organizations responsible for policy, marketing, research, and sustainability in the Canadian beef industry. In September 2020, Canadian Beef Advisors announced a series of economic and sustainability goals for 2030, including reducing primary production GHG emissions intensity by 33% by 2030, from an 11.59 kg CO_2e/live weight baseline in 2013. This baseline was obtained via an LCA conducted by Canadian Roundtable for Sustainable Beef (CRSB), a member of Canadian Beef Advisors.[46] This target reduction is based on the premise that there will be a major breakthrough in technology that allows for this reduction. There is also a scenario that targets a less ambitious reduction based on historical trends. To reach this goal, Canadian Beef Advisors is looking to increase soil organic carbon, increase steer carcass weight, improve feed yields, and improve reproductive efficiency, as can be seen in Exhibit 13. In 2023, CRSB released the results of a 2021 LCA, which showed that the kg CO_2e/live weight had fallen to 10.4, an 11% reduction.

Exhibit 13 **Canadian Beef Advisors historical trends and major breakthrough scenarios including levers**

Historical trends scenario



Major breakthrough scenario



RMI Graphic. Source: Canadian Beef Advisors

Exhibit 14 outlines whether each of the several scenarios includes agricultural commodity pathways, has regional coverage and is 1.5° aligned.

Exhibit 14 Scenario summary

Scenario	Agricultural commodity pathways	Regional coverage	1.5° temperature alignment
SBTi FLAG Commodity pathways	9	26 countries and regions (including Canada)	Yes
SBTi FLAG Sectoral pathway	N/A	Global	Yes
NGFS Net Zero 2050	N/A	GCAM - 38 (including Canada) MESSAGix-GLOBIOM - 18 REMIND-MAgPIE - 18	Yes
OECM	N/A	22 countries and regions (including Canada)	Yes
DFC Net Zero Strategy	1 (Dairy)	Canada	Unclear (but net zero)
CBA Industry Goals to 2030	1 (Beef)	Canada	Unclear

RMI Graphic. Source: SBTi, NGFS, OECM, DFC, CBA

Key Takeaways

A major opportunity in target setting for agriculture is the variety of roadmaps available. However, challenges persist in the selection of the most suitable. If it is a priority to have one IAM satisfy the needs of a variety of subsectors and regions/nations, then the pool narrows. IMAGE, GCAM, MESSAGEix-GLOBIOM, and REMIND-MAgPIE are all detailed models that could serve as a roadmap for financial institutions. However, none innately produce benchmark emissions intensity factors of commodities for a region or nation. Thus far, the work done by PBL on IMAGE data to produce the benchmark emissions factors used in SBTi FLAG is the only example of this kind of dataset. This could be replicated using the other IAMs, but this would require extra effort and research time. Subsector roadmaps are also an option, but this would require banks to have multiple roadmaps for different subsectors and regions, which may lead to a lack of harmonization within reporting.

7. Data

7.1. Financed Emissions and Other Metrics

Emissions attributed to financing activities are known as financed emissions. As defined by the Partnership for Carbon Accounting Financials (PCAF) initiative, the financed emissions from business loans and unlisted equity are calculated by multiplying an attribution factor by the emissions of the borrower, shown in the equation below:

$$\text{Financial emissions} = \sum_{c} \text{Attribution factor}_c \times \text{Company emissions}_c$$

c = Borrower or investee company

The attribution factor is defined as the proportional share of a given company. For private companies, this is the ratio between the outstanding amount to total equity and debt, and for listed companies it is the ratio between outstanding amount to enterprise value including cash (EVIC).

For business loans and equity investments to/in private companies:

$$\text{Financial emissions} = \sum_{c} \frac{\text{Outstanding amount}_c}{\text{Total equity and debt}_c} \times \text{Company emissions}_c$$

For business loans to listed companies:

$$\text{Financial emissions} = \sum_{c} \frac{\text{Outstanding amount}_c}{\text{EVIC}_c} \times \text{Company emissions}_c$$

For company emissions, PCAF identifies three different options:

1. Reported emissions: Either verified or unverified emissions are collected from the borrower or investee company directly. An advantage of directly reported emissions is that they are unique to the client, and thus represent the highest quality of data because differences in management practice can be quantified. However, it is by far the most laborious and time-consuming form of emissions reporting.

2. Physical activity–based emissions: Emissions are estimated by the reporting financial institution based on primary physical activity data collected from the borrower or investee. The production figure is then multiplied by an emissions factor expressed per physical activity, obtained from a credible source. An advantage of physical activity–based metrics is that they are more accurate than economic activity metrics, but do not require the same laborious emissions measurement as reported emissions. However, they do not represent differences in individual management practices, which is possible with reported emissions.

3. Economic activity–based emissions: Emissions are estimated by the reporting financial institution based on economic activity data collected from the borrower or investee company. The production figure is then multiplied by an emissions factor expressed per physical activity, obtained from a credible source. The economic figure is then multiplied by an emissions factor expressed per economic activity, obtained from an official statistical data sources or acknowledged environmentally extended input-output (EEIO) tables that provide region- or sector-specific average emissions factors. An advantage of economic activity–based metrics is that the data required is likely the easiest to obtain. However, it is less accurate than the other methods because it can be distorted by foreign exchange (if EEIO tables output information that is in a different currency to the user) and inflation.

PCAF also provides data quality scores for each of the above options that can be used to calculate the financed emissions for business loans and unlisted equity. These scores can be seen in Exhibit 15. Score 1 represents the highest quality data score, and 5 represents the lowest quality data score.

Exhibit 15 **Data quality score table for business loans and unlisted equity**

Options to estimate the financed emissions	When to use each option	Data quality
Option 1a: Reported emissions	Outstanding amount in the company and total company equity plus debt are known. Verified emissions of the company are available.	Score 1
Option 1b: Reported emissions	Outstanding amount in the company and total company equity plus debt are known. Unverified emissions calculated by the company are available.	Score 2
Option 2a: Physical activity- based emissions	Outstanding amount in the company and total company equity plus debt are known. Reported company emissions are not known. Emissions are calculated using primary physical activity data for the company's energy consumption and emission factors specific to that primary data. Relevant process emissions are added.	Score 2
Option 2b: Physical activity- based emissions	Outstanding amount in the company and total company equity plus debt are known. Reported company emissions are not known. Emissions are calculated using primary physical activity data for the company's production and emission factors specific to that primary data.	Score 3
Option 3a: Economic activity- based emissions	Outstanding amount in the company, total company equity plus debt, and the company's revenue are known. Emission factors for the sector per unit of revenue are known (e.g., tCO_2e per euro or dollar of revenue earned in a sector).	Score 4
Option 3b: Economic activity- based emissions	Outstanding amount in the company is known. Emission factors for the sector per unit of asset (e.g., tCO_2e per euro or dollar of asset in a sector) are known.	Score 5
Option 3c: Economic activity- based emissions	Outstanding amount in the company is known. Emission factors for the sector per unit of revenue (e.g., tCO_2e per euro or dollar of revenue earned in a sector) and asset turnover ratios for the sector are known.	Score 5

RMI Graphic. Source: PCAF

7.2. Current Challenges

Data (or the lack thereof) is arguably one of the greatest challenges faced in baselining emissions and setting targets for agriculture lending books. This issue arises primarily due to four factors:

- Diverse client base: Agriculture lending portfolios typically comprise a small number of large clients with whom direct engagement to obtain emissions and production data may be feasible. However, these portfolios also often include thousands of smaller clients, with whom direct engagement is impractical.

- Regional specificity: The emissions profile of a commodity grown in one region is often, for a variety of reasons, different from the same commodity grown in another. This can be true even in one country, especially a large one like Canada, which can have significant differences between provinces in terms of geography and industry. Obtaining data that reflects these differences is a significant challenge in baselining emissions.

- Complex emissions sources: Emissions sources in the agricultural sector are highly complex, arguably more so than other sectors. This complexity leads to significant uncertainty in measurements, making the acquisition of high-quality, granular, client data a substantial challenge.

- Lack of measurement tools and the cost of measurement: The risk–reward balance of adopting emissions reduction activities is often unclear to farmers, and is further complicated by the fact that the tools available for measuring client emissions in agriculture are not as developed or ubiquitous as those in other sectors, making accurate data collection and analysis even more challenging. The cost of measurement is another challenge. An example of this includes soil testing, which is relatively expensive, especially because soil conditions vary within fields and farms, requiring significant testing for reliable results for any area.

7.3. Calculating a Portfolio Alignment Score

To apply the SBTi methodology for obtaining a portfolio alignment score, emissions data and production data (or intensity data) is essential. This data is required for the non-LUC module, the LUC module, and the removals module and must be available for the base year and assessment year.

Options for Generating an Emissions Intensity Baseline

Fortunately, there are several options available for banks to obtain the necessary data. Below are three feasible methods:

1. **Direct communication with clients.** Banks engage with the largest clients in a portfolio to calculate their carbon footprint using environmental assessment tools such as Holos.

2. **Geographic-based proxies.** Banks utilize LCAs and peer-reviewed papers to generate emissions factors based on geographic regions, such as provinces. They can also leverage novel tools that generate emissions factors using spatial data.

3. **Database emissions factors.** Banks use emissions factors from databases such as FAOSTAT or EXIOBASE.

Holos

The Holos tool is a software application that estimates GHG emissions and changes in soil carbon in Canadian farming systems. Users build their model farm using available cropping, livestock, and machinery components, and the tool estimates the emissions caused by that farm. Although this tool allows for the quantification of differences in management practice, using it to generate emissions for each client would be highly time-consuming. Therefore, banks should prioritize their largest clients in each subsector for this method.

Geographic-Based Proxies

For clients that are too small for direct engagement, banks can leverage emissions factors generated by LCAs, which are often regional and allow differentiation based on postal codes. Similarly, peer-reviewed papers provide commodity emissions factors, although some of these are outdated (for example, many of the emission factors in “The Carbon Footprints of Agricultural Products in Canada” are from 2011[47]).

If the commodities produced by clients are unknown, banks can use a combination of maps generated from the Canada Annual Crop Inventory and LCA or peer-reviewed emissions factors to calculate a weighted average emissions factor per region. Additionally, emissions factors from LCAs have the potential to be NZBA compliant. NZBA target-setting guidelines state that “no specific methodology is required to be used” to calculate absolute emissions targets or sector-specific emissions intensity targets, but that banks should use “credible sources.”[48] However, LCAs track changes made by the industry, rather than individual clients. Although some LCAs have regional granularity (sometimes to the provincial level), it will be difficult to track progress against a decarbonization target without farm-specific data. Also, LCAs in Canadian agriculture have been done on (approximately) a five-year cadence, sometimes longer; thus, tracking progress toward targets from a data availability perspective is also difficult.

Database Emissions Factors

Another option is to use preexisting emissions factors from FAOSTAT or EXIOBASE. FAOSTAT provides emissions intensity data from as recent as 2021, offering flexibility in baseline start date. Financial institutions have demonstrated the feasibility of using EXIOBASE factors in baselining financed emissions figures. However, both databases have significant limitations, such as a lack of provincial or regional granularity. Additionally, EEIO models such as EXIOBASE can be imprecise for regions and subsectors with relatively small trade volumes. Moreover, EXIOBASE reports emissions per euro, necessitating additional steps — and added uncertainty — to convert the data into Canadian dollars and then into emissions intensity based on a physical parameter, such as kilograms of product.

7.4 Example of Calculating a Portfolio Alignment Score

Exhibit 16 shows an example of how a portfolio alignment score can be calculated for beef using LCA emissions factors. These emissions factors were obtained from the 2013 and 2021 CRSB LCA of Canadian beef, obtaining the 2019 figure via linear interpolation.

Exhibit 16 **Sample portfolio using LCA emissions factors**

Company	Subsector	Region	Unit	Non-LUC 2019 emissions intensity	Non-LUC 2019 benchmark	Non-LUC 2021 emissions intensity	Non-LUC 2021 benchmark	Non-LUC 2021 SDA benchmark
A	Beef	West Canada	(ton CO_2/ton fresh weight)	18.42	21.84	17.50	21.11	17.99
B	Beef	West Canada	(ton CO_2/ton fresh weight)	18.42	21.84	17.50	21.11	17.99
C	Beef	East Canada	(ton CO_2/ton fresh weight)	17.39	21.84	16.30	21.11	17.05

Company	Exposure ($M)	Weight	2021 Non-LUC company emissions intensity	Non-LUC 2021 benchmark	2021 Non-LUC SDA benchmark
A	10	12.5%	17.50	21	17.99
B	50	62.5%	17.50	21	17.99
C	20	25.0%	16.30	21	17.05

RMI Graphic. Source: CRSB

Then the portfolio emissions intensity can be calculated by adding the products of the financial exposure and individual company emissions intensities. This is shown in the equation below.

$$\text{Portfolio emissions intensity (PEI)} = \sum_{i=1}^{N} w_i \text{CEI}_i$$

$$\text{PEI} = (12.5\%)(17.50) + (62.5\%)(17.50) \ldots = 17.2(\text{tons CO}_2/\text{ton fresh weight})$$

The same math can be done to calculate the portfolio emissions intensity sectoral benchmark and the portfolio emissions intensity SDA benchmark.

$$\text{Portfolio emissions intensity BM}(\text{PEI}_{\text{BM}}) = \sum_{i=1}^{N} w_i \text{BMEI}_i$$

$$\text{PEI}_{\text{BM}} = (10.53\%)(21.11) + (52.63\%)(21\ldots) = 21.11\ (\text{tons CO}_2/\text{ton fresh weight})$$

$$\text{Portfolio emissions intensity SDA BM}(\text{PEI}_{\text{SDA}_{\text{BM}}}) = \sum_{i=1}^{N} w_i \text{SDA\_BMEI}_i$$

$$\text{PEI}_{\text{SDA}_{\text{BM}}} = (12.5\%)(17.99) + (62.5\%)(17.\ldots) = 17.76\ (\text{tons CO}_2/\text{ton fresh weight})$$

Now that the portfolio emissions intensity is calculated, as well as the emissions intensity of both benchmarks, it is possible to calculate the portfolio alignment score against both benchmarks. Both scores being negative indicates that this hypothetical portfolio is aligned. This can be seen below.

$$\text{SDA Portfolio alignment score (PAS)} = \frac{\text{PEI} - \text{PEI}_{\text{SDA}_{\text{BM}}}}{\text{PEI}_{\text{SDA}_{\text{BM}}}} * 100\%$$

$$= \frac{17.2 - 17.76}{17.76} * 100\% = \mathbf{-3.15\%}$$

$$\text{Portfolio alignment score (PAS)} = \frac{\text{PEI} - \text{PEI}_{\text{BM}}}{\text{PEI}_{\text{BM}}} * 100\%$$

$$= \frac{17.2 - 21.11}{21.11} * 100\% = \mathbf{-18.52\%}$$

7.5. Analysis of Data Options and Tools

Direct communication with clients

Advantages	Disadvantages
Highly accurate information	Time-consuming and requires a lot of resources and communication with clients
Granular to each respective client and reflects differences in management practice	

Geographic-based proxies

Advantages	Disadvantages
Bottom-up developed emissions factors that reflect differences in production often at the provincial level (some even sub-provincial)	Long cadence (~5 years) between LCAs
	Lack of boundary alignment in some cases
	Complex technical documentation

Database emission factors

Advantages	Disadvantages
PCAF approved	Economic emissions factors are not preferable to physical emission intensity
Proven viability	EXIOBASE and FAOSTAT lack provincial granularity

8. Opportunities and Challenges

Agriculture is a particularly challenging sector for target setting due to its inherent complexities. The sector encompasses a vast range of practices, from cattle management to wheat farming, each with distinct emissions profiles, necessitating different methodological approaches and benchmarking requirements. Additionally, the lack of granular, client-specific data, essential for accurately benchmarking emissions and comparing management practices, exacerbates this challenge. This issue is especially pronounced concerning client-specific LUC and emissions data. Moreover, there is a need to balance decarbonization efforts with production requirements because maintaining food security and economic livelihoods is of paramount importance. Additionally, there is a need to equitably distribute the decarbonization efforts across the agricultural value chain to ensure that undue burden is not laid at the feet of the Canadian farmer, especially because decarbonization levers are more readily available in areas such as food transport than enteric fermentation emissions mitigation.

Despite these challenges, particularly in the Canadian context, there are significant opportunities. The SBTi FLAG methodology, which has been adopted by other banks, provides a workable framework. Furthermore, a commodity-specific emissions intensity roadmap for Canada and the open-source farm emissions calculation tool Holos offer valuable resources.

Below are summary tables outlining the identified opportunities and challenges associated with each target-setting building block. It should be noted that this is not an exhaustive list.

Methodology

Opportunities	Challenges
Financial institutions such as Rabobank and Nordea have found success in target-setting using SBTi FLAG	Target-setting methodology options are limited.
	It is possible to use SBTi FLAG to calculate portfolio alignment for the non-LUC module using LCA emissions factors. However, significant data availability challenges persist in applying the methodology fully.
	SBTi FLAG will require big lift in terms of client data to be gathered at a granular enough level. Clients may not have emissions data, and while there are tools available implementation will require significant effort.
	Applying SBTi FLAG is complicated, and will require training for banks and clients.
	SBTi FLAG's intended user is not financial institutions, making application more difficult.

Roadmaps

Opportunities	Challenges
There are several relevant roadmaps in agriculture.	In agriculture, there is a lack of a default scenario.
SBTi FLAG commodity pathways found to be most suitable as it has Canadian-relevant commodity pathways. Furthermore, the SDA has been shown to be usable for determining portfolio alignment.	The lack of transparency around mitigation lever contribution in multiple roadmaps makes it difficult to assess legitimacy.
	There is a significant reliance on carbon removals in many roadmaps.
	Further discussion is needed with SBTi on 1.5°C alignment, as well as the possible addition of a canola pathway.

Data

Opportunities	Challenges
A Canadian-specific tool (Holos) that can be used to measure client emissions directly and incorporates differences in management practice.	Lending books can consist of combination of large clients and many small clients. Direct communication with large clients is time and resource consuming.
Wide availability of LCA emissions factors for various agriculture commodities.	Emission data sources may not align with emissions boundary used in methodologies.
Database emissions factors from FAOSTAT and EXIOBASE.	Emissions data sources are not as ubiquitous as other sectors, especially for removals and land use change.

9. Conclusion and Potential Future Work

The path forward to target setting in agriculture is not without its challenges. However, as noted in this paper, there are options available, albeit imperfect ones. To fully realize these opportunities, further work must be done. Canadian financial institutions should continue their efforts to create more transparency in the emissions profiles of their agricultural lending portfolios to ensure long-term sustainability and resilience in the face of climate change. Canadian financial institutions can help foster innovation, drive the adoption of sustainable practices among borrowers, and contribute to the overall health of the Canadian economy.

With just six growing seasons left to achieve the 2030 climate goals that Canada, and the world, have set, it is time for financial institutions to work together to address these target-setting and data measurement challenges. By aligning with existing industry metrics and each other, lenders can enable and support transition processes for producers, accelerate meaningful emissions reductions, and foster a thriving agricultural sector.

Farm Credit Canada, FCC, a Canadian Crown Corporation providing financing and other support to more than 100,000 agriculture and agri-food customers, is well positioned to lead this collaborative effort. Work is already underway to develop a viable collaboration model to share information, engage stakeholders across the entire agriculture and food value chain, and develop tools for standardizing data, setting targets, and delivering sustainable financing. The goal is for financial institutions to support a resilient, climate-smart, nature-positive food system while improving economic viability and global food security.

Appendix A. Glossary

Endogenous variables. Variables determined within the model run.

Exogenous variables. Variables external to the model, typically supplied as inputs or assumptions.

Farm gate. A term used to define the boundary of the farm, often to describe emissions originating from farm or ranching activity, i.e., farm gate emissions. Often used interchangeably with the term “on-farm.”

General equilibrium model. A modeling approach that considers the interactions and interdependencies among the various sectors of a global economy. In the context of a climate–economy integrated assessment model, general equilibrium models provide analysis of the interaction between sectors such as energy, agriculture, transportation, and the environment. The more developed representation of the global economy–environment relationship results in a model that is more complex, and inevitably results in fewer targeted assumptions in comparison to a partial equilibrium model.

Intertemporal. A modeling approach that outputs results with perfect foresight. This means that models of this nature allocate resources and make decisions with the knowledge of the impact those decisions have over the entire time period.

Land use, land use change, and forestry (LULUCF). A greenhouse gas inventory sector that covers the impact of human activity on carbon sinks, such as deforestation.

Partial equilibrium model. A modeling approach that assumes certain factors are isolated from the rest of the economy. In the context of a climate–economy integrated assessment model, partial equilibrium models provide analysis of the interaction between environmental impacts and a particular sector of the economy.

Pre-/postproduction emissions. Terms used to describe a variety of emissions sources that occur before and after farming or ranching activity. For instance, one preproduction emissions source is fertilizer manufacturing, whereas one example of a postproduction emissions source is food transport.

Recursive dynamic. A modeling approach that outputs results one period at a time, and then uses the resulting outputs to inform the next set of results. A model of this nature does not know the future when creating an output.

Appendix B. Atmospheric Emissions Calculated in IMAGE, by Source and Method Applied

Source	Activity	CO_2	CH_4	N_2O	SO_2	NOX	CO	Nonmethane volatile organic compound	F-gases	Black carbon	Organic carbon	NH_3
Enteric fermentation, cattle	Feed type and amount		GM									
Animal waste, all animal categories	Number of animals		GEF	GEF		GEF						GEF
Landfills	Population		GEF									
Deforestation	Carbon burnt	GM	GEF	GEF	GEF	GEF	GEF	GEF		GEF	GEF	GEF
Agricultural waste burning	Carbon burnt	GM	GEF	GEF	GEF	GEF	GEF	GEF		GEF	GEF	GEF
Traditional biomass burning	Carbon burnt	GM	GEF	GEF	GEF	GEF	GEF	GEF		GEF	GEF	GEF
Savanna burning	Carbon burnt	GM	GEF	GEF	GEF	GEF	GEF	GEF		GEF	GEF	GEF
Domestic sewage treatment	Population, GDP		GEF	GEF								
Wetland rice fields	Area wetland rice		GEF									
Crops	N fertilizer and manure input, crop type			GM		GM						GM
Managed grassland	N fertilizer and manure input			GM		GM						GM
Indirect emissions	N crops, fertilizer, and manure input			GM								
Land use change	Clearing forest areas			GM								

Note: EF = regional emissions factor applied to the specified activity level; GEF = grid-specific emissions calculated from gridded activity level and (regional) emissions factor; and GM = gridded, model-based emissions (statistical or process-based model).

Appendix C. Overview of Mitigation Options in GCAM, MESSAGEix-GLOBIOM, and REMIND-MAgPIE

	GCAM 6.0	MESSAGEix-GLOBIOM 1.1	REMIND-MAgPIE 3.2-4.6
Number of demand-side mitigation options	14	16	15
Examples of demand-side measures	Energy efficiency improvements; electrification of buildings, industry, and transport sectors; CCS in industrial process applications	Energy efficiency improvements; electrification of buildings, industry, and transport sectors; CCS in industrial process applications	Energy efficiency improvements; electrification of buildings, industry, and transport sectors; CCS in industrial process applications
Number of supply-side mitigation options	18	20	17
Examples of supply-side measures	Solar PV, wind, nuclear, CCS, hydrogen	Solar PV, wind, nuclear, CCS, hydrogen	Solar PV, wind, nuclear, CCS, hydrogen
Number of AFOLU options	8	8	7
Examples of AFOLU measures	Reduced deforestation/forest protection/avoided forest conversion, forest management, CH_4 reductions in rice paddies, nitrogen pollution reductions	Reduced deforestation/forest protection/avoided forest conversion, forest management, CH_4 reductions in rice paddies, nitrogen pollution reductions, conservation agriculture	Reduced deforestation/forest protection/avoided forest conversion, CH_4 reductions in rice paddies, nitrogen pollution reductions

Note: CCS = carbon capture and sequestration; PV = photovoltaic.

Appendix D. Overview of Key Model Characteristics

Name	GCAM	MESSAGEix-GLOBIOM	REMIND-MAgPIE
Solution concept	Partial equilibrium	General equilibrium	REMIND: General equilibrium MAgPIE: Partial equilibrium model of the agriculture sector
Anticipation	Recursive dynamic	Intertemporal	REMIND: Intertemporal MAgPIE: Recursive dynamic
Solution method	Cost minimization	Welfare maximization	REMIND: Welfare maximization MAgPIE: Cost minimization
Temporal dimension	Base year: 2015 Time steps: 5 years Horizon: 2100	Base year: 1990 Time steps: 5 (2005–60) and 10 years (2060–2100) Horizon: 2100	Base year: 2005 Time steps: 5 (2005–60) and 10 years (2060–2100) Horizon: 2100
Technological change	Exogenous	Exogenous	Endogenous for solar, wind, and batteries
Technology dimension	58 conversion technologies	64 conversion technologies	50 conversion technologies
Demand sectors and subsector detail	Buildings (residential and commercial buildings with heating, cooling, and other services), industry (cement, chemicals, fertilizer, steel, aluminum, construction, mining energy use, agricultural energy use, other), transport (passenger and freight with various modes and technologies)	Buildings, industry (cement, chemicals, steel, nonferrous metals, other), transport	Buildings, industry (cement, chemicals, steel, other), transport (various modes and technologies)

Appendix E. Worked examples with Market Share Parameter

To test this methodology and to see the intricate parts at play, below are some worked examples. First, the target emissions intensity is calculated (for both LUC and non-LUC) for a Canadian beef producer.

User inputs:

CP_b = Production = 10,000

TE_B = Total baseline emissions = 200,000

Region = Canada

Commodity = Beef

2020 $\text{Scenario}_{\text{non–LUC-intensity}} = 21.59$

2020 $\text{Scenario}_{\text{LUC-intensity}} = 1.34$

$$\boldsymbol{E}_{\textbf{non–LUC}} = 200{,}000 * \frac{21.59 * 10{,}000}{(21.59 * 10{,}000) + (1.34 * 10{,}000)}$$

$$\boldsymbol{E}_{\textbf{non–LUC}} = \mathbf{188{,}313}$$

$$\boldsymbol{E}_{\textbf{LUC}} = 200{,}000 * \frac{1.34 * 10{,}000}{(21.59 * 10{,}000) + (1.34 * 10{,}000)}$$

$$\boldsymbol{E}_{\textbf{LUC}} = \mathbf{11{,}687}$$

$$d_{\text{non–LUC}} = CI_{b(\text{non–LUC})} - SI_{2050(\text{non–LUC})}$$

$$d_{\text{non–LUC}} = \frac{E_{\text{non–LUC}}}{P_b} - SI_{2050(\text{non–LUC})}$$

$$d_{\text{non–LUC}} = \frac{188{,}313}{10{,}000} - 13.34$$

$$\boldsymbol{d}_{\textbf{non–LUC}} = \mathbf{5.49}$$

$$d_{\text{LUC}} = CI_{b(\text{LUC})} - SI_{2050(\text{LUC})}$$

$$d_{\text{LUC}} = \frac{E_{\text{LUC}}}{P_b} - SI_{2050(\text{LUC})}$$

$$d_{\text{LUC}} = \frac{11{,}687}{10{,}000} - 0$$

$$\boldsymbol{d_{\text{LUC}} = 1.17}$$

$$m = \frac{\text{Market share in base year}}{\text{Market share in target year}} = \frac{\left(\frac{CP_b}{SP_b}\right)}{\left(\frac{CP_y}{SP_y}\right)}$$

m = Market share parameter

CP_b = Production activity of the company in the base year

SP_b = Production activity of the sector in the base year

CP_y = Expected production activity of the company in target year y

SP_y = Expected production activity of the sector in target year y

SP_b = 1,724,298.60 tons

CP_y = 10,000 tons

SP_y = 2,244,764.57 tons

$$m = \frac{\text{Market share in base year}}{\text{Market share in target year}} = \frac{\left(\frac{10{,}000}{1{,}724{,}298.6}\right)}{\left(\frac{10{,}000}{2{,}244{,}764.57}\right)}$$

$$m = 1.302$$

$$p_y = \frac{SI_y - SI_{2050}}{SI_b - SI_{2050}}$$

p_y = Decarbonization index of the sector in target year
SI_y = Sector emissions intensity in target year y
SI_{2050} = Sector emissions intensity in 2050 as per roadmap
SI_b = Sector emissions intensity in base year

If the target year in this case is 2050, then $p_y = 0$.

$$CI_{y(\text{non-LUC})} = d_{(\text{non-LUC})} \times p_y \times m + SI_{2050\,(\text{non-LUC})}$$

$$CI_{y(\text{non-LUC})} = 5.49 \times 0 \times 1.302 + 13.34$$

$$CI_{y(\text{non-LUC})} = 13.34 \text{ tons } CO_2\text{e/ton fresh weight}$$

For target year LUC intensity, the following equation is used:

$$CI_{y(\text{LUC})} = d_{(\text{LUC})} \times p_y \times m + SI_{2050\,(\text{LUC})}$$

$$CI_{y(\text{LUC})} = 1.17 \times 0 \times 1.302 + 0$$

$$CI_{y(\text{LUC})} = 0 \text{ tons } CO_2\text{e/ton fresh weight}$$

Now the removals intensity throughout the pathway is calculated.

$$\text{Removals intensity} = \frac{\text{removals per hectare}}{\text{yield per hectare}} = \frac{\frac{\text{yearly removals}}{\text{hectare of cropping land}}}{\text{yield per hectare}}$$

For the starting year 2020, yearly removals are set at 0. For the starting point of removals intensity, the equation is simple:

$$\text{Removals intensity} = \frac{\text{Input total removals}}{\text{Production}}$$

Therefore, if starting at 0, the above equation becomes:

$$\text{Removals intensity} = \frac{0}{10{,}000}$$

$$\text{Removals intensity} = 0 \text{ tons } CO_2\text{e/ton fresh weight}$$

What about year 2 (2021)? After the starting year, the yearly removals are dictated by the roadmap data. The required amount of removals in 2021 for Canadian beef is 0.8486 gigatons CO_2e/year.

$$\text{Removals intensity} = \frac{\text{removals per hectare}}{\text{yield per hectare}} = \frac{\frac{\text{yearly removals}}{\text{hectare of cropping land}}}{\text{yield per hectare}} = \frac{\frac{0.8486 * 10^9}{3{,}269{,}000{,}000}}{0.2232}$$

$$\text{Removals intensity} = 1.16 \text{ tons } CO_2\text{e/ton fresh weight}$$

For completeness, one more iteration of this is calculated for year 3 (2022). The required amount of removals in 2021 for Canadian beef is 0.8641 gigatons CO_2e/year.

$$\text{Removals intensity} = \frac{\text{removals per hectare}}{\text{yield per hectare}} = \frac{\frac{\text{yearly removals}}{\text{hectare of cropping land}}}{\text{yield per hectare}} = \frac{\frac{0.8641 * 10^9}{3{,}269{,}000{,}000}}{0.2232}$$

$$\text{Removals intensity} = 1.18 \text{ tons } CO_2\text{e/ton fresh weight}$$

The graphical representation of this can be seen in Exhibit A2 **(page 59)**.

This process will now be repeated with high initial removals. Every other variable remains the same, but there are initial removals at 100,000 tons CO_2e. As before, the equation for the starting year is:

$$\text{Removals intensity} = \frac{\text{Input total removals}}{\text{Production}}$$

Which in this case is:

$$\text{Removals intensity} = \frac{100{,}000}{10{,}000}$$

$$\text{Removals intensity} = 10 \text{ tons } CO_2\text{e/ton fresh weight}$$

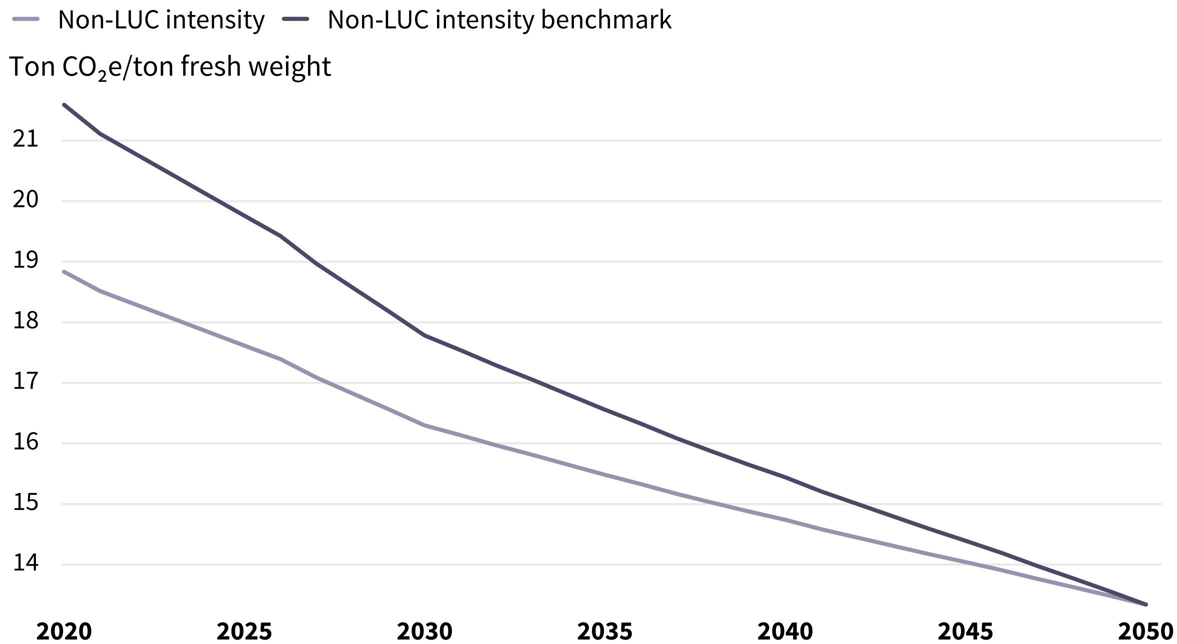
What about after the base year? Does the high starting point change the shape of the curve going forward? As stated above in the methodological notes, the answer is no.

$$\text{Removals intensity} = \frac{\text{removals per hectare}}{\text{yield per hectare}} = \frac{\frac{0.8486 * 10^9}{3{,}269{,}000{,}000}}{0.2232}$$

$$\text{Removals intensity} = 1.16 \text{ tons } CO_2\text{e/ton fresh weight}$$

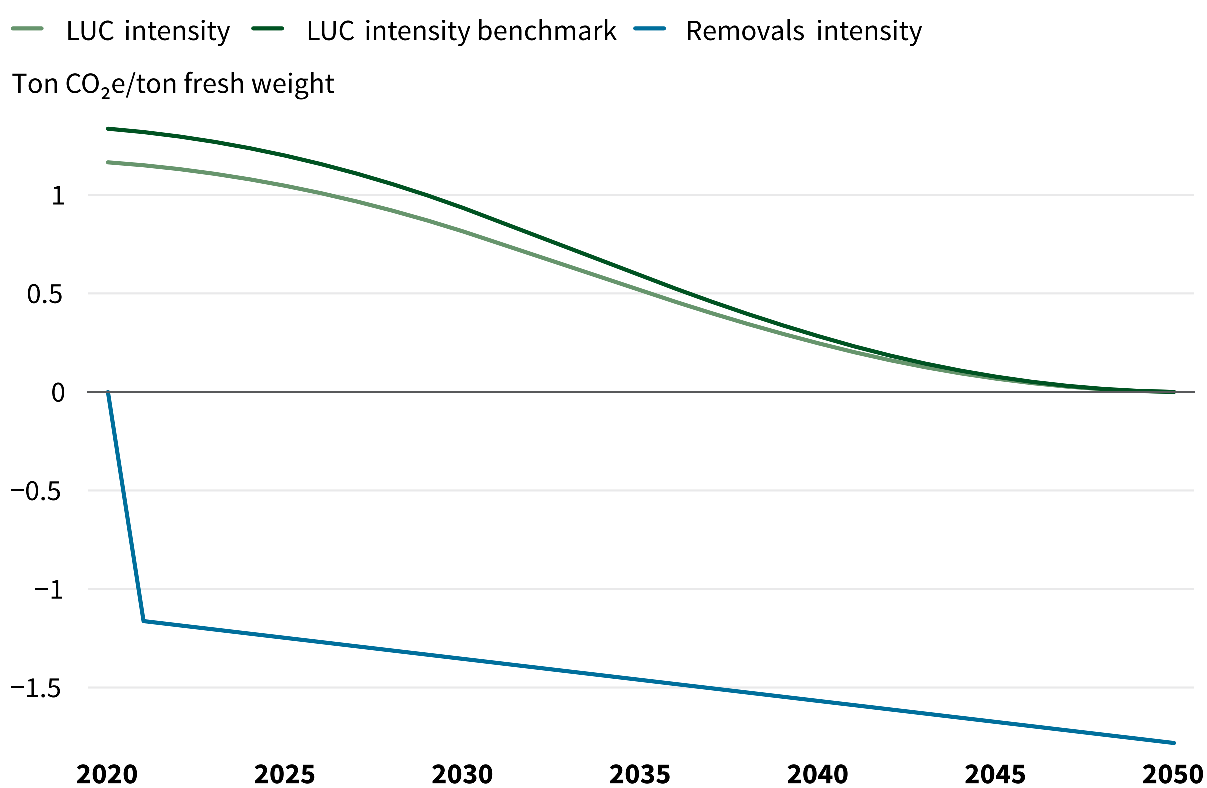
The graphical representation of this can be seen in Exhibit A3 **(page 60).**

Exhibit A1 Convergence approach for Canadian beef (non-LUC emissions intensity)



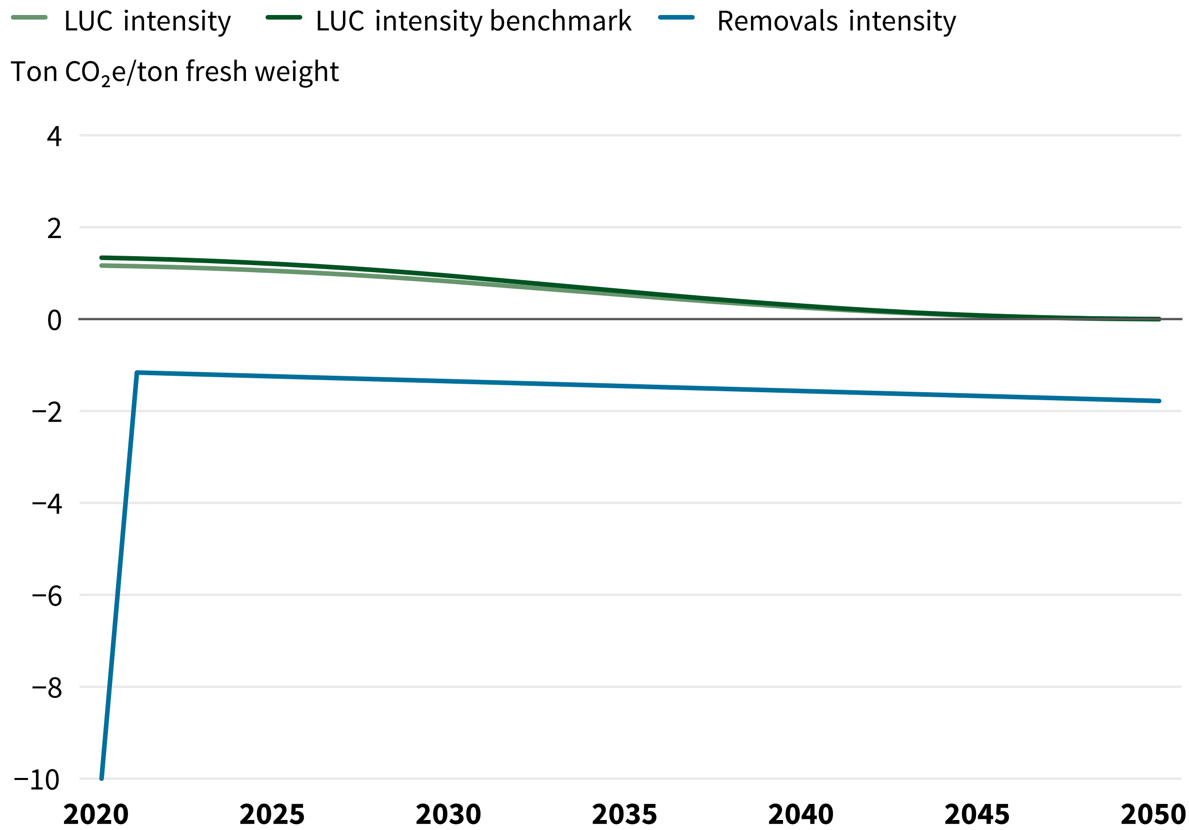
RMI Graphic. Source: SBTi FLAG

Exhibit A2 Convergence approach for Canadian beef (low removals)



RMI Graphic. Source: SBTi FLAG

Exhibit A3 Convergence approach for Canadian beef (high removals)



RMI Graphic. Source: SBTi FLAG

The next commodity to be considered is wheat. Canada remains the selected region with 10,000 tons of production. However, the starting emissions from this entity is 5,000 tons CO_2e because wheat production is significantly less carbon-intensive than beef production. As before:

$$E_{\text{non-LUC}} = 5{,}000 * \frac{0.4346 * 10{,}000}{(0.4346 * 10{,}000) + (0.1086 * 10{,}000)}$$

$$\mathbf{E_{\text{non-LUC}} = 4{,}000}$$

$$E_{\text{LUC}} = 5{,}000 * \frac{0.1086 * 10{,}000}{(0.4346 * 10{,}000) + (0.1086 * 10{,}000)}$$

$$\mathbf{E_{\text{LUC}} = 1{,}000}$$

$$d_{\text{non-LUC}} = CI_{b(\text{non-LUC})} - SI_{2050(\text{non-LUC})}$$

$$d_{\text{non-LUC}} = \frac{E_{\text{non-LUC}}}{P_b} - SI_{2050(\text{non-LUC})}$$

$$d_{\text{non-LUC}} = \frac{4{,}000}{10{,}000} - 0.28$$

$$\boldsymbol{d_{\text{non-LUC}} = 0.12}$$

$$d_{\text{LUC}} = CI_{b(\text{LUC})} - SI_{2050(\text{LUC})}$$

$$d_{\text{LUC}} = \frac{E_{\text{LUC}}}{P_b} - SI_{2050(\text{LUC})}$$

$$d_{\text{LUC}} = \frac{1{,}000}{10{,}000} - 0$$

$$\boldsymbol{d_{\text{LUC}} = 0.1}$$

$$m = \frac{\text{Market share in base year}}{\text{Market share in target year}} = \frac{\left(\frac{CP_b}{SP_b}\right)}{\left(\frac{CP_y}{SP_y}\right)}$$

m = Market share parameter
CP_b = Production activity of the company in the base year
SP_b = Production activity of the sector in the base year
CP_y = Expected production activity of the company in target year t
SP_y = Expected production activity of the sector in target year t

SP_b = 46,376,848.22 tons
CP_y = 10,000 tons
SP_y = 54,837,465.29 tons

$$m = \frac{\text{Market share in base year}}{\text{Market share in target year}} = \frac{\left(\frac{10{,}000}{46{,}376{,}848.22}\right)}{\left(\frac{10{,}000}{54{,}837{,}465.29}\right)}$$

$$m = 1.182$$

$$p_y = \frac{SI_y - SI_{2050}}{SI_b - SI_{2050}}$$

p_y = Decarbonization index of the sector in target year
SI_y = Sector emissions intensity in target year y
SI_{2050} = Sector emissions intensity in 2050 as per roadmap
SI_b = Sector emissions intensity in base year

If the target year in this case is 2050, then $p_y = 0$.

$$CI_{y(\text{non-LUC})} = d_{(\text{non-LUC})} \times p_y \times m + SI_{2050\ (\text{non-LUC})}$$

$$CI_{y(\text{non-LUC})} = 0.12 \times 0 \times 1.182 + 0.28$$

$$CI_{y(\text{non-LUC})} = 0.28 \text{ tons } CO_2\text{e/ton fresh weight}$$

For target year LUC intensity, the following equation is used:

$$CI_{y(\text{LUC})} = d_{(\text{LUC})} \times p_y \times m + SI_{2050\ (\text{LUC})}$$

$$CI_{y(\text{LUC})} = 0.1 \times 0 \times 1.182 + 0$$

$$CI_{y(\text{LUC})} = 0 \text{ tons } CO_2\text{e/ton fresh weight}$$

Now the removals intensity throughout the pathway is calculated.

$$\text{Removals intensity} = \frac{\text{removals per hectare}}{\text{yield per hectare}} = \frac{\frac{\text{yearly removals}}{\text{hectare of cropping land}}}{\text{yield per hectare}}$$

For the starting year 2020, yearly removals are set at 0. For the starting point of removals intensity, the equation is simple:

$$\text{Removals intensity} = \frac{\text{Input total removals}}{\text{Production}}$$

Therefore, if starting at 0, the above equation becomes:

$$\text{Removals intensity} = \frac{0}{10{,}000}$$

$$\text{Removals intensity} = 0 \text{ tons } CO_2\text{e/ton fresh weight}$$

What about year 2 (2021)? After the starting year, the yearly removals are dictated by the roadmap data. The required amount of removals in 2021 for Canadian wheat is 0.8486 gigatons CO_2e/year.

$$\text{Removals intensity} = \frac{\text{removals per hectare}}{\text{yield per hectare}} = \frac{\left(\frac{\text{yearly removals}}{\text{hectare of cropping land}}\right)}{\text{yield per hectare}} = \frac{\left(\frac{0.8486 * 10^9}{3{,}269{,}000{,}000}\right)}{3.32}$$

$$\text{Removals intensity} = 0.08 \text{ tons } CO_2\text{e/ton fresh weight}$$

The removals pathway follows a similar linear increase in removals as the previous examples. The difference here is the increase of yield per hectare (i.e., more tonnage of wheat is derived from 1 hectare than beef from the same 1 hectare), which reduces the removals intensity required.

1. The starting emissions intensity performance of the company in the baseline year is determined by how far it is from the 2050 sector intensity.

$$d = CI_b - SI_{2050}$$

d = Initial performance in base year relative to 2050 sector target
CI_b = Company emissions intensity in base year
SI_{2050} = Sector emissions intensity in 2050 as per roadmap

2. The market share parameter is determined. This adjusts for the growth of companies to prevent exceeding the sector carbon budget when using an intensity metric. It is used by SBTi but frequently ignored when the SDA is adopted by other methodologies due to the inherent uncertainties of projection company and sector production volumes.

$$m = \frac{\text{Market share in base year}}{\text{Market share in target year}} = \frac{\left(\frac{CP_b}{SP_b}\right)}{\left(\frac{CP_y}{SP_y}\right)}$$

m = Market share parameter
CP_b = Production activity of the company in the base year
SP_b = Production activity of the sector in the base year
CP_y = Expected production activity of the company in target year t
SP_y = Expected production activity of the sector in target year t

3. The decarbonization index determines how much progress a company should have made from the baseline to the 2050 intensity by the target year.

$$p_y = \frac{SI_y - SI_{2050}}{SI_b - SI_{2050}}$$

p_y = Decarbonization index of the sector in target year
SI_y = Sector emissions intensity in target year y
SI_{2050} = Sector emissions intensity in 2050 as per roadmap
SI_b = Sector emissions intensity in base year

4. All these parameters are combined into a company intensity for the target year. This company intensity can be determined for all years from the base year to 2050 to establish a company trajectory.

$$CI_y = d \times p_y \times m + SI_{2050}$$

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