

The Transition
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Canada's Opportunity Playbook:
Pathways to Strategic Decarbonization

AGRICULTURE AND AGRIFOOD



The agri-food sector is a significant source of GHG emissions in Canada and presents distinct challenges for decarbonization



11. Agriculture and Agrifood

Function of the Sector	Provides food, fiber, and fuel. Foundational for health and prosperity.
GHG emissions	70 Mt CO₂e or 10.2% of Canada's total emissions from agriculture in 2024.[61] 6.4 Mt CO₂e or 1% of Canada's total emissions from food and beverage manufacturing in 2022. [490]
Options for decarbonization	Animal agriculture: Reduce emissions intensity (feeds, genetics, methane inhibitors, manure management); longer-term shifts toward lower-emission proteins. Cultivation & soils: Improved nitrogen management, diversified cropping, soil carbon-building practices (region-specific). Energy: Electrification, biofuels, hydrogen, and efficiency improvements on farms and in food processing.
Stage of transition	Early emergence.
Nature of the problem today	Emissions are biologically driven, geographically dispersed, and highly heterogenous. Production systems are optimized for yield using high input models, while markets and policies weakly incentivize emissions reduction and sustainable agriculture.
Other systemic issues	Soil degradation, biodiversity loss, water pollution, food waste, health impacts of processed diets, supply-chain concentration, labour constraints.
Strategic opportunities and concerns	Opportunities to strengthen rural resilience and position Canada in sustainable food markets. Climate change increases production risk (extreme weather, drought/flooding, vulnerability to pests and disease) but can make the growing season longer and warmer.

Priorities for action	Reform support programs to reward emissions reduction and resilience; reduce fertilizer- and livestock-related emissions; scale proven practices through research, trials, and extension; align processors, retailers, and finance with low-emission value chains; encourage alternative proteins.
Longer-term issues	Managing climate impacts on yields; clarifying the role and limits of soil and land-use carbon sequestration; transitioning toward agroecological production systems at scale.
Indicators of progress	Methane and nitrous oxide emissions intensity; fertilizer use efficiency and nutrient losses; soil organic carbon (context-specific); fossil fuel share of energy use; lifecycle emissions per unit of protein; food loss and waste.

11.1.1 Current Status

Canada is a major agri-food producer and exporter, with the sector accounting for about 7% of the country's GDP.[491] Crop production is dominated by field crops, including wheat, canola, corn, barley, soybeans, oats, and lentils, while beef, dairy, pork, and chicken are the major livestock products.[492,493] Approximately 2.3 million people are employed in the agri-food sector, equivalent to 1 in 9 Canadian jobs.[491]

About half of agri-food production by value is exported, with more than 60% of exports going to the United States while the remainder is consumed domestically.[494,495] Due to its export orientation, the sector is highly exposed to disruption in international trade patterns from disputes or geopolitical tension.

Despite its economic significance, primary agriculture accounts for only about 10% of total sector employment. Most jobs are found downstream and upstream in the supply chain, including inputs and services (3%), food and beverage processing (14%), retail and wholesale (28%), and the food service industry (43%). In 2021, Canada had just under 190,000 farms.[491] In that year, total farm operating revenues were \$87.0 billion, with the top 10% of farms (with revenues exceeding \$1 million) generating approximately 69% of national farm revenues, while the 52% of farms with revenues below \$100,000 accounted for only 3%.[496,497]

These trends are reflected in the long-term decline in farm numbers and the increase in average farm size (Figure 38), as well as the highly uneven distribution of farm operating revenues (Figure 39). Beyond farms, corporate concentration is significant throughout the agri-food supply chain. This is particularly true for input supply (seeds, fertilizer, herbicides, pesticides, and equipment), food processing (meat packing, manufacturing) and retail (supermarkets).[498] In 2021, five food retailers had nearly 80% of the Canadian grocery market.[499]

In contrast to other social provisioning systems such as transport or buildings, agriculture relies directly on natural cycles and

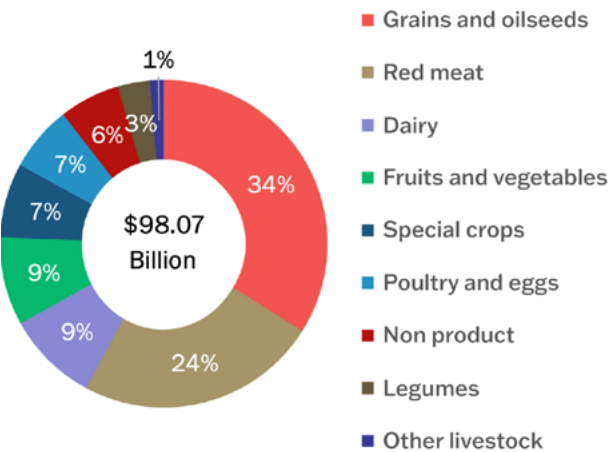


Figure 37. 2024 Farm cash receipts

1 All noted references can be found in the full Playbook document.

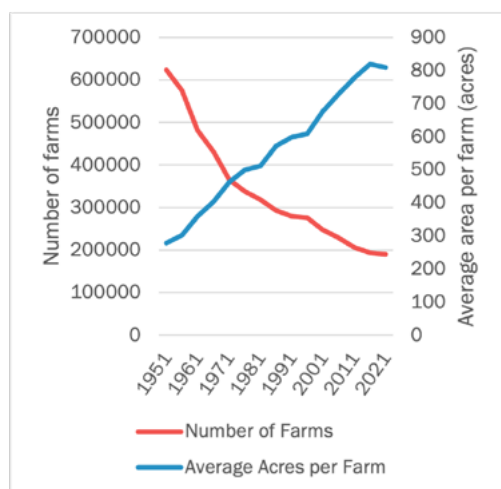


Figure 38. Number of farms and average area per farm (1951–2021)[254]

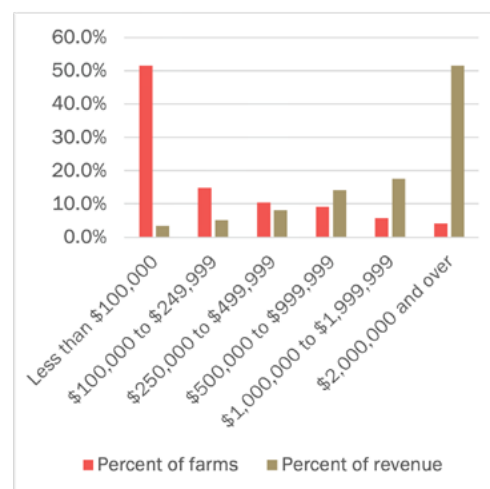


Figure 39. Distribution of farms by operating revenues, 2021

ecological systems, depending on local soil conditions, rainfall, and climate. Climate change is already impacting the sector, resulting in reduced revenue per hectare and sharply rising crop insurance payouts (\$1.9 billion in 2018 to \$5.7 billion in 2023). Larger impacts are expected in the future.[500]

At the same time, farming has a substantial environmental footprint, contributing to biodiversity loss and climate change, with pressures arising primarily from input-intensive land-use practices such as monocropping.[501] In Canada, about 6% of the total land area is currently in agricultural production, but this is often in the most settled areas, which historically supported high levels of biodiversity, such as the mixed wood plains ecozone and Carolinian forest.[491,502,503]

Despite these environmental and economic risks, agricultural support programs in Canada are comparatively less generous than in other OECD countries, contributing approximately 8% of gross farm receipts, compared with an OECD average of 13%.[504] Sector risk prevention, including crop insurance payouts, represents the largest component of federal agricultural spending at \$2.03 billion out of \$3.94 billion planned for 2025-2026.[505]

Two major technological revolutions are impacting the sector. Digital technologies like computer vision, edge computing for internet of things, remote and smart sensing, robotics (including drones), machine learning, and artificial intelligence are changing the ways crops and livestock are managed. Advances in biotechnology, including genome editing, nanotechnology, and marker-assisted selection are permitting new crop development, novel pest and nutrient control strategies, and the emergence of precision fermentation and synthetic proteins.[506,507]

11.1.2. Nature of the Problem

The agri-food sector is a significant source of GHG emissions in Canada and presents distinct challenges for decarbonization. Most emissions are from primary agriculture (within farm boundaries). In 2024, the agricultural sector accounted for 70 Mt or about 10.2% of Canada's total emissions, with food and beverages accounting for an additional 5.5 Mt in 2022.[61,490] Within agriculture, emissions arise primarily from animal production (53%), crop production (27%), and on-farm fuel use (20%).[508]

These figures, however, understate the full climate footprint of food production, as lifecycle emissions from the broader agri-food system also include upstream and downstream sources such as fertilizer and packaging production, retail, waste management, and transport, which are accounted for elsewhere in national GHG inventories.

Structural Emission Drivers in Modern Agriculture

Modern agricultural systems are emissions-intensive, reflecting decades of optimization for yield, scale, and cost reduction. High-yield cropping depends on mechanization and the extensive application of nitrogen fertilizers and other chemical inputs, while large-scale livestock production, particularly in high-income countries, is required to meet demand for animal protein.

Although most on-farm energy comes from diesel and other fossil fuels, fuel use only accounts for about a fifth of agricultural emissions; the majority stem from nitrogen fertilizer use and livestock production, including manure management and enteric emissions.[509] As a result, agriculture

accounts for almost 30% of national methane emissions and 75% of nitrous oxide emissions.[186] This underscores the limits of decarbonization strategies focused only on electrification or fuel substitution.

Nitrogen Fertilizers

The widespread adoption of nitrogen fertilizers in the second half of the 20th century enabled major gains in agricultural productivity and, together with fossil fuel combustion, roughly doubled the amount of reactive nitrogen circulating in the environment.[510,511] Nitrogen fertilizer use generates significant direct emissions in the form of nitrous oxide, a highly potent GHG, as well as indirect emissions from ammonia volatilization and nitrogen leaching from agricultural soils.[512]

In Canada, under a business-as-usual trajectory, fertilizer-related emissions could nearly double again by 2050.[509] Beyond climate impacts, fertilizer runoff contributes to air pollution and eutrophication of surface waters, driving toxic algal blooms that degrade water quality and harm aquatic ecosystems.[512]



Livestock Production

Livestock production, especially beef and dairy cattle, represents a central challenge within the agri-food system. Enteric fermentation and manure management account for a substantial share of agricultural emissions (37% and 12%, respectively), with cattle alone responsible for slightly more than a third of agricultural emissions.[186,490] When emissions associated with growing feed grain and farm fuel use are included, cattle-related emissions contribute an estimated 40% of Canada's agricultural emissions.[509]

Beef production is also characterized by low conversion efficiency: one analysis suggested that for the U.S. agricultural system, caloric conversion rates are about 3% for beef, 9% for pork, 17% for dairy, and 13% for poultry.[514]

Structural Emission Drivers in the Broader Agri-Food Supply Chain

Food loss and waste occur across the entire agri-food system, from farms and processing facilities to distribution, retail, food service, and households.[515–517] The scale is staggering, analysis suggesting that in Canada, 46% of food is wasted annually. This waste significantly amplifies the environmental footprint of the agri-food system. The total GHG impact of Canada's avoidable food waste in 2024 was estimated to be 25.7 Mt of CO₂e.[515]

Until recently, much of the problem was framed as a household issue, driven by overbuying, poor meal planning, spoilage, and the disposal of edible food. Research now highlights substantial losses in production, processing, and manufacturing, where inefficiencies, quality standards, and logistical constraints play a major role.[518] Thus, meaningful progress will require coordinated interventions across the supply chain to better integrate the environmental costs of

waste into food system design, production, distribution, and marketing.

Soils and Environmental Trade-offs

Conventional industrial farming systems have prioritized simplification and control of ecological interactions through monocropping and chemical inputs. While this approach delivers high yields, it has often done so at the expense of biodiversity, water quality, groundwater availability, and soil health, increasing pollution as well as reliance on synthetic pesticides, herbicides, and fertilizers.[519]

Soils play a pivotal but variable role in agricultural emissions. Depending on management practices, weather, and broader ecological conditions, soils can act as either net GHG sources or sinks.[520] The development of more farmland and poor maintenance of existing soil can disrupt soil carbon storage.[521] Maintaining or increasing soil organic carbon supports emissions reduction, improves soil structure, reduces erosion, enhances nutrient and water retention and delivery, and supports crop productivity.[522]

Why Agriculture Is Complicated to Decarbonize

The agri-food system will be among the most challenging sectors to transition to net zero. Emissions are highly dispersed across millions of acres and thousands of farms, making them difficult to measure, manage, and regulate. The sector is also extremely heterogeneous, with GHG footprints varying widely for the same product due to differences in feed composition, manure management, soils, yields, and climates.[523] These technical challenges are compounded by fragmented and underfunded public agricultural extension services, limiting the dissemination of practical mitigation options, constraining both awareness and adoption of decarbonization practices.[524–527]

Long-standing corporate, institutional, and political factors further limit intervention. Canada lacks a clearly articulated 2030 and 2050 decarbonization pathway for agri-food, contributing to uncertainty and delayed investment in emissions reductions.[488]

Addressing these challenges requires a rethink of established production paradigms and raises fundamental questions about both what is produced and how.[519] Most existing agricultural support programs focus on stabilizing prices, risk management, and encouraging exports, and in some cases may inadvertently reinforce environmentally damaging practices, such as reduced crop diversification.[500] Increasingly, however, there is recognition that sustainability and credible documentation of low-carbon supply chains can be a competitive advantage both in domestic and international markets.[529] While transition pathways remain contested, there is growing consensus that emissions reductions must be pursued alongside farm viability, healthy diets, biodiversity protection, water quality, and trade competitiveness.[519]

11.1.3 Net-Zero Pathways

Three emissions mitigation areas must be in place to move agri-food systems towards net zero:

- Addressing emissions from animal agriculture
- Reforming cultivation practices and managing soils
- Displacing fossil fuels across farms and food systems

No single intervention can deliver net zero. Instead, pathways will involve different combinations of these elements depending on region, production system, available infrastructure, and commodity.

1. Addressing Emissions from Animal Agriculture

Animal agriculture, particularly ruminant livestock, is the largest single source of emissions in the agri-food supply chain. Two broad and complementary strategies are available: reducing emissions intensity within existing livestock systems and shifting production and consumption toward lower-emission protein sources.

a. Improving Livestock Production Practices

The GHG performance of the Canadian beef industry has improved significantly over the past decades.[530,531] Mitigation measures include improved animal genetics, higher-quality and more digestible feed, feed additives to reduce enteric methane, more advanced manure management systems, modified grazing practices, and enhanced soil and pasture management.[532]

Recent modelling suggests that combining these measures, rather than adopting them in isolation, may allow beef and dairy production to approach very low or net-zero emissions, particularly where soil carbon sequestration is increased. High-impact options like planting trees on pastureland and anti-methanogenic feed supplements deliver substantial emission reductions with relatively low costs compared to other measures.[533] How widely such outcomes can be replicated across Canadian producers remains uncertain and will depend on cost, scalability, verification, and producer adoption.

b. Shifting Protein Production and Consumption

A second pathway involves changes in both supply and demand. Over the past 40 years, Canadian meat consumption overall has decreased almost 10% (per capita beef consumption declined more than 40%, while chicken consumption has grown by almost 110%).[534–536] Decreasing meat

consumption broadly and moving to meats with higher calorie conversion efficiencies, particularly poultry or some farmed fish, could yield further emission reductions. There is increasing scientific evidence that diets high in fresh vegetables, legumes, nuts, and fish, with only a moderate quantity of animal protein, are conducive to health.[537,538] Although the proportion of the population committed to vegan principles remains small, there is a broad tendency to reduce consumption of red meat and dairy-based beverages.[539]

More transformative change would involve expanding the role of alternative protein sources:

- **Plant-based proteins:** Meat substitutes like vegetable-based burgers and non-dairy beverages like oat or almond milk have achieved commercial success over the past decade.[540] The trend has been driven by consumer concerns over health, animal welfare, and the environment, but also by advances in manufacturing that have improved flavours and textures in meat substitutes.[541]
- **Fermentation-based and cultured proteins:** Biotechnology advances have dramatically reduced the cost of creating animal proteins through enhanced fermentation, though commercial cost parity is uneven across production methods and scales.[542,503] Milk proteins such as casein are already being used in U.S. food products, with research on cellular meats advancing rapidly.[544] By producing proteins without raising a whole animal, these approaches could dramatically reduce emissions from enteric methane, manure, and feed production, while freeing agricultural land for other uses.[545,546]

Adoption of alternative proteins in Canada has been gradual and is likely to remain so, given its dependence on consumer acceptance and

preference. More rapid market disruption could occur if alternative products simultaneously meet consumer expectations and achieve price advantages over conventional livestock products. Changes are unlikely to result in a complete replacement of meat across all contexts.

The shift is made more complex by the export intensity of Canadian agriculture, since domestic production and domestic consumption are loosely coupled, especially in the beef and grain sectors. As a result, a shift by Canadians toward more plant-based diets would not necessarily reduce agricultural GHG emissions if meat production continues to be driven by export demand.

Despite their mitigation potential, uncertainties remain around consumer acceptance, regulatory frameworks, and the long-term health and environmental impacts of these technologies. Initial adoption is likely to be cost-led, particularly where fermentation-derived proteins undercut conventional animal protein prices. While shifts toward alternative proteins involve consumers more directly, demand is not independent; the agri-food industry has a significant role in shaping preferences through pricing, marketing, and product design.

2. Reforming Cultivation Practices and Managing Soils

Crop production and soil management are the second major source of agricultural emissions, largely due to nitrous oxide emissions from nitrogen fertilizers and soil processes. Addressing these emissions without compromising yields requires fundamental changes in cultivation practices and input management that are tailored to regional conditions and crop types. Key strategies include improving nitrogen management, enhancing soil organic carbon, and diversifying cropping systems.

a. Nitrogen Management

Synthetic nitrogen fertilizers are the dominant source of agricultural N₂O emissions.[186] To mitigate these emissions, multiple approaches are required to reduce inorganic nitrogen inputs (without yield loss). These include improving nitrogen use efficiency through the 4R principles (right source, right rate, right time, and right place) and adopting enhanced-efficiency fertilizers such as controlled-release products and nitrification inhibitors.[547,548] Precision agriculture tools, such as variable-rate application and real-time monitoring (guided by sensors or satellite data), can further reduce nitrogen losses by better matching inputs to crop demand.[549]

b. Soil Management and Organic Carbon

Managing soils to increase organic carbon is central to reducing emissions while improving soil fertility and water-holding capacity, and preventing erosion and nutrient loss. Practices that reduce soil disturbance and enhance organic carbon, such as residue retention with reduced or no-till cultivation, greater use of cover crops, and adding organic amendments (manure, green manure, biochar, and compost), can reduce emissions and improve the fertility of soils, especially in degraded soils or where land is restored from intensive agricultural use to grasslands, forests, or wetlands.[550,551]

In Canada, no-till practices are common, particularly in Western Canada.[512] The amount by which soil quality improves, nitrous oxide emissions reduce, and yields are impacted by no-till depends largely on climate and soil type.[553] As a result, reduced tillage is most effective as part of an integrated soil and nutrient management strategy rather than as a stand-alone mitigation measure.

Cover crops can reduce nitrate leaching and improve soil resilience by retaining residual soil nitrogen between growing seasons, and

one Canadian study identified increased cover cropping as the third most impactful natural climate solution, after avoiding disturbance of grasslands, peatlands, and wetlands.[548] However, emissions outcomes remain context-dependent, influenced by species selection, biomass production, termination timing, and local soil and climate conditions.[554]

More broadly, improved soil management is recognized as an important component of broader natural climate solutions, but there is significant uncertainty around the long-term magnitude, durability, and climate sensitivity of soil carbon storage. Sequestration rates are region-specific, vary by soil type, climate, and management, and often decline as soils approach saturation.[555–557] As such, increases in soil carbon should be viewed as complementary to, rather than a substitute for, direct emissions reductions from fertilizer management and energy use.[548]

c. Diversify Cropping Systems

Diversifying cropping systems through intensified rotations (less summerfallowing), greater inclusion of legumes, vertical farming, and in some cases multicropping can reduce emissions while improving nutrient cycling, pest control, and soil structure. Legume crops reduce reliance on synthetic nitrogen fertilizers by fixing atmospheric nitrogen, while vertical farming can reduce chemical use and facilitate electrification of machinery. [550,558–560]

Multicropping practices were displaced by the expansion of high-input monocropping, but when combined with modern crop varieties and technologies, more diverse cropping systems can maintain, or even improve, productivity while reducing emissions. [561,562] Evidence from organic farming systems demonstrates that cropping systems that avoid synthetic nitrogen can be productive under certain conditions, with

potential long-term benefits for soil fertility. However, outcomes are variable, and productivity may decline depending on crop type, soil conditions, and management practices.[563,564]

There are longstanding debates over the climate and biodiversity performance of conventional and alternative farming systems, including concerns that lower-yield approaches may increase land requirements. [565] While large-scale conversion to organic agriculture is unlikely in the near term (organic production currently represents about 3.3% of Canadian farmland), achieving emissions reductions will nonetheless require a clear shift away from business-as-usual cropping systems and wider adoption of diversified, lower-input practices where they are agronomically and economically viable.[566]

While the impact of organic farming requires context-specific fine-tuning, a significant domestic opportunity remains largely untapped. In 2020, Canadian organic imports outpaced exports—\$789 million versus \$461 million—revealing a substantial gap that domestic production could expand to fill.[567]

3. Displacing Fossil Fuels

Displacing fossil fuel end-use on the farm and throughout the food manufacturing industry, is conceptually straightforward: replace fossil-powered equipment with low-carbon alternatives. While this transition mirrors decarbonization efforts across the broader economy, it faces additional challenges in rural and remote settings. Today, fossil energy is used primarily for vehicles, machinery (e.g. tractors, harvesters, pumps), and heating (e.g. buildings, drying, food processing). On the farm, diesel engines dominate because of their high-power density and existing fuel infrastructure.

The main decarbonization pathways are electrification, hydrogen (or related net-zero

energy carriers), and biofuels, each with distinct benefits, constraints, and levels of readiness for on-farm deployment. Alongside these options, improving energy efficiency, such as better insulation in barns and buildings or reducing vehicle and machinery idling, can lower emissions while delivering immediate operational cost savings.

a. Electrification

Where clean grid electricity is available, light- and medium-duty vehicles and equipment can transition to battery electric options.[528] Some electric tractors have begun to enter the Canadian market.[529] Farm and food manufacturing heating can also shift to high-efficiency electric heat pumps, which often deliver operating cost savings alongside emissions reductions.[570]

In more remote or off-grid locations, on-site renewable energy including solar, wind, or bioenergy can supply electricity. These systems reduce reliance on diesel or propane generation, lower emissions and operating costs, and can provide revenue diversification where excess electricity is sold back to the grid.[571]

b. Hydrogen

Heavy machinery and long operating hours present challenges for electrification due to current battery energy density and charging limitations in rural settings. Hydrogen fuel cells offer a promising high-energy alternative for heavy-duty equipment and off-grid power, especially where long runtimes and quick refuelling are needed. However, widespread use depends on the availability of low-carbon hydrogen and rural infrastructure build-out, which is still nascent.[572]

c. Biofuels

Biofuels such as renewable diesel or biogas can also displace fossil fuels, particularly where electrification or hydrogen are less

feasible. Renewable diesel is a drop-in fuel compatible with existing diesel equipment, while biogas can be upgraded to renewable natural gas and used as a direct substitute for fossil natural gas in heating applications on farms and in food manufacturing. These fuels are made from biomass and can reduce greenhouse gas emissions compared to their fossil fuel counterparts, though their scalability and sustainability depend on feedstock and production methods.

Agricultural and agri-food operations have a unique advantage in biofuel production, as on-site wastes and residues can be repurposed into usable fuels in closed-loop systems or sold downstream. The appropriate biofuel pathway depends on operation scale and waste type, with options including fermentation, anaerobic digestion, pyrolysis, and gasification.[533] Many of these processes also retain nutrients in by-products such as digestate or biochar, which can be returned to fields as fertilizers, supporting nutrient cycling alongside energy production.[574]

Pathways Selection

There is no simple “one size fits all” solution for moving the agri-food system onto a net-zero trajectory.[525,535] Progress will require combining multiple strategies, reducing emissions from animal agriculture, reforming cultivation and soil management practices, and displacing fossil fuels, implemented in different proportions depending on region, production system, infrastructure, and commodity. No individual technology or farming model can deliver net zero on its own. Considerable practical experimentation and research, including participatory on-farm research, will be required to develop approaches suited to different conditions, regions, and sub-sectors.[576]

Competitiveness Implications

Canada is among the world's largest pulse producers (lentils, peas, and beans that rank among the lowest-emission protein feedstocks available), and plant-based proteins represent the sector's top-rated economic development opportunity. But the economic return depends on where the processing occurs. The margin in protein markets sits downstream: in ingredient isolation, formulation, product manufacturing, and the IP that surrounds them. Canada's pulse sector leads at the farm gate, yet R&D and capital investment in the country's food-processing industry have been declining, exactly the wrong trajectory for capturing this segment. Domestic processing capacity is also what converts a commodity export position into an export platform for finished, low-emission protein products. The structural advantage is real, but until processing capacity follows the feedstock, Canada will continue exporting low-margin pulse crops while importing the higher-value protein products made from them.

11.1.4 Priorities for Action

In the near term, priorities should focus on accelerating emissions reductions using measures that are already available while strengthening the institutions needed for deeper change. This includes intensifying research, trials, and scaleup of more sustainable cropping and livestock practices, reducing reliance on synthetic nitrogen fertilizers, and expanding the use of low-carbon energy across farms and food processing.[577–579] This can be integrated with efforts to address other challenges, including farm debt, high land costs, the difficulty of attracting young farmers, and corporate concentration.[577]

Reform of agricultural support mechanisms is already under active discussion, and emphasis on mitigation of GHGs and resilience in the face of climate risks could be built into program design. Existing programs could place greater emphasis on emissions reduction, soil health, and climate resilience, rather than only on income stabilization and production risk. Priority measures include support for cover crops, diversified rotations, tree planting, wetland restoration, improved pasture management, and verified reductions in fertilizer- and livestock-related emissions.

Public research and extension capacity must also be strengthened. Canada has a strong history of publicly supported agricultural research, but extension services that once provided farmers with practical, independent advice have been substantially reduced. Addressing climate risks and emissions at scale will require renewed investment in public research, education, and on-farm advisory services, including targeted support for young farmers, Indigenous producers, women, and new entrants.

Agri-food supply chains have a critical role in enabling change. Although agri-food emissions occur mainly on farms, they are shaped by decisions made by processors, distributors, and retailers. Better coordination across supply chains can reduce risk for producers, accelerate adoption of low-emission practices, and support credible documentation of emissions performance. Food processors and distributors can play a major role in building innovative and collaborative supply chains that mobilize knowledge, capital, and organizational capacity to work with primary producers to accelerate change. Recent efforts to market Canada as a sustainable agri-food producer could help expand markets while reinforcing incentives for lower-emission production.

Reducing emissions from nitrogen fertilizer and livestock production should be a priority. This includes wider use of enhanced-efficiency fertilizers, precision application, alternative cropping systems that build soil fertility, and regulatory or market mechanisms that encourage the adoption of lower-emission fertilizer products.[540] In animal agriculture, greater emphasis is needed on proven approaches to reduce enteric methane and improve manure management.

Promoting the uptake of battery electric or hydrogen fuel cell machinery and vehicles, on-farm renewable electricity generation, use of locally produced biofuels, and energy efficiency measures can lessen dependence on fossil fuels. Current fuel tax exemptions reduce incentives to shift away from fossil fuels, and alternative policy mechanisms will be needed to encourage low-carbon energy use.

Encouraging greater investment by the food industry in plant-based processed foods and early exploration of fermentation-based and cultured proteins (including careful assessment of their health, environmental,

and social implications) should begin now. On the consumer side, public education on healthy diets, food safety, and the environmental footprint of food (Figure 40) can support informed choices. Measures that strengthen connections between producers and consumers, such as local and regional markets, can further raise awareness while supporting farm incomes.

Over the longer term, it will be important to support research and trials of alternative agricultural paradigms, including approaches that operate at the landscape scale across multiple farms and land uses. This includes integrating GHG management into all aspects of the agri-food sector and establishing clear parameters for achieving negative emissions through soil management practices and land-use changes.

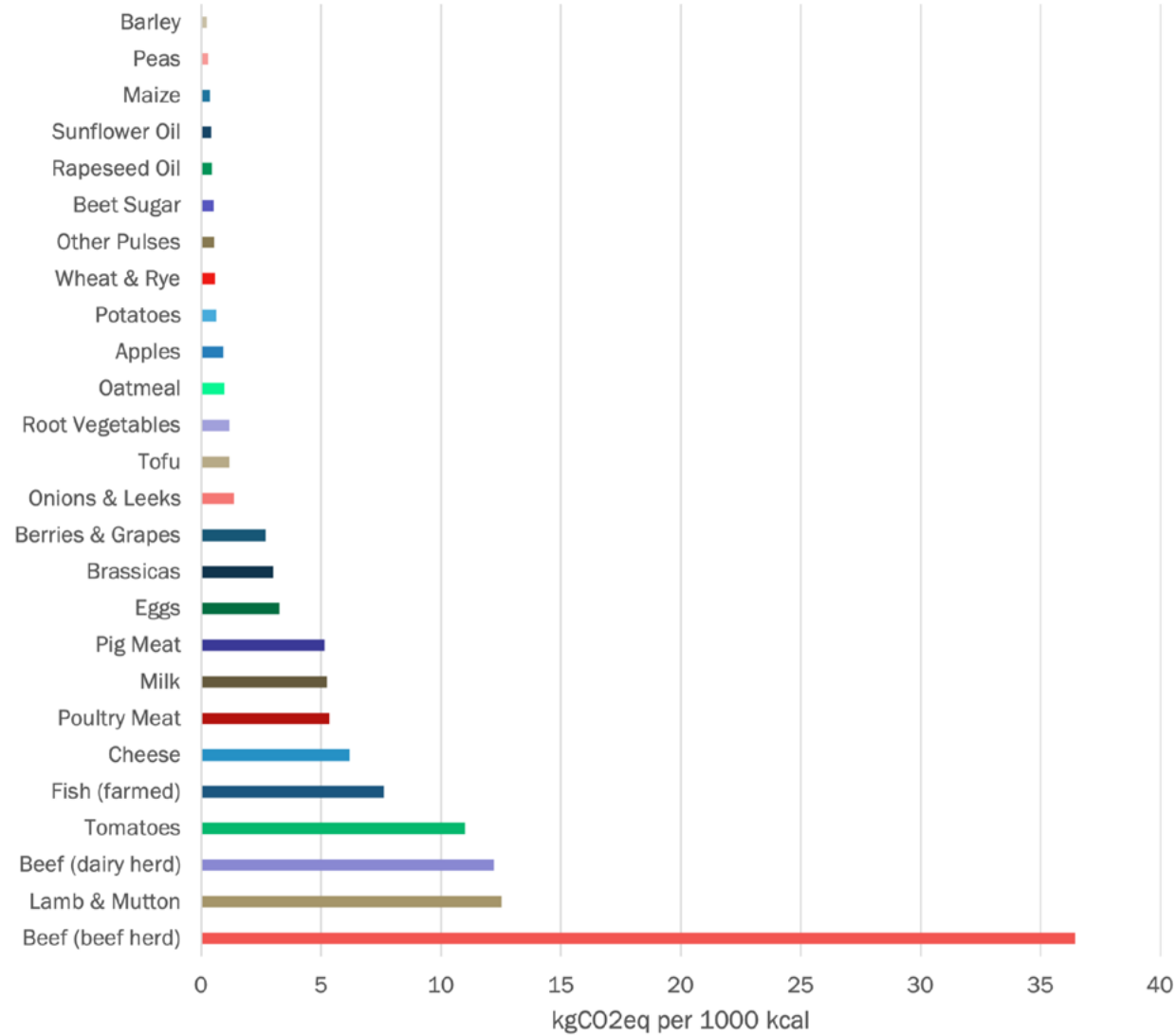


Figure 40. Comparing the carbon footprints of foods 1000 per kilocalorie[581]

Criteria Status

- Fails to meet criteria
- Meets in some respect
- Not promising
- Potentially meets criteria
- Meets criteria

11.1.5 Agriculture and Agrifood Pathways Table

Not promising Potentially meets criteria Meets criteria			ALIGNMENT WITH CARBON NEUTRALITY	Economic		Technical			Social		
PATHWAY ELEMENTS	ROLE IN NET-ZERO SYSTEM	SIGNAL TO DECISION-MAKERS		ECONOMIC VIABILITY	ECONOMIC DEVELOPMENT OPPORTUNITY	MATURITY	OPERATIONAL FIT	INFRA-STRUCTURE AND SUPPLY CHAIN SUITABILITY	SOCIAL ACCEPTABILITY	RELEVANCE TO STAKEHOLDERS	RELATED BENEFITS AND COSTS
 Animal Agriculture											
Advanced Manure Management	<i>Priority Decarbonization Pathway</i> Substantially reduces methane from manure systems, but residual emissions remain, requiring integration with broader livestock decarbonization strategies.	Deploy Offer financing mechanisms and/or adopt offset protocols with financial benefits. Provide extension services on selecting economical options relevant to farm size.	 Anaerobic digestion, acidification, or separation substantially reduce manure methane. Residual emissions remain.	 Some methods low cost while more advanced systems are capital intensive. Project economics depend on scale, off farm substrates, and credit/incentive access.	 Development of manure management technologies and expertise. Co-development of biogas generation. Buildout of nutrient recovery. Reduced dependence on imported fertilizers.	 Most techniques are mature with commercial adoption occurring in Canada. Capital-intensive technologies are more limited.	 Some strategies (i.e. more frequent manure removal) require few changes. Other strategies require installation of technologies, retrofit of existing buildings, and worker training.	 Infrastructure for equipment supply largely established. Biogas offtake is difficult; consuming on-site reduces challenges.	 Acceptance is generally high as long as odour and traffic remain limited.	 Many farms already employ manure management techniques with uptake in technology adoption.	 Improved nutrient recycling and displacement of synthetic fertilizers reduces lifecycle emissions and water pollution. Biogas reduces reliance on fossil fuels.
Fermentation-Based and Cultured Proteins	<i>Potential Decarbonization Pathway</i> Offers potential for major livestock emission displacement, but scalability, cost, and lifecycle performance remain uncertain.	Incubate Support research and development. Build out regulatory environment.	 Potential for large reductions if powered by clean energy and scaled.	 Cost competitiveness at scale is expected soon. Costs currently remain higher than most conventional products.	 Canada has a large primary agricultural industry which can support growth in bioprocessing. Opportunities for IP and R&D from established research organizations.	 Some products are commercial. Many others are in various phases of research, development, and scaling.	 New food manufacturing facilities will need to be built out with novel processes. Regulatory environment needs development.	 Commercial manufacturing and ingredient supply chains are nascent, with limited retail availability.	 Acceptance is mixed as products can be perceived as highly processed. Safety and health are concerns.	 Ongoing research in Canada. Some companies present in Canada.	 Can reduce land use and air and water pollution. Creates food supply resilience. Further studies of health and environmental implications required.

PATHWAY ELEMENTS	ROLE IN NET-ZERO SYSTEM	SIGNAL TO DECISION-MAKERS	ALIGNMENT WITH CARBON NEUTRALITY	Economic		Technical			Social		
				ECONOMIC VIABILITY	ECONOMIC DEVELOPMENT OPPORTUNITY	MATURITY	OPERATIONAL FIT	INFRA-STRUCTURE AND SUPPLY CHAIN SUITABILITY	SOCIAL ACCEPTABILITY	RELEVANCE TO STAKEHOLDERS	RELATED BENEFITS AND COSTS
Plant-Based Proteins	<i>Priority</i> Enabling Pathway Gradual shifts in demand toward less livestock and emissions-intensive products. Enables deep structural emissions reductions where applicable.	Deploy Support expanding manufacturing of higher value chain plant-based protein products with financing mechanisms. Provide education to consumers on the benefits of plant-based proteins.									
			Can achieve net zero with zero-emissions crop practices.	Plant based proteins are typically lower cost to produce and purchase than animal-based proteins.	Canada has a major pulse market. Development and production of plant-based proteins (higher-value products) in the same supply chain would create significant IP, export, and job opportunities.	Plant-based protein products produced and consumed regularly in Canada. Some development underway to improve nutritional equivalence, scalability, and digestibility.	Some scaling of food processing facilities or buildout of new manufacturing processes will be required.	Canada has an established and well-positioned plant-based protein supply chain which can readily be expanded. Infrastructure to transport crops and food products is established.	Plant-based proteins are widely accepted. Most consumers choose both animal and plant-based proteins and choices in diet vary by region. Concern over high salt, fat, sugar, and additives in many products.	Increasing demand for plant-based proteins from consumers drives market interest. Pulse producers looking for value add.	Reduced water and land use when replacing animal-based protein, potential health benefits when a part of balanced diets. Many products are not nutritionally equivalent to livestock-based products.
Enhanced Animal Genetics	Enabling Pathway Reduces livestock emissions intensity. Cannot eliminate biogenic methane and must be combined with other livestock measures.	Incubate testing and demonstration. Provide extension services to farmers on how to select for and the benefits of selecting low methanogenic genetics.									
			Selective breeding reduces enteric methane intensity but does not eliminate emissions. Must pair with other measures.	Low incremental cost. Leverages existing breeding programs and AI. Benefits accrue herd wide over time. Operational savings from improved feed conversion.	Some opportunity for Canadian IP and R&D. Expands Canada's leadership in dairy genomics and exportable genetics services.	Genetic selection used widely today for a variety of purposes. Canadian research groups testing large-scale low-cost ways to select for low methanogenic genetics.	Integrates seamlessly into existing breeding programs.	Uses established milk recording, mid infrared spectroscopy, and genomic platforms.	Non intrusive and animal welfare neutral. Generally, well accepted.	Many stakeholders are involved in data sharing for ongoing research. Herd-level emissions reductions without changing facilities.	Tracking genetics accurately improves diversity, animal health and longevity.
Improved Feed Digestibility and Quality	Enabling Pathway Reduces enteric methane per unit output. Doesn't eliminate emissions. More effective when combined with other measures.	Deploy Provide regionally specific information on growing and selecting high quality feed. Support development of additives.									
			Higher forage quality and specific additives cut methane per unit output but not to zero.	High quality feed may have cost increases, but these can be balanced by the improvements in performance.	Builds demand for Canadian feed innovations and forage quality services.	Practices are commercial today. Efficacy varies by diet. More advanced approaches, including additives are in R&D.	High compatibility. Some changes to harvest timing and storage but fits with existing systems. Implemented through routine ration adjustments.	Uses existing feed supply chains, labs, and advisory networks.	Seen as positive as it aligns with better animal nutrition.	Recognized by all stakeholders as a path forward. Seen positively due to alignment with efficiency and emissions intensity.	Improved productivity and feed efficiency. Some approaches also reduce upstream emissions associated with crop production.

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Modified Grazing Practices	Enabling Pathway Improves soil carbon and pasture efficiency in suitable regions, but impacts are context-specific and insufficient alone to achieve net zero.	Deploy Provide regionally specific extension services to farmers including case studies. Support local demonstrations.	Can build soil carbon and reduce emissions if optimized. Outcomes are climate/soil dependent.	Lower-cost measure requiring better planning, fencing and water distribution.	Growth in advisory services and R&D.	Grazing best management practices (rotational, adaptive, rest periods) are widely practiced. Better provision of information required to improve grazing practices.	Fits with existing practices; may require small modifications such as the addition of more fencing and improved planning.	Infrastructure and supply chain are in place.	Acceptance high with improved pasture productivity.	Producers can benefit from improved animal performance and forage utilization. Research is still ongoing.	Improved soil carbon stocks, water retention, drought resilience, soil structure, and biodiversity. Pasture productivity is maintained or improved.
Enhanced Soil and Pasture Management	Enabling Pathway Builds soil carbon and reduces input needs, but sequestration limits and variability mean it must complement direct methane reductions.	Deploy Provide regionally specific extension services to farmers including case studies. Support local demonstrations.	Practices increase soil organic carbon and reduce inputs but are complementary to enteric/manure abatement.	Measures such as adding trees to pastures or nutrient planning have low to moderate costs and can improve forage yields.	Growth in advisory services and R&D.	Pasture reseeded and soil nutrient management are mature. Other techniques are not well documented or standard in Canada.	Compatible with existing livestock systems. Mainly requires changes to planning.	Infrastructure and supply chain are in place.	Acceptance high with improved yields and low costs.	Valuable to farms with grazing animals. Some practices are commonplace others are less understood and in R&D phases.	Improved soil carbon stocks, nutrient and water retention, soil stability and biodiversity in pastureland. Reduced nitrogen runoff. Shade and shelter where trees are planted.

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 Crop Agriculture											
Efficient Fertilizer Application and Use	Decarbonization Pathway Reduces nitrous oxide emissions through improved nitrogen management but cannot fully eliminate soil emissions.	Deploy Continue to provide high-quality extension services on fertilizer application best management practices and their benefits.	 Lowers N ₂ O emissions materially. Not a full abatement to zero. Requires other measures to offset remainder.	 Potential return on investment from reducing fertilizer inputs through optimizing rate, source, timing and placement.	 Growth in advisory and training services.	 Nutrient stewardship is well established in Canada.	 Small modifications to planning and application practices may be required.	 Infrastructure and supply chains are largely in place.	 High acceptance for water quality benefits.	 Policy and government support is high. Lower operational costs are relevant to farmers.	 Demand reduction of primary fertilizers, improvements in water quality from reduced nitrogen loss.
Vertical Farming	<i>Potential Niche Pathway</i> Can significantly reduce land and input pressures for select crops if powered by clean electricity, but scale and crop applicability remain limited.	Incubate Support R&D. Assist with financing in favourable economic conditions.	 Can reduce land and pesticide use. Dependent on electricity carbon intensity.	 Economics remain challenging due to high capital and power costs. Profitable niches exist near urban markets and for premium produce.	 Opportunity for more variety in plants grown in Canada. Development of IP. Generates agricultural jobs in urban, remote, and northern communities.	 Commercial for some crops. Largely still in demonstration and pilot phases as economic outcomes are mixed.	 Requires buildout of new facilities, specialized skills and training, and tightly controlled climates.	 Depends on access to low-cost, reliable, clean power.	 Generally positive for local year-round food supply.	 Viewed as complementary to traditional farming. Relevance in limited markets. Costs and power constraints limit widespread interest.	 Significantly reduces water, pesticide, and fertilizer use. Shortens transport distance to consumers. Can integrate waste heat and renewables.
No or Low Till	Enabling Pathway Supports soil carbon retention and reduces fuel use, but sequestration is variable and insufficient on its own for net zero.	Deploy Provide regionally specific extension services. Support monitoring soil organic carbon to ensure effectivity in local conditions.	 Supports soil organic carbon retention and fuel savings. Effects vary by region/soil.	 Can improve yields under the right conditions. Reduces operational fuel costs. Stronger economics in the Prairies.	 Growth in advisory and training services and supply of specialized agriculture tools.	 Practices are widely adopted in Canada. Long-established in Prairies.	 Fits with existing farming practices.	 Used widely today across Canada with established equipment supply chains.	 High acceptance low public impact.	 Used widely by farmers for lower fuel costs, soil health, and potential yield benefits.	 Can improve or conserve soil water and nutrient retention. In the right conditions higher yield can occur.

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Greater Use of Cover Crops	Enabling Pathway Enhances soil resilience and nitrogen retention.	Deploy Provide regionally specific extension services. Support research and monitoring focused on optimizing crop selection in local conditions.	Potential to reduce N ₂ O emissions and increase soil organic carbon but effects are variable depending on crops, climate, and soil properties.	Relatively low-cost measure. Potential to increase yield in some cases when optimal cover crops are chosen. Optimal combination of amendments can improve yields.	Advisory and training services.	Use of cover crops is common. Resources exist provincially and federally advising on species selection.	Typically fit with growing seasons. Main modifications are to planning.	Seed supply chains are well established in Canada.	High acceptance low public impact.	Relevance is high to producers due to potential yield increases. Many government organizations offer advisory materials, but financial support is low.	Reduces or prevents soil erosion. Can assist with pest or weed control. Improves overall soil health.
Adding Organic Amendments	Enabling Pathway Improves soil health and nutrient cycling, but net emissions depend on amendment sourcing and management practices.	Deploy Support further buildout of organic fertilizer market with financing mechanisms, regulatory changes, and extension services on best management practices.	Improves soil quality and can lower net emissions. Benefits are context dependent.	Many organic amendments are low cost as they are sourced from waste (i.e. compost, manure, sludge). Optimal combination of amendments can improve yields.	Market generated around use of otherwise wasted materials.	Organic amendments are used widely today. Research occurring to optimize combinations to simultaneously maintain productivity and reduce GHGs.	Fits within existing cropping systems and equipment. Some concern over metals and other contaminants in sludges.	Compost, sludge, and manure used widely today. Established supply chains.	Mostly accepted. Some amendments require management of pathogens and odour.	Interest from producers in low-cost fertilizer supplements or replacements. Attractive for soil health and waste diversion goals.	Increased microbial diversity and soil health. Waste management solutions. Improved nutrient cycling and reduced reliance on primary fertilizers. Odour issues.
Biochar Addition	Enabling Pathway Can increase soil organic carbon and may mitigate N ₂ O emissions from soil.	Enable Support R&D and demonstration projects. Develop carbon credit protocols and quality standards.	Can increase soil organic carbon, reduce N ₂ O emissions, and sequester carbon but efficacy varies by feedstock, soil type, and climate.	Production costs are high. Requires policy support.	Supports domestic biochar production. Market generated around use of otherwise wasted materials.	Demonstration and trials occurring in Canada. Further research on long-term impacts on soil health, productivity and carbon retention required.	Can be applied using equipment, but density makes handling and application more difficult.	Supply chain is emerging. Production in Canada is being built out.	Accepted when produced from forestry residues.	Some interest in terms of carbon credit generation.	Can increase microbial activity, reduce nutrient leaching and improve water retention. May reduce biomass available for other sectors' decarbonization.

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Greater Inclusion of Pulses in Rotations	Enabling Pathway Reduces reliance on synthetic nitrogen through biological fixation, but broader system emissions persist.	Deploy Provide regionally specific extension services. Monitor soil nitrogen levels to ensure effectivity in local conditions.	 Legumes (pulses) can fix nitrogen from atmosphere, reducing required synthetic nitrogen fertilizer needs. Type of pulse and environmental conditions dictate effectivity.	 Can increase yields, diversify revenues, and decrease risk over time. Reduces operational costs associated with nitrogen fertilizer input.	 Can encourage value added processing and export growth for Canada's pulse sector, strengthening domestic supply chains.	 Mature agronomic practice widely used in Canada. Improvements continue with research selecting for higher nitrogen fixing genetics.	 Fits within existing cropping systems and equipment. Main changes are to planning.	 Seed supply chains well established in Canada.	 High acceptance; low public impact.	 Supported by producers, processors, and governments as a practical lever to reduce fertilizer related emissions and improve resilience.	 Improves soil structure and rotation diversity. Can reduce nitrate leaching and upstream fertilizer manufacturing emissions. Can break pest/disease cycles.
Multicropping (Including Intercropping, and Increased Frequency and Diversity of Rotations)	Enabling Pathway Improves nutrient cycling and reduces input intensity, but emissions reductions vary by crop, region, and management.	Deploy Provide regionally specific extension services to farmers, including case studies. Support local R&D and pilots on optimizing rotations to reduce GHGs.	 Reduces emissions by increasing soil organic carbon, reducing nitrogen fertilizer application, and withdrawing CO ₂ from the atmosphere. Impacts are rotation specific.	 Economics depend largely on selecting crops and rotations optimized for the soils and climate. Improves long-term profitability and diversifies revenues.	 Growth in seed sales and advisory and training services. Can support local processing facilities.	 Multicropping is mature, but optimizing crop rotations to reduce GHGs is still in R&D.	 Modifications to planning are required. May require investment in equipment or training. Adds complexity to operations	 Generally compatible with existing systems. May require regional market development for new crops .	 High acceptance; low public impact.	 Involvement from government and academia with ongoing R&D. Used by farmers but uncertainty around which systems are best.	 Diversifies revenue streams. Improves resilience to pests and environmental impacts (i.e. drought or late frosts). Improves nutrient cycling and soil structure.
Precision Agriculture	Enabling Pathway Improves input efficiency and reduces waste, but emissions reductions depend on adoption levels and integration with broader crop reforms.	Deploy Provide extension services on precision agriculture and financing mechanisms for small or remote farms to enable equitable access to tools.	 Reduces input related emissions through better timing, rate, and placement.	 Capital costs may require larger-scale operations. Can reduce operating costs including chemical and fuel inputs improving profitability.	 Growth in advisory and training services and supply of digital or precision agriculture tools.	 Used on some farms in Canada, especially in the Prairies. Some technologies in R&D.	 Some training on new digital or precision agriculture tools.	 Access to newer digital or precision agriculture tools may be difficult in remote areas and for small operations.	 High acceptance with reduced water pollution.	 Relevant to producers as operational costs and yields can be improved.	 Lower inputs (chemicals and fuels). Improved soil health and crop resilience. Reduced nutrient and pesticide runoff. Better data for decision making.

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 All Agriculture											
Improved Regional-Specific Data Collection and Monitoring	Priority Enabling Pathway Foundational for accurate measurement, verification, and targeted mitigation. Essential for scaling credible, region-specific net-zero strategies.	Deploy Support mass deployment with financing mechanisms and extension services. Continue support of R&D to optimize systems.	Enables accurate measurement of emissions and carbon retention, improves policy design, carbon credit integrity, and mitigation strategies.	Upfront costs can be high for software, sensors, and data systems. Improved measurements reduce uncertainty, optimize inputs, and can improve yields.	Growth in ag-tech firms in Canada and analytics and advisory services.	Many technologies are emerging with increasing adoption. Optimization of these systems is occurring with further research and development.	Integrate with existing operations.	Implementation depends on broadband access, cloud computing infrastructure, and standardized data frameworks.	Broadly accepted, with concerns around data privacy and ownership.	Relevant to all stakeholders. Many ongoing projects collecting and aggregating data relevant to GHG reductions.	Can improve yields, soil health, waste management, biodiversity, and climate resilience.
			Organic Farming	Enabling Pathway Reduces synthetic input reliance and can lower emissions intensity in some systems but yield trade-offs and livestock emissions may limit net-zero potential.	Enable Support demonstration and extension services focused on minimizing yield losses. Improve supply chain regulations for organic certifications.	Can reduce reliance on synthetic fertilizers, fuel, and pesticides lowering emissions. Can improve soil carbon retention, but may lower yields. GHG outcomes depend on circumstances.	Viability depends on price premiums and certification costs. Some producers benefit from lower input costs, but yield penalties can reduce margins. Production does not yet satisfy consumer demand in Canada.	Moderate opportunities in certification, advisory services, and value added markets/export niches.	Mature and widely practiced, with established standards and supply chains, though adoption remains limited in Canada.	Requires land management changes including a transition period. May require new equipment or more labour.	Supply chain traceability and certifications add complexity.

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 On-Farm Energy use											
Battery Electric Vehicles and Equipment	Potential Decarbonization Pathway Electrifies on-farm energy use	Enable Support electrical grid expansion and upgrade in rural areas. Provide financing mechanisms to assist with piloting and demonstrating new technologies on farms.	 Net zero with clean electricity.	 Lower energy and maintenance costs than incumbent. High upfront costs and uncertain resale value. Expected to improve over time.	 Creates opportunities for Canadian clean tech manufacturing and service jobs and rural electrification services.	 Entering the market for small/medium equipment and specialty tractors. Heavy duty applications are still in demonstration.	 Good fit for light to medium duty tasks with predictable schedules. Requires charging access and may face downtime constraints during peak seasons. Currently prohibitive for heavy-duty vehicles.	 Grids may require expansion or capacity upgrades in many rural areas.	 Accepted as noise and air pollution are reduced.	 Lack of access to high-capacity power limits interest from producers. Some equipment models emerging in Canada.	 Reduces air and noise pollution. Enables greater ability to automate.
Heat Pumps	Potential Decarbonization Pathway Can significantly reduce emissions from fossil fuel heating applications.	Enable Support electrical grid expansion and upgrade in rural areas. Provide financing mechanisms to assist with piloting and demonstrating new technologies on farms and food and beverage manufacturing facilities.	 Can eliminate emissions from space and water heating in farm buildings, grain drying, greenhouses, and some food manufacturing. Emission reductions depend on availability of net-zero electricity.	 Often cost effective where electricity is low carbon and competitively priced. Economics improve with efficiency upgrades and incentives, though retrofit costs can be a barrier.	 Moderate opportunities for Canadian HVAC manufacturing/ins tallation and rural electrification services.	 Technologies are commercial globally. Agricultural applications are emerging with pilots and applied research underway. Limited models for very cold weather or high-temperature operations.	 Potential fit in many applications but may require some modifications or retrofits to existing heating systems.	 Requires grid access, high capacity, and clean grids. Grids may require expansion or capacity upgrades in many rural areas.	 No particular concerns.	 Some interest from Canadian research groups. Proven efficiency increases for greenhouse operations. Government support is limited.	 Eliminates air emissions and reduces fuel price exposure.
Hydrogen Powered Heavy Machinery	Potential Niche Pathway Offers a potential zero-emission option for heavy equipment.	Incubate Fund R&D of heavy-duty hydrogen farming equipment.	 Hydrogen could decarbonize heavy equipment where electrification is impractical. Net emissions reductions depend on low-carbon hydrogen supply.	 Currently high cost due to hydrogen production, storage, and limited refuelling infrastructure. Not competitive yet in most use cases.	 Longer term opportunity for Canadian hydrogen and heavy equipment innovation—partic ularly in regions investing in clean hydrogen hubs.	 Largely in research and pilot phases.	 Could offer fast refuelling and long runtimes, but handling/storage and safety protocols add operational complexity for farms. Would need new equipment.	 Requires refuelling infrastructure. Hydrogen transport/storage logistics and standards are still developing.	 Some safety perceptions and unfamiliarity may slow uptake.	 Interest from governments is growing, but farmers are unlikely to adopt hydrogen until costs and fuelling access improve.	 Reduces noise/air pollution. Potential to pair with renewable H ₂ production.

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Renewable Diesel (RD)	Bridge Pathway Provides near-term emissions reductions using existing equipment, but may require removals for net zero.	Enable Develop policies that assist with increased fuel costs and limited rural access to RD. Support until maturity increases for electric or hydrogen equipment.	 Lowers lifecycle GHGs compared to fossil diesel but not a net-zero end-state. Emission reductions depend largely on feedstock sustainability and carbon intensity.	 Not currently cost competitive in rural areas without policy supports.	 Opportunities in Canadian biofuel production but limited by feedstock supply.	 RD is mature. Procurement can be difficult especially in rural areas.	 RD is drop-in.	 Large volumes required to make economic case for fuel distribution.	 Concerns of competition with food crops.	 Appeals to farmers as it reduces emissions in the near term without changing equipment.	 Reduces waste and associated management as fuels are typically produced from waste. Land-use change concerns. Air pollution persists.
On-Farm Renewable Power Generation (Wind and Solar)	Enabling Pathway Can use land simultaneously for power generation and farming. Can also supplement grid-supplied electricity for farming operations.	Deploy Develop supportive policies where appropriate. Provide resources that assist implementation.	 On-farm wind and solar can displace fossil energy use on farms and/or farmland can generate renewable electricity without compromising farming operations.	 Economics have improved. Upfront capital and interconnection can be barriers.	 Supports local economic development through installation/maintenance jobs and domestic clean energy supply chains. Potential revenue diversification for farms.	 Technology is mature and applications are commercial on many farms in Canada.	 Generally practical where land/roof space and grid interconnection exist. Can support remote/off grid operations but add complexity.	 Interconnection regulations and distribution capacity can constrain projects.	 Some rural opposition to large utility scale developments.	 Strong interest from farms, rural communities, and utilities. Adoption is rising as reflected in Canadian farm surveys.	 Can reduce fuel use and air pollution. Can improve energy resilience, and enables pairing with electric vehicles/heat pumps.
On-Site Biogas Production (Biomethane /Renewable Natural Gas Production)	Enabling Pathway Can create closed-loop energy systems using agricultural residues, but scalability and lifecycle performance vary.	Enable Provide resources and develop policy to lower barriers to interconnection and fuel offtake. Support R&D and demonstration.	 On-site biofuel can cut emissions and displace fossil fuels for heat and power. Emissions reductions depend on feedstock sustainability and processing methods.	 Mostly economic where scale is large. Capital costs high, especially for digesters; operational complexity can increase costs. Interconnection and offtake can be cost prohibitive.	 Creates rural jobs and generates economic product from wastes.	 Biogas production is mature. Deployment can be difficult and limited to regions with policy support and larger-scale farms.	 Training for operators and feedstock logistics and planning are required. Requires consistent feedstock, which can be difficult to obtain from a single farm's operations.	 Interconnections can be cost prohibitive or unavailable in remote locations. Permitting and standards can be complex.	 Generally accepted as process produces energy from waste. Odour and truck traffic can introduce public concerns.	 Mainly relevant to large livestock farms for energy cost reductions and diversified revenue. Governments interested in biogenic methane reductions.	 Provides methane mitigation, renewable energy, and digestate. Recycles nutrients and may reduce reliance on synthetic fertilizer.