A CIRCULAR AGRICULTURE AND AGRI-FOOD ECONOMY FOR CANADA

A REPORT OF THE CLEAN GROWTH IN AGRICULTURE AND AGRI-FOOD PROJECT

DECEMBER 2021

Smart Prosperity Institute

About Smart Prosperity Institute

Smart Prosperity Institute is a national research network and policy think tank based at the University of Ottawa. We deliver world-class research and work with public and private partners – all to advance practical policies and market solutions for a stronger, cleaner economy.

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EXECUTIVE SUMMARY

Achieving Canada's aggressive growth targets for agri-food exports, concurrent with making progress on the government's ambitions for a 30% reduction in methane emissions by 2030, net-zero emissions by 2050, and overall improvements in environmental quality indicators and food security means that more food will need to be produced with a smaller environmental footprint. While this is a tall order it is not impossible. Done right, it can unlock significant opportunity and create new value.

The agriculture and agri-food sector is a cornerstone of the Canadian economy, accounting for 7.4% of GDP and one in eight jobs. In 2018, it generated $59.4 billion worth of export sales, making it the fifth largest exporter of agriculture and agri-food products in the world.[1] Canada's ambition is to grow these exports to at least $75 billion by 2025.[2]

Can this growth ambition be squared with environmental goals? The sector has a significant impact on water, soil quality, biodiversity and climate. In 2019, agriculture alone contributed to 8% of Canada's GHG emissions.[3] An estimated 58% of all the food produced in Canada goes uneaten as a result of being lost or wasted across the food value chain.[4] Much of this ends up in landfill where it generates methane and contributes to another 2% of national emissions.[5] At the same time, at least four million Canadians, including 1.15 million children, are food insecure; a figure that does not even include three groups at high risk of food insecurity: people living on First Nations reserves, people in some remote northern areas, and people who are homeless.[6]

The circular economy model presents a vision for meeting the needs of an increasingly populous and wealthy global society within the safe boundaries of key ecological systems and processes.

The circular economy model presents a vision for meeting the needs of an increasingly populous and wealthy global society within the safe boundaries of key ecological systems and processes. This model has been gaining traction across the globe as a means to build a more sustainable and equitable economy. It is based on three principles: (i) eliminating waste and pollution, (ii) circulating biomaterials and products, and (iii) regenerating natural systems. These principles and their related strategies have much to offer to Canada's agriculture and agri-food economy.

This report aims to inform future research and policy recommendations to support the transition to a more circular agriculture and agri-food sector in Canada. It synthesizes academic and practitioner literature on the subject, including best practices, benefits, barriers, and policy supports.

Transitioning to a more circular agriculture and agri-food economy is a multi-dimensional and complex challenge that will require systemic change including innovations in practices, technologies, products, and business and socio-cultural practices.

Key Findings:

- The circular agriculture and agri-food model intersects with other key agricultural sector approaches, but also has distinct components. Regenerative agriculture is a key pillar of circular agriculture, however circular agriculture and agri-food also includes the processing, distribution and consumption, disposal and recovery of food. Like the bioeconomy, circular agriculture and agri-food uses biological and renewable materials, but further seeks to also prevent, recover, or repurpose waste.

- A circular agriculture and agri-food economy promises economic, environmental, and social benefits:

    - Reduced costs of food loss and waste management; increased revenue from utilizing/selling food loss and waste; and increased export-market competitiveness.
    - Improved soil quality; reduced water requirements and improved water quality; reduced GHG emissions; and decreased land conversion.
    - Improved health outcomes; lower food insecurity; and job creation.

- Transitioning to a more circular agriculture and agri-food economy is a multi-dimensional and complex challenge that will require systemic change including innovations in practices, technologies, products, and business and socio-cultural practices. This starts with smaller-scale practices which can grow into a comprehensive and complementary system overall.

- These practices take different forms in different geographies and contexts. This report identifies over 30 circular agriculture and agri-food practices, categorized into four objectives and 13 strategic approaches:

    - Rethinking production and consumption practices: by using sustainable inputs; process optimization; food loss and waste prevention; reduced and alternative material use; and sustainable consumption.
    - Intensifying the use of products: by increasing the lifespan of food; and redistributing food for human consumption.
    - Extending the life of resources: creating new food, feed, industrial and bio-economy products from food loss and waste; and material recycling.
    - Giving resources new life: by nutrient cycling; and energy cycling.

- Circular practices are hampered by many, often mutually reinforcing barriers that must be addressed across supply chains. The presence of these barriers, found in markets, finance, regulation and policy, technology and infrastructure, culture and research, presents the case for strong government intervention to effectively unleash industry initiatives for change.

- A full suite of public policy interventions, across the full innovation chain, is needed to drive a more circular Canadian agriculture and agri-food economy. This includes supporting the development of new ideas through research, competitions and challenges; financial and technical support for the development, commercialization, and demonstration of specific solutions; stimulating market demand through procurement, pricing and regulatory tools; and coordinating the ecosystem of policies, partnerships, institutions, and workforce around a shared vision for greater circularity.

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INTRODUCTION

Canada has the opportunity to further advance the dual objectives of economic growth and emissions reductions in the agriculture and agri-food sector. This report is one in a series of publications exploring strategies for how the country can seize this opportunity. The 2017 recommendations of the federal government's Advisory Council on Economic Growth (the Barton Report) called for aggressive economic growth in Canada's agriculture and agri-food sector, and that same year's budget set an ambitious target to grow Canada's agri-food exports from $55 billion in 2015 to at least $75 billion by 2025.[7] Canada has also announced ambitious greenhouse gas (GHG) emissions reduction targets of 40 to 45 per cent below 2005 levels by 2030 and net-zero by 2050 as well as support for the Global Methane Pledge, which aims to reduce global methane emissions by 30 percent below 2020 levels by 2030. Recognising the agriculture sector's contribution to GHG emissions, the 2021 Federal Budget committed to investing over the next two years, $200 million to support farmers to reduce emissions (by improving nitrogen management, increasing adoption of cover cropping, and normalizing rotational grazing), $60 million to protect existing trees and wetlands on farms, and $10 million to power farms with clean energy.[8]

It aims to contribute to the transition of Canada's agricultural and agri-food systems towards greater circularity and to inform future research and policy recommendations to support this. It does this by synthesizing academic and practitioner literature on the circular economy for agriculture and agri-food, including circular economy practices, benefits, barriers, and policy supports.

Transitioning to a more circular agriculture and agri-food sector can help realize many economic, environmental, and social benefits.

In the report that follows, Section 1 briefly reviews the importance of the agriculture and agri-food sector to Canadian employment and gross domestic product. Section 2 introduces the circular economy, its intersections with regenerative agriculture and the bioeconomy, and its potential application to create sustainable value in the agriculture and agri-food sector.

Transitioning to a more circular agriculture and agri-food sector can help realize many economic, environmental, and social benefits. Section 3 highlights key benefits identified from the reviewed literature. Section 4 outlines emerging circular economy practices that have the potential to support this transition. These practices focus on regenerating natural systems and designing out and preventing waste, as well as prioritizing food recovery for human consumption first followed by the valorization of secondary materials.

Despite the potential benefits, the application of circular economy practices and initiatives in the Canadian food industry faces many barriers that prevent these opportunities from being realized. Section 5 reviews barriers identified by sector practitioners and the academic community.

Addressing these barriers needs to be deliberate and strategic. Section 6 outlines SPI's circular innovation framework, which identifies four clusters of policies to support further innovation and implementation of a circular economy – PUSH, PULL, STRENGTHEN, GROW. It then maps recommended circular economy policies for the agriculture and agri-food sector, as identified in the academic and practitioner literature, onto this framework to reveal a menu of potential policy supports for encouraging circular practices in the Canadian agriculture and agri-food sector.

1. THE CANADIAN AGRICULTURE AND AGRI-FOOD SECTOR

The agriculture and agri-food sector is a cornerstone of the Canadian economy. The overall sector is made up of several industries: primary agriculture, food and beverage processing, food retail & wholesale, foodservice, and inputs & service suppliers. In 2018, the sector created $143 billion in value with exports valued at $59.4 billion and employed 2.3 million people. This positions Canada as the fifth largest agriculture exporter globally.[9] The 2017 recommendations of the federal government's Advisory Council on Economic Growth (the Barton Report) called for aggressive economic growth in Canada's agriculture and agri-food sector, and that same year's budget set an ambitious target to grow Canada's agri-food exports from $55 billion in 2015 to at least $75 billion by 2025.[10]

The agriculture and agri-food sector is a cornerstone of the Canadian economy. Canada is positioned as the fifth largest agriculture exporter globally.

Primary agriculture in Canada includes the production of many commodities including grain, oilseeds, red meat, dairy, seafood and fruits and vegetables. Roughly 7% of Canada's land is used as farmland and is shared amongst 193,492 farms.[11] Of these farms, 56% earn under $100 thousand annually, contributing to 5% of the sector's total revenue, while 8% earn over $1 million, contributing to 60% of sector revenue (Figure 1).[12]

Food and beverage processing is the largest employer in Canada's manufacturing sector, with 290,000 employees. This labour force is spread among 7,800 companies, mainly small- and medium-sized enterprises (SMEs): 91% have under 100 employees, 8% have 100 to 500 employees, and only 1% have over 500 employees.[15] In 2019 the industry produced $117.8 billion in value, of which 33% was exported.[16]

Figure 1: Distribution of Canadian farms across revenue brackets in 2016[13]

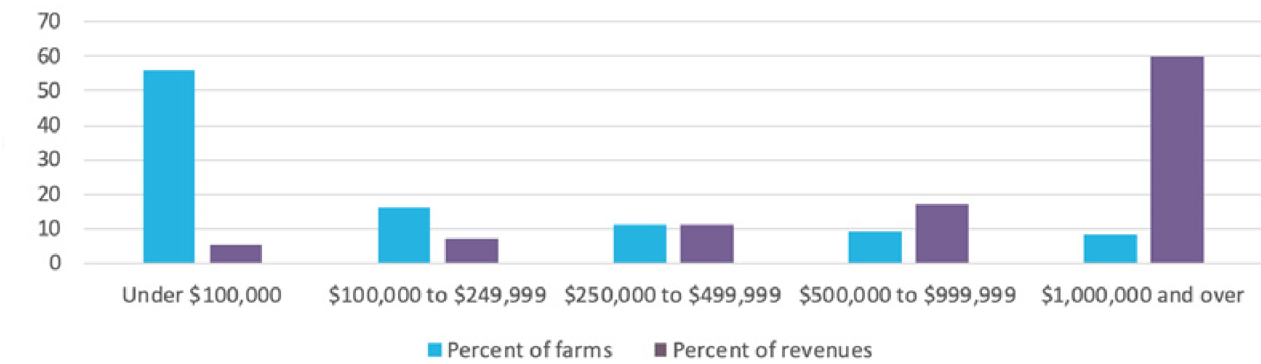
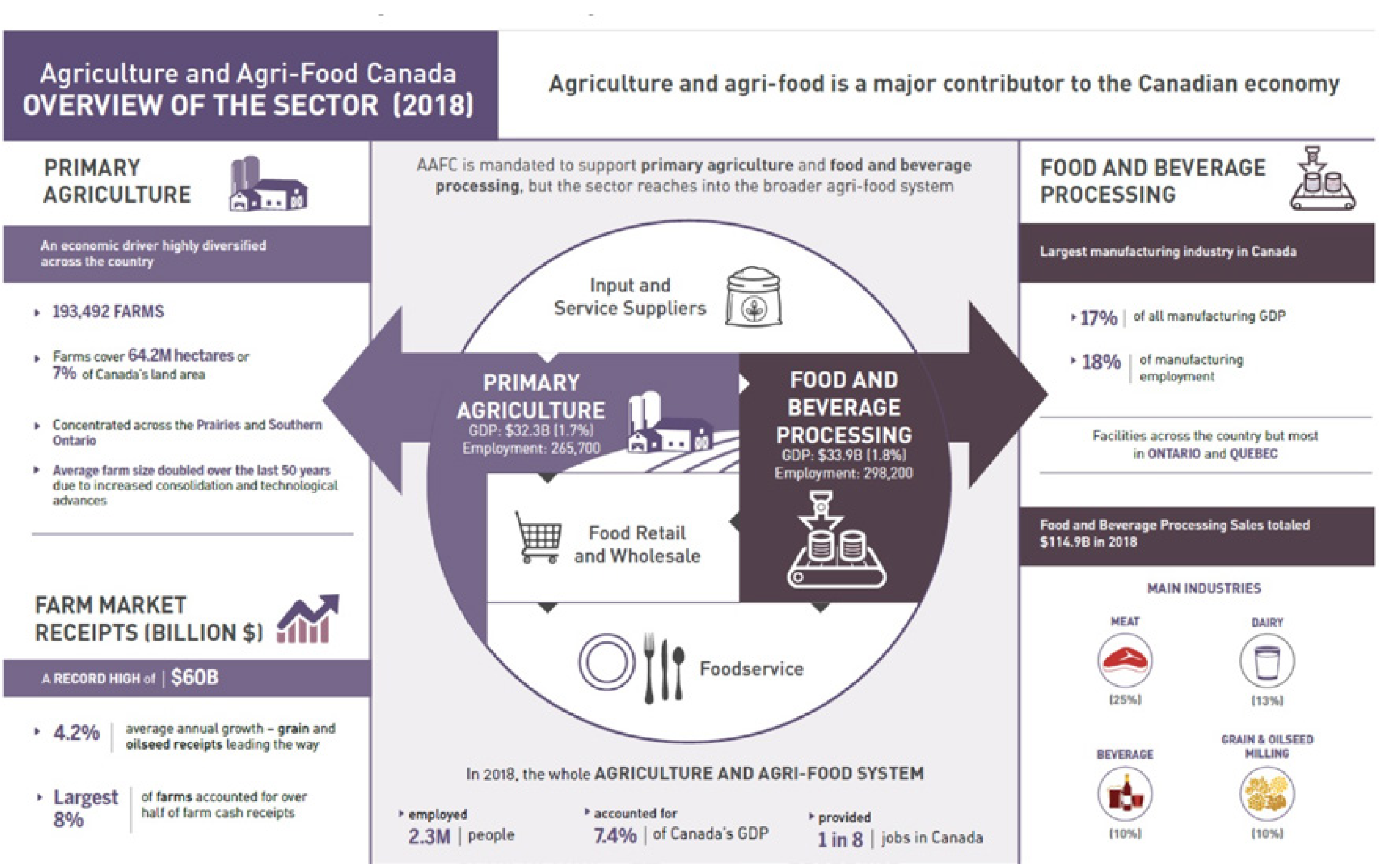


Figure 2: Overview of the agriculture and agri-food industry in Canada[14]



2. THE CIRCULAR ECONOMY

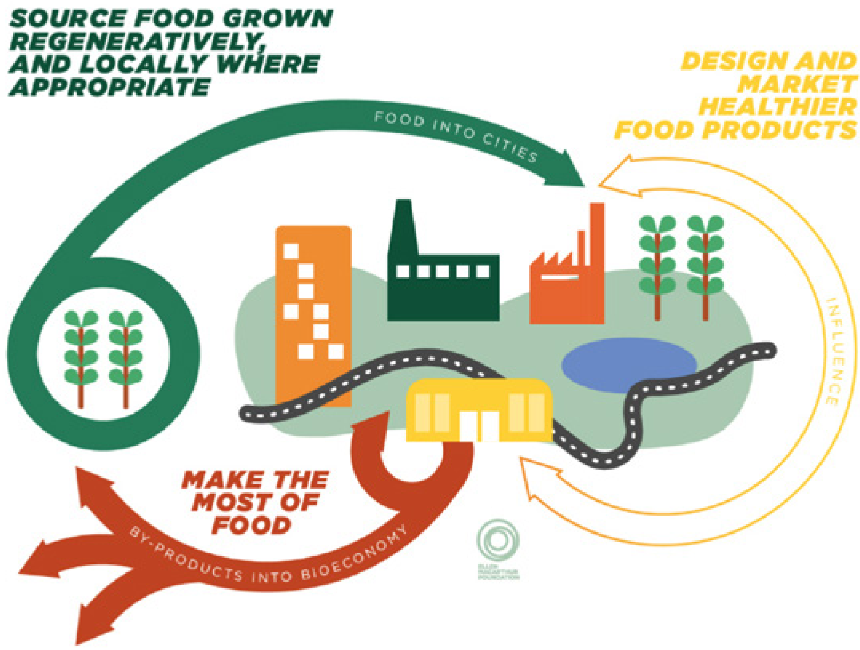
2.1. What is a Circular Economy?

The circular economy is a conceptual model that has begun to emerge in business, policy, and civil society as a response to emerging global challenges of unsustainable resource use, and the environmental impacts (including carbon emissions and other environmental degradation) that this causes. The circular economy model promotes three main principles: (i) design out waste and pollution, (ii) keep products and materials in use, and (iii) regenerate natural systems.[17] Importantly, circularity represents a potentially powerful economic strategy to capture value from current waste materials. This maximizes the value of resources and product life, minimizes the impact on the environment, and reduces the demand for virgin resources in the production system. This system design results in continuous material flow that prevents value loss (Figure 3).

The circular economy approach has been slower to advance in Canada than in European countries, which have been circular innovation leaders over the last decade and more. The European Commission has fostered the growth of a circular economy in the EU, publishing manifestos on circular economy as early as 2012, and recently implementing a Circular Economy Action Plan.[18] With abundant and comparatively low-cost natural resources and a low population density, Canada has not faced the same urgency to implement circular practices in its economy despite the potential for immense benefits. These approaches are only now coming to the fore as Canada looks to embodied carbon and scope 3 emission reduction opportunities to meet strengthened emissions reduction targets.

The circular economy model promotes three main principles: (i) design out waste and pollution, (ii) keep products and materials in use, and (iii) regenerate natural systems.

Figure 3: Ellen MacArthur Foundation's model of a circular economy for the food system[19]



2.2. Intersections with Other Key Approaches

A circular approach in the agriculture and agri-food sector has intersections with other agricultural sector approaches, such as regenerative agriculture and bioeconomy. These three strategic approaches share some core visions but have distinct components (Figure 4).

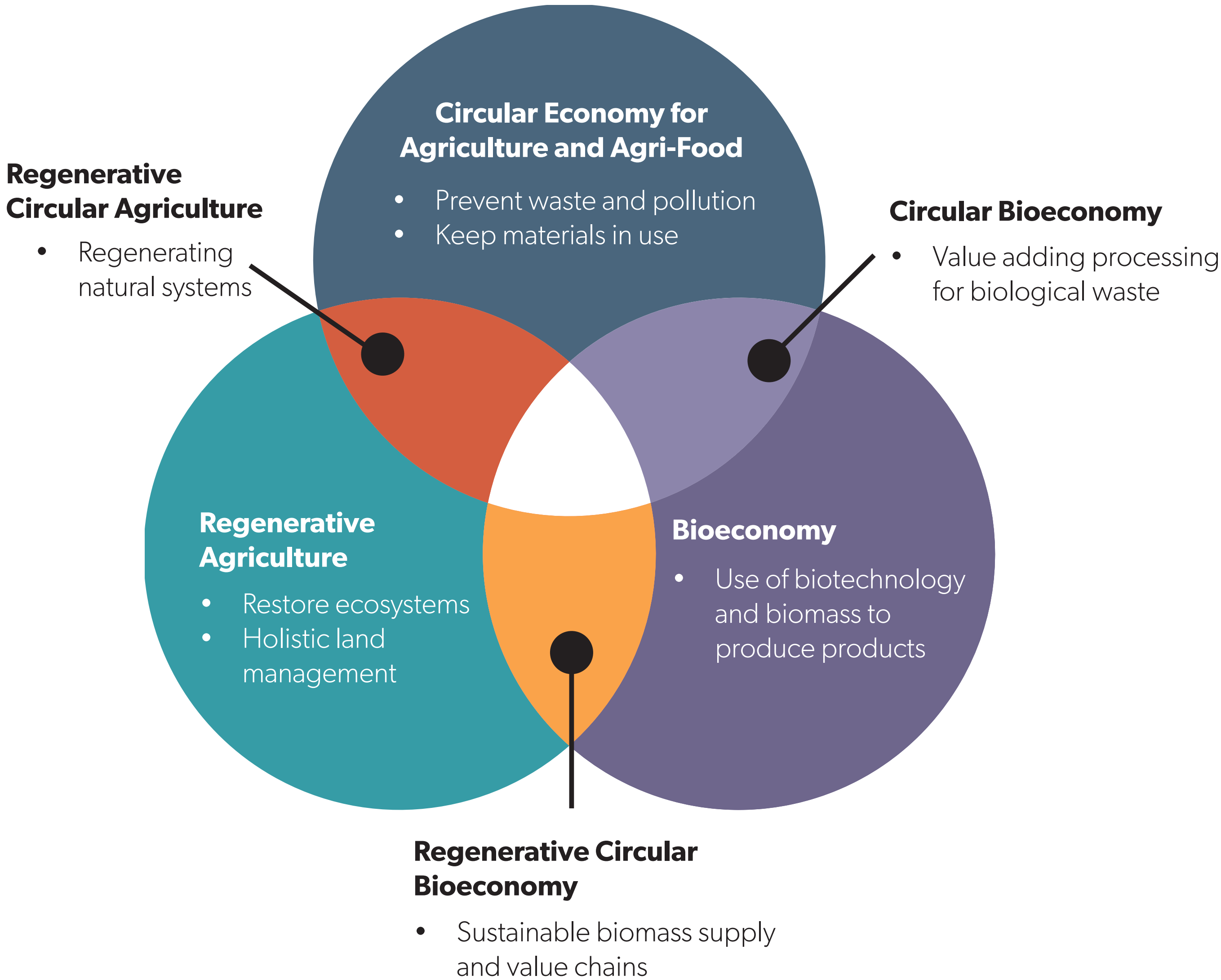
Regenerative agriculture is a key pillar of circular economy in agriculture,[20] although the circular economy is broader, also covering the processing, distribution and consumption, disposal and recovery of food. Regenerative agriculture is the practice of farming in a way that restores natural ecosystems. This is achieved through holistic management which uses the power of natural element cycles to reverse and prevent ecosystem damage through human activities.[21] Select regenerative practices include no-tillage, cover cropping, crop rotations, soil amendment with compost and/or manure and strategic grazing.[22] Benefits of such practices include improved soil quality, increased carbon sequestration to the soil, improved biodiversity of soil microbes, insects and plants, and reduced run-off, reduced soil erosion.[23]

The concept of the bioeconomy shares the circular economy goal of using biological and renewable materials but lacks the circular economy emphasis on also seeking to prevent, recover, or repurpose waste. The bioeconomy encompasses all industries that deal with biological materials at different stages of the value chain: for example, agriculture, forestry and fishing at the primary stage; food processing, textile manufacturing and biotechnology in the processing stage; and retail and resource management in the consumption stage. It focuses on supporting the economy with more bio-based resources by integrating them in processes and products that have customarily used inorganic resources.[24] Agriculture and agri-food can support the bioeconomy strategies of other industries by providing feedstocks and other resources.

Circular economy principles can be implemented through the entire supply chain from primary production to consumption and waste disposal, which requires a systemic perspective and the participation of stakeholders at every level.

Circularity in agriculture and agri-food can regenerate the natural systems that support agriculture, prevent food waste and pollution, and capture lost value. Unnecessary use of virgin resources is avoided by searching for opportunities to create new sustainable value from what is currently considered "waste" and capturing the highest value of all resources in the system. The circular economy in agriculture and agri-food is highly multifaceted, drawing on innovative technology, research and development, regenerative farming practices, public awareness, community involvement and more. Circular economy principles can be implemented through the entire supply chain from primary production to consumption and waste disposal, which requires a systemic perspective and the participation of stakeholders at every level.

Figure 4: The intersection of circular agriculture and agri-food economy, regenerative agriculture, and the bioeconomy



Regenerative Agriculture

Regenerative agriculture is a holistic approach to agriculture production that uses alternative farm practices to conventional farming. The practices and boundaries of regenerative agriculture are subjective, though many of the core ideals remain consistent. Regenerative agriculture, as a movement, has roots dating back to the late 1980s with the approach gaining traction since.[25] The core principles of regenerative agriculture are i) improve soil health, ii) improve water quality, iii) increase biodiversity, and iv) reverse climate change.[26] However, these practices are not necessarily new and in many cases were practised by older generations and Indigenous communities before industrial agriculture took root.

Regenerative agriculture reduces the environmental impacts of agriculture through practices such as no-till or reduced-tillage soil management, strategic crop management, organic inputs and integrated livestock practices. Tilling is the practice of turning over the first 6 to 10 inches of soil before seeding. Doing this leaves bare soil and disrupts its natural structure leading to increased erosion and runoff. No-till practices can play a role in contributing to each of the regenerative agriculture principles. For instance, no-till results in improved soil organic matter, reduced erosion, decreased GHG emissions, and improved biodiversity.[27] Strategic crop management is also a core practice of regenerative agriculture, in the form of cover cropping, crop rotations and intercropping, which can increase the organic matter content of soils, soil fertility, reduced pest presence, and improved yields.[28] Regenerative agriculture also strives to minimize the input of synthetic compounds favouring the use of organic fertilizers, including the application of manure, biosolids or compost. The use of organic soil amendments also benefits the microbial biodiversity of the soils and improve the organic content of the soil leading to more resilient soils.[29] Keeping livestock allows farmers to supplement income when leaving a field to pasture for a rotation or when using cover crops.[30] The manure produced by these animals can be used as a fertilizer, reducing the reliance on synthetic fertilizers. In the overall system, livestock are credited with providing beneficial ecosystem services such as reducing erosion, increasing carbon sequestration, and increasing biodiversity.[31]

Regenerative agriculture and its practices play a key role in a circular agriculture system.[32] The implementation of regenerative agriculture can reduce the number of synthetic inputs required. Synthetic fertilizer application can be reduced by using organic fertilizers and rotating diverse and nitrogen-fixing crops. The application of pesticides can be reduced by using crop rotations to minimize the success of pest species. By reducing the need to input these substances, circularity is improved as the production of these substances is highly energy-intensive, the use of virgin resources is lowered, and the pollution risks of pesticide inputs are reduced. Additionally, the use of no- and reduced-till soil management helps preserve soil through reduced erosion, sequesters carbon, improves water retention, and reduces the emissions of GHGs from fossil fuels burned to operate ploughs. Overall, regenerative agriculture plays an important role in achieving aspects of circularity at a farm level and offers farmers the opportunity to reduce inputs and optimize ecosystem services.

The adoption rate of regenerative agriculture in Canada is not known but many farmers are already implementing select practices (e.g., reduced- or zero tillage). The Canadian government supports research on regenerative agriculture best practices through the Living Laboratory initiatives in the Eastern Prairies,[33] as well as financially assisting farmers in the process of transitioning to environmentally friendly farming practices through the Canadian Agricultural Partnership. Some of the programs vary provincially but can include cost-sharing for cover cropping, use of organic soil amendments, reduced or no-till practices and many others.[34]

The Bioeconomy

There are many definitions of the bioeconomy. In the broadest sense, a bioeconomy is all sectors and systems that rely on biological resources (animals, plants, micro-organisms and derived biomass, including organic waste), their functions and principles.[35] This is the definition presented by the European Commission and used in Canada's Bioeconomy Strategy by Bioindustrial Innovation Canada.[36] Other definitions put more focus on the role of innovation when defining the bioeconomy. The OECD, for example, defines bioeconomy as, "transforming life science knowledge into new, sustainable, eco-efficient and competitive products".[37] Due to this lack of consistency, the scope of what is considered as the bioeconomy may differ between countries. However, for the most part, food production and security play a large role in bioeconomy strategies.

The bioeconomy and the circular economy are conceptually linked since shifting from non-renewable resources to biomaterials is an important aspect of the circular economy.[38] Bioeconomy practices that can contribute to the development of a circular economy include the creation of biofuels, bioenergy, innovative bio-based products such as textiles, composites, pharmaceuticals, and chemicals.[39] Biofuels and bioenergy, a lower-carbon substitute for fossil fuels, can be created through the industrial processing of lumber, crops such as soy and corn, used or virgin plant oils, and food waste. [40] There are also many innovations in bio-textiles and bio-composites made from purpose-grown crops including perennial grasses, hemp and flax.[41]

The Canadian Agricultural Partnership supports the development of bioeconomy opportunities in Canada's agricultural industry.[42] As of 2015, Canada had 5,618 individuals employed in the bioeconomy sector, producing biofuels, plant-based plastics, biocomposites and chemicals. These activities produced $4.27 billion in revenue.[43] In 2019, the BioDesign consortium published a national bioeconomy strategy with Bioindustrial Innovation Canada, Forest Products Association of Canada, FPInnovations, BIOTECanada, and BioNB.[44] This laid out the industry's vision for achieving the highest value for Canadian biomass and residuals alongside reducing the carbon footprint of these activities.

Given Canada's large biomass stock and skilled workforce, continued growth in the sector is expected as Canada aims to become one of the world's most competitive bioeconomies.[45] This in turn is likely to increase the demand for feedstock from the agriculture and agri-food sector and support for circularity.

Sustainable Value Creation from Food Loss and Waste

While designing out waste is a key principle of the circular economy, the generation of some food waste is inevitable in the agriculture and agri-food sector. However, this represents a tremendous opportunity for new value creation.

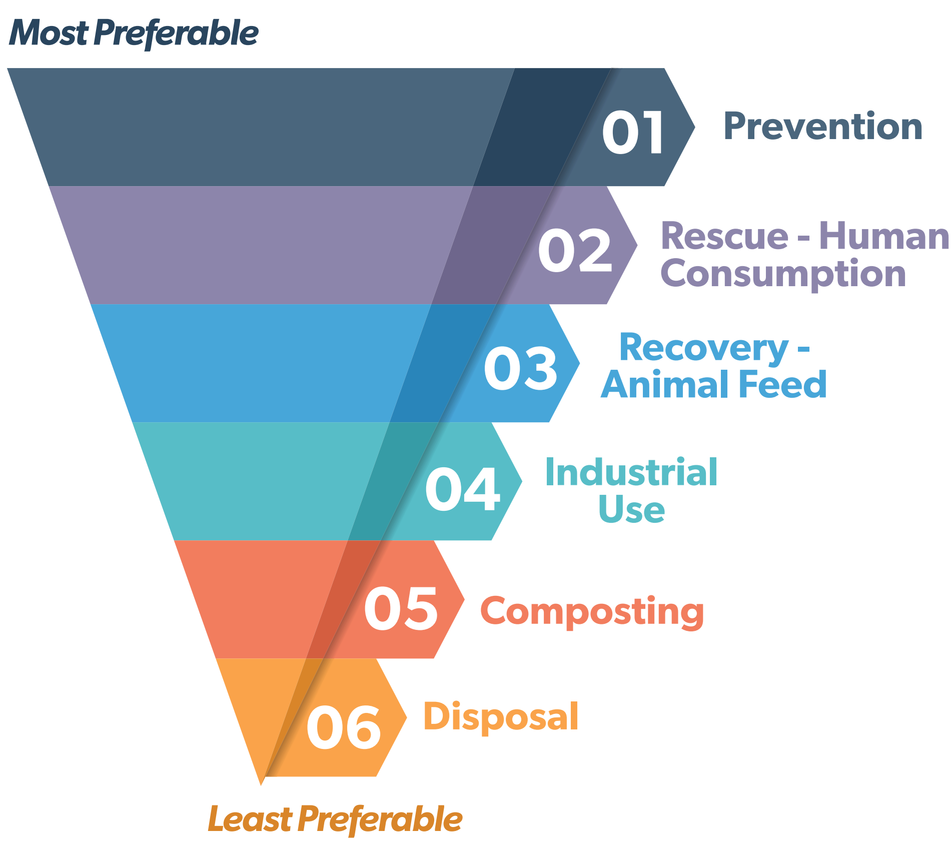
According to the Commission for Environmental Cooperation, food loss and waste (FLW) represents the total amount of food in the supply chain that is not consumed. Food loss is defined as food that is intended for human consumption but, through poor functioning of the food production and supply chain, is reduced in quantity or quality and, therefore, discarded. This includes food that is not harvested, that spoils during distribution or is disposed of due to food grading during the processing stage. Food waste is defined as food for human consumption that is discarded (both edible and inedible parts) due to intentional behaviours.[46] Examples include food thrown away by retail stores, catering businesses, hospitals, and schools, as well as household waste.

Food loss: food that is intended for human consumption but, through poor functioning of the food production and supply chain, is reduced in quantity or quality.

Food waste: food for human consumption that is discarded (both edible and inedible parts) due to intentional behaviours.[47]

There exist many avenues to realise value from FLW. Many organizations that strive to recover food loss and waste use a food recovery hierarchy to guide decision making regarding recovery choices. This hierarchy (presented in Figure 5) prioritizes actions taken to recover FLW in a way that seeks to simultaneously optimise environmental, social and economic value. The first step is prevention, and all stakeholders have a role. For farmers, this could be better demand forecasting, sourcing network opportunities for labour shortages etc. For retail stores, it could be enhanced forecasting of sales. In hospitality and restaurants, source reduction could be achieved by conducting waste audits to identify and prevent waste, and at a household level, source reduction could involve meal planning and shopping using a grocery list. Surplus food, which is defined as food that is not being used for its intended purpose but is still safe for human consumption, can be rescued for human consumption and donated or processed into a product with higher demand or a longer life span.[48] Food not suitable for human consumption can be fed to animals as food scraps or processed into animal food products, where laws and regulations permit. Resources that are fit for neither human nor animal consumption can be rerouted into industrial processing. This can include the capture of bioenergy and biofuels, the production of biocomposite products, biotextiles and other bioproducts. Any remaining organic products can be composted to reclaim the nutrients. The last resort, for resources not suitable for composting, is landfill.

Figure 5: Food waste hierarchy adapted by authors from Commission of Environmental Cooperation; United States Environmental Protection Agency & Teigiserova et al. [49]



FLW occurring annually along the Canadian food value chain is estimated to be 35.5 million tonnes, accounting for 58% of total food produced (Box 1).[50] Of this, 32% is thought to be avoidable and is valued at $49.46 billion- representing a tremendous opportunity to recover value.[51]

FLW has been a long-recognised issue in Canada, with several government initiatives undertaken for mitigation. Under the *Strategy on Short-lived Climate Pollutants* (2017), Canada committed to consulting on strategies to reduce avoidable food waste, in a bid to reduce methane emissions from landfills. Canada's *Food Policy* (2019) includes a challenge to fund the most innovative food waste reduction proposals from farm to plate. It also includes an initiative to support leadership by the federal government to cut its own food waste.[52]

Box 1

Sustainable value creation from food loss and waste: the Canadian opportunity

The exact amount of food loss and waste (FLW) in Canada is not officially measured, but 35.5 million tonnes is a broadly accepted estimate, representing 58% of all food produced in Canada.[53] Of this, 32%, or 11.17 million tonnes valued at $49.46 billion, is considered avoidable: food that was produced as an edible food product that was never consumed. The balance, 68% or roughly 24.3 million tonnes, is classified as unavoidable: by-products of an edible food product that are not edible themselves, such as animal bones.[54]

FLW is produced at every stage of the food industry supply chain. However, the proportion of total FLW and avoidable FLW varies. Total FLW is greatest at production and processing stages: an estimated 24% and 34% of total FLW in Canada is estimated at these stages, respectively [Figures 6 & 7].[55] The largest sources of avoidable FLW are manufacturing, household, and processing waste at 23%, 21% and 20% of avoidable waste, respectively.

In addition to the creation of new sustainable value, the benefits from lessening FLW include reducing the 4% of Canada's GHG emissions estimated to come from organic waste, largely food, in landfills,[56] reducing air pollution and water use, and increasing food availability.[57]

Figure 6: Tonnages and percentage of total food loss and waste in Canada throughout the supply chain.[58]

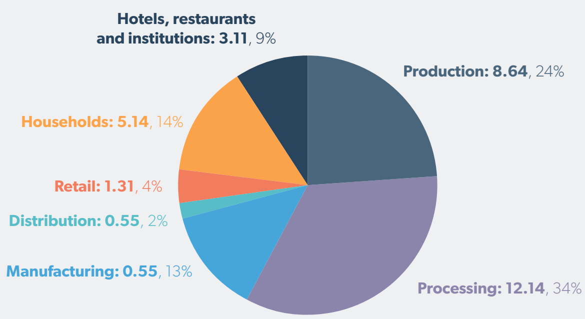


Figure 7: Tonnages and percentage of avoidable food loss and waste in Canada throughout the supply chain.[59]

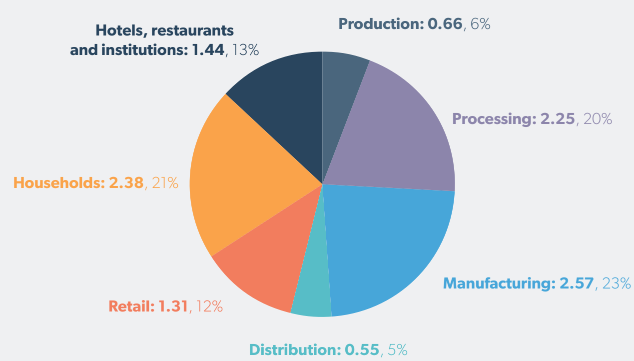
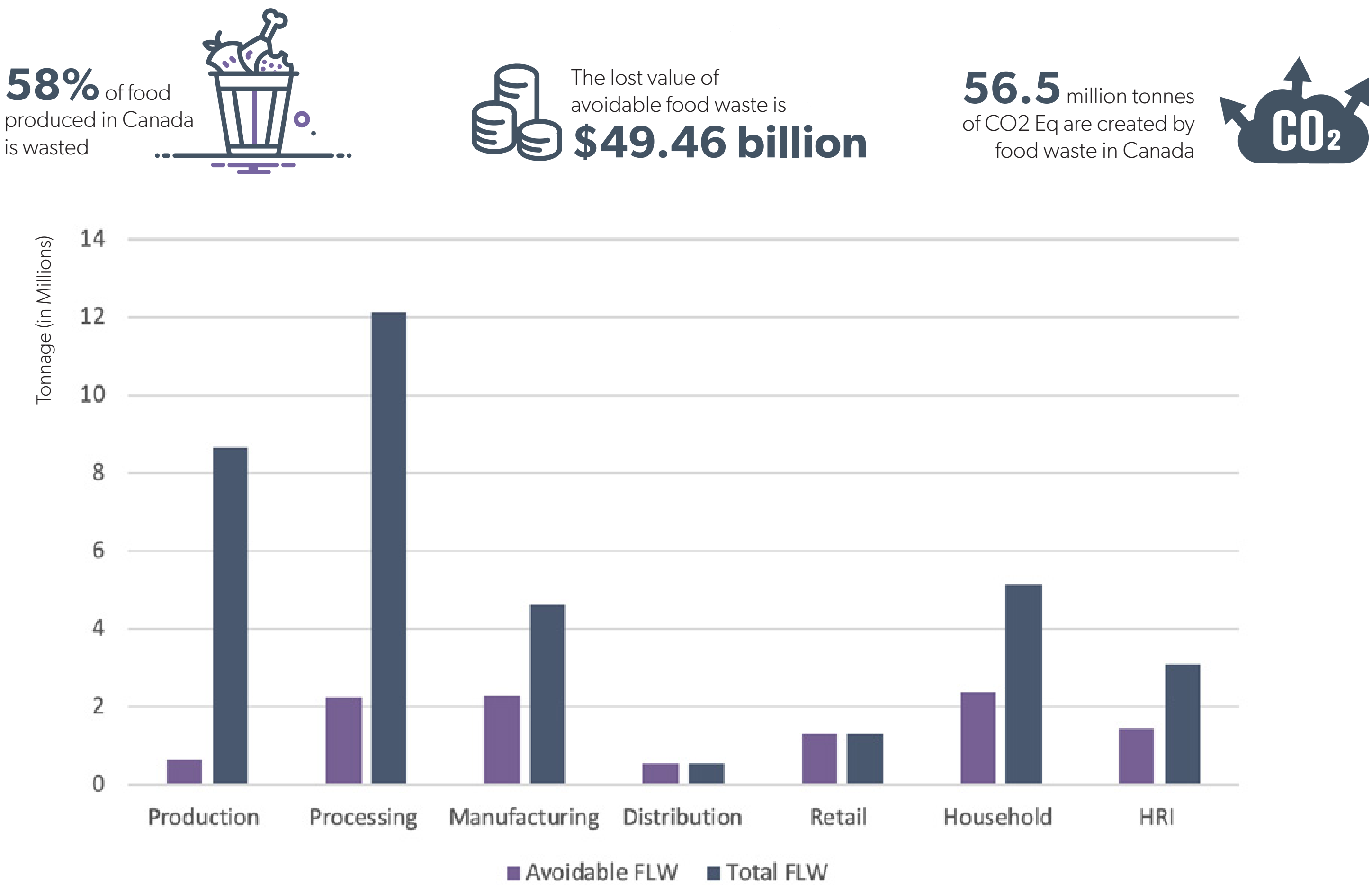


Figure 8: Overview of food loss and waste in Canada[60]



3. BENEFITS OF A CIRCULAR AGRICULTURE AND AGRI-FOOD ECONOMY

Transitioning to a more circular agriculture and agri-food sector promises many benefits to the economy, the environment, and society. The following highlights key benefits, identified through a literature review.

3.1. Economic Benefits

During the COVID-19 pandemic, many businesses have recognized the need to consider the resilience and competitiveness of their supply chains. Implementing circular practices in the food industry can offer many advantages, including enhanced supply chain security, economically efficient production, new opportunities for value creation, novel consumption experiences for consumers,[61] and additional sources of revenue for businesses from the sales of by-products.

Transitioning to a more circular agriculture and agri-food sector promises many benefits to the economy, the environment, and society.

Reclaiming Lost Resource Value

Resource loss along the agriculture and agri-food supply chain is largely considered business as usual. But over time the cumulative cost of these untapped resources adds up and makes reclaiming this lost value appealing to businesses. In Canada, avoidable food waste is valued at $49.46 billion.[62] Globally, the value of food waste is estimated to be up to USD 1 trillion.[63] While there are costs associated with reclaiming the value of these resources, such as labour, processing and transportation, there can also be sizeable payoffs to realizing the value of these resources.

Circular practices implemented along the agriculture and agri-food supply chain can help realise this value. For example, the direct additional GDP contribution of harvesting left in field crops in Canada has been estimated at $1.4 billion.[64] Avoidable and unavoidable food waste can be used as inputs for bio-based products. These products are often highly innovative and provide significant value creation. Examples of bio-based products include bio-textiles, biofuels, bioplastics and bio-composites. Finally, value along the agriculture and agri-food supply chain can also be optimized by increased resource efficiency through better water conservation and energy efficiency, process efficiencies that lead to savings in energy and water use. For example, the Sons Bakery in Brampton, Ontario, working with the Provision Coalition, lowered the use of electricity by 12%, natural gas by 6% and water consumption by 4%, and achieved zero waste to landfill, saving $45,000 annually.[65]

Export-market Competitiveness

Canada's agriculture and agri-food sector is export oriented: 35% of unprocessed agriculture resource are exported, as well as 37% of processed agriculture and agri-food resources. In the 2017 federal budget, Canada set the goal to increase agriculture exports to at least $75 billion by 2025.[66] In 2018, the value of these exports stood at $59.4 billion.

As the global demand for sustainably produced goods rises, the OECD has identified increasing interest and potential for the circular economy to boost international trade.[67] Therefore, accelerating the adoption of circular practices in the agriculture and agri-food sector, specifically in the primary production, processing, and manufacturing industries, can create opportunities to increase the competitiveness of Canadian products in the international export market. It may also help reduce the likelihood of facing future barriers to international trade and contribute to national economic growth.[68]

3.2. Environmental Benefits

Circular practices in the agriculture and agri-food system have documented environmental benefits, such as improved soil quality and water quality, reduced GHG emissions and decreased land conversion.

Soil Quality

Soil quality is an important indicator for the sustainability of agriculture operations. A farm with good soil quality has the potential for improved yield, higher resilience, and increased biodiversity. Farms without good soil quality may be indicated by low organic matter, high levels of erosion, low water holding capacity, and reduced soil depth. Conventional farming can result in soils that are of lower quality and rely heavily on the application of fertilizers.

Implementing a circular approach to primary agriculture production facilitates the development of higher quality soils, through the application of regenerative practices.[69] No-till soil management for example can improve soil organic matter, reduce erosion and increase the water holding potential of soil. Cover cropping can improve soil organic content, reduce erosion, increase soil fertility, reduce pest presence, and improve yields. Such practices help deliver more resilient and consistent yields with fewer inputs. Over the past five decades, Canadian farmers have been significantly reducing the amount of tilling and fallowing on their land which has led to an increase in soil organic matter from an index value of 48 in 1981 to 74 in 2011.[70]

Water Quality

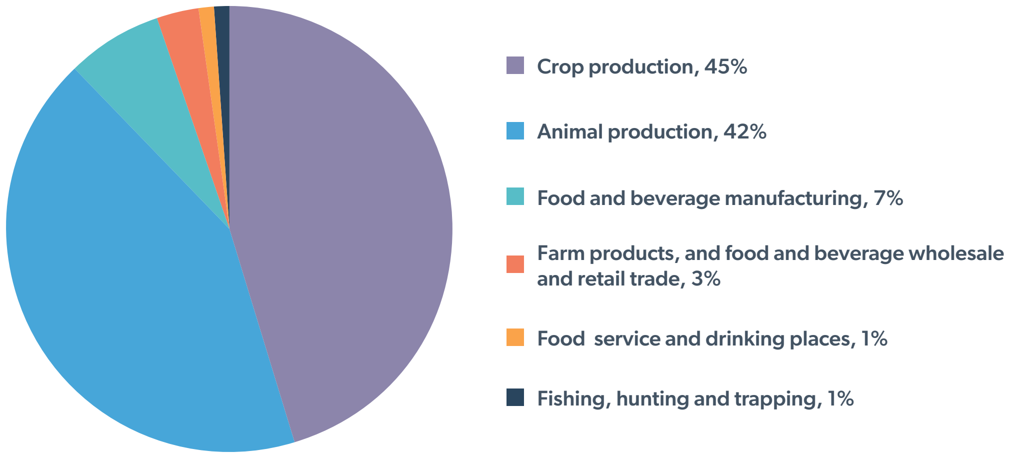
Water quality can deteriorate from excess nutrient loading as a result of fertilizer application or livestock operations or pesticide contamination.[71] Excess nutrients can lead to algae blooms, which cause dead zones that negatively impact the aquatic and non-aquatic ecosystems that depend on this water. This also impacts water potability.

The application of circularity and regenerative agriculture practices reduces the need for pesticides, while regenerative practices combined with precision application techniques reduce the likelihood of fertilizer over-application. This in turn can minimize leaching and the runoff of substances to waterways, thereby improving ecological health as well as crop yield.

Food processing and manufacturing may also contribute to deteriorating water quality. Wastewater from these stages of the supply chain can be high in fats, suspended solids, nutrients, and chemicals, depending on the production.[72] Food processors commonly release wastewater to the public water treatment system to be treated by the municipality before being released to the environment.[73]

Circular economy practices can help improve the quality and reduce the quantity of wastewater produced. For instance, starch can be recovered from wastewater in potato processing plants to improve the wastewater and recover value through additional resource streams.[74]

Figure 9: Direct emissions for food-related industries by final demand, 2015 [75]



Greenhouse Gases

The agriculture and agri-food sector emits greenhouse gases at all stages of the supply chain.[76] In 2019, the agriculture sector contributed to 8.1% of the total CO_2e emitted in Canada.[77] A majority of these emissions are generated during crop production and by livestock (Figure 9).[78] Food waste emit 56.5 million tonnes of CO_2e, of which 22.2 million tonnes is deemed potentially avoidable and 34.3 million tonnes as likely unavoidable.[79] Sources of GHGs in agriculture and agri-food supply chain include burning of fossil fuels for machinery for primary production (tractors and vehicles), transportation (trucks, generators for climate control), and the generation of electricity for food processing (milling, baking, drying), storage (refrigeration), and retail (refrigeration, lighting). Additional emissions come from soils as a result of microbial activity that increases with fertilizer application, from ruminating livestock, and from the decomposition of organic waste.

A more circular agriculture and agri-food system can reduce GHG emissions through various pathways. By encouraging the use of renewable energy, the circular economy can reduce the dependence on fossil fuels for various uses through the agriculture and agri-food economy. Regenerative agricultural practices such as no-till and cover cropping can reduce emissions from soil. Further, the use of production inputs made from waste material can reduce the overall energy required for production. Increasing process optimization during processing, manufacturing, transportation and distribution can also lead to energy efficiency. Finally, reducing food loss and waste can reduce methane emissions from organic waste decomposition in landfills.

Land Use

A potential impact of the Canadian government's goal of increasing agricultural and agri-food exports is that more land may be converted to agriculture. In Canada, the total area of farms has been relatively consistent, declining slightly between 1996 and 2016 from 168 million acres to 158 million acres.[80] This has been managed by increasing productivity. However, the increase in production to reach Canada's export goal may well require converting new land for agriculture use. This would result in emissions of carbon stores and biodiversity losses.

The application of circular practices at the primary production level can minimize this land-use effect. Researchers at Wageningen University in the Netherlands stress that applying circular economy principles to agricultural production can increase productivity and resilience, thereby reducing the amount of land needed to produce the same amount of food.[81]

3.3. Social Benefits

Social benefits that emerge from the implementation of circular practices in the agriculture and agri-food sector economy come indirectly out of enhanced environmental health, increased availability of food and the creation of jobs.

Health

Agriculture provides Canadians with healthy food to eat. However, some of the effects of agriculture can result in negative impacts on human health. Health complications can arise from exposure to environmental factors such as pesticides, air pollution, and contaminated water. Those most at risk of experiencing these health complications have close contact with a high concentration of containments (including farms), live in areas of high manufacturing, and experience contamination of drinking or recreational water sources. While many communities have access to carefully treated potable water, there are still communities, including Indigenous and rural communities, that do not have access to safe drinking water because of agricultural run-off.[82]

Using regenerative agriculture, holistic pest management approaches such as strategic crop rotation can reduce the application of pesticides. Precision agriculture can reduce the quantity of amendments required when these are needed, and the likelihood of exposures. Reduced application of agri-chemicals reduces the risk exposure of the general public as well as those working closely with these substances.

Resources that would become food waste also have the opportunity to improve human health. Innovations in using food wastes and by-products are creating health-promoting products such as supplements and probiotics, and medicine. For example, GSK pharmaceuticals can use bread and potato wastes to create medical-grade glucose, a key ingredient for many of their products.[83]

Food Availability

In 2018, 1.2 million households in Canada experienced food insecurity,[84] a number that has increased since the onset of the Covid-19 pandemic. In response, the Canadian Government has allocated increased funding to support food initiatives, including $8.9 million to Second Harvest, Canada's largest food rescue charity.

Although increased circularity and food rescue in a food system does not guarantee increased food security for its members, it can increase food availability for redistribution to those in need. If all rescued edible food were to end up on plates, it would feed 260 million people in North America.[85] A circular food economy can potentially increase food affordability for low-income communities by lowering the cost of food through lower production costs and increased resource utilization, while also increasing opportunities to purchase discounted food.[86]

A more circular agriculture and agri-food system can reduce GHG emissions through various pathways.

Job Creation

The International Institute for Sustainable Development (IISD) suggests that economic activity pursued according to the principles of circular economy can create job opportunities and reduce regional inequalities beyond the possibilities available in the traditional linear economy.[87] Jobs will be created by the new circular and social enterprise businesses developed to take advantage of zero-waste or value-added opportunities (e.g., creating new products from waste streams, such as fresh juices and beer varieties made from food scraps) and product-as-a-service business models. Research by Canada's National Zero Waste Council has found that the implementation of circular practices can create a significant number of jobs specifically related to primary agricultural production in Canada. Just under 30,000 jobs (9,370 direct and 20,964 indirect) could be created by addressing left-in-field crops, alone.[88]

4. CIRCULAR STRATEGIES AND PRACTICES

A transition to a more circular agriculture and agri-food sector will require a system-wide shift that begins with smaller-scale practices and grows into a comprehensive and complementary system overall. Knowing that implementation of new or different practices and relationships will take time, initial support for the adoption of actionable circular practices can build trust in the principles of circular economy and stimulate further growth and development. This transition approach is reflected in the majority of the literature.

To highlight the opportunities for circularity in the existing system, the authors have reviewed key Canadian and international reports addressing circular economy in agriculture and agri-food and have synthesized key circular strategies and practices recommended in this literature. These have been organized and presented in an adapted framework from RECYC-Quebec's work in collaboration with Institut EDDEC, on the circular economy in the food sector.[89]

Thirteen strategic approaches and 34 practices specific to the agriculture and agri-food sector were identified, and organized according to the four overarching objectives of the RECYC-Quebec/ Institut EDDEC framework:

- Rethinking production and consumption practices
- Intensifying the use of products
- Extending the life of resources, and
- Giving resources new life

In addition, to focus these actions on applicable stakeholders, the sub-section for each objective concludes with a table mapping these practices onto the supply chain stages of primary production, manufacturing & packaging, distribution & retail, consumption, and waste recovery (Figure 8).

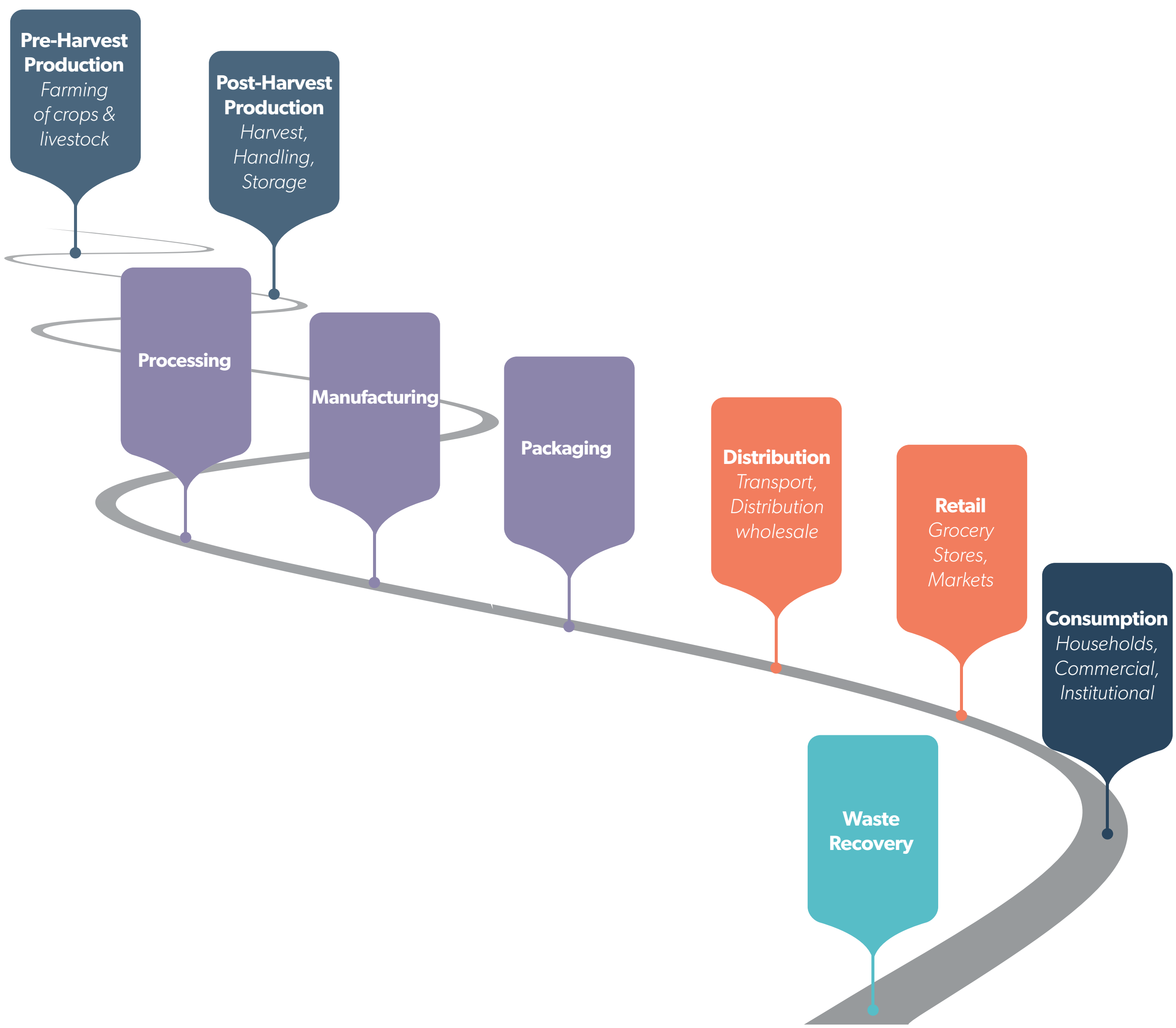
4.1. Rethink Production and Consumption of Resources

Key strategies for rethinking production and consumption of resources includes sustainable production inputs, process optimization, food loss and waste prevention, rethink and reduce material uses, and rethinking consumption.

Sustainable Production Inputs

The use of sustainable production inputs can help maintain a closed nutrient cycle in agriculture. Inputs for crops or pastures can include manure and **fertilizer created from composted organic waste**.[90] It is also possible to produce **fertilizer from recovered nutrients** including from agricultural run-off

Figure 10: The agriculture and agri-food supply chain



recovery and wastewater recovery (Box 2). Organic waste can also be used to **create pesticides from food waste**. [91] For example, food scraps can be used to culture the bacteria bacillus *thuringiensis* which is a popular active ingredient in bacterial pesticides. Another example is the use of by-products from olive milling which can effectively protect against fungus, weeds and nematodes.[92] These kinds of sustainable production inputs help maintain a closed-loop production system.

Another circular practice is the **creation of livestock rearing inputs from waste**. This can include the use of crop residues and food waste products as animal feed, or the use of dried anaerobic digestate to be used as bedding instead of crops such as straw.[93]

Process Optimization

Optimizing the use of resources in production as well as processing and manufacturing can increase the circularity of the supply chain by lowering the requirement for virgin inputs and reducing the generation of waste and pollution. As discussed in Section 2.2 **regenerative agriculture** is a key pillar of the circular agriculture economy. By applying regenerative practices, farmers can stabilize yields while increasing crop resilience. **Precision agriculture** makes use of technologies to gather information about agronomic and environmental conditions to optimize input use**.** This can be supported using remote sensing, drones, and artificial intelligence (Box 3). These practices reduce the cost of inputs and prevent the likelihood of runoff and emissions from the soil.[95]

In agri-food processing and manufacturing, process optimization practices can reduce environmental footprints as well as operating costs. Food processing typically requires a large amount of water and energy. Implementing water management strategies for **efficient water use** can minimize water use, reclaim water where possible, and treat wastewater.[96] Similarly, **energy efficiency** practices and the use of **low-carbon energy sources** can be put in place to reduce fossil fuel-based energy use and costs. [97] The use of renewable energy sources is another key pillar of the circular economy.

Box 2

Phosphorus Recovery [94]

Phosphorus (P) is a non-renewable resource, which has limited geographical availability. Because Canada has only negligible available phosphorus reserves, it is at risk for market supply and price fluctuations.

Phosphorus is an essential nutrient for all living things, meaning that plants and animals need to consume it from their environment. Due to this, a large amount of the phosphorus that gets imported is used to produce fertilizers. However, the application of fertilizer can result in nutrients being lost through runoff to watercourses, where the effect on the environment can be detrimental. An excess of phosphorus in a body of water can cause algae blooms to occur, releasing toxins into the aquatic ecosystem.

In Canada, research into nutrient recovery has been led by Dr. Richard Grosshans with the International Institute for Sustainable Development and has primarily been focused on the Lake Winnipeg watershed. This research, completed over the past twenty years, has focused on the use of cattails planted in wetlands and watersheds to capture excess nutrients, as cattails are particularly efficient at taking up phosphorus. The cattails are harvested from nutrient overloaded watersheds, which removes some of the excess nutrients. The biomass from the cattails is then available to be used as a feedstock for various forms of bioenergy, including anaerobic digestion and clean energy pellets. Once used to generate energy, the by-product, i.e. digestate or ash, can be used to recover the phosphorus and has the opportunity to be applied back to the agriculture industry as a fertilizer. The cattail biomass costs less than wheat and grain bioenergy feedstocks, and just above the cost of wood. The affordability of the feedstock is due in part to the lack of inputs that are required. In some jurisdictions, further economic value can be realized by the producers through generation of carbon offset credit for the use of a low carbon energy source.

Box 3

Agricultural Drones

To facilitate the activities of precision agriculture, drones are increasingly being used. Some of the abilities of agricultural drones include crop spraying, spot spraying, crop mapping and surveying, irrigation monitoring and management, livestock monitoring and seed planting.

With global supply chains become increasingly complex and opaque, strategically **shortening supply chains for specific commodities** may help build resilience and efficiency. Diversifying local food production to meet the needs of cities and communities within the peri-urban area can reduce the need to import products, increase opportunities for local industrial symbiosis, limit the use of fossil fuels for distribution, and minimize the amount of packaging required for some food products.[98]

Additionally, establishing **functional linkages** between the agri-food sector and other economic sectors can support circularity through network development and coordination of stakeholders (Box 4). Continued stimulation and support for sector linkages and networks can encourage further circularity and improve the functionality of programs and frameworks that are already in place.

Box 4

Functional Linkages in Canada's Agriculture and Agri-food Sector

Canada's agriculture and agri-food sector have a number of emerging networks, which work to encourage functional linkages with the sector. Including the Canadian Food Innovators Network (CFIN) which expands strategic connection and collaborations in Canada's food innovation industry. The Canadian Agri-Food Automation and Intelligence Network (CAAIN) which strives to make connections between technology corporations and agri-food companies to drive growth, and the Canadian Agricultural Partnership program. which provides investment for further growth and development of Canada's agriculture and agri-food sector.

Food Loss and Waste Reduction

As highlighted in Section 2.2, food loss and waste is a major challenge in the agriculture and agri-food sector. One practice to reduce food loss and waste generated from primary production through retail is improved **demand forecasting.** Accurate food demand forecasting using artificial intelligence technologies have been shown to prevent food loss and waste by eliminating excess crop production or product distribution, or by providing the opportunity to find alternative markets for excess food.[99] This can also help farms to plan for hiring seasonal labour. Unharvested food is, unfortunately, a common occurrence in the agricultural sector. Even with access to affordable labour, some crops go unharvested because they are unwanted due to excess yield, deterioration of purchasing contract, or abnormal crops that have a low food grading.[100] In these cases, **building gleaning networks** can reduce food waste by helping donate farm produce that would otherwise be left to rot or be turned under in-field. **Marketing "ugly" produce** can also help to ensure that oddly-shaped or -coloured produce that doesn't meet food-grade contract requirements is still harvested and put to use in the food system (Box 4). [101] This has the potential to Improve consumer welfare (by allowing them greater choice) and potentially enables farmers to capture greater revenue by selling some of their food-grade produce into higher value domestic or export markets.

Box 5

Loblaws - Naturally Imperfect [102]

In 2015, Loblaws launched a campaign titled "Naturally Imperfect" bringing physically abnormal produce to its customers at a lower cost. The line started with only fresh produce but has experienced such success that it expanded in 2017 to include frozen products.

At the processing and manufacturing stage, one way to reduce food loss and waste is source prevention by ensuring that machinery and technology are operating in optimal ways to prevent the loss or diversion of food resource.[103] Integrating **advanced technology** in food processing can include using water pigging systems instead of flushing to increase resource capture and reduce water use, contaminant detection technology to reduce false food product rejections or recalls, and using artificial technology for food quality inspections which can significantly reduce the amount of acceptable food inputs rejected based on human sorting.[104] These technologies can all work to keep resources in the cycle and at their highest value while increasing profits for companies and decreasing associated costs such as waste disposal and wastewater treatment fees.

At the retail stage, food loss and waste can be prevented by improving the **clarity of date labelling**. Unclear date labelling leaving consumers to decipher many different label formats, meanings and date codes, may lead to misunderstanding causing wastage. Standardization and simplification for labelling on products can reduce the amount of food waste thrown out prematurely as a result of caution and confusion.[105] Improving **purchasing models** to ensure that stores are not overstocking products due to the perception that consumers purchase more product from fully stocked shelves and displays is another way to reduce food loss and waste at the retail stage.[106]

Food processing clusters are a cross-cutting practice that allows for better and more efficient collaboration, particularly between small and medium enterprises (SMEs). Clusters can facilitate industrial symbiosis, encouraging the use of one manufacturer's waste (material or energy) as another's input. Clusters can also act as hubs for innovation and technology, and to further develop the market.[107]

Finally **measuring and tracking** food loss and waste by various stakeholders across the supply chain is key to setting targets and goals to mitigate food loss and waste and monitoring progress on these.[108]

Rethink and Reduce Material Waste

In addition to organic waste, inorganic material waste is another key waste stream in the agriculture and agri-food sector. Food packaging is a significant contributor to these waste streams. While some packaging is necessary to keep valuable food products safe and unspoilt, practices that reduce excessive packaging can reduce the environmental footprint.[109] These include using compostable materials such as paper-based packaging where possible, incorporating recycled and recyclable content into packaging material, and as technology and facilities allow, using compostable bio-based plastics or plastic alternatives.

Another key waste stream in the sector is plastic from the use of plant pots, fertilizer bags, haybale twine, and pesticide containers etc. Conscious efforts to **reduce and rethink the use of these material** wastes can prevent excess waste from going to landfill and value loss. Material wastes that cannot be reduced should be directed to material recycling to reclaim as much content as possible.

Rethinking Consumption

Some food choices are inherently more sustainable than others. Encouraging the selection of products that are more sustainable through labelling, and marketing can increase the circularity of the food industry. These include products having a smaller carbon or water footprint, such as **plant-based protein** alternatives and products that use resources that are typically disposed of such as **upcycled food products**.[110]

Conscious **meal planning** that incorporates locally or seasonally produced foods can potentially increase the circularity of food consumption for households, restaurants and other food services. These plans can also work to maximise the alignment of food service with the lifespan of products and can incorporate cascading use of products over time within the meal plan.

Table 1: Mapping of "Rethink Production and Consumption" practices onto the supply chain

Rethink Production and Consumption of Resources – Strategies and Practices by Supply Chain Stage						
Strategies	Practices	Primary Production	Processing & Manufacturing	Distribution & Retail	Consumption	Waste Recovery
Sustainable Inputs	Creating pesticides from organic waste	■				
	Creating fertilizer from organic waste	■				
	Creating livestock feed from organic waste	■				
Process Optimization	Regenerative agriculture	■				
	Precision agriculture	■				
	Improving resource efficiency		■			
	Shortening supply chain	■	■	■	■	
	Establish functional linkages	■	■	■	■	
Food Loss and Waste Prevention	Ensuring availability of sea-sonal labour	■				
	Better demand forecasting	■	■	■		
	Building gleaning network	■				
	Marketing "ugly" produce	■		■		
	Advancing technology for sorting, processing, and food safety		■			
	Improving date labelling			■		
	Developing food clusters	■	■			
	Measuring and tracking FLW	■	■	■	■	
Rethink and Reduce Material Use	Reducing material use		■			
Rethinking Consumption	Making alternative food choices				■	
	Meal Planning				■	

4.2. Intensify Use of Products

Key Strategies to intensify the use of products include increasing the lifespan of foods, redistributing food, and equipment sharing.

Increase the lifespan of food

Food products have a limited lifespan, however, this can be extended by ensuring that food is stored appropriately and transported as quickly and efficiently as possible. **Cold chain infrastructure** is essential to ensure food remains safe for human consumption throughout transportation and storage.[111] In many cases, it is difficult to ensure the fulfilment of temperature requirements throughout the supply chain due to the seasonal variations in temperature, the long transportation distances and the fact that many transportation journeys require many steps including the transition from trailers to planes and trains.[112] Improved cold chain infrastructure and increased real-time monitoring can help reduce the amount of food waste and improve food safety. In addition to the condition in which food is transported, speed and efficiency largely influence the lifespan of products. Longer transportation trips for produce and animal livestock are linked to decreased quality and nutritional value.[113] **Improved transportation logistics** using artificial intelligence, for example, can increase efficiency and fluidity (Box 5).

Box 6

Canada's Artificial Intelligence Super-cluster [114]

Scale AI is a super-cluster for artificial intelligence development headquartered in Montreal, Canada. The platform is currently funding several projects in relation to Canada's food industry, including AI for customized packaging, a project focused on the efficiency of the supply chain for packaged goods. Farm to Market is a project tailored to the use of AI for farms and farmers looking at deliver, demand and access to markets. Rapid Distribution Capacity of Essential Cargo is another AI focused project seeking to provide solutions for supplying essential good at a rapid pace to the market. The development of AI technology for applications such as these can pave the way for better demand forecasting, improved delivery networks and more agile supply chains.

Food lifespan can also be increased through the use of **innovation and technology**. An increasing number of options are coming to market to help extend the life of perishable products, particularly fruits and vegetables. Some examples of these technologies include surface treatments to prevent spoilage (Box 6), hormonal storage options to slow ripening, and genetic modification for longer lifespans. Appropriate **food packaging** and packaging procedures can also extend the life of food products ensuring the protection from microorganisms and oxygen.

Box 7

Apeel [115]

Apeel has created an innovative treatment for produce that extends the life of produce up to twice as long by creating a barrier against oxygen. The treatment is edible and made from naturally occurring material found in produce skins, peels and seeds. Apeel works with farmers, food brands and retailers to extend the life of fruits and vegetables.

Redistribution of Food for Human Consumption

Despite the amount of food wasted every day, food availability remains is a significant issue for many communities. Redistributing edible food for human consumption level addresses both food waste and food security. Much of the food waste throughout the supply chain is edible food that remains safe for consumption well beyond the best-before-date and can be rescued and donated. However, these products often do not make it to food rescue and donation platforms for reasons including fear of liability, lack of labour, and lack of transportation. **Growing platforms and networks** supported by technological solutions to facilitate food rescue can help address barriers (Box 7).[116]

Box 8

Food Sharing Ottawa [117]

Food Sharing Ottawa is a platform that was created to address food loss and waste in their community. It aims to tackle several streams of food loss and waste, including, facilitating food donations from local retailers for distribution to community centres and food banks, and campaigning for the use of ugly produce that is not harvested due to its appearance and gleaning. The platform uses volunteers to collect food donations from retailers and other organizations, sort the collected items and distribute the edible donations throughout the community. To date, the platform has rescued 37,478 lbs of food.

Equipment Sharing

Farm equipment and tools can be a large capital investment for farmers. They may also require regular and expensive maintenance. Much of this equipment is only required and used for short periods of time (although there may be considerable overlap in peak demand among producers). By creating **sharing models** for equipment, farmers can potentially save money and get greater use of these products (Box 8). Though the distance between Canadian farms is a barrier to equipment sharing, improved networks and collaborative mindsets may help increase equipment sharing in Canada. [118]

Table 2: Mapping of "Intensify Use of Products" practices onto the supply chain

Intensify Use of Products – Strategies and Practices by Supply Chain Stage						
Strategies	Practices	Primary Production	Processing & Manufacturing	Distribution & Retail	Consumption	Waste Recovery
Increasing the Lifespan of Food	Designing efficient transportation and logistics			■		
	Using technology-based solutions for increasing food lifespan		■	■		
	Using packaging solutions for increasing food lifespan		■			
Redistribution of Food	Growing online platforms and networks	■	■	■	■	
Equipment Sharing	Sharing on-farm equipment	■				

Box 9

Grainnews [119]

In an instance of successful equipment sharing, two neighbouring farms in Saskatchewan share a clearance sprayer. It was purchased with equal investment five years ago and the cost of upkeep has also been split. It was not obtainable for either farmer individually at the time, but has been key to their joint success.

4.3. Extending the Life of Resources

Key strategies to extend the life of resources include new products from surplus or unwanted food, new products from by-products and material recycling.

New Products from Surplus or Unwanted Food

Surplus or unwanted food products are those which were intended for human consumption but that are in quantities that will not be consumed or have become unwanted due to age, ripeness or condition such as bruising or discolouration. Surplus food at the manufacturing stage can be used to **create new food or beverage products** (Box 9). Within the food industry excess products, especially fresh produce and animal products, that are not in demand can be further manufactured into new products (this is processing that was not originally intended).[120] For example, excess fresh fruit can be made into jam.

Box 10

Confiture Rebelle [121]

Confiture Rebelle is a food upcycling start-up that repurposes unwanted and surplus fruits into jam and vegetables into chutney. The company networks with local partners to collect unsold produce and managed to recover 21 tonnes of food in 2020. Their line of products includes 8 types of jam and 3 types of chutney.

These food products also have value as **new non-food products** such as for the creation of pharmaceuticals (Box 10), bio-pesticides, bioplastics and others. Finally, surplus and unwanted food can be transformed into **new animal feed products**. This can include feeding livestock with food scrap products or collecting these food products for further processing into a prepared animal feed that may be marketed for farm or domestic animals.

Box 11

GSK Pharmaceuticals [122]

GSK Pharmaceutical in partnership with Biorenewables Development Centre has identified the opportunity to create high quality glucose, a key ingredient in many of their products, from food waste. This process uses unwanted bread and potatoes to create this valuable pharmaceutical component. Commercial scaleup is under development to bring the full value of this development to the corporate level.

New Products from By-products

By-products are resources resulting from the production or processing of a product. The production and processing of food products often result in the creation of valuable by-products. These can be edible such as soy meal or fruit pulp, or inedible such as corn stover or nut shells. The value of these by-products is often not be recognized and captured in the supply chain.[123] When not used, these by-products can cost manufacturers to dispose of and end up in landfills, emitting GHGs. Alternatively, finding uses for these by-products can turn a financial and environmental cost into a new source of profit such as through the creation of **new food or beverage products** (Box 11).

Box 12

Dairy Distillery: Vodkow [124]

Dairy Distillery is an Ontario based company that specializes in converting unused dairy sugar into an original vodka, aptly named "Vodkow". This dairy-based sugar is the result of the production of ultrafiltered milk products that would otherwise go to waste. Other sustainable practices by Dairy Distillery include a lighter weight packaging and an efficient production process that cuts their carbon footprint by half as compared to standard practice.

The creation of **new non-food products** is also highly valuable. These products can include medical materials, textiles, bioplastics and building material.[125] For example, orange peels can be used to create textiles (Box 12), rice husks and almond shells can be used to create PHB for bioplastics, and cellulose from organic waste can be used to create bio-resins. By-products like agricultural residues such as stover and stocks or nut meals from food processing can often also be used to create **animal feed products.**

Box 13

Orange Fiber [126]

Orange Fiber is an Italian start-up that produces silk-like textiles from the peels of citrus juice. In Italy alone, 700,000 tonnes of by-products from citrus juicing are produced, per year, and the disposal of these by-products is costly. The technology created and patented by Orange Fiber can create value out of these resources. Their materials have been used in apparel sold by H&M clothing.

Material Recycling

Inorganic waste materials such as plastic and aluminium from any stage of the supply chain that cannot be reused can be **recycled** where possible. Recycled materials can re-enter the same process cycle or a different process cycle in either an open or closed-loop cycle.[127] Certain materials are more efficient to recycle than others and product design can play an essential role in increasing the success of material recycling and the upholding of recycled materials quality.

4.4. Giving Resources New Life

Key strategies to give resource new life includes nutrient cycling and energy cycling.

Nutrient Cycling

Food that is no longer edible or agriculture resources that are inedible can be composted to reclaim nutrient value. That can be used to supplement soils for crops or pastures.[128] **Composting** is the most straightforward circular practice, recapturing the nutrients from food and returning them to the ecosystem for use in producing more food. However, since it does not capitalize on the potential energy cycling of organic waste like anaerobic digestion does, composting is considered a lower-value commercial outlet for organic waste.

Table 3: Mapping of "Extend the Life of Resources" practices onto the supply chain

Extend the Life of Resources – Strategies and Practices by Supply Chain Stage						
Strategies	Practices	Primary Production	Processing & Manufacturing	Distribution & Retail	Consumption	Waste Recovery
New Products from Surplus or Unwanted Food	Creating new food and beverage products					
	Creating new non-food products					
	Creating new animal feed products					
New Products from By-products	Creating new food and beverage products					
	Creating new non-food products					
	Creating new animal feed products					
Material Recycling	Recycling					

Energy Cycling

Food that is no longer edible or agriculture resources that are inedible can be repurposed for energy. **Anaerobic digestion** is one option for the conversion of organic waste into energy.[129] Modern anaerobic digestion plants can be compact and easily operated compared to large bioenergy facilities. Some regions and individual farms run their own plants to eliminate transportation costs and use the final digestate product on their farms as fertilizer or animal bedding. The economic viability of on-farm operations varies greatly depending on the size and profile of each farm.[130] **Biofuel production** including biogas and biodiesel is an alternative to anaerobic digestion (Box 13).[131] These processes can typically process more diverse and larger quantities of feedstocks than anaerobic digestion facilities.[132]

Box 14

Darling Ingredients [133]

Darling Ingredients was the first commercial bio-diesel facility in Canada, located in Sainte-Catherine, Quebec. This operation uses cooking oil and animal rendering to produce 45 million litres of biodiesel a year. Additional by-products of the conversion process include ingredients for animal food, fertilizers, cleaning products and rubber.

Table 4: Mapping of "Giving Resources New Life" practices onto the supply chain.

Giving Resources New Life – Strategies and Practices by Supply Chain Stage						
Strategies	Practices	Primary Production	Processing & Manufacturing	Distribution & Retail	Consumption	Waste Recovery
Nutrient Cycling	Composting					
Energy Cycling	Generating bioenergy					
	Producing biofuel					

5. BARRIERS TO A CIRCULAR AGRICULTURE AND AGRI-FOOD ECONOMY

Despite many potential benefits of a transition to a circular economy approach in the agriculture and agri-food sectors, there are many barriers to unlocking these benefits. Many of these barriers are mutually reinforcing and must be addressed across supply chains. These include market barriers, financial barriers, regulatory and policy barriers, technology and infrastructural barriers, cultural barriers and research barriers. Those identified through a literature review are briefly described below.

5.1. Market Barriers

Market barriers largely stem from the unpriced externalities arising from food production, manufacturing, transport, consumption and disposal.[134] It is estimated that Western and Central Canada's* primary agriculture sectors generate an estimated $4.3 billion in net environmental damages** annually, the majority of which stem from water pollution, soil erosion, GHG emission, and particulate matter.[135] The eutrophication in

* More specifically, British Columbia, Alberta, Saskatchewan, Manitoba, Ontario and Quebec
** That is, the monetized value of environmental damages minus the monetized value of environmental benefits such as wildlife habitat and improved aesthetics.

The transition to a circular agriculture and agri-food economy is hampered by many, often mutually reinforcing barriers that must be addressed across supply chains.

Canada's Lake Winnipeg Basin due to phosphorus runoff on the Red River is an example of such externalities.[136] Since producers, firms and households generally do not pay for these costs*, consumer food prices do not fully reflect their environmental impact.

The failure to fully account for the environmental costs of food production have contributed to artificially depressing the price of food. While this is beneficial for consumers (and from a food access perspective), it may reduce the urgency for new policies and regulations that encourage value creation from organic and in-organic waste materials which have a lower environmental footprint. Additionally, it could contribute towards food waste being considered an acceptable business expense instead of a potential cost-saving strategy.[137] As a result, there is little incentive for the development of secondary markets designed to keep surplus, lower-quality food and by-products in use.

5.2. Financial Barriers

Agriculture and agri-food businesses, especially SMEs, often lack the capital and financing required to develop more circular processes, products, and business models. This could either be due to the scale of the capital required-- industrial composting and recycling facilities, for instance, are very capital-intensive projects--or because circular technologies and business models are often new and unproven, with a large reliance on novel supply chains with uncertain demand for new products.[138] Further, securing funding may also be challenging given that investors, banks, and funding agencies may be unfamiliar with circular projects. Financial institutions have historically not accounted for environmental risks such as soil degradation and biodiversity loss in lending portfolios. They also lack the tools to assess the value of novel production methods that can lead to positive financial returns. The lack of precedent also creates a perception of high market risk, further preventing financial decision-makers from investing in circular practices.[139]

5.3. Regulatory and Policy Barriers

Regulatory and policy barriers can take many forms. Given the relatively new emphasis on circularity, existing regulatory and policy and frameworks may be inadequate to support a circular agriculture and agri-food sector. Without the application of a circular lens, they may inherently promote the linear economy status quo. For instance, existing public food procurement policies may seek to minimize cost rather than use their market power to incentivize more circular food practices.

In other cases, policies have unintended negative consequences, which discourage the use of circular and regenerative practices. For example, two of Canada's largest agricultural business risk management programs (AgriInsurance and AgriStability respectively) have been found to unintentionally incentivize increased fertilizer and pesticide use, and reduce the incentive for producers to diversify their agricultural production (all else being equal).[140] Finally, food products imported into Canada that don't meet the legal requirements for labelling are not allowed to be sold or even donated, even though they may be safe for consumption.[141]

5.4. Institutional Barriers

The agriculture and agri-food system touches on a number of closely related issues such as health and nutrition, environment and natural resources, finance and trade, and sanitation and waste management.[142] These are currently by different federal government departments and agencies such as Agriculture and Agri-Food Canada, Health Canada, Fisheries and Oceans, the Canadian Food Inspection Agency and others, as well as by various levels of government – each of which has its own specific mandate. While important for accountability and specialization purposes, this division of labour hinders the coordination and collaboration that is required to send signals to markets and individuals about circular technologies, practices, and consumption behaviours.[143] A lack of coordination can lead to each silo focusing on solutions that unknowingly work against each other, instead of achieving more holistic solutions.

5.5. Technology and Infrastructure Barriers

Technological barriers are hard barriers that typically arise from the absence of technical solutions or the limited uptake and use of available and cost-effective solutions. There are numerous examples of how technology can be deployed to further circular practices. As mentioned in section 4, drone and remote sensors can be used at the farm level to support precision agriculture. Another example is the use of digital technologies like blockchain that can enable more efficient food redistribution of better food inventory management, by for example identifying food surplus in a timely manner. Technological barriers may be especially relevant in Canada's agriculture and agri-food given that it is largely made up of SMEs.[144]

* Although some modest inroads have been made through agri-environmental cost-share programs and through the inclusion of nitrogen fertilizer and agrichemical manufacturing under federal and provincial output-based carbon pricing systems.

In addition, many circular practices require public infrastructure such as access to internet, equipment to capture post-harvest losses, cold storage, efficient transport and logistics systems, recycling and energy recovery facilities. For example, without separate collection systems for organic waste, feedstocks can become contaminated with plastic and other hazardous organic contaminants, reducing the effectiveness of composting and anaerobic digestion systems.[145] Even where there is separate collection, unclear guidance, use of plastic bags to line food waste bins, and overpackaging of food products can lead to plastics contamination entering waste streams. Hence the absence of adequate infrastructure can act as an impediment to the uptake and mainstreaming of circular practices.[146] Building up the infrastructure required for a more circular agriculture and agri-food economy may be especially challenging in Canada given its vast geography, particularly in remote northern communities.

5.6. Cultural Barriers

Cultural barriers exist across society. Within a business, they can take the form of low staff engagement in circular economy initiatives, and resistance to change from individuals in management and leadership roles.[147] Among consumers, cultural barriers can include an unwillingness to change daily consumption patterns such as over-purchasing of perishable food or a preference for resource-intensive food products like meat and dairy. It also includes hesitation towards more sustainable circular practices, such as buying upcycled foods and beverages or food in non-plastic packaging, due to perceptions about quality. While new information and awareness can help overcome some cultural barriers, complementary intervention strategies are typically required for long-lasting behavioural changes.[148] These include combinations of awareness campaigns, marketing, price incentives, regulations, and other strategies.

5.7. Research Barriers

While some circular strategies and practices are currently underway in the agriculture and agri-food sector, gaps in research and understanding can act as a barrier to the acceleration of the transition to circularity. While many of these gaps have started to be filled by government and private researchers, some globally identified areas of research that can further this understanding are:[149]

- Mapping where scalable, productive, regenerative farming practices might have the highest adoption potential
- Mapping hotspots of food loss and waste across value chains and geographies with a standardized, cost-effective quantification methodology
- Analyzing the effectiveness of interventions to reduce food loss and waste so they can be showcased and scaled
- Mapping organic waste flows and agricultural systems to enable optimal nutrient recycling
- Identifying alternative uses for commonly wasted organic materials to help keep them in use
- Understanding how advances in behavioural and data science can be leveraged to nudge consumer demand toward more environmentally sustainable diets
- Developing methods to calculate the true price of food products and the financial value of wasted materials to demonstrate the economic and environmental value of repurposing them

6. POLICY TOOLS

Previous sections make the case for a transition towards a more circular agriculture and agri-food economy in Canada. However, this transition will not be easy to make. It is a multi-dimensional and complex challenge that requires systemic change including innovations in practices, technologies, products, and business and socio-cultural practices. This represents a tremendous opportunity to innovate and redesign our agriculture and agri-food system in a way that reconciles economic growth with our ecological limits.[150]

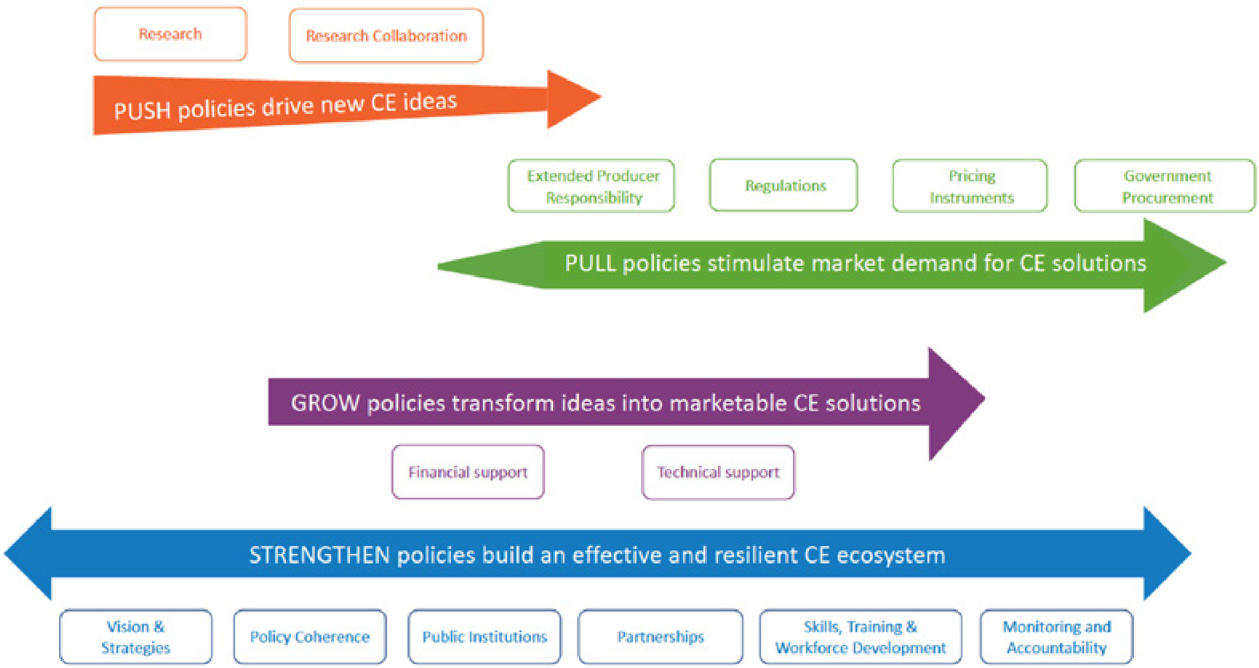
However, the presence of numerous barriers outlined in Section 5 suggests that the pace of this transition will lag without stronger government support. Such support is not unprecedented in Canada and can be seen in Canada's ongoing clean innovation policy agenda. While this was designed primarily around carbon reduction commitments, it offers a comprehensive framework for understanding the broad range of public policy support that will also be needed to accelerate the transition to a circular agriculture and agri-food economy.

The pace of the transition to a circular agriculture and agri-food sector will lag without strong government support.

An analysis of Canada's needs for the transition towards clean growth identified four categories of government policies required to effectively unleash industry initiatives for change, described below.[151] These are used as a basis for classifying the menu of policy tools available to increase circularity in the agriculture and agri-food sector, policy tools identified through a literature review.

The list is intended to serve as a menu of options for consideration, and deliberately stops short of recommending specific policy instruments or policy packages for Canada, pending further research and stakeholder input. The list is also agnostic to the level of government having jurisdiction to employ the policy tool.

Figure 11: Elements of a full suite of public policies to support circular innovation
(Adapted from an original diagram in SPI's Discussion Paper: Canada's Next Edge)



PUSH policies focus on the early stages of innovation and generate ideas that carry through to later stages. They generally do one of two things. One, incentivize private research initiatives, either through direct incentives (e.g. tax credits) or by helping firms capture the economic returns from that research (e.g. through intellectual property rights). Or two, supplement private research with public research through funding for government labs and universities.

PULL policies are particularly important in the commercialization phase of innovation. They generate market demand for innovations that might otherwise not appear profitable given that there is little market reward for solving problems (like pollution) that firms and households do not pay for in the first place (i.e., environmental externalities).

GROW policies are the bridge between PUSH and PULL. They help take promising innovations from the research and development (R&D) stage to the point where they are ready for market entry. They help entrepreneurs and firms secure financial and non-financial support required to turn their ideas into demonstration products and services and then scale up their solutions to meet market demand.

Finally, STRENGTHEN policies support the system as a whole. Government interventions to bolster this system include defining a clear vision and translating it into strategies, strengthening public institutions, building partnerships, investing in new skills, identifying and measuring key performance indicators and metrics, enriching the policy mix and ensuring accountability and continuity.

6.1. PUSH Policies

Innovation begins with research. Research by academics, entrepreneurs, business, and government, all contribute to the generation of intellectual property, which after multiple levels of refinement can become a commercial success. PUSH policies aim to drive new ideas and support the earliest stages of innovation. These public policies include those that stimulate government-funded, academic, and business research, as well as those that stimulate research collaboration. They are particularly important to kickstart the innovation chain because evidence suggests that innovation geared towards better environmental outcomes (like waste reduction) is more at risk of the knowledge spillover market failure than other forms of innovation. The knowledge spillover market failure is the phenomenon whereby when researchers discover something new, their findings may, at least in part, 'spill over' to benefit other researchers, firms, or sectors, making them unable to capture the full value of their discoveries.[152]

There exist several tools through which such research can be stimulated by different actors. Government research can be stimulated by making it a sustained priority in public research labs. University-based research can be stimulated by targeting funding through granting councils. Private R&D could be encouraged by research tax credits. In addition, innovative tools such as prizes, competitions and challenges could also be explored.[153] Finally, given the systemic nature of the circular economy, it is also crucial to encourage joint research efforts by researchers, technology centres, industry, entrepreneurs, users, governments, and civil society.[154]

Box 15

Horizon 2020 Programme [155,156]

Horizon 2020 was Europe's flagship research programme aimed at securing Europe's global competitiveness through an emphasis on "excellent" science, industrial leadership and tackling societal challenges. A major focus area in Horizon 2020's 'Climate Action, Environment, Resource Efficiency and Raw Materials Challenge' was waste. Under this focus area was research and action on developing a system approach for the reduction, recycling and repurposing of food waste.

A key research project funded by Horizon 2020 between 2015-2019 was "REFRESH: Resource Efficient Food and dRink for the Entire Supply cHain". REFRESH focused on the reduction of avoidable waste and improved valorisation of food resources. Backed by research to better understand the drivers of food waste, the project supported better decision-making by industry and individual consumers. The project took an innovative, systemic approach to curb food waste through a holistic 'Framework for Action'. REFRESH built on and went beyond existing initiatives to develop, evaluate, and ensure the spread of social, technological, and organisational insights and practices related to food waste. This was underpinned by guidance to legislators and policy makers to help support effective governance to tackle food waste.

6.2. PULL Policies

Currently, there is little market stimulation to grow the demand for circular products and services, due to the environmental externalities described in the market barriers section. PULL policies aim to overcome these barriers by stimulating market demand for environmental solutions through tools such as regulations, pollution pricing, and procurement. While the primary goal of such policies is to solve an environmental problem, they also incentivize innovation. Further, if such innovation can bring down the cost of achieving environmental objectives, they also create competitive advantages. OECD research on this topic has found that environmental policies that drive innovation share key features including stringency, flexibility, predictability, incidence, and depth.[157]

When designing such policies, it is equally important to ensure that they don't unintentionally hinder innovation. Rigid compliance can discourage innovation approaches and practices, while prescriptive policies that focus on the lowest short-term cost can impede the development and/or implementation of solutions that might have lower costs (and environmental impacts) in the longer run.[158] For instance, foods imported into Canada can run into issues if the label does not meet Canada's legal requirements. In many cases, this results in foods being sent to landfill rather than being able to be sold or donated, even if the issue does not pertain to food safety.[159] Where such policies exist, they should be reviewed and updated.

Regulations

A regulatory approach is often used in the agriculture and agri-food sector. Where consumers are insensitive to price changes in the markets, regulations can be used to drive change in the status quo.

In the earlier stages of the food supply chain, a recurring cluster of proposed regulations relate to date labelling. Date labels often cause consumers to avoid buying or consuming foods that are close to "best before", "use by", "sell by" and "expiry" dates. By creating regulations that require food processors to differentiate between expiry dates and "best before/use by/sell by" dates, governments can provide greater clarity about what these labels mean. They could also avoid confusion by improving the physical placement of the text, legibility, and consistency of formats. This in turn could reduce the unnecessary disposal of safe and healthy food, either by consumers or businesses who remove them prematurely from their shelves.[160]

Box 16

California's Law on Food Data Labelling [161]

In 2017, the state of California in U.S.A passed a law to standardize date labels on food. The law encourages food manufacturers, processors, and retailers to use the terms "BEST if Used by" or BEST if Used or Frozen by" to indicate quality, and "USE by" or "USE by or Freeze by" to indicate safety.

Regulations could also be used to tackle the ever-growing problem of packaging waste, including from the agriculture and agri-food sector. While food packaging plays an important role in helping to retain and optimize the value of food by extending its shelf life, it generates a significant amount of waste. To mitigate this waste, governments could create regulations that enable the development and use of more environmentally friendly packaging. They can also introduce the practice of Extended Producer Responsibility where those who manufacture and distribute the packaging are assigned full financial and physical responsibility for their packaging waste[162] (versions of this are in place in many Canadian provinces). Another option could be to introduce labelling for food packaging materials to enable better post-consumption management.

A popular downstream regulation cited in the literature is the introduction of organic landfill bans. In addition to supporting waste management, this regulation could also support climate mitigation objectives by eliminating methane emissions that would otherwise have been created from landfilled food waste. Also, this diverted food waste could be used as feedstock for bioenergy facilities thereby reducing the need for fossil fuel-derived energy. Additionally, food waste could be diverted to composting facilities to produce soil amendment that can return fertility to degraded soils and reduce the need for chemical fertilizers. Ideally, a ban on organics should be a coordinated policy initiative across jurisdictions and take into consideration rural-urban contextual differences.[163]

Pricing

Pricing instruments, such as taxes and user fees, stimulate market demand for circular innovation by establishing a price for environmental damage. Because they allow the firms and households impacted the flexibility to take actions that best suit their situation, pricing instruments are considered to be more cost-effective than regulation.[164] They are especially attractive tools because they simultaneously improve environmental performance and generate government revenue that can be re-invested to help compensate producers, firm and households for the increased costs, or build the knowledge, skills and infrastructure required to address a given type of environmental damage.[165]

Such instruments could be applied at various stages of the supply chain. At the farm level, regenerative agricultural practices can be promoted by taxing harmful products like synthetic pesticides and fertilizers that contribute to greenhouse gas emissions, harm wildlife, and pollute the air and water. Alternatively, taxes could directly target environmental externalities from food production, processing and transportation. For instance, taxing soil phosphorus content that exceeds a certain threshold rather than taxing phosphorous fertilizers.[166]

Another example is a tax incentive for manufacturers, retailers and others in the food industry to donate nutritious food to registered charities supporting local communities. Such a tax credit or deduction could offset the costs of operational changes required to separate nutritious food from food that should be discarded, as well as the costs associated with transporting this food to registered charities.[167] This could be supplemented by support to build capacity and/or infrastructure in these charities to efficiently handle food donations.

More downstream, municipal landfill tipping fees can be used to send the right market signals, especially when working in tandem with individual producer responsibility. This could involve introducing new tipping fees (in municipalities where these currently do not exist), or increasing fees to account for the full environmental cost of waste disposal (e.g. methane emissions, risk of leaching Into the environment, etc.). While setting tipping fees, efforts should be made to harmonize these fees between neighbouring jurisdictions to deter the practice of waste exports to jurisdictions where the fees are lower. Tipping fees could also be differentiated for different materials like organics to specifically incentivize their diversion from landfill. In addition to municipal tipping fees, provincial governments could also implement tipping-fee surcharges that can help generate revenue to fund other waste management projects throughout the province.[168]

Box 17

UK's landfill tax on biodegradable waste [169]

In 1996, the U.K. introduced a national landfill tax on biodegradable waste (e.g. organics) and inactive wastes (e.g. concrete). The tax applies to all landfills-public and private- and is levied on top of local tipping fees. Over time it has increased from $17 per tonne in 1999 to $150 in 2017. It has been shown to lower quantities of landfill waste and increase diversion rates significantly.

Procurement

Government procurement is considered a powerful public policy tool to encourage circular economy practices. Circular procurement, and the closely related practices of Green Public Procurement* and Sustainable Public Procurement**, emphasize the need for purchasing decisions to contribute to closed energy and material loops within supply chains. This practice has a dual benefit—it allows governments to lead by example, and offers a test-bed for new innovations, which helps with their commercial growth and with attracting private investment.[170]

Large government institutions that provide meals, like schools, hospitals and prisons, are major purchasers of food. By introducing circular principles in their purchasing policies and practices, they can not only achieve significant food waste

* Green Public Procurement (GPP) is a process by which public authorities seek to purchase goods, services and works with a reduced environmental impact throughout their life-cycle compared to goods, services and works with the same primary function which would otherwise be procured.

** Sustainable Public Procurement (SPP) is a process by which public authorities seek to achieve the appropriate balance between the three pillars of sustainable development - economic, social and environmental - when procuring goods, services or works at all stages of the project.

reductions in their own operations but also influence suppliers and bring about change in the whole food supply chain. For instance, by shifting to increase sustainably produced healthy plant-based food offerings, governments could signal the importance of making dietary choices based on both human and environmental health.[171] In order to reduce food waste in government institutions, procurement policies should consider food ordering within the context of meal types and size options for consumers. They could also encourage more timely food purchasing decisions and consider the types and amounts that can be eaten, alongside the cost factors that go into food procurement decision-making. Where food waste is unavoidable, procurement policies should include recommendations for food donations.[172] Governments could also consider supporting food redistributors to develop the resources, skills and capacities required to implement effective and efficient solutions for rescuing safe edible food from government institutions.

Finally, governments can set an example by reporting and valuing the lost and wasted food that they generate.[173]

Box 18

Canada's Food Waste Reduction Challenge [176]

In 2020, Agriculture and Agri-Food Canada launched a $20M Food Waste Reduction Challenge, under Canada's Food Policy. This challenge aims to encourage more solutions to food waste in order to increase food availability, save consumers and businesses money, reduce GHG emissions, and strengthen the food system. The challenge is open to innovators of all types and sizes who are developing business models that either prevent food waste or that divert food waste, food by-products and/or surplus food.

6.3. GROW Policies

Unfortunately, not all good ideas that are researched and developed convert into marketable goods and services. While some ideas stumble in the early stages of innovation, many do not reach commercialization due to prevailing market barriers such as capital intensity, long timelines for investment return, and the absence of a price reward. GROW policies seek to fill this gap by helping firms secure the capital and business support required to turn their ideas into market-ready solutions.[174]

As described in the financial barriers section above, circular businesses, in particular, can struggle with access to capital. This makes public investment or assistance in obtaining financing a key government lever to enable circularity in the agriculture and agri-food economy. Financial policy interventions in this area include grants, loans, tax credits for capital investments, and green bonds. In addition, governments could provide non-financial business support such as technical and advisory support, training, demonstration of best practices, and development of new business models for circular solutions.[175]

6.4. STRENGTHEN Policies

STRENGTHEN policies help to overcome systemic barriers that are distributed throughout the innovation process. STRENGTHEN policies fill in these gaps and reinforce the effectiveness of the policies that stimulate ideas, convert them into marketable solutions, and create the market demands for them. As a result, they make the innovation ecosystem more effective and resilient. They do this through creating visions and strategies, establishing policy congruency and coherence, strengthening public institutions, building partnerships, investing in skills, training and workforce development and ensuring monitoring and accountability. [177]

Vision and Strategies

One of the important precursors to establishing circularity in the agriculture and agri-food economy is setting a bold, inclusive, and shared guiding vision. Such a vision should be supported by concrete strategies built on both existing experience and expertise as well as new research and ideas.[178]

Setting measurable targets is often proposed as the first step to track progress on established strategies. For example, food loss and waste reduction targets can be set as a driver for designing out waste from the agriculture and agri-food sector. This target could be set at the local, provincial and federal level. It could also include sub-targets for retail businesses, manufacturers, and consumers, to increase awareness and demonstrate a commitment to act. In addition to setting their own targets, governments could also consider measures to incentivize private businesses, industry associations and other organizations active along the food chain to create their own targets.[179, 180]

Policy Coherence

A common vision is also a foundation for greater policy coherence. Agri-food businesses are often part of a complex and spread-out supply chain that spans local, provincial, territorial, and national boundaries. This implies that while municipalities, regions and provinces with different mandates should develop policies that serve their contexts, it is important that these are harmonized and aligned as much as possible to avoid confusion, duplication and inefficiencies. [182]

Box 19

Dutch Circular Agriculture Vision [181]

In 2019, the Dutch Government announced its vision for Circular Agriculture and set out the ambition of making the Netherlands a global leader in circular agriculture by 2030. The vision entails a paradigm shift from aiming only for growth in production volumes and cost reductions, towards "optimisation in resource use and food production in harmony with nature." Practical components of the plan to achieve this vision include:

- Improving soils and water quality
- Reducing emissions and pollutants
- Closing nutrient cycles
  Collaboration at a regional level
- Collaboration along the agriculture and food supply chain

The vision is intended to be inclusive and recognises the need to offer new prospects for all types of agricultural activities and for all farmers and growers, including family businesses. The Dutch government hopes that the transition to circular agriculture will stimulate new economic activities and types of businesses, and they have committed to working with all stakeholders in the farm and food industry to create the necessary conditions for a transition to circular agriculture and create room for experimentation and learning.

For instance, food innovation hubs that conduct R&D on new upcycled food products can support linking food processors with investors researchers and other businesses in the food supply chain. They could also support business in accessing capital to pilot new ideas. Further, they could provide an opportunity for investors to act as brokers between ideas, projects, practices, and a place where capital could be pooled to build out larger projects.[185]

Box 20

Guelph-Wellington's Our Food Future [186]

In the City of Guelph-Wellington County region in Ontario, the local governments are working with farmers, innovators, researchers, businesses, tech and data experts to explore the possibilities of making the existing local food system more circular. Guelph-Wellington aims to create Canada's first "circular food economy" with three bold goals:

- 50% increase in access to affordable, nutritious food
- 50 new circular food businesses, collaborations and social enterprises
- 50% increase in economic benefit by unlocking the value of waste

Public Institutions

Around the world, circular economy policies and initiatives have been driven by pioneering public institutions. Hence strengthening these by making them nimble, risk-tolerant, smart, and adaptable can make them more effective vehicles of driving a circular policy agenda.[183]

Partnerships

While increasing circularity in the agriculture and agri-food economy undoubtedly requires government support, it cannot be achieved by government action alone. It will require a collective effort from governments and public and private researchers, public and private finance, small and large businesses, and consumers among many others. Such collaboration is key to push the transition forward and can take many forms including public-private agreements, R&D clusters, and voluntary industry initiatives.[184]

Food hubs or clusters are another example of how partnerships could be developed in the agriculture and agri-food sector. These hubs promote the acceleration of networking and industrial symbiosis between stakeholders at different levels of the agriculture and agri-food supply chain. The growth and development of such hubs could be stimulated by creating development zoning and land-use planning policies to support a mix of commercial, industrial and residential infrastructure that would encourage symbiotic activity from food production to consumption. As a result, could help reduce distribution distance and can reduce food spoilage due to transportation.[187] They could also enable efficiently pooling resources, allowing members to share the costs and benefits of food and/or bioenergy production.

Skills, Training & Workforce Development

As the agriculture and agri-food economy moves towards being more circular, it may require some new skills, training, and workforce development. For instance the development of technical skills such as those needed for the development and testing of new products from FLW, recycling of food packaging etc. In addition, some capacity building amongst financial institutions may also be required, so they are able to provide innovative financial solutions to meet the unique needs of the circular economy.

Governments can support the development of such skills through practical training pathways such as government-funded skills and training programs. Governments can also provide support through academic education pathways such as by introducing sustainable food education in high schools nationally and funding the development of circular thinking training or curriculum components for future food scientists as well as for students studying business, management, commerce and food preparation/handling related disciplines.[188]

Box 21

University of Guelph's graduate course on Innovation and Entrepreneurship in Agri-Food Systems [189]

In 2019/2020 the University of Guelph began offering a formal course for graduate students with an interest in the circular economy. UNIV 6050: Innovation and Entrepreneurship in Agri-Food Systems is designed for students in the OMAFRA/UoG HQP Scholarship program, scholars from the Arrell Food Institute and scholars from Food from Thought. Space permitting, it is also open to any graduate student working on a thesis topic related to agri-food.

In this course, students work in groups to collaborate with NGOs, government agencies, or businesses on agri-food projects. Through these projects and a series of modules, students build knowledge and competencies in business development, communication, social innovation, project management and entrepreneurship.

Monitoring and Accountability

Monitoring and accountability are key to track progress on visions, strategies, and targets outlined above. For example, a lack of accountability is often cited as the key reason for the quantity of food loss and waste currently generated.

One way to build accountability is by improving monitoring efforts. This largely depends on good data. Currently, there is limited availability and accessibility to data that tracks how circular the agriculture and agri-food economy is. While there are no universally recognized indicator of circularity to date, these could include, for example, indicators that measure the extent to which specific production practices advance regenerative agricultural principles; the extent to which food and other agricultural materials are recovered, reused and recycled; the value generated from valorizing surplus food and by-products, etc. To fill this gap, governments can independently or through partnerships with civil society and research institutes develop more open-source data sets with agronomic, climate, and market information.[190] They could also legislate making FLW reporting by private businesses compulsory. Better data can further guide more informed policy, regulatory and legislative development as well as its implementation and evaluation.[191] Data collected and packaged in user-friendly formats could also serve a number of other stakeholders. It could help farmers make more informed production decisions that could support regenerative practices. On the consumption side, it could help consumers understand the impacts of their food choices and waste and build awareness that translates into more sustainable buying decisions. Finally, it could also help entrepreneurs to develop new contextually appropriate digital tools and business models to support circular practices in the agriculture and agri-food economy.[192]

Today, new digital technologies can greatly support data collections initiatives. For example, technological approaches such as blockchain can assist with authenticating, monitoring, or modifying food inventories in ways that could significantly reduce food loss and waste. Inventory management supported by good data can provide easier, real-time ordering, help capture value from unsold food, and can help track solutions that work at preventing, rescuing, and recovering food.[193]

7. CONCLUSION

Achieving the Government of Canada's ambitious growth targets for agri-food exports, concurrent with making progress on the government's ambitions for net-zero emissions by 2050 and overall improvements in environmental quality indicators, means that more food will need to be produced with a smaller environmental impact. The circular economy, with its core principles of regenerating natural systems, designing out waste, and keeping materials in their highest use, is an effective strategy to meet these potentially competing ambitions.

While the circular economy has intersections with other strategic approaches, such as regenerative agriculture, promoting the bioeconomy and creating sustainable value from food loss and waste, it is a more holistic approach that offers a broad value proposition. By offering a framework to rethink many existing production and consumption patterns, it promises benefits to the economy and business competitiveness, and solutions for many pressing environmental challenges as well as greater societal well-being. In short, it has the potential to deliver a more profitable and sustainable agriculture and agri-food economy sector in Canada.

While there are endless ways to imagine how circular principles can be applied, this report draws from 4 overarching objectives for a circular economy to identify 13 strategic approaches and 34 practices specific to the agriculture and agri-food sector that find mention in many critical and highly regarded reports. These practices span across the food supply chain, encompassing agriculture production, processing, distribution, consumption and waste recovery, hinting at both the scale of the innovation challenge and opportunity it presents.

However, implementation of these circular practices may face barriers including market and financial barriers, regulatory and policy barriers, technological and infrastructure barriers as well as cultural and research ones, which the market alone cannot overcome. Hence government interventions of various types will be required.

The full suite of public policy support that can be put in place increase circularity in the sector is also summarized in this report. In assessing and developing such interventions, Canadians have the opportunity to learn from the experience of jurisdictions that are well ahead in their adoption of circular agriculture and agri-food practices. Importantly, experiences in these jurisdictions demonstrate that government support should span the entire innovation chain from research to ideate new circular solutions; to using regulatory, pricing, and procurement policies to create market demand for these solutions; as well as offering early-stage businesses financial and non-financial support; and supporting the growth of wider platforms for the sharing of vision, partnerships, ideas, data and technology that will accelerate the adoption of these approaches.

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