Food Sustainability in the North

Skills challenges and opportunities in community greenhouse projects

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GREEN IGLU

Green Iglu improves food security and overall wellness through community-led partnerships across Canada providing greenhouse infrastructure, educational programming, and community training to reach a period of sustainability and operate greenhouse infrastructure without any direct oversight.

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Executive Summary

Community greenhouse farming initiatives aim to address food insecurity and environmental challenges in Canada, from urban centres to the Far North. New technologies have created opportunities to address existing challenges, such as access to renewable energy and productivity. Yet, as the technology evolves, gaps persist in the labour and skills needed to support greenhouses, and agriculture as a whole.

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In total, the report lays the foundation for further work to understand competencies for greenhouse agriculture, particularly in community settings and northern and Indigenous communities, by providing:

> a review of the literature on food insecurity, greenhouse farming and its applications in community settings

> case studies of several community-based projects in urban, northern and Indigenous communities, with a focus on the lessons learned regarding approaches to engaging with Indigenous Peoples and equity-deserving groups, as well as training and capacity-building programs

> areas for further investigation with respect to the design, implementation, and evaluation of programs, competency frameworks, training programs and wraparound supports.

The context for additional research is set using a range of methods, including key informant interviews and program evaluations from a range of projects.

Key insights

1. Demand exists for labour and skills in the greenhouse agriculture sector. There are opportunities for innovation in approaches to greenhouse farming to support local community-based initiatives aimed at addressing food security and self-sufficiency.

2. Technological innovation and the expansion of community-based initiatives are transforming the sector. This has the potential to improve food access and self-sufficiency, create job opportunities, and develop essential greenhouse farming skills in remote and urban communities across the country.

3. Labour and skills are a challenge in remote communities, as well as urban settings where community projects rely heavily on volunteers. Training programs in greenhouse management and sustainable agriculture foster economic growth and empower community members to take control of their food systems. Equity, diversity and inclusion issues are critical, given the deep contextual and cultural dimensions associated with food as well as farming.

4. More work needs to be done to define competencies to support greenhouse farming in different contexts, with attention needed on the approaches that will best serve equity-deserving groups and remote Indigenous communities.

Introduction

Despite Canada's role as a major global agricultural producer and importer, many Canadians face daily struggles with food insecurity. In Canada, food insecurity is the state where an individual lacks the availability, access, utilization, and stability of food sources of sufficient quality.[1] Across the country, about one-quarter of Canadians live below the poverty line and without access to affordable food.[2]

The problem in the country's northern-most regions is particularly acute.[3, 4] Nunavut continues to face the greatest food security challenges in the country.[5] Almost two-thirds (63%) of Nunavut's total population is food insecure, compared to 28% of people in the Northwest Territories, and 22% of those in the Yukon, according to a comprehensive Statistics Canada survey that covered more than 90% of these regions.[6]

In Newfoundland and Labrador, 47.6% of the population experiences food insecurity, the highest in Eastern Canada.

Statistics Canada data from 2023 indicate that, across the 10 Canadian provinces, 8.1% of households are food insecure. Of these, 5.1% are marginally food insecure, and 4.5% are severely food insecure. This is up 16% from 2021.[7] Notably, those figures do not include First Nations reserves and territories. Insecurity is likely higher for Indigenous communities, as the mainstream definition of food insecurity does not include access and availability of traditional food sources, nor participation of members in the sovereign activities involved in food systems, that ultimately empower communities to define their own food and agricultural practices.[8]

In 2024, Food Banks Canada recorded its highest use of food banks, with seven million to nine million Canadians struggling to afford food for their households. This represents a 90% increase since 2019.[9,10] An estimated 5.8 million Canadians,[11] including 1.8 million children, struggle due to financial or geographical barriers.[12] For some, this means going days without eating. For others, it means relying on health-damaging, heavily processed foods.[13]

Recent data shows food insecurity issues across the country, with stark regional disparities in northern territories (Figure 1). The national average of 22.9%, representing 8.7 million Canadians struggling with food insecurity, signals a pressing public health challenge of grave importance and a social equity crisis.

Only four out of 13 provinces and territories have household food insecurity levels lower than the national average, yet just Yukon (13%) and Quebec (16%) are below the 20th percentile range.

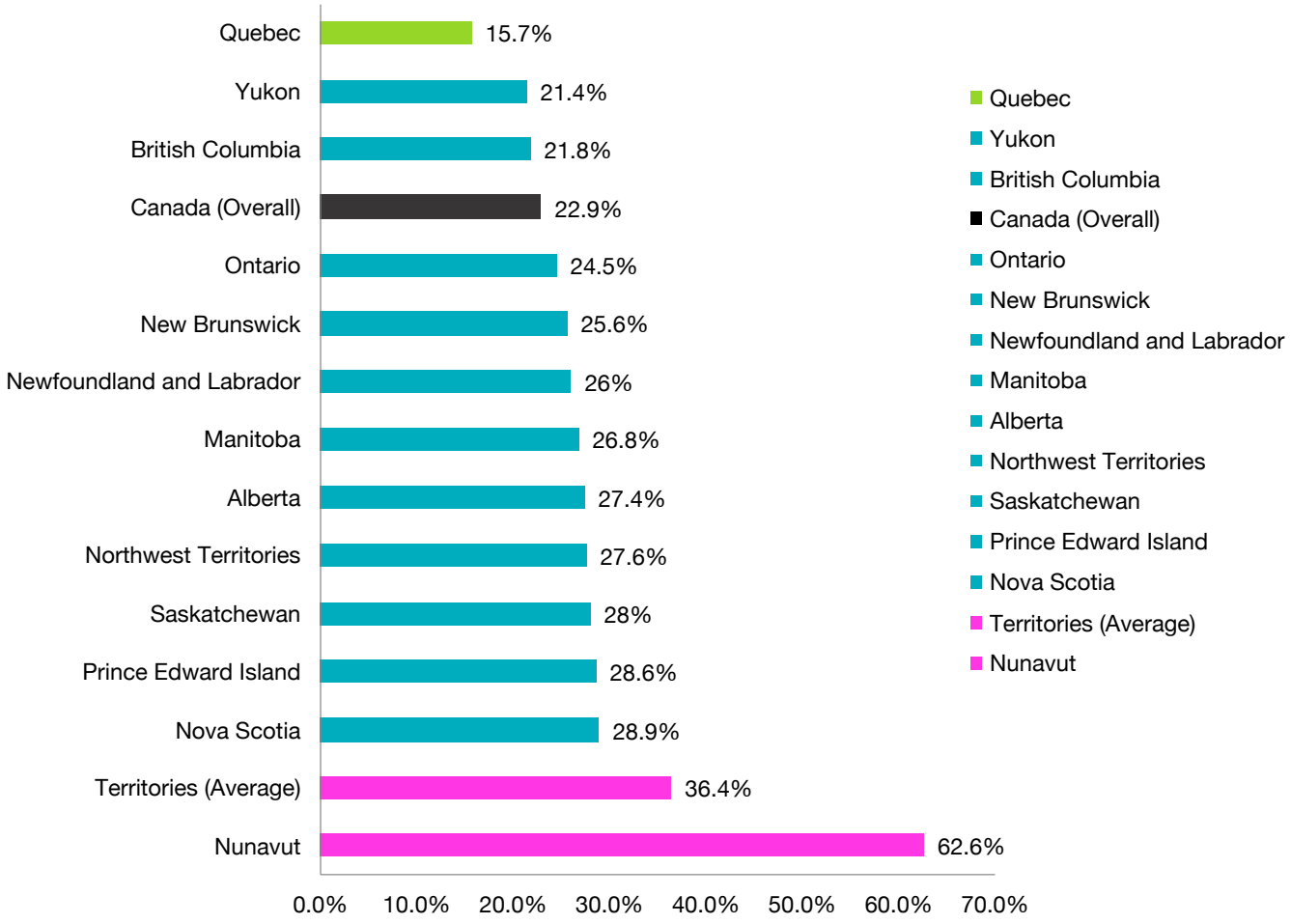
In the Atlantic provinces, 669,000 people, or 27.2% of the population, do not have secure access to food. For the Prairie provinces, the average is virtually the same (27.4%), yet this affects almost three times the amount of people at 1.9 million.

The territories exhibit the strongest variation in food insecurity rates. Nunavut has the highest food insecurity (63%) across the country, nearly 36% more than the regions with the second-highest rate, Nova Scotia and Prince Edward Island at 29%.

A large part of that is due to Nunavut's very high poverty rate, which reached 29.1% in 2022. This compares to the national poverty rate of 8.7%, and neighbouring Yukon's 8% poverty rate in 2021. Geographic isolation and a highly rural population, a higher cost of living, limited employment opportunities, and chronic housing shortages are all contributing to this crisis. This complex mix of factors is underpinned by long-standing marginalization due to its colonial history.

Figure 1

Food insecure households in Canada, by province and territory[14, 15, 16]



In Canada's North, high costs and the impact of long-distance food transportation heavily affect food insecurity.[17, 18] This also has implications for Canada's environmental sustainability goals. The transportation sector contributes 22% of Canada's total national emissions, with a 4.2% year-over-year increase in 2022.[19]

Establishing larger-scale local food production in transportation-challenged areas could significantly reduce reliance on long-distance transport from the south, contributing to efforts to reach Canada's 2050 net zero emissions target.[20] In addition, current uncertainty around U.S. tariffs and food prices across Canada brings opportunities to explore new ways to augment traditional

food supply chains with more community-based programs.[21] To ensure programs do not perpetuate colonial legacy, as well-intentioned programs may,[22] and can provision culturally-appropriate food and support food sovereignty, diverse lived experiences need to be braided into the discourse, strategy, and execution of community cropping efforts.

Canada has a strong tradition of local gardening and food production. As people moved from farms to urban settings, they often continued to grow at least a portion of the food needed for their families.[23, 24] With densification and the emergence of high-rise living, fewer and fewer Canadians have access to private land and some have turned to community gardens, though that number remains low.

Additionally, community organizations have innovated new ways to address food security. They have worked with greenhouse technologies and hydroponics to produce new food and complement more conventional food collection and distribution mechanisms. For example, Phase 2 of the Northern Food Innovation Challenge, a federally funded initiative investing in community-led projects in Canada's territories, focuses on Indigenous and local food production systems. It emphasizes scaling innovative solutions to improve food security in isolated northern communities.[25]

Food is deeply intertwined with cultural identity and practices. As a result, working with newcomer and racialized populations, as well as Indigenous Peoples whose food

traditions and preferences may not align with conventional agriculture practices, contains a certain complexity. Indigenous-led food sovereignty initiatives in northern regions, such as community gardening and traditional harvesting, highlight viable pathways to improve food access while preserving cultural practices.[26]

Greenhouse farming in urban centres, as well as Canada's North, is a slowly emerging sector that has significant potential as a sustainable way to address food security, climate resilience, and socio-economic inequalities.

It requires more attention, increased research in innovation, and widespread targeted supports. While adoption remains gradual, evidence highlights both opportunities and systemic challenges requiring targeted interventions. Targeted investments in research into energy-efficient systems and socio-economic impact assessments are critical to unlock the sector's potential.

By harnessing innovation and technological tools, and aligning resources with community-specific needs, Canada can use urban and northern greenhouse farming to improve food security and enhance climate adaptation.[27] For example, agroecological transitions can leverage the scalability offered by vertical farming in regions with land and energy constraints.[28, 29] Underutilized spaces across urban areas, such as apartment rooftops and hydro corridors, have also been converted into unconventional gardens.[30] An urban farming program model from Montreal showcases the potential to foster community engagement and local job creation by intertwining sustainable agriculture with equitable economic development.[31] Individual case studies of Indigenous and non-indigenous collaborative programs provide guidance for effective food insecurity intervention.[32, 33]

Food security in Canada

All levels of government employ approaches to address food insecurity for low-income families and in remote communities. For example, Nutrition North provides $131 million per year in subsidies. However, these don't address the issues of poor produce quality due to transportation times affecting preservation.[34] This affects nutrition and cultural practices that rely on fresh, caloric-dense, high-quality ingredients to improve current food access, and support appropriate food practices and mental and physical well-being.[35, 36]

Regionally, Inuit Taapririit Kanatami efforts include wraparound coordination and competency support to target food insecurity. These include community freezer projects, and traditional and modern cooking and gardening programming, food delivery systems through NiKigijavut Nunatsiavutinni,[37] and the Inuit Nunangat Food Security Strategy (INFSS) to coordinate Canadian and Inuit governments and stakeholders towards resolving food insecurity[38]. These begin to address subsidy distribution inequities, which often preference larger companies in northern food supply chains like the North West Company, as seen in Table 1.

Table 1

Nutrition North Canada government subsidy distribution[39, 40]

Company	Total Government Subsidy (%)	Location
North West Company	50	Across Canada (128 locations)
Arctic Cooperatives	19	Across Canada (32 locations)
Fédération des coopératives du Nouveau-Québec	12	Northern Quebec (14 locations)
Other, Independent	23	Three stores

Extreme weather also challenges roads and transportation routes, while increasing costs. The ensuing disruption to logistics may continue to further complicate food supply chains and access to remote areas. Climate change factors such as shortened winter road periods, melting sea ice, wildfires and flooding are significantly affecting transportation in northern regions.[41, 42] In 2023, Canada experienced its worst wildfire season on record due in part to El Niño events. More than 18 million hectares burned, six times the 10-year average.[43]

Food inflation in Canada reached 10.4% year-over-year in October 2024,[44] and in 2025, the Canada Food Price Report showed continued increase in consumer food costs from 3% to 5%,[45] far outpacing general inflation due to rising costs of labour, fuel and climate-related agricultural losses.[46] Global conflicts, economic tensions and political uncertainty continue to exacerbate food inflation in Canada, with cascading impacts on agricultural inputs, supply chains, and consumer costs.

For instance, the imposition of tariffs by the United States on Canadian agricultural goods in 2025, such as a 25% duty on fertilizers and machinery, has increased domestic production costs and reduced export competitiveness.[47,48]

Concurrently, supply chain disruptions, exacerbated by geopolitical conflicts, are another factor. For example, the 2022 Russian invasion of Ukraine and resulting war has resulted in soaring fertilizer and grain prices, directly affecting Canadian farmers' input costs and contributing to inflation in the agricultural sector.[49] The combination of global conflicts has heightened costs and supply chain disruption, raising food prices across the globe, including all regions of Canada.[50]

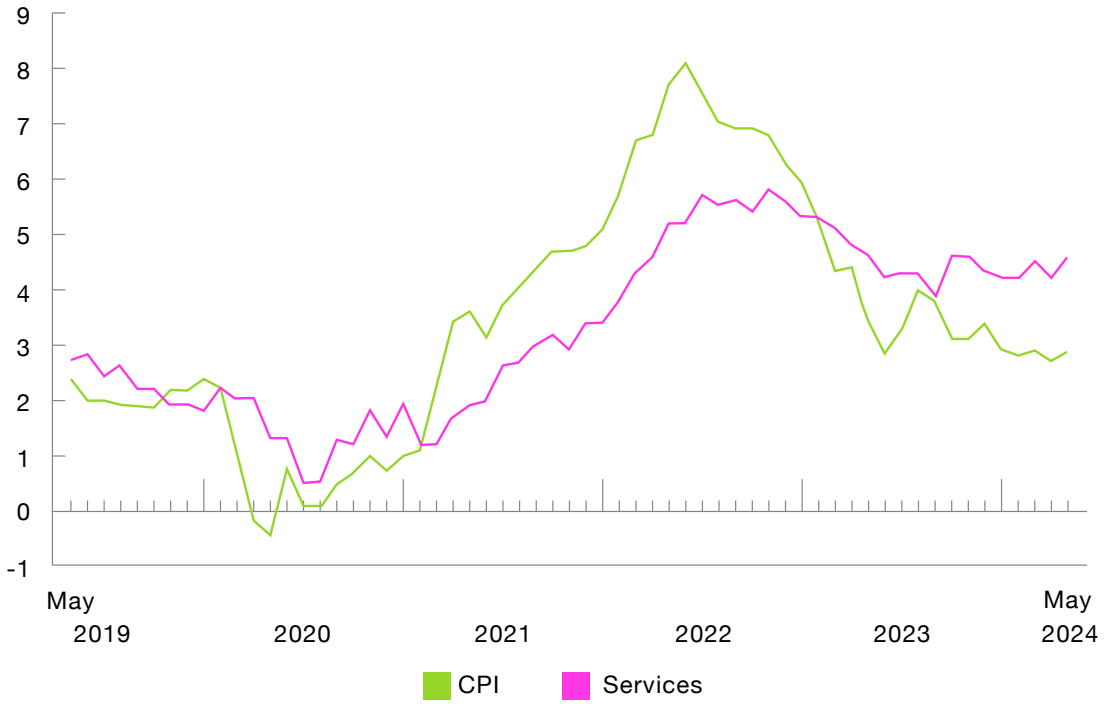
The COVID-19 pandemic highlighted the fragility of food production and transportation systems, emphasizing the urgent need for local food sources.[51] The pandemic strained national food supply chains due to border closures, temporary trade suspensions affecting international supply, and labor shortages caused by restricted migration of seasonal workers.[52]

In remote regions, limited access to fresh, nutritious food has led to poor health outcomes, including higher rates of chronic diseases such as obesity, diabetes and cardiovascular conditions.[53,54] Additionally, the provision of culturally appropriate food and the ability for self-determination of food resources cause attendant individual and community level mental, wellbeing, and cultural impacts.[55] Increasingly remote areas also correlate with reduced physical and mental health.[56] Strengthening local food systems is critical for addressing the needs of low income Canadians and for improving health outcomes and ensuring sustainable food security, particularly in vulnerable regions.[57]

Despite post-pandemic inflation becoming the "new normal" in Canada, consumer price index (CPI) fluctuations suggest that high costs may lie within the distributors themselves (Figure 2).[58] The divergence between the trajectory of index for food purchased from stores and the all-items index, particularly in 2021, indicates that factors within the food supply chain, such as distribution costs, are contributing to the rising CPI for food

Figure 2

Consumer price index for food, 12-month change, 2019 to 2024[59]



Greenhouse Farming: Innovation and Skills

Canada's agricultural sector faces a looming workforce shortage. In 2022, RBC conducted a study projecting that 40% of Canadian farmers will retire by 2033.[60] The study also anticipates a decline of about 24,000 workers in greenhouses, nurseries and farm labour. To address this, an estimated 30,000 new workers will be needed to support the industry and alleviate the concerns of 66% of producers who face uncertainty about the future of their operations. The RBC study highlights the urgent need for skilled workers in the agricultural sector and an increase of skilled Canadian workers on farmland and in greenhouse food production.[61]

Greenhouse farming already accounts for about 39% of produce grown in Canada,[62] and one-third of the $6 billion total value of Canadian horticultural produce.[63] It enables year-round production of key crops such as tomatoes, cucumbers, peppers, herbs, microgreens, sprouts, hydroponic lettuce, and eggplant.[64] Indoor greenhouse farming effectively helps mitigate the challenges posed by cold climates and short growing seasons across the country.[65] Climate-controlled environments regulate the growing environment -including temperature, light, humidity and carbon dioxide levels, ensuring consistent yields irrespective of external weather.[66, 67]

Notably, the Canadian greenhouse sector has experienced significant growth, with the farm gate value of greenhouses specializing in fruits and vegetables reaching $2.5 billion in 2023. This represents a 9.2% year-over-year increase and double the value from a decade ago. Canada has about 920 active greenhouses dedicated to fruits and vegetables, covering more than 5,000 acres and producing over 800,000 tonnes of crops.[68]

In recent years, technological advances have enabled more affordable, scalable greenhouse construction to support community food security strategies. The community-based greenhouses, particularly those aimed at addressing the needs of Indigenous Peoples and vulnerable communities, require attention to context, competencies, and wraparound supports in the design, implementation and evaluation of programs. For example, Scadding Court Community Centre in Toronto was a pioneer, with its greenhouses augmented with hydroponics and a community kitchen to support low-income,

primarily racialized communities in Toronto.[69] To date there are more than 100 community gardening projects in Toronto alone and hundreds more across the country.[70]

Other organizations have focused on applying new technologies to support year-round growing in the Far North.[71] In 2020, a study published in *Canadian Food Studies* identified 53 community garden and greenhouse projects run by municipalities, band councils and others in the Far North.[72,73]

Green Iglu, a charity that emerged from a student project at Toronto Metropolitan University (then Ryerson University) in 2015, has worked with partners to construct and implement food security programs in more than 16 communities, primarily in remote northern regions. Co-founders Stefany Nieto and Benjamin Canning, then students at the Ted Rogers School of Management, constructed their first dome-shaped greenhouse in Naujaat, Nvt., as part of the Enactus Ryerson Growing North project[74] along with other organizations such as AgriTech North,[75] Inuvik Community Greenhouse,[76] Growing North,[77] and Naurvik Project.[78] Current greenhouse infrastructure in the North includes includes some year round cultivation, through closed growth chambers and indoor vertical farms and glass or poly greenhouses, as well as seasonal interventions, through low-tech plastic hoop houses.[79,80]

Table 2 below provides an overview of urban greenhouse farming organizations in Canada. Although most of Canada's greenhouses are located in southern regions — driven by proximity to large consumer markets, established transportation networks, and favourable climatic conditions — a growing number of programs have been designed as a targeted response to address extreme food insecurity in Canada's North.[81] These greenhouse farms primarily produce vegetables, although some also cultivate fruits and herbs.

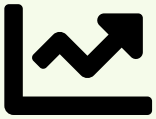
Table 2

Greenhouse farming-related production in Canada

Organization	Location	Description
Ontario Greenhouse Vegetable Growers	Windsor-Essex, Ont.	Non-profit represents more than 170 greenhouse operations in Ontario, growing tomatoes, cucumbers and peppers on more than 4,100 acres
Sioux Lookout First Nation Health Authority	Sioux Lookout, Ont.	Supports 33 First Nations communities with food infrastructure and security solutions
Northern Manitoba Food, Culture, Community Collaborative (NMFCCC)	Winnipeg	Supports northern Manitoba communities in healthy food access and economic development
Arctic Acres	Toronto	Designs and builds geodesic dome year-round greenhouse technology
Western Environment Centre	Corner Brook, N.L.	Engages members in sustainability through community gardens, fruit rescue, and composting
Canadian Organic Growers	Ottawa	Builds resilient organic food systems with farmers, supporting sustainable development goals
Food Matters Manitoba	Winnipeg	Supports traditional harvesting and gardening initiatives in Manitoba's northern communities
B.C. Greenhouse Growers Association	Abbotsford, B.C.	Produces 96% of local vegetable production in British Columbia
Agriculture Knowledge Centre	Moose Jaw, Sask.	Saskatchewan has 165 greenhouse operations with an estimated area of production of about 35 acres, employing more than 1,500 people.
Growcer Inc.	Ottawa	37 hydroponic year-round farms, based on shipping containers across Canada. Aims to decentralize the food system and make local food accessible for everyone.
The Nova Scotia Greenhouse industry	Yarmouth-Cape Breton, N.S.	About 100 growers who together have more than two million square feet of production space under glass or plastic. This makes it one of the most important sectors of the Nova Scotia agricultural economy.
Fruit and Vegetable Growers of Canada	Canada-wide	Has 892 greenhouse vegetable farms across southern Canada.

Organization	Location	Description
BC Hothouse	Vancouver	Large-scale production, multiple locations, greenhouse farming of night-shade produce and cucumbers
Arctic Focus, Naurvik greenhouse	Gjoa Haven, Nvt.	Community-led hydroponic food system, 250 kilometres north of Arctic Circle.
ArctiConnexion	Arviat, Nvt.	Uses local soils and fertilizers to grow vegetables, including potatoes, carrots, radishes, beets, and salad greens. Local experiments contrasting soil types and fertilizers are run over the summer to improve the yield. The annual crop, high in quality and nutrient value, is distributed in the community promoting healthy food habits.
Iqaluit Greenhouse Society	Iqaluit	This not-for-profit organization was established in 2001 by residents who wished to build and operate a community greenhouse. It is developing a five-year strategic plan, including a mission statement, goals and values
Naujaat Greenhouse	Naujaat, Nvt.	Growing dome that has the capacity to grow more than 2,000 plants
Kuujjuaq Greenhouse	Kuujjuaq, Nvt.	Two community greenhouses in a 40-foot shipping container operating between May and October. It includes individual and team plots equipped with a hydroponic system provided by Growcer
Kinngait Community Greenhouse	Kinngait, Nvt.	This is a 26-foot growing dome.
Yukon Gardens	Whitehorse	This year-round, 2,800-square-metre greenhouse sells large-scale hydroponic tomatoes, cucumbers, and lettuce to local grocery stores
Yukon Agricultural Association	Whitehorse	The association promotes sustainable Yukon agriculture through education, infrastructure and partnerships.
ColdAcre	Whitehorse	Offers faster plant growth using nutrient-rich water and light systems.
Tr'ondëk Hwëch 2014	Dawson City, Yukon	The 3,000-square-foot cold climate greenhouse utilizes biomass energy as a renewable source of heat. It extends the season by up to 10 months.
Klondike Valley	Dawson City, Yukon	Explores cold-climate growing boundaries, specializing in high-latitude fruit production.
Sunnyside Farm	Yukon	Produce is grown seasonally using a greenhouse, caterpillar tunnel, raised beds and outdoor garden areas.
Inuvik Community Greenhouse	Inuvik, N.W.T.	This is North America's northern-most commercial greenhouse.

Organization	Location	Description
Yellowknives Dene First Nation Greenhouse	Yellowknife	Community members are assigned growing plots annually. Youth and elders share produce with community members in need.
Hay River Community Garden	Hay River, N.W.T.	These 60 greenhouse plots are used to extend the growing season and grow more extensive varieties of vegetables for the community.
Gameti Greenhouse & Farm, Tlicho Government	Yellowknife, N.W.T.	This 1,500-square-foot greenhouse has increased health and improved employability in the community.
Lutselk'e Community Greenhouse	North Slave Region, N.W.T.	This is a well-established greenhouse operation. Limited information is available.
Tuktoyaktuk Community Greenhouse, 2015	Tuktoyaktuk, N.W.T.	Limited information is available.



Key emerging trends include energy efficiency, automation and robotics, AI and machine learning, optimized growing methods, integrated smart sensors, and management systems.

Innovation and digital skills in greenhouse farming

Greenhouse farming is undergoing rapid technological advancements in sustainable and efficient agricultural practices.[82,83] When technology changes, the configuration of labour and skills required follows suit. For example, agriculture in Canada has labour shortages that include high demand for physical labour alongside specialized digital skills.[84,85] The Canadian agriculture sector is harnessing innovative applications of artificial intelligence (AI), the Internet of things (IoT), data analytics, sustainable energy and other modes of technological advancements.[86] Key emerging trends include energy efficiency, automation and robotics, AI and machine learning, optimized growing methods, integrated smart sensors, and management systems. Worker skills and competencies for greenhouses should be developed with and for equity deserving groups and Indigenous communities, ensuring programs address food insecurity and reconcile settler legacies of food intervention programs in the North.

Alternative energy sources

Solar energy systems are revolutionizing greenhouses by making them self-sustaining.

Photovoltaic (PV) panels convert sunlight into electricity, where electrons excite a semiconductor material, generating an electric current that is used to power heating and cooling systems.[87] Solar-powered temperature regulating systems reduce dependence on traditional energy sources that can help lower the carbon footprint.[88] Hybrid renewable energy systems such as combining solar and geothermal sources offer year-round efficiency.[89] This can be used in residential, commercial, and industrial solar power systems, and also in remote locations where electricity access is limited.

Advancements in soil and growing mediums

Studies emphasize the advantages of alternative cultivation substrates, including biochar-enriched substrates and soilless systems like hydroponics and aeroponics. Ultimately, substrate and system selection will depend on the cropping optimization requirements for improving water retention, nutrient availability, and overall plant growth.[90,91] Greenhouse innovations allow for the precise, and increasingly automated, control of environmental parameters.[92] They support reductions in organic matter and arable land requirements for cultivation, and flexibility in cultivation location and

intensity. Greenhouse coincide with trends toward localized food production, and thus food system resilience to climate shocks, inconsistent community access for food distribution, thus enabling sustainable and resilient farming systems. These systems use up to 90% less water than traditional farming, maximizing space efficiency and optimizing resource use, making them crucial in supporting sustainable agriculture initiatives.[93]

Turnkey vertical farming units integrate advanced lighting systems, environmental parameter controls, different substrate types and automation to reduce space use, water and nutrient consumption. This results in up to 98% less water use and 99% less land use.[94] These environmental and capital benefits may offset the challenges of scaling vertical farming, emphasizing its potential to meet the increasing global demand for food while minimizing environmental impact.[95]

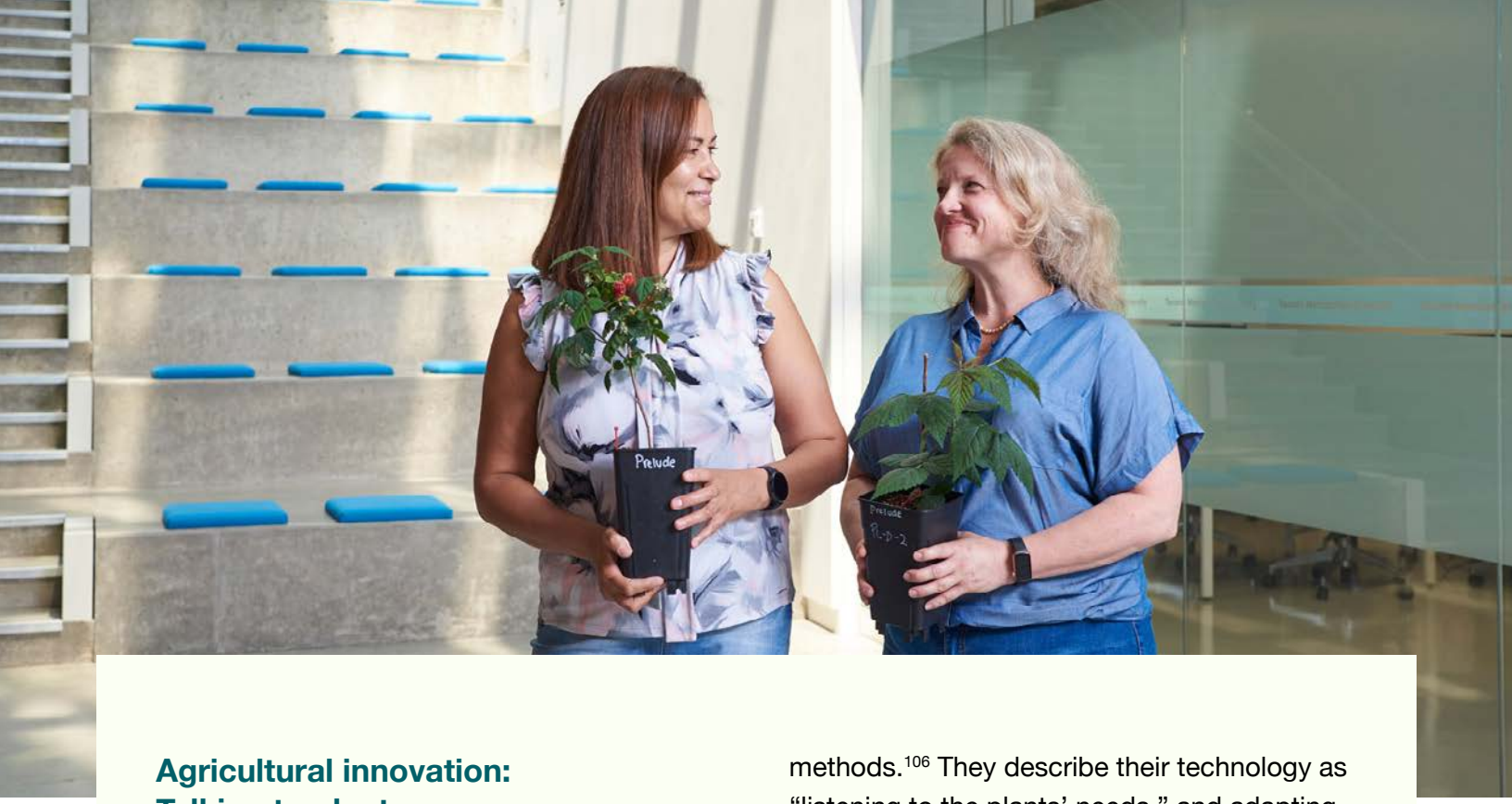
Artificial intelligence and machine learning

Machine learning and AI are transforming agriculture enabling advanced precision farming techniques.[96] For field agriculture these technologies analyze large datasets, including satellite imagery and sensor data, to optimize crop health, predict yields, and manage resources efficiently.[97] AI systems can monitor plant health using vegetation indices and multispectral imagery from satellites, helping to forecast crop performance and address potential environmental challenges.[98] Machine learning enhances pest control and maintenance predictions, driving

efficiency.[99] In greenhouses, the same data processing infrastructure can be applied to onboard sensors to monitor plants, and implement changes to environmental controls, pest management, and supporting yield optimization.

Sensor technology and automation

The so-called Internet of things is made up of hardware components like sensors, actuators, gadgets, appliances or machines designed for applications that are capable of transmitting data over the Internet or other networks.[100] Smart sensors, or IoT devices, are becoming integral to precision agriculture, monitoring temperature, humidity, and soil moisture in real time.[101] Automated systems respond to environmental changes, and IoT devices allow remote monitoring and control, optimizing resource use and reducing labour.[102]



Agricultural innovation: Talking to plants

Engineer Habiba Bougherara and plant scientist Lesley Campbell, both from Toronto Metropolitan University(pictured), are leading the development of the iGrow platform, a microclimate-controlled, multilayered growing system designed to optimize crop production.[103] This system aims to revolutionize berry production in Canada , supporting year-round berry production in off-seasons and harsher climates.[104] The iGrow platform is notable for its pesticide-free approach, which supports cleaner food production, and its focus on sustainability.[105] By utilizing solar energy, biosensors, and AI technology, the system monitors and adjusts growing conditions in real time to promote optimal plant health. The platform's design integrates with existing modular vertical farming units for scalability, works hydroponically, and supports energy-efficient continuous food. Moreover, it allows for increased food yield, producing 350% more per square foot than traditional farming methods.[106] They describe their technology as "listening to the plants' needs," and adapting environmental controls to facilitate optimized yield. This innovative system addresses critical traditional agriculture challenges in short growing seasons, dependency on pesticide use and builds local capacity in lieu of food providers depending on climate-, policy and market-based shocks, which impair food resilience. Their platform, which received a $1 million grant from the Weston Family Foundation's Homegrown Innovation Challenge, and $4 million in infrastructure funding through the Canadian Foundation for Innovation for pilot deployment at Toronto Metropolitan, a Canadian research greenhouse network, and a greenhouse network across Quebec.[107] Additionally, iGrow's bee-free pollination technology is advantageous in controlled indoor environments where pollination necessary and difficult given external environmental isolation.[108] This self-pollinating system opens possibilities for farming in regions where traditional agriculture cannot thrive.

Water, nutrient management systems and AI

Advanced water and nutrient management systems are important for enhancing agricultural sustainability in environments where water resources are scarce or expensive to operate on a larger scale.[109] Controlled indoor environment systems rely on imported crop amendments, particularly phosphorus, nitrogen, and potassium, which are environmentally deleterious following synthesis (e.g., the Haber-Bosch process) and intercontinental transport to Canadian farmers.[110] Nutrient procurement is increasingly expensive, following geopolitical tensions in major exporters – particularly Ukraine - and continued reduction in finite mined sources. Precision irrigation and nutrient amendment systems, such as those integrated with AI and IoT technologies, allow for optimized usage.[111] For example, AI-driven models can predict the right time and amount of water needed for crops reducing crop fouling and water expenditure. These models use the foundational multi-sensor data infrastructure to continually monitor environmental parameters, such as soil moisture and adjust irrigation schedules in real time to ensure water is applied efficiently to enhance yield.[112]

Nutrient management systems can adjust fertilizer composition and application based on real-time data regarding soil conditions, crop life stages, and environmental factors.[113] Nutrient optimization reduces excess fertilizer usage, and thus minimizes environmental pollution of effluent to local water systems. Additional methods such as such as drip irrigation distribute water and nutrients more uniformly compared to traditional methods. Drip irrigation is a simple tool that can be highly efficient in greenhouse farming.[114]

Solar-powered greenhouses

Solar-powered greenhouses harness the energy of the sun to regulate in controlled indoor environments, reducing reliance on external power sources, making them an eco-friendly alternative to conventional land farming systems.[115] These greenhouses are designed to optimize solar energy absorption and manage direct and diffuse radiation effectively.[116] Performance optimization requires extensive site evaluation, to ensure appropriate ventilation strategies complement crop growth requirements. Ventilation in a greenhouse is key[117] to attenuate elevated solar radiation in the summer and heat loss during the winter months.[118]

Solar passive greenhouse with geodesic dome structure

Innovative greenhouses need to be scalable, compatible platforms for existing and new greenhouse technology, and withstand the greenhouse deployment context. The solar passive greenhouse is built for Northern environments. It has a geodesic dome design and is engineered to withstand northern wind speeds of up to 180 km/h and has been tested to endure gusts reaching 210 km/h.[119] The design utilizes solar ventilation for cooling and heating, eliminating the need for electricity. Its foundation can be made from affordable

materials like concrete or gravel, and the hub system connects struts covered with one-half-inch thick polycarbonate material, offering hail resistance and durability.[120] The solar mass in the greenhouse holds and releases heat to regulate temperature, while a reflective wall on the north side directs sunlight to a thermal mass pool, which acts as a passive solar heater,[121] providing year-round warmth equivalent to a 40,000 BTU heater. With a high R-value of 1.6 and low U-value insulation, the structure ensures optimal heat retention. The yield depends on what is grown, and how it is grown vertically or horizontally. For example, a 42-foot geodesic dome can support modular hydroponics that sustain produce for up to 100 people if crops are grown vertically or about 12 people if grown horizontally.[122]

During colder months, geodesic dome greenhouses can grow vegetables such as *Brassicaceae* family plants (e.g., kale, leafy greens and herbs) that do not require intense light to start vegetative development.[123] Energy-intensive crops like tomatoes and cucumbers would require intermittent full spectrum lighting for year-round cultivation.[124] The greenhouse's passive thermal system helps maintain a stable temperature, resulting in a 30-degree difference between the inside and outside temperatures.[125, 126] The dome is sealed with ultraviolet (UV)-resistant aircraft tape, ensuring it remains clear for up to 10 years and prevents UV damage to plants and the external environment.[127]

Additional heating options, such as plug-in heaters, water trough heaters or wood stoves can be installed. Electricity is required for year-round production in northern latitudes.

Despite these advantages, challenges exist, such as limited access to water sources, electricity prices for year-round growing, difficulty in replacing damaged thermal pool liners, algae maintenance in hydroponic systems, and drainage issues when the dome is not used year-round. Building the structure requires specialized industrial equipment like a zoom boom, lift, or a professional with access to safety equipment, which may not always be available in remote areas.[128] The process can take one to two days for taping in suitable weather.

In fact, many geodesic domes have been abandoned if the community was not fully invested in the project. Committed community engagement is vital, and precise work must be done during the building phase to ensure long-term success.

Additionally, building the dome requires an experienced carpenter and skilled local builders, a challenge in many communities where skills gaps are common. Precise measurements and properly constructed knee walls are essential to the dome's shape and structural integrity.

Equity, diversity and inclusion issues in greenhouse agriculture

Gender issues, Indigenous perspectives and diversity all figure prominently in agriculture. While women play a significant role across the country and are often partners in the ownership of farms, gender stereotypes prevail. Farming is seen as a man's occupation, whereas gardening is for women.[129]

The aging population presents a challenge, as do massive retirements without clear succession planning. Generational attitudes to farming vary considerably. The younger generation of potential farm workers in Saskatchewan says a significant factor deterring them from pursuing careers in farming is notably not a lack of interest or willingness, rather the steep financial barriers associated with starting or maintaining a farming operation. Farm Credit Canada's 2024 report highlights farmland values increased by 9.3% across Canada, with the highest provincial increase in Saskatchewan at 13.1% and the lowest increase in Prince Edward Island at 1.4 though no data by Farm Credit Canada is available for Canada's three northern territories. [130]

Engaging Indigenous communities in conventional farming presents requires integrating traditional Indigenous methods of obtaining food. In Indigenous communities, "food is medicine." Practices of hunting, gathering roots, berries, and using region-specific medicines have all long been integral to many communities. Knowledge of plants and growing in the Far North is regional and community specific.

A conventional notion of a "healthy diet" is culturally specific and often not well received by communities. Western agriculture has historically been used in land dispossession and assimilation, and communities in the North may experience trauma from agriculture approaches, diets, and food cultures, which force assimilation to traditional foods.[131] Gardening, for instance, is sensitive through its associations with the residential school system.[132]

Collaborating and co-developing agriculture systems with each community individually is essential to foster trust and connect Canadians and Indigenous community members with healthy, fresh and available produce. Any agricultural system needs to deeply understand and braid data on the community's needs and wants from elders, schools, and other local leaders to ensure that sustainability can be achieved in the long term. Involving the community, including schools, teachers and elders, from the outset of a greenhouse sustainability program is key.

This will help to empower the communities to achieve food sovereignty and work toward long-term food security. In the area of controlled environmental agriculture, women and members of equity-deserving groups are increasingly common compared

to conventional cultivation, but remain below parity and not without barriers to participation, as discussed above. Other equity deserving groups, including, newcomers to Canada, also face barriers in engaging in agriculture.[133, 134] For this reason, training programs need to be carefully designed with an eye to gender, culture and other dimensions of equity, diversity and inclusion (EDI).

Competencies, Design and Delivery of Skills Development Programs

This section investigates the current offering of agriculture programs at Canadian post-secondary institutions. It identifies competencies and proposes considerations, including EDI implementation, to guide the design and development of skills training. A review of competency frameworks for the agriculture sector, greenhouse technical expertise, policies for community-led agricultural projects, and agricultural strategies for Indigenous regions has been conducted. Key components are synthesized into an Indigenous-led competency framework for agriculture projects.

Sustainable and greenhouse agriculture training programs[135]

While new programs are emerging on a regular basis, limited attention is focused on clear competency frameworks for agricultural training, upskilling and reskilling, or clear connections to career pathways. Program offerings range from full university degrees to college diplomas and certificates, as well as a growing number of microcredentials and short courses. Labour shortages in the sector must be urgently addressed and education and training better mapped to opportunities.

This is especially true for community-based greenhouses, which can leverage the network of existing and emerging automation technologies for energy and nutrient consumption, as well as yield optimization.

Universities and colleges in Ontario offer a variety of programs to prepare students for entry into Canada's agriculture industry. The Ontario College Application Service (OCAS) provides a general standard for what potential agriculture students may expect as they embark on their educational journey. Courses in these programs will have coverage of traditional agriculture topics such as farming techniques and livestock management. Students can expect to learn about agriculture from the perspective of sustainability, where topics such as organic agriculture, pest ecology and soil science will come into play. After completing these programs, students generally go on to work on established farms or start their own farms. A variety of other agriculture-related career pathways are also available, including warehousing, food safety, marketing and business, and transportation.

Looking forward to the future of Canada's agricultural industry, a clear need for a shift in skills training for the agricultural sector

appears. RBC's *Farmer 4.0* report describes a critical junction in the country's agriculture sector, with 37% of Canada's aging farmer workforce on track to retire over the next decade,[136] and an overall declining trend in labour force statistics over the past 48 years.[137] The report positions a skills revolution as the way forward, with digital competency, business acumen and data analysis listed as the likely skills that agriculture professionals will need to innovate in the industry and stay employable. In contrast, general labour workers face a high risk of automation, with the report predicting a 94.2% probability of agriculture-based labour skills giving way to automation by 2030.[138]

Canadian post-secondary institutions offer agriculture programs at all credential levels, from microcredentials to PhD programs. Shorter programs, such as microcredentials, certificates and diplomas, are generally narrower in scope and place a strong focus on experiential learning. For example, an agricultural management diploma from Olds College of Agriculture and Technology is a two-year program that trains students in communication, accounting and marketing skills. Students can specialize in agricultural production or agricultural finance. This subset of programs also serves as a gateway for non-agriculture students to enter the industry.

Academic degrees at the bachelor's, master's and PhD levels are generally more comprehensive in course coverage and often include some form of internship and/or research component. In addition, agriculture degree programs often include in-depth science courses, encompassing topics such as biology, and food and environmental sciences.

The tables below explore the landscape of agriculture training programs in Canada.

> Table 3 lists the existing university and college agriculture program offerings, alongside each of their subfields of study and the credentials that students can pursue. Additionally, it covers free training programs for agriculture professionals in Canada. Many of these programs are provided online or mostly online and offer training on the farming and business aspects of agriculture operations.

> Table 4 outlines a series of shorter programs focusing on greenhouse operations and their associated costs.

> Table 5 displays a couple of regulatory certifications for facilitating greenhouse-based exports between Canada and the United States.

Table 3

Sustainable and greenhouse agriculture training programs in Canada

Institution and Department	Relevant Areas of Study	Credentials Offered	Description
University of Guelph Ontario Agricultural College (OAC)	> Animal biosciences > Food, agricultural and resource economics > Food science > Plant agriculture > Environmental design and rural development > Environmental sciences	> Certification > Diploma > Bachelor's > Master's > PhD	Renowned for its agriculture, veterinary and food-related training, it's considered Canada's oldest and top-ranked institution in these fields.
University of Alberta Faculty of Agricultural, Life & Environmental Sciences (ALES)	> Agricultural, food and nutritional science > Human ecology > Renewable resources > Resource economics and environmental sociology	> Bachelor's > Master's > PhD	It offers strong programs in agriculture, including research in fields like energy and artificial intelligence. It also contains course coverage on Indigenous knowledge systems.
University of British Columbia Faculty of Land and Food Systems (LFS)	> Applied biology > Food, nutrition and health > Global resource systems > Food and resource economics	> Microcredential > Bachelor's > Master's > PhD	Known for its diverse and high-quality agriculture courses, it offers a range of study levels for international students. It integrates Indigenous perspectives in its food systems courses.
McGill University Faculty of Agricultural and Environmental Sciences (AES)	> Animals and plants > Biological sciences and engineering > Ecosystems and environmental management > Food and nutrition > Sustainable agriculture > Farm management and technology	> Certificate > Diploma > Bachelor's > Master's > PhD	It facilitates hands-on learning with its waterfront Macdonald campus, offering professional certifications and degree programs. It houses the Centre for Indigenous Peoples' Nutrition and Environment (CINE), which facilitates workshops and research initiatives in relation to Indigenous food systems and environment.

Institution and Department	Relevant Areas of Study	Credentials Offered	Description
University of Manitoba Faculty of Agricultural and Food Sciences	> Agribusiness and agricultural economics > Agriculture > Animal science > Biosystems engineering > Entomology > Food and human Nutritional Sciences > Plant and soil Sciences	> Diploma > Bachelor's > Master's > PhD	It offers a wide variety of agriculture-related programs. Research strengths include crop and livestock systems, food quality and processing, and data-forward decision making. It features a dedicated course exploring Indigenous issues in food systems.
Dalhousie University Faculty of Agriculture	> Animal science and aquaculture > Business and social sciences > Engineering > Plant, food and environmental sciences	> Certificate > Diploma > Bachelor's > Master's > PhD	This comprehensive program features a state-of-the-art aquaculture facility. Its research focuses on sustainability of animal and aquaculture systems.
University of Saskatchewan College of Agriculture and Bioresources (AgBio)	> Agricultural and resource economics > Animal and poultry science > Food and bioproduct sciences > Plant and soil sciences > Kanawayihetaytan Askiy program (management of federal reserve lands)	> Certificate > Diploma > Bachelor's > Master's > PhD	A well-connected agriculture college with a unique certificate/diploma program, it features studies in land governance, resource management, and economic development relating to Indigenous communities.
University of the Fraser Valley Agriculture Department	> Agriculture technology > Agriculture science > Crop and livestock production > Business administration and agriculture management	> Certificate > Diploma > Bachelor's	It offers specialized professional programs in addition to degrees in agriculture science and management.

Institution and Department	Relevant Areas of Study	Credentials Offered	Description
Olds College	> Agriculture > Agriculture technology > Animal health > Horticulture > Land and environment > Meat processing > Trades and apprenticeship	> Microcredential > Certificate > Diploma > Bachelor's	A historical landmark with deep roots in agriculture, it offers career-focused credentials and degree programs. The college features a "smart farm" that leverages technology to enhance agriculture operations.
New Brunswick Community College	> Agricultural equipment repair > Sustainable agriculture > Agribusiness	> Certificate > Diploma	The college's agriculture programs prepare students to perform technical repairs on farm equipment and practice sustainable crop and livestock production.
North Island College	> Farm working > Greenhouse operations > Business management and marketing > Seaweed production and processing > Coastal forest management	> Statement of Completion (non-credit) > Microcredential > Diploma	It offers hands-on training in agriculture operations, as well as coastal-specific niches such as seaweed production and coastal forestry. Students gain practical business experience by participating as vendors in local markets.
Algonquin College	> Agribusiness > Horticulture > Environmental management > Forestry	> Certificate > Diploma > Bachelor's	The college offers a study in agriculture through a business perspective in addition to several agriculture-adjacent niches focusing on sustainability and preservation.
Collège Boréal	> Agricultural techniques > Veterinary care	> Certificate > Diploma	It offers a couple of agriculture programs focusing on farm management, crop production and sustainable farming. Programs are offered in French.
Conestoga College	> Agribusiness > Agriculture technology	> Certificate	Its agri-business management program touches on business operations, technology usage and marketing as they relate to agriculture.

Institution and Department	Relevant Areas of Study	Credentials Offered	Description
Durham College Faculty of Hospitality and Horticultural Science (HHS)	> Horticulture	> Diploma	The college facilitates experiential learning through its urban farm, where students learn to develop a sustainable food system.
Fanshawe College	> Agribusiness > Agricultural equipment > Environmental design > Veterinary studies	> Certificate > Diploma > Bachelor's	The college offers programs covering various agriculture subfields, including business operations, equipment repair and maintenance, environmental planning, and animal care.
Humber Polytechnic Faculty of Social & Community Services	> Sustainable urban farming > Vertical agriculture	> Microcredential	It offers microcredentials for programs focused on urban and enclosed agriculture settings.
University of Guelph Foundations in Agricultural Management	> Business planning and strategy > Financial literacy > Human resources > Risk management > Farm transition planning	> Certificate	This free online course, developed in partnership with Farm Credit Canada and RBC's Future Launch program, focuses on business management skills for farm owners.
University of Guelph Ridgetown Campus Agriculture and Food Education in Ontario	> Food safety foundations > Human resources management > Food recall management > Sanitation > Traceability systems > Water use > Worker practice	> Certificate	This platform offers a variety of free, self-paced courses and resources for producers and processors, focusing on business growth and development. Additionally, it offers a Growing Your Farm Profits component covering production and financial management, marketing, social responsibility, succession planning, and goals.

Institution and Department	Relevant Areas of Study	Credentials Offered	Description
Ontario National Farmers Union (NFU-O) New Farmer Training Program	> Foundational knowledge and language for basic farm work > Application of farm language and knowledge > Beyond basics to build skills for a specialized farm > Entrepreneurship training for operating a farm business	> Certificate	In partnership with Ignatius Jesuit Centre and the Ecological Farmers Association of Ontario, NFU-O offers free online skills training for new farmers and farm employers.
Agricultural Research and Extension Council of Alberta (ARECA) Alberta Environmental Farm Plan	> Assess areas of strengths and potential environmental risks on a farming operation > Individualized site-specific planning	N/A	This free, confidential, whole-farm self-assessment tool helps producers to understand and address environmental risks on their farms.
Cultivation Quebec Cultivation	> Urban (or peri-urban) food growing environments > Small plot intensive farming methods > Community food systems > Social economy-based urban farm > Permaculture methods > Gardening cycles > Foraging in urban areas > Natural methods for pest control	N/A	This is for learning about gardening, urban farming, and urban permaculture.

Institution and Department	Relevant Areas of Study	Credentials Offered	Description
Toronto Urban Farming Training TUFT	> Farm viability > Risk assessment and mitigation in urban farm businesses > Business planning > Food justice and reconciliation > Growing space identification > Marketing strategies > Business planning and support networks	N/A	This eight-module, 11-week program has two in-person sessions that support urban farmers in creating sustainable businesses. It is open to anyone interested.

Table 4

Programs for greenhouse careers in Canada

Institution - Credential	Cost[a]	Description
Olds College Indoor Agriculture Certificate	**Five courses** Domestic students: $673.32/course International students: $1,685.91/course	Olds College introduces Canada's first indoor agriculture certificate program. The classroom courses introduce controlled environment agriculture (CEA), basic horticulture, technology for CEA, and business practices for the CEA sector. Enrolment this fall is open for 30 students. Admission requirements include English proficiency and high school credits for two science courses. Mid-career adults who want to upgrade skills or change careers to work in this emerging field also are welcome. Students can optionally complete an industry placement after courses.
University of Guelph OpenEd Horticulture Certificate	**Five courses** $595/course	Online course delivery includes three foundation courses and two electives. Students learn principles of plant and soil science in addition to pest management techniques. Elective courses span various subfields of horticulture, including turf management, greenhouse production, cannabis production, landscape management, landscape design and urban agriculture.
Olds College Greenhouse Crop Production	**One course** $749 **Required texts** $217.95 + GST $89.95 + GST	A two-term online course introduces the prairie greenhouse industry and covers greenhouse crop production, pest control and production economics.

a These costs are estimates and may not take into account tuition rate changes and auxiliary program costs. Auxiliary costs have been included where information was available.

Institution - Credential	Cost[a]	Description
University of Saskatchewan Prairie Horticulture Certificate - Greenhouse Crop Production Stream	**Eight courses[b]** Domestic: $555.00 to $772.26/ course International: $832.50 - $3737.73/ course **Required text and materials** $475 **Student fees** $129/year	The program offers four specialized streams of study, including greenhouse crop production. Students in this stream are trained on greenhouse horticulture and soil science. They will also choose from electives in management, marketing, pesticides, plant propagation, and landscaping.
Niagara College Greenhouse Technician Diploma	**Program total** Domestic: *No Co-op,* $9,701.76 *Co-op,* $10,236.76 International: *No Co-op,* $36,351.80 *Co-op,* $37,146.80	The two-year program has an additional optional co-op component. Students are trained on indoor plant and crop growth, pest management principles, business practices, and related greenhouse technology. A large training greenhouse on-campus serves as a student lab and offers experiential learning working with its integrated pest management system.
Niagara College Horticultural Technician Diploma	**Program total** Domestic: *No Co-op,* $10,176,76 *Co-op,* $10,711.76 International: *No Co-op,* $36,826.80 *Co-op,* $37,621.80	A two-year program with an additional optional co-op component. Students learn horticulture skills, maintenance procedures and design practices. In a similar way to Niagara College's greenhouse technician program, students have access to a large training greenhouse to conduct projects and gain experience via hands-on learning.

b Tuition is displayed as a range since individual courses are selected by the student and have separate costs.

Institution - Credential	Cost[a]	Description
Assiniboine College Horticultural Production Certificate	**Program total** Domestic: $6,670 International: $19,970	This nine-month program prepares students for entry-level positions in horticulture. Areas of study include plant characteristics, horticulture principles, pest management, and greenhouse operations
Vancouver Island University Horticulture Technician Foundation Certificate	**Program total** $7,276.96	A nine-month horticulture program that features a 50% program split for hands-on learning either in industry or at the on-campus horticulture centre.
University of Fraser Valley Horticulture Crop Production and Protection Certificate	**Two-semester cost** $2,195.28	This two-semester certificate program exposes students to horticulture principles, covering topics such as greenhouse production, pest treatment, and crop production.
St. Clair College Greenhouse Technician Diploma	Program total Domestic: $4,374.77 International: $15,665.55	A two-year program with a co-op component. In the third semester, students can choose to take either the production or the integrated pest management (IPM) stream.

Table 5

Regulatory certifications for greenhouse-based exports between Canada and the United States

Program	Description
Canadian Nursery Certification Program (CNCP)	This program is for Canadian nurseries and greenhouses that ship nursery stock to the United States or to other certified facilities within Canada. It ensures the phytosanitary certification of nursery stock, meaning it's free from pests and diseases.
United States - Canada Greenhouse-Grown Plant Certification Program (GCP)	This program facilitates the export of greenhouse-grown plants between Canada and the United States. It ensures that plants meet phytosanitary standards for both countries.

In designing and implementing agriculture training programs a range of considerations must be addressed:

1. Does the program target a specific role or job?
2. What foundational skills does it require? For example, what is needed for success, literacy, etc.?
3. What are the contextual issues, learning needs and preferences of the targeted communities?
4. What modalities of delivery are most effective for whom?
5. What wraparound supports are needed?

Based on the review of existing programs, a series of skills and competencies have been identified and can be grouped into two categories:

1. **Essential skills**: Identify and develop the skills necessary for individuals to operate sustainable growing practices in urban or rural settings. This includes skills like problem-solving, collaboration and adaptability.
2. **Greenhouse agriculture**: Create and assess programs that promote sustainable agricultural practices using controlled indoor environment systems. This involves understanding the technology, techniques and benefits of controlled indoor environment systems farming, and ensuring these practices are environmentally friendly and economically viable.

Applying an EDI lens is essential to design equitable agricultural education programs. Consideration for diverse populations must be embedded throughout the program development and delivery. This should address barriers faced by Indigenous Peoples, women, other members of equity-deserving groups, as well as varying contexts. Mapping regional disparities, such as digital access and literacy, embedding anti-racist frameworks, and prioritizing land-based Indigenous knowledge should be integrated into overall program design. Additionally, programs should consider engagement modalities that center on co-development and co-implementation of training programs, which have marked success across Canada.[139, 140]

The design should begin with research and analysis to clarify goals and understand the unmet needs of diverse student populations. It should also evaluate existing programs to assess successes and failures. Embedded evaluation frameworks ensure measurable outcomes.

Program design requires clear competencies, tailored pedagogy, flexible delivery methods (i.e., in-person, online, or hybrid), and should consider forms of wraparound supports. This can be achieved during the development of the program by co-creating curricula with various equity-deserving groups to identify needs. For example, collaborating with Indigenous knowledge holders and relevant communities, depending on where the program is intended to be delivered (understanding the regional differences between rurality and urban-based communities), can pair western agriscience with culturally traditional practices. This is particularly important in the North, as access to culturally-appropriate food sources.

This form of program development with EDI integration tailors pedagogy and optimizes delivery of educational courses for diverse learners. Furthermore, providing wraparound supports such as digital literacy training, culturally informed counselling, and grants or stipends for low-income students, and providing tailored resources and support addressing diverse needs of equity-deserving groups, can increase access to educational programming. It can also improve learning outcomes and success in the course while preparing students for agricultural work, further expanding the potential of agricultural initiatives.

To improve implementation, working with community advisors and, if possible, establishing co-creation councils provide culturally relevant and nuanced insights to shape equitable and inclusionary programs. This can be in the form of anti-bias training and trauma-informed teaching for educators and staff that includes cultural, historical, and contextual elements.

Adapting delivery models, depending on available resources and applicability, is beneficial. For example, programs closer to urban centres can focus on agri-tech innovation, while courses in more remote and rural regions may emphasize land-based

knowledge and local food security. Leveraging evaluation frameworks that harness feedback loops (e.g., blending Indigenous talking circles with disaggregated data analysis) to track progress and outcomes by gender, Indigeneity, and demographic characteristics, informs iterative redesign.[141] This can improve the reach and success of agriculture educational programming.

Increasing access to programs by establishing flexible admissions that address the needs of equity-deserving groups, while adapting to the unique barriers faced by diverse learners, will improve inclusion. It will also create pathways to valuable skills and essential technical expertise required to successfully engage in evolving agricultural practices.

Programs should recognize diverse forms of prior learning, life experience, and community involvement, rather than relying solely on traditional admission requirements for academic and certification programs. This approach values the skills, knowledge and perspectives that learners bring from informal educational experiences, making programs more accessible for those who may have not followed conventional educational pathways. This creates new opportunities for individualized learning plans targeting those who may have been pushed away from developing these valuable skills otherwise.

A core component of embedding EDI to create holistic education programs is tailoring the course to equip diverse learners with the skills and knowledge to harness the tools

and resources specific to their contextual objectives. In the North, food is very culturally specific, and attention should be paid to not imposing Western conventions of 'healthy' food into communities, cognizant of the trauma from Western agriculture approaches, diets, and food cultures that forced assimilation.[142] Specific competencies are needed to interrelate existing and emerging agricultural sector requirements to local food knowledge, practices and requirements. Community-driven approaches, coupled with competency frameworks, can form part of a larger framework. Once tailored to the type of project and demographic, it can drive equitable and inclusive agricultural strategies. Embedding these frameworks within community-led agriculture projects can address both systemic barriers and hyperlocal needs (i.e., food insecurity, climate and environmental conditions).

Competency frameworks for community-led agricultural projects

To develop a competency framework for community-led agricultural projects, we reviewed agricultural competencies from various frameworks. Additionally, our examination identified multiple policy frameworks developed to guide community-led agricultural initiatives.

Competency frameworks developed for agri-businesses and organizations are a valuable tool to identify and assess evolving skills needs, inform training plans, and ensure effective long-term viability of projects. They delineate required personnel, resources and various forms of support depending on the environment and objectives.

Programs and initiatives require those involved to possess various skills and knowledge to achieve successful outcomes. This can be achieved through selecting project leaders and workers with the right skill sets, as well as empowering community members and volunteers by equipping them with valuable competencies and tools relevant to the project.

Integrating competency-based approaches into community-led sustainable agricultural projects offers structure to address the technical and socio-emotional skills needed across various roles. By identifying and promoting literacy for local food systems, it can improve the quality of community engagement and participation, project design, and prevent project failure. As food systems literacy improves, so does the community's ability to grow and prepare. It can tackle food insecurity by reducing reliance on inefficient supply chains that are commonly costly, leading to more holistic and resilient community-led food systems.

Adopting competency frameworks can transform struggling greenhouse projects into thriving community-driven initiatives. They do this by building capacities among community stakeholders and the participants needed for effective planning, ongoing management, and adaptation. With this in place, it is possible to build toward the goal of creating more food-secure, empowered and resilient communities.

Frameworks for community-led agricultural initiatives with competencies embedded incorporate technical skills as well as structural needs. This bridges food security strategies with broader foundational supports, such as infrastructure, policy, and cultural or social considerations. For example, the Granny Gardens initiative adapted their delivery model by distributing planters, seeds, and soil to community members to enable Indigenous communities throughout British Columbia to garden at home during the COVID-19 pandemic.[143] Adapting this program model enabled Indigenous communities to use their own ancestral foods and plant science knowledge to develop food resilience-based skills to address food insecurity, and respond to increased isolation and the inability to gather at community gardens. By pinpointing comprehensive interdisciplinary competencies specific to food systems and community-

led agricultural projects, the range of skills required for the development of effective, well-equipped systems can also be identified.

The Skills Framework for Agriculture from CABI, an international non-profit organization, is used to detect skills gaps and assess competencies to inform the development of training plans across various roles, occupations, and pathways to careers in the agricultural sector. It can be applied by individuals for self-assessment, as well as organizations to evaluate skills development and identify shortages in educational programming and training.[144] As agricultural processes evolve, so do the roles and skills to conduct and facilitate them. Given the advancement of proficiencies, CABI's framework facilitates the identification of transforming and critical skills areas. It then informs the development of CABI's growing range of courses and training through their learning platform CABI Academy.

Competencies include crop pest diagnosis and management, bio-protection products, water management, sustainable soil management practices, seed and planting materials, and improving crop nutrition practices. Additionally, the framework outlines skills for entrepreneurship in agribusiness and embeds EDI through gender-inclusive strategies for improving agricultural productivity.[145] While the framework is positioned toward agri-service providers working with agricultural workers and employers, the capacity training courses and skills framework have direct application across a range of practices integral to agricultural operations and are widely applicable.

The Agricultural Marketing Service from the U.S. Department of Agriculture, in cooperation with Iowa State University, has developed the Food System Core Competencies project. These competencies are designed to address the growing need for professional skills development among practitioners working to build equitable, thriving local and regional food systems.[146] The initiative's goal was to collectively identify the essential knowledge, skills and practices required for effective food systems. The framework was structured using a competency-based education model that organized skills and knowledge. The nine core competency categories encompassed community capacity, food systems, equity, governance and policy, assessment of natural and built environment, economic development, health and wellness, leadership, and evaluation.[147] Within these categories, skills relevant to community-led and local food system projects, such as greenhouse farms and community-operated gardens, were included.

Table 6 includes capacity and learning objectives in terms of training, resources and collaboration extracted from the project and mapped for community-led food systems to structure skills development.

Table 6

Key competencies and capacities for community-led food projects based on the Food System Core Competency project[148]

Competency Area	Skills and Learning Objectives for Community-Led Projects
Community capacity	> Build partnerships, facilitate meetings, identify community needs (resources and skills gaps) > Create coordination and support, participatory approaches, community ownership > Align operations with community values
Food systems	> Skills related to local food production depending on geographic context and demographic needs > Resource management, production and harvesting, different scales of farming and harvesting > Relevant technical expertise and knowledge depending on production scales, type of farming activity > Skills required for the management of community gardens or greenhouse farms
Environment	> Best practices for farming and harvesting based on local environmental conditions, sustainable management, and developing appropriate production and harvesting systems
Financial capacity	> Financial and funding components to ensure sustainability, viability and potential growth of community-based food initiatives
Equity	> Cultural relevance, inclusion, addressing demographic disparities, ensuring equitable access and outcomes

Researchers from the University of Guelph created the Food Systems Literacy Competencies Framework to address growing food security challenges. It uses a systems thinking approach that identifies activities related to diverse and complex food systems, food security, governance, sustainability, and Indigenous food systems.[149] The framework provides a roadmap for food systems education and knowledge evaluation to create holistic food systems literacy encompassing 50 key competencies. These competencies are context-specific and interconnected, while integrating development over time. Researchers used a two-round Delphi study, a structured process that gathers and refines expert opinion, to design competencies for younger generations and help them better understand and engage with food systems. This framework is specific to the Canadian context, and its intended use for food systems literacy for youth ensures that the design is beginner friendly. This is broadly applicable for community-based agricultural projects where members are typically at a novice proficiency level in terms of agricultural skills.

Agricultural projects require skilled personnel, as well as structural supports that create the foundation and provide resources necessary for operations. Competency and policy frameworks for community-led agricultural projects are mutually reinforcing tools that, when combined, address systemic and skill-based barriers. Differentiated from regular community-led food systems competencies, communities should be extensively involved in projects to ensure ensures that or the success of projects. Policy frameworks provide funding approaches (grants for community gardens), legal clarity (governance, land-access-ownership models for equity deserving groups), and address structural needs (infrastructure, resources). Competency frameworks, ensure those participating have the capacity to use resources effectively. Table 7 details identified policy frameworks and respective components tailored to community-led agriculture initiatives.

Table 7

Indigenous-led competency framework for greenhouse projects

Framework for Indigenous-Led Greenhouse Projects	
Foundational pillars	
Cultural sovereignty and traditional knowledge	> Embed Indigenous land stewardship, seasonal cycles, and ancestral food and growing practices (i.e., seed saving, medicinal plant use, weeding) into greenhouse goals and operation > Host co-design sessions to align greenhouse goals with cultural priorities and regional needs, integrating community feedback > Create a sovereign platform by and for community youth and Elders to engage in and preserve cultural knowledge > Work with community to employ local languages in training and greenhouse operation materials > Advocate for Indigenous-led food sovereignty policies to secure long-term support and resources.
Technical and adaptive Skills	> Teach climate-resilient cultivation techniques in controlled environmental systems (i.e., hydroponics, passive solar heating), and work with community to apply these models to sub-Arctic greenhouses. > Incorporate feasible renewable energy systems (solar panels, geothermal heating, and rainwater harvesting) and integrate projects within existing community practices (i.e., ideal site placement, nutrient circularity opportunities) to improve greenhouse sustainability. > Harness data by teaching the use of IoT sensors for growing environment tracking (i.e., temperature, humidity management, and yield tracking) to optimize plant production, including clear data sovereignty expectations and co-interpretation opportunities.
Governance and community ownership	
Community-engaged decision-making	> Co-establish inclusive governance structures with communities (i.e., community councils), which may be co-led by Elders, knowledge keepers, and youth from targeted communities > Align greenhouse goals with land-back initiatives and Indigenous-led land-use planning in project sites selection, use, and decommissioning.
Financial and policy infrastructure	> Co-build sustainable funding models by integrating grants, social enterprises (i.e., selling surplus produce), and public-private partnerships to garner investments that meet co-developed greenhouse goals. > Strategically align policies integrating greenhouse projects into regional climate resilience and Indigenous-led sustainable food security planning.

Framework for Indigenous-Led Greenhouse Projects	
Capacity building and skills training	
Greenhouse design and infrastructure	> Co-develop and deliver education for greenhouse building (e.g., hoop houses, polycarbonate structures, glass construction, and suitability for different climate and environments) and maintenance, including site selection (e.g.., topography, sunlight exposure, drainage, wind protection, proximity, adequate land size) > Review greenhouse roofing design options with greenhouse community members (e.g., arch-style, Venlo, lean-to, post and rafter) > Collaborate to integrate layout optimization (i.e., floor production zones, efficient space use, head house integration for storage and workspace), types of foundations and flooring (e.g., concrete or gravel for durability and drainage), and Indigenous crop planning systems (e.g. companion gardening). > Work with community greenhouse operators to determine water needs, as dependent on climate, irrigation system in use, and crop (e.g., about 0.3 gallons day-1 square foot-1) > Determine the use of ventilation (e.g., natural airflow strategies like roof vents) and water/irrigation management (e.g., reuse of runoff water, boom systems, drip lines, or ebb-and-flood tables) > Consider existing and future utility demands (i.e., natural gas services, electrical, water treatment)
Crop production and plant health	> Co-select plants (native crop varieties, environmentally appropriate cultivars) with communities that consider greenhouse project food cultivation goals and indoor environment cultivation optimization (climate-appropriateness, yield, such as Brassicaceae crops) > Educate participants on the differences between growing platforms and substrates (e.g., hydroponics, aeroponics, and substrate types) > Collaboratively planning the planting of important community crops and seasonally appropriate crops, to maximize efficiency, resources use and crop yields > If greenhouse objectives include market production, inform participants on harvesting methods and produce handling regulations (e.g., CanadaGAP food safety program) > Consider the perishability of crops to reduce food waste, and work collaboratively on waste reduction and reuse strategies. > Collaborate on responsible and compliant pest control (, composting, and nutrient management (i.e., fertilizers and monitoring soil pH) > Collaboratively assess associated equipment needs

Framework for Indigenous-Led Greenhouse Projects	
Business acumen and entrepreneurial skills	> Co-develop training plans and deliver to participants to identify and access local and regional markets, (e.g., farmers markets, institutional buyers), and support Indigenous branding and enterprise models > Collaborate to identify business practices related to supply-chain and budget management that support long-term greenhouse goals (e.g. bolstering community food security, return-on-investment) > Work together to identify new business opportunities, and build wraparound supports for project success (e.g., value-added processing, medicinal crop production, agritourism) > Support long-term financial plans and work with greenhouse project members to understand applicable and value-aligned of funding sources, grants, and Indigenous-specific financial supports to improve access to capital
Evaluation and adaptation	
Metrics	> Co-develop food security indicators for the community, which may include household dietary need and diversity, areas of food insecurity, and the impact of harvest yields on overall household food expenditure > Measure overall engagement by community to greenhouse goals > Review data and feedback from the community, with the community, to iterate operations and strategic future planning

Assessing community-readiness based on these criteria enables systematic evaluation of current skills and resource gaps that should be addressed to inform the development of training programs. Required skills should be developed with community members, to ensure training meets community and greenhouse goals. Skills training is essential to deliver successful project outcomes and ensure sustainability of greenhouse initiatives. By working collaboratively to identify skills and knowledge gaps pertaining to technical expertise of overall greenhouse operation and functioning, while recognizing and implementing cultural knowledge of Indigenous food practices, Indigenous-tailored greenhouse initiatives can preserve traditions and expand Indigenous food sovereignty.

Introducing technical know-how ensures preparedness with existing and emerging agriculture and agrifood practice. Collaboration ensures that knowledge and science is exchanged, sovereign knowledge is retained, and integrative strategies between Indigenous Peoples and agricultural experts support traditional and modern cultivation practices, and set the stage for innovative practice. This framework combines education, sustainable technology, community engagement and cultural integration to enhance food security and sovereignty, grounded in the respect for Indigenous traditions through collaboration throughout all phases of project development.

Community Greenhouse Farming: Case Studies

The following section presents case studies examining Green Iglu's community greenhouse farming projects and their partnership model with Relay Education. They assess the strategies implementation, impact and community engagement in strengthening food sovereignty and resilience in Canada's North. Based on the findings, we propose targeted areas for optimization with the aim of enhancing the long-term sustainability and effectiveness of Green Iglu's community greenhouse farming projects in remote regions.

Green Iglu

Green Iglu[150] is a non-profit charitable organization addressing food security challenges in northern communities. It does so by leveraging Growing Dome technology, introduced in 2015 in collaboration with Arctic Acres, the holder of the Canadian patent for this infrastructure. This innovative approach helps overcome Canada's remote and northern regions' short growing seasons, expensive produce, and limited access to fresh, healthy fruits and nutrient-rich and caloric-dense vegetables, including watermelon, strawberries, and herbs, as well as medicinal plants such as echinacea, eucalyptus and calendula.

The selection of produce is guided by direct feedback from community members of all ages, including input from local schools and elders. While respecting and not intending to influence cultural diets, Green Iglu acknowledges the passion and community need for a broad range of fresh produce to complement traditional diets.

The Growing Dome is uniquely designed with the capacity to withstand almost two-and-a-half metres of snow load and 180 km/h wind speeds. It utilizes solar passive heating, a thermal mass heat sink, and solar-powered ventilation, eliminating the need for electricity to cool or heat the greenhouse. The model has proven successful many times over; extending the growing season and effectively producing fruits and vegetables in Canada's Arctic regions. By harnessing such sustainable, low-impact technologies, the project's aim enhances food security while fostering self-reliance and resilience in remote communities. The initiative promises to deliver environmental and social benefits, contributing to the overall well-being and sustainability of Indigenous populations in Canada's most challenging environments.

Green Iglu has successfully completed 14 projects at Wasaho First Nation, Ont., Mississauga First Nation, Ont., Kinngait, Nvt., Nelson House, Man., Wemindji, Que., Bilijk, N.B., Red Deer Food Bank, Alta., NunatuKavut, N.L., as well as several other locations and schools across Canada.

Each community decides how they would like to distribute their yields, either for profit locally to vendors, restaurants, local food banks, or share at no cost to community members; usually run by volunteers or a hired greenhouse manager.

The project goals include the organization and shipping of greenhouse infrastructure, tools, supplies such as seeds and soil, safety equipment, and a Workers Safety Certificate. A greenhouse specialized builder is on site to complete the project over a two-to-three-week timespan. A local carpenter works to build the internal raised beds, alongside three to five local labourers and/or volunteers. Hiring locally reduces costs associated with travel, accommodations, car rentals and per diems, while also creating local job opportunities and directing more funds into the food security project. The food security project includes local volunteers, if available. However, this is not always a guaranteed or reliable source of labour, since many skilled labourers leave their communities during the summer months.

Green Iglu offers an online portal that includes forums for communities to exchange knowledge, alongside resources ranging from basic plant biology, natural pest control methods to companion planting. Remote online training is available for the greenhouse manager hired within the community to run the greenhouse. All students at the community school can also access the education portal to engage in learning sustainable local agriculture.

Securing access to fresh produce creates a ripple effect in remote regions. For instance, in 2022, the Cree Nation of Wemindji collaborated with Green Iglu to build a 42-foot Geodesic Growing Dome, inspiring the Mistissini Cree Nation to partner with Green Iglu in 2023 for the development of a commercial-sized plant greenhouse. Similarly, an Ontario Swampy Cree community worked with a local regional health authority to complete a 33-foot dome project, sparking interest from more than 30 other communities that are now exploring investments in food security infrastructure.

The Green Skills Academy

In 2023, Green Iglu partnered with Relay Education to secure funding for the delivery of a Green Skills Academy sustainable agriculture course. This program included hands-on training across 10 locations. It aimed to reach a total of 200 students minimum (ages 15 and above) and provide each with 120 hours of structured education. The training intent was designed to equip

participants with practical skills for future roles in the agri-food and greenhouse industry sectors, with modules tailored to the needs and backgrounds of each location's participants.

The goal of this pilot project is to address emerging skills needs in a growing sector – greenhouse farming – while addressing issues of food security in the North, with respect to the needs of Indigenous Peoples and those living in remote and vulnerable communities. Agriculture is one of the highest producers of greenhouse gases and therefore a major target in Canada's strategy for the transition to net zero emissions. There is increased focus on how technologies can increase food production while reducing the carbon footprint. At the same time, growing emphasis on local and small-scale production aims to address food security and reduce costs of transportation, particularly to remote regions. Greenhouses are an important part of the solution and increasingly are being used in the Far North and remote regions.

Constructing, managing and operating greenhouses requires a range of skills. However, the foundational knowledge in northern communities, including essential skills for success such as literacy levels or basic knowledge of plants and growing cycles, is missing. Operators of greenhouse facilities in the North have indicated that labour and skills shortages are a challenge to their success.

Program goals

The goal of the training program is to prepare youth and adults (ages 15 and above) from across Canada to pursue careers related to sustainable agriculture, support food security projects, and build agricultural talent. The program was to be completed from February 2023 to March 2024 and the key performance indicators (KPIs) included the engagement of six communities in greenhouse construction and delivering the course to 120 participants across a minimum of six cohorts.

While six target communities — Kinngait, Red Deer, Bilijk, Ga Gitigemi Gamik, Ont., Bear Waters Gathering, Ont., and Enterprise, N.W.T. — were engaged, only five greenhouses were ultimately constructed due to design and logistical challenges. The Enterprise greenhouse was not built following wildfire-related disruptions.

COURSE OUTLINE

The course structure included nine core modules: Greenhouse Overview, Growing Basics, Plant Care, Planning and Layout, Harvesting, Hydroponics, End of Season, Community Engagement, and Markets. Between May and December 2023, 90 participants registered for or completed the on-site training (excluding Enterprise), with 70 successfully finishing the program. Completion rates varied by location: Ga Gitigemi Gamik had seven registrations, Bilijk 37, Red Deer 27, Kinngait three, and Bear Waters Gathering had 16.

An online version of the nine-module course was offered from August to September 2023, resulting in four completions. A revised online program, condensed to 60 hours over eight weeks, was launched from February to March

2024, attracting 96 registrants and producing 46 completions. These included participants from Kinngait (four), Red Deer (seven), and 33 others primarily from NunatuKavut, N.L., Northwest Territories, British Columbia, Saskatchewan, and Alberta. In total, Green Iglu organized 191 registrations across all formats.

The curriculum combined 30 hours of foundational education, including WorkSafe certification, 50 hours of on-site greenhouse training, and 40 hours of hands-on building at each location.

Feedback and impact

While there was limited formal evaluation, the organizers felt that there had been a positive impact on learners of all levels, regardless of prior gardening experience. Participants from diverse populations across Canada reported benefiting from the course. Learnings on the importance of program design, implementation and evaluation process were among the most important lessons from the project.

FINAL OUTCOME AND PROJECT STATUS TO DATE

The greenhouse infrastructure established through Green Iglu's sustainable agriculture training program varied across participating communities. In Kinngait, a 26-foot Growing Dome was completed, while the completion status of two 26-foot Planta Greenhouses remains unknown. The community of Ga Gitigemi Gamik experienced the same outcome. Bear Waters Gathering planned for the installation of a 33-foot Growing Dome and two additional 26-foot Planta Greenhouses, but it is unknown if any of the three were completed. In Bilijk, a 26-foot Growing Dome and two 26-foot Planta Greenhouses were successfully completed. The Red Deer Food Bank completed construction of a 26-foot Growing Dome, with a ColdAcre unit planned for completion in 2024. In Enterprise, a 33-foot Growing Dome and one 26-foot Planta Greenhouse were planned, but completion status is unknown in large part due to the community being severely impacted by wildfires delaying progress.

The training component of the program was designed for participants with little to no prior farming experience. Workplace safety was integrated throughout, and the program highlighted employment and business opportunities within the agriculture sector. Funding for the initiative was allocated to enable Green Iglu to deliver six sustainable agriculture training programs, with expenditures dedicated solely to eligible program costs.

*Learnings on the importance of program design, implementation and evaluation process were among the **most important lessons from the project.***

Evaluation

The evaluation was developed well into the program delivery and as a result included limited data and analysis. Further work is needed to undertake a well-designed evaluation of such programs. However, through the course of the programming, the organizers did collect some data and report on progress.

The available information included:

- An outline of what the in-person training consisted of (topics covered, learning outcomes achieved, transferable skills gained, etc.)
- A general understanding of each participant's mode of training (online, in-person, a combination, or received alternatively, e.g., on a USB stick)
- How many hours of training were completed by each participant
- Names of participants participating in the training, contact information and sessions completed and any survey results to date
- Sources of materials used in the online courses

Table 8a

Planned to actual program implementation

Program Deliverables - Relay		
Planned	**Implemented**	**Comments**
Registering participants and maintaining ongoing communication to support their learning process success	There was limited formal registration and communications with participants until the program was in process	Limited levels of literacy and education, as well as basic knowledge of plants and growing, meant that the curriculum had to be provided at a very basic level with a large gap between what was intended (i.e., work-related skills) and what was possible.
Reviewing participant eligibility requirements and collecting participant reporting requirements	There was limited data collected regarding participants, demographics, education, interests or capacity to learn	There was no screening of applicant eligibility before the program and, given limited demand for the training, no real eligibility requirements were imposed on participants. This made it challenging to achieve the learning outcomes, completion rates and results anticipated.
Communication and reporting with program funders	This was managed by Relay	This was managed by Relay
Providing participant equipment and tools	No equipment or tools were provided to participants by Relay which created challenges in communities with limited internet capacity	No information on equipment or tools provided by Relay
Co-ordinating with Green Iglu to set, monitor and track KPIs on a regular basis	The KPIs were only established midway through the project and, as a result, were challenging to meet	The initial KPIs included six communities and not having established KPIs at the outset made it difficult to collect the necessary data
Providing ongoing support to participants on non-conceptual inquiries	No information	No information
Managing the overall program progress	In September, issues were flagged regarding the progress on the project and brought to the attention of the board of directors	Payments for the project were made without full accounting of expenses and deliverables. In January, Relay indicated it was holding back payment and demanding repayment.

Table 8b

Planned to actual program implementation

Program Deliverables - Green Iglu		
Planned	**Implemented**	**Comments**
Marketing and promotion of the training program within host communities	The program was marketed extensively through a variety of channels	Seven communities agreed to proceed with projects, however natural disasters (wildfires and flooding) prevented execution as planned and introduced delays.
Co-ordinating project development with each community including, but not limited to, liaising with host communities, determining project dates, locations and other project details	Projects were developed with communities	Because of the lack of screening during the registration process, the quality of participants was uneven and the level of their capacity to learn varied dramatically. In some communities, such as Red Deer, there were high levels of education. In others, such as Kinngait, basic literacy and access to technology was limited.
Managing project construction and overseeing subcontractors when necessary	Construction was completed in two communities. Changes to requirements delayed some construction.	A total of six greenhouses were constructed out of 10 planned. The totals were: Kinngai, one of three; Ga Gitigemi Gamik, one of three; Bilijk, three of three; and Red Deer, one of one. Note: Changes to plans were introduced in Red Deer at the request of the partner, as the Red Deer Food Bank wanted a larger facility. However, the vendor was unable to deliver before the project ended.
Preparing content and teaching activities for each module and sub-module	The content was prepared appropriate to the level of the participants	Nine online modules were prepared. 30 hours of in-class content was also prepared and offered in Kinngait, Ga Gitigemi Gamik, Bear Waters Gathering, Bilijk and Red Deer. Given the challenges with interest and completion, the entire curriculum was redesigned and offered in additional two modules that predate the Green Iglu portal
Approving and assessing participants' deliverables and participation	This was difficult because of issues with registration, screening and tracking of participants.	As noted, there was limited formality in the screening and registration of participants. As a result, it was challenging to track their progress and follow up with them.

Program Deliverables - Green Iglu		
Supporting Relay to set, monitor and track the KPIs on a regular basis	This was difficult because of issues with registration, screening and tracking of participants.	Tracked KPIs included the number of communities that participated in the program, the number of builds completed, the modules and curriculum developed and the number of students that registered in the program. However, completion rates and learning outcomes were not consistently tracked.
Providing support to participants on curriculum related inquiries	Support was provided	Inquiries were fielded online and through formal office hours offered to participants.
Providing ongoing support to communities on farm related inquiries	Support was provided	Visits, face-to-face and virtual meetings, calls and correspondence were used to address questions about the program
Provide photos and marketing documents when requested	Photos and documents were provided	Extensive documentation was provided and is available on the Green Iglu Google Drive.
Provide Relay with receipts for expenses	Financial reporting was completed	Full accounting of expenses was provided on a quarterly basis with the final expenses submitted April 15, 2024.

Lessons learned

Needs assessment

There was limited consultation with employers regarding the job opportunities, skills and competencies needed to operate the greenhouses.

More consultation with communities was needed regarding their capacity to support the programs, the infrastructure available and resources. Education and community engagement must be conducted online and face-to-face in full before a project begins. Community engagement poses many challenges when it comes to food security initiatives. Simplifying food security projects may be the best way to overcome many of the challenges associated with completing the construction and education timelines leading up to success.

Project management

While the complexity of these types of projects naturally demands time and many resources, as well as many unanticipated contingencies,

strong project management is also essential. It must be backed up with clear documentation on KPIs, expectations, decisions and status reports involving the funder, delivery partners, and, most of all, the communities.

Feasibility study

While Green Iglu had experience with the technical, economic and operational feasibility of greenhouse construction and training programs, the differences within communities were significant and the cost projections were not accurate, given the many contingencies.

Program design

The goals of the program were to take people with limited literacy, limited formal education and no basic knowledge of agriculture and to prepare them for sustainable jobs in agriculture in about 15 days of training (120 hours). This ambitious goal was not achievable given the resources available.

The learning levels of most participants in most of the communities was such that capacity for learning was assessed at elementary school level. While the program was designed to address the full range of competencies defined in the memorandum of understanding, it was not possible to bridge the gap to achieve the goals.

Additionally, a significant difference exists between preparing someone to work in a greenhouse and readying them to work in sustainable agriculture or run a farming business. While the expectation was that participants would engage in asynchronous and synchronous learning, there was limited capacity for self-study, limited access to the Internet and limited interest in fully engaging in sessions. The challenges with weather, fires and flooding created barriers to in-person delivery of the program.

Further research is needed to understand the emerging trends with greenhouse-based agriculture, the experience of greenhouse operators and the communities in which they operate, and the potential labour force. This will help to define the competency framework, pedagogy, infrastructure and culturally appropriate wraparound supports needed to expand greenhouse agriculture and the skills needed in the North.

Key learnings from the Relay Education partnership model

Although the development of the Relay syllabus and content was successfully completed, the final textbook wasn't finished until May 2023, which coincided with the first build at Bear Waters Gathering and complicated the build schedule.

The program was accelerated to align with the funder's timeline, resulting in the Green Iglu team facing challenges due to insufficient preparation time. The first location project was unprepared to host participants or volunteers, which caused delays, especially due to complications with foundation preparation. Furthermore, the absence of initial guidance or delivery demonstrations by management affected the construction timelines and the

rollout of the education program throughout the season.

These key challenges highlighted the importance of operational readiness, structured delivery support, and effective coordination as essential elements for future partnership models. To address these needs, a system for tracking program progress is necessary. This includes outlining the in-person training content, such as topics covered, learning outcomes, and transferable skills gained. Additionally, it will be crucial to understand the type of training each participant received (online, in-person, or a combination). Along with tracking hours completed, participant details, and feedback, this will be essential in assessing the program's effectiveness and ensuring future success.

Green Iglu self-reflection

Green Iglu has experienced multiple protocol transitions over the past several years, each supported by dedicated teams. However, these transitions have also been accompanied by high turnover, stress-related leaves, and instances of unprofessional work environments being tolerated on-site. Despite these challenges, management worked diligently to ensure operations continued as smoothly as possible under difficult circumstances. For future success, it is crucial that management has a comprehensive understanding of how the organization functions at every level, especially to effectively lead sustainability projects.

Lessons learned from implementation

Recognizing what to avoid is just as crucial as understanding the right approach. The following outlines important factors when collaborating community with sustainability projects in northern or remote areas of Canada:

SETTING ACHIEVABLE GOALS

While setting ambitious goals is crucial for the success of any project, ensuring those goals are realistic and achievable is just as important for fostering positive outcomes and ensuring long-term impact. Complex projects, especially in community food security and greenhouse initiatives, require substantial time, community trust, effort, and resources. However, many of these initiatives fail to reach completion due to insufficient guidance and a lack of sustained support from the lead organization — key factors originally intended to drive progress. A common pattern has emerged, where projects that start strong end unfinished, leaving communities uncertain about how to proceed and causing fractured relationships often too damaged to repair. This leads to abandonment.

STRATEGY

1. **Realistic goal setting:** Ensure that goals are not only ambitious but also feasible within the project's scope, resources, and timelines to prevent burnout and ensure steady progress.

2. **Sustained community engagement:** Foster long-term relationships with

communities by providing consistent support, clear communication, and guidance throughout the project lifecycle.

3. **Phased implementation:** Break down complex projects into smaller, manageable phases, with clear deliverables and achievable goals together.

4. **Monitoring and evaluation:** Establish a system for regular monitoring and evaluation, allowing adjustments to be made as necessary to keep projects on track. This should be consistent with one person in the organization with a minimum of two contacts from the community as high turnover in the community is common.

5. **Post-completion support:** Provide support after project completion to ensure that communities have the resources and knowledge to sustain their initiatives over the long term.

*Note: Not everyone relies on computers for communication, and in remote locations, phones may also be inaccessible.

Transparency and accountability: Maintain transparency about challenges, timelines, and resources, ensuring communities understand the scope and limitations of the project from the outset.

By integrating the above strategies, organizations can mitigate the risk of abandonment and ensure that projects have a lasting, positive impact.

Education

Green Iglu's education package, while promising in-depth training for communities, often fell short due to logistical challenges. Many project sites lacked shelters, and build conditions were frequently unfavourable. The primary issue was the insufficient time allocated to construct the infrastructure and deliver the promised training within the limited and expensive northern project timelines. As a result, communities were often left without the comprehensive training they had been promised and paid for, creating significant gaps in the intended education component.

STRATEGY

1. **Pre-project preparation:** Develop and deliver educational content online before construction begins to familiarize key community members with the key concepts and operational procedures.

2. **On-site training focus:** Dedicate the final week of completed construction to intensive, hands-on training in the greenhouse.

3. **Post-project support:** Provide ongoing remote support to address emerging questions, troubleshoot challenges, and reinforce training outcomes.

4. **Resource planning:** Ensure sites have adequate infrastructure, such as temporary shelters, to facilitate smoother builds and training sessions. This is not always possible, in this case the education portion must be discussed and organized beforehand.

5. **Feedback loops:** Establish a system for collecting feedback from communities post-project to refine training methods and address any gaps proactively.

By implementing this strategy, sustainability projects can better ensure that training is delivered effectively, fostering long-term community success and maintaining trust in its programs.

Excess options

Offering multiple greenhouse types and a wide range of material options has created significant challenges, including sourcing the necessary components for interior setups and foundations. The variety of materials required for each project, coupled with scattered suppliers across the country, often led to issues such as incorrect or missing materials. Green Iglu encountered these challenges in every build, as well as in general construction projects. Additionally, the abundance of choices, though intended to increase community engagement, has often resulted in excessive and unnecessary spending. Options like raised gardening beds made from metal or lumber, hanging baskets, outdoor gardening beds, heating sources, and lighting for ambiance, while appealing, have complicated decision-making and driven costs beyond what was practical or essential.

STREAMLINE OPTIONS

1. **Standardization of materials:** Limit the range of materials and greenhouse types to streamline sourcing, reduce the risk of errors, and ensure consistency across projects.

2. **Centralized sourcing:** Establish partnerships with a select group of suppliers to ensure the timely and accurate delivery of materials, reducing the logistical challenges of scattered sources.

3. **Cost control and budgeting:** Carefully assess the cost-effectiveness of each option and prioritize essential materials and features to prevent overspending.

4. **Community engagement with clear guidelines:** Provide clear, guided choices for communities, offering options that still fall within a manageable framework to avoid overwhelming decision-making and spiraling costs.

5. **Prioritize core needs:** Focus on the functional needs of the greenhouse, such as structural integrity and efficient food production, while limiting the inclusion of non-essential features like ambiance lighting and outdoor beds, unless they directly contribute to the project's success. Canada is home to ground-dwelling animals that are a menace to crops, so outdoor growing needs hardware cloth and other means of deterring pests.

Training protocol for onboarding employees

The reality of these types of projects is that reliable data is limited. Communities often prefer to be left alone after the build, and the success of this type of organization hinges on a specific kind of individual. This is someone willing to travel to remote locations with limited to no Internet, and work with limited resources, a limited fresh diet and the ability to troubleshoot challenges over extended periods. This person also needs to exhibit cultural sensitivity, alongside an interest in gardening and or sustainable agriculture. The seasonal nature of the work further complicates organizational sustainability, often resulting in the loss of experienced workers. This disrupts the continuity needed to develop and retain the specialized knowledge critical for food security projects to thrive.

To effectively address the challenges Green Iglu faces in onboarding new employees, implementing a more structured and comprehensive training protocol is crucial. By focusing on the key areas outlined in Table 9, we can develop a training program that supports sustainability and equips staff with the necessary skills and knowledge to contribute to the organization's success and more sustainable programs.

Table 9

Evaluation metrics for sustainable agriculture projects

Increase

- Nutrition access
- Quality and freshness of produce
- Diversity in food options
- Physical and mental health
- Localized seed storage for long-term sustainability plan
- Local food production during emergencies (environmental, global, etc.)

Decrease

- Produce costs
- Dependence on southern producers
- Plastic pollution from packaged produce

Research and Development

- Explore new technologies to enhance food security in Canada
- Share new information to drive system change

Opportunities for

- Jobs
- Training
- New skill sets
- Empowerment of diverse northern communities to:
  - Address food insecurity through shared knowledge
  - Drive community-led initiatives by building sustainable agriculture skills
  - Grow produce locally by utilizing greenhouse infrastructure to extend the growing season

Steps

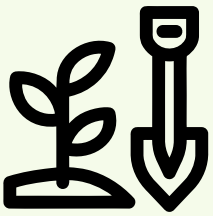
1. Identify communities in need
2. Build trusted relationships with remote and Indigenous communities
3. Assess and understand individual community needs
4. Construct infrastructure to secure access to fresh, diverse, affordable, and culturally appropriate produce
5. Provide the tools and resources for long-term success
6. Establish a support network (seeds, greenhouse supplies, remote troubleshooting assistance)

Context matters

Remote regions often face challenges in maintaining cultivation initiatives when initiated by settlers. It is important that projects are community-led, and supported to adequately accomplish community goals. Low job availability in Northern communities often leads to people relocating for work. Greenhouse projects can generate new skills and job opportunities within a community, with a potential for expansion based on community needs and program success. It is essential that these projects are approached with cultural sensitivity. Projects must enhance, not influence, traditional diets; despite Settler intentions which may be to provide diverse and fresh produce, projects must support community food rights and self-determination.

Building trust is critical when collaborating with Indigenous communities on sustainability programs. This means being educated on important cultural events such as harvesting, hunting, fishing, and community-specific dates like solstices and equinoxes, and asking for clarity when uncertain. Additionally, it is crucial to recognize that in the event of a community death, activities may pause for up to a week or more out of respect for the grieving process.

In regions where English is not the first language, such as Nunavut, translation services are required. Identifying fluent speakers in the community to translate materials into the native language is essential for effective communication and program participation.



Each community brings its own set of skills, and given the varied historical relationships with gardening, sustainability programs should be designed with accessibility in mind, ***ensuring everyone has the tools they need to achieve project goals.***

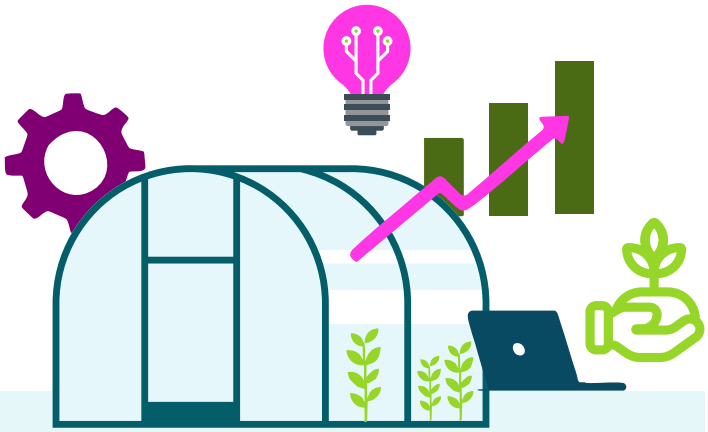
Many remote communities have already initiated greenhouse projects or have members who garden individually. However, gardening supplies are often scarce, and are made out of recyclable and salvage materials, including plastic from discarded southern shipment packaging or spare wood planks.

Each community brings its own set of skills, and given the varied historical relationships with gardening, sustainability programs should be designed with accessibility and be informed by an anti-trauma approach, ensuring everyone has the tools they need to achieve community greenhouse project goals.

Conclusions and Next Steps

The growing urgency of food insecurity in Canada — particularly in northern and remote Indigenous communities — demands inclusive, innovative, and scalable approaches.

Community greenhouse farming initiatives can address growing food insecurity across, and equity-deserving group discrepancies in appropriate food production and access. Community greenhouse initiatives and attendant educational programs serve as a strategic model to address climate change and socio-economic disparities faced by urban regions and isolated northern communities.



The findings of this study highlight the considerable demand for skilled labour in the agricultural greenhouse sector and indicate evolving opportunities for innovation in practices, technologies and job creation. Technological advancements, coupled with the development of community-based agricultural projects, such as those undertaken by Green Iglu, create great potential in improving food access and self-sufficiency. These advancements spur new employment opportunities and trigger the development and training of advanced greenhouse farming skills and competencies in both remote and urban communities.

However, this research shows that challenges remain. In rural and Indigenous communities as well as urban settings, community projects often rely on volunteer labour. Culturally sensitive considerations in the development, design and deployment of these projects are an important dimension given the deeply contextual and cultural significance associated with food and farming practices.

Furthermore, the unique food culture and preferences of Indigenous Peoples must be considered. Co-development of greenhouse projects with communities ensures they are respectful of Indigenous cultural identity and successfully engage community members in their food sovereignty. Continued research is imperative to identify and define the competencies required to support greenhouse farming in diverse contexts. Attention should focus on approaches that effectively serve equity-deserving groups, especially remote Indigenous communities that face more severe climate conditions and difficulty accessing stable and affordable food supply chains.

Addressing systemic challenges, such as the high and variable costs, logistical complexities of long-distance food transportation to northern regions, and traditional agriculture system inefficiencies (nutrient waste and ineffective circularity), requires the exploration of new ways to augment traditional food supply chains. Community-based programs and innovative technology require wraparound supports, including government and organizational funding, as well as partnerships, can help tackle food insecurity and environmental sustainability concerns. Solutions such as vertical farming and agricultural-ecological innovations show promise for further systems optimization.

Looking forward, further investigation into program design, delivery and evaluation to introduce and equip new and current agricultural workers with advanced skills is needed to address labour and skills shortages in Canada's growing and evolving greenhouse horticulture and agricultural sector. Competency frameworks, training programs, and wraparound supports should be designed to unlock the full potential of urban and northern greenhouse farming.

Key areas for future research and action include:

> **Developing and expanding the reach of targeted training programs**, with models designed for remote and Indigenous communities, to address identified labour and skills gaps with culturally respectful consideration and community-led approaches

> **Building competency frameworks** to support greenhouse farming in diverse contexts that consider climate and environmental conditions, community, inclusion, sustainability, and attention to local food customs and practices

> **Evaluating existing programs** to identify best practices, assess socio-economic impacts, and address systemic challenges in community-based greenhouse initiatives

> **Piloting innovative approaches** leveraging technology (i.e., energy-efficient systems, vertical farming techniques, AI and machine learning, IoT) that promotes community involvement and ensure accessibility and relevance for small-scale, community-led operations

> **Investing in research** that explores energy-efficient systems, assesses socio-economic impacts, and develops sustainable solutions for urban and northern greenhouse farming

> **Designing initiatives that encourage and support entrepreneurship** within the realm of sustainability. This includes fostering innovation, providing resources and training for sustainable greenhouse and growing practices

By addressing these critical areas, Canada can harness the transformative potential of greenhouse farming. Greenhouses can serve as a viable and sustainable strategy to strengthen food security, promote climate resilience, and foster socio-economic equity across diverse communities with a range of unique needs.

In summary, a focus on greenhouse farming as a community-led, skills-based pathway toward food justice must be as strong as the focus on advancing greenhouse farming innovation.

With a collaborative mix of policy advocacy and support, investments, research, and grassroots leadership, these efforts can redefine food systems and empower communities facing the greatest hardship.

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