Best Available Technologies for Community Food Cultivation in Nunavut

Qikiqtani Food Sovereignty Implementation Solution

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Qikiqtaaluk Business
Development Corporation

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Introduction

Inuit have been masters of sustainably harvesting local flora and fauna for thousands of years; the ability to self harvest is a key part of Inuit culture. But the impacts of settler society and colonialism over the last two centuries has meant that many Inuit are less reliant on harvesting traditional food, especially in younger generations. In addition, there has been less intergenerational knowledge transfer, meaning that many youths have not had hunting and harvesting mentors to rely on.

The Nunavut's 26 communities rely on the southern regions of Canada for vital goods and services, including food. Northern grocery stores have brought with them a wide variety of non-traditional foods, from nutritious fruits and vegetables to highly processed foods. This over-reliance on non-traditional foods and food systems has led to a dependence, and hence less control over community-based food harvesting.

Implementing and updating community infrastructure to address the dual challenges of food sovereignty and food security will require, among other things, a suite of best available technologies. A scalable solution that grows, produces and processes food in Nunavut requires an analysis of technologies that exist on the market today. This goes for both traditional and non-traditional food. Advances in agricultural technology (Ag Tech) over the last few decades have transformed farming. Not only have crop varieties been engineered to become bigger, more nutritious, and resistant to pests and harsh climate conditions, advances in Ag Tech have also enabled farming to be possible indoors.

Gardening and agriculture in the north are nascent industries but not new. Various forms of agriculture, from traditional farming to greenhouses and indoor farms have been practiced for decades, and in some cases, centuries across the North. Little research exists on indoor farming in the Canadian North in particular, but what research that is available shows numerous examples of indoor farming facilities from the Yukon in the West to Nunavik and Nunatsiavut in the East.

Inuit have expert traditional knowledge of hunting, fishing and gathering, but perhaps less knowledge or experience with agriculture, unlike many First Nations and Metis communities further South. There are many reasons for this, a main one being the extreme climate in the High Arctic. As a result, agriculture and horticulture are not traditional activities practiced by Inuit. This doesn't mean, however, that the interest is lacking. As food security and food sovereignty issues have increased in prominence in recent decades, studies have shown that many Inuit are open minded to the idea of growing their own produce. Indeed, many similarities exist with gathering and gardening practices. Inuit are resilient and adaptable; as more technology and western lifestyle has influenced Inuit culture, Nunavummiut have managed to retain their cultural traditions, through the blending of customs and technology such as hunting using snowmobiles and motorboats, for example.

This paper discusses current applicable technologies that could be implemented across Nunavut to increase food security and promote food sovereignty. It is broken down into two sections. Part 1 gives an overview of current indoor farming technologies. Part 2 begins with an overview of the history and current landscape of indoor farming in northern Canada. This section also highlights some organizations and technologies that are operating indoor farming facilities in the North and discusses elements of indoor farming that could be incorporated as part of action towards the Qikiqtani Food Sovereignty Vision.

Part 1 - Indoor Farming

Indoor farming encompasses a wide variety of methods for growing crops indoors. Indoor farming can be as simple as growing vegetables and ornamental plants in a backyard greenhouse, or as technically complex as a factory-sized building which includes vertical farming technology. The many processes of indoor farming utilize many different technologies and terminologies; there is no single definition for an indoor farm. For the purposes of this report indoor farming is collectively defined as Controlled Environment Agriculture (CEA). CEA can be further categorized into **vertical farming systems** (VFS), and **greenhouses.**

CEA is when growing crops is done under strictly controlled environmental conditions. In these systems, virtually all elements that plants need for growth are controlled, such as type and amount of light, nutrient levels, temperature, humidity, and CO_2. CEA systems can range from simple greenhouses, from simple greenhouses to fully automated vertical farms. There are a wide range of technologies that are typically found in a modern CEA system. They include, LED growing lights, advanced heating, ventilation and air conditioning (HVAC) systems, dehumidifiers, CO_2 enrichment instruments, humidifiers and coolers. The precise control of these variables means that they can be fine tuned to produce optimum growing climates[1]

Controlled Environment Agriculture Terminology

The world of growing crops is vast, and so are the various terms used to describe the different crop cultivating techniques used in CEA.

Agriculture is essentially an all-encompassing word for farming. It is the science of cultivating, or growing crops and raising livestock for farming, generally practiced at a large scale.

Horticulture, on the other hand, is a branch of agriculture that specifically deals with the science, management and development of cultivated food crops and garden plants, such as fruits, vegetables, nuts and ornamental plants. There are several types of horticultural methods that are used in indoor farming (greenhouses, VFS, hybrid systems). They can be categorized into CEA, as most of these growing methods require precise control of environmental variables required for plant growth. The methods are broken down into four main categories – soil-based horticulture, hydroponics, aeroponics and aquaponics[2].

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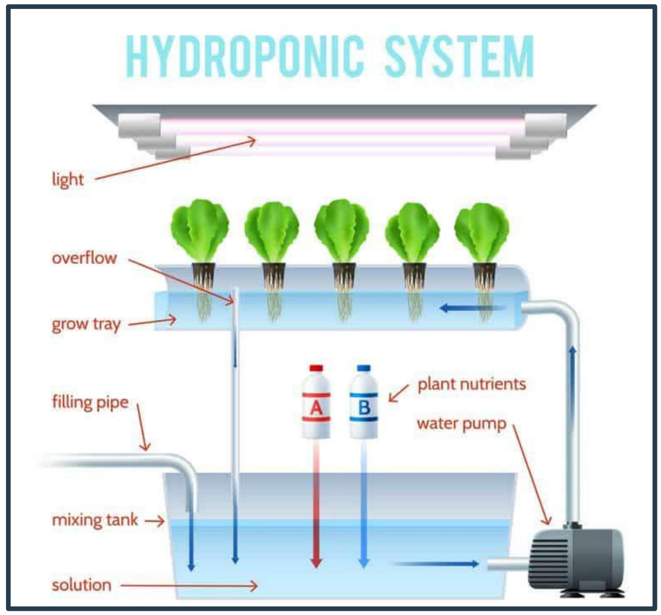
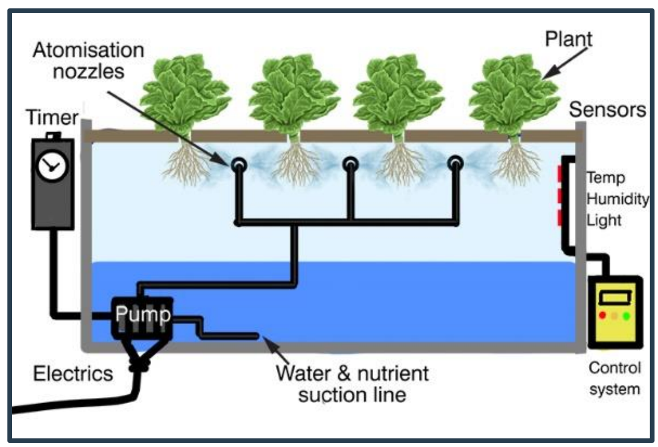
[1] Rajan, P., Lada, R. R., & MacDonald, M. T. (2019). Advancement in indoor vertical farming for microgreen production. *American Journal of Plant Sciences*, *10*(08), 1397.
[2] https://education.nationalgeographic.org/resource/agriculture

In **soil-based horticulture**, seeds are planted in soil where they absorb a variety of nutrients and grow in the soil medium. Fertilizers can also be applied to increase plant yields, while pesticides are also used to minimize the spread of pests and diseases.

Hydroponics is a type of horticulture or gardening method that grows plants in the absence of soil. In this growing method, a liquid nutrient solution is used in the growing of plants. Through hydroponics, plants can be grown in a variety of mediums like sand, gravel, rockwool, coconut fiber and oasis cubes. The main crop varieties grown under hydroponic methods include microgreens, leafy greens, tomatoes, peppers, strawberries, herbs and medicinal cannabis. Although almost any plant can be grown in a hydroponic system, including root vegetables, larger crops are still uneconomical to produce due to high energy input costs[3].

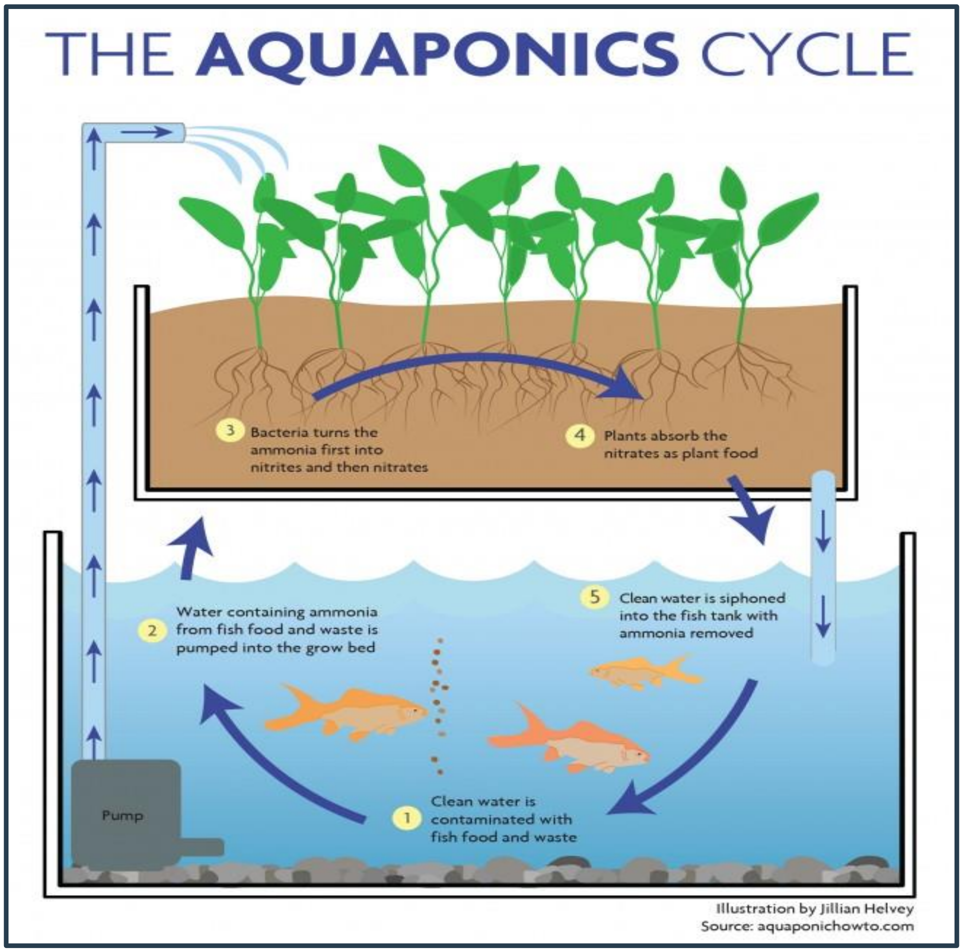


Aeroponic growing methods are an extension of hydroponics, in which roots are suspended in a soilless growing medium. The difference is that aeroponic systems provide nutrients to plants with nutrient-laden mist, rather than being suspended in water. The plant roots are suspended in air, rather than water, where they are periodically sprayed by specially designed misting or atomizing devices. Seeds are 'planted' in pieces of foam stuffed into mini pots, which are then exposed to light on one end and the nutrient mist on the other. The foam serves to hold the stem and root mass in place while the plants grow.



[3] Agrylist (2016). State of Indoor Farming. Retrieved from: www.agrylist.com

Aquaponics is a growing method that utilizes a combination of aquaculture (raising fish) and aquaponics. In this type of CEA, fish waste (ammonia and urea) and bacteria in the system provide the required nutrients to the plants. These systems rely on fast growing fish such as tilapia, perch, catfish and trout to supply the needs of plants. The water used in this process is then recycled back to the fish. The fish and plant species under this environment nurture each other, without the need for chemical fertilizers[4].



[4] Agrylist (2016). State of Indoor Farming. Retrieved from: www.agrylist.com

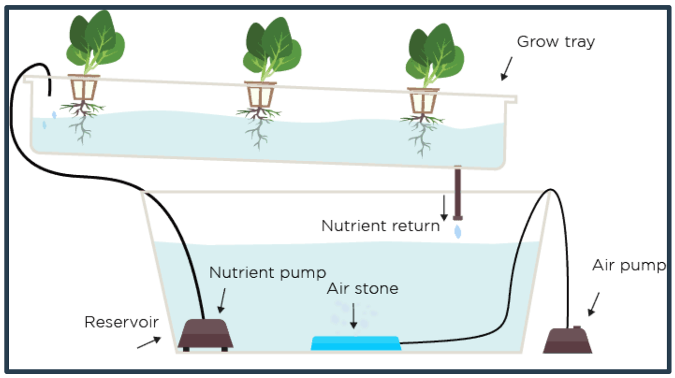
Vertical Farming Systems

Vertical farming systems (VFS) are indoor farms that utilize a combination of CEA technologies and are characterized by the several vertical layers of crops that are stacked on top of each other. These indoor vertical farms are usually constructed in existing warehouses or other structures that have been retrofitted to provide controlled HVAC to maximize plant production and artificial light. In addition, VFS utilize various types of hydroponic, aeroponic and aquaponic systems. By controlling for these variables, VFS offer several benefits over traditional farming techniques, such as reduction of pests, diseases, increased efficiencies, increased yields, and potential cost savings[5].

The growing methods for VFS also vary from farm to farm, but typically include an array of hydroponic methods explained below. The use of these techniques, combined with CEA means that plants can be grown all year round.

Nutrient Film Technique

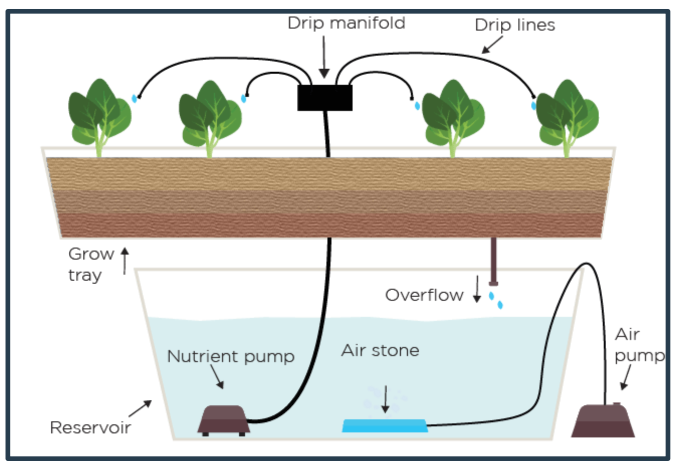
In this hydroponic method, a shallow stream of nutrient-rich water recirculates past the bare roots of the plant in watertight channels.



Source: https://plantsheaven.com/wp-content/uploads/2021/06/Nutrient-Film-Technique-Advantages-And-Disadvantages-2.jpg

Drip System

Nutrient-rich water is fed to the plant roots via drip irrigation, which can supply the solution above or below the growing medium.

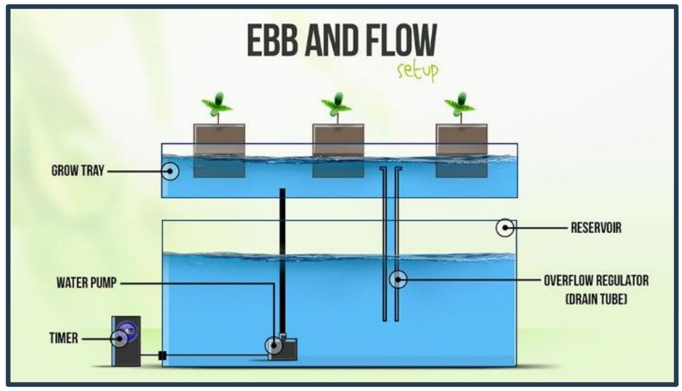


Source: https://www.trees.com/wp-content/uploads/files/inline-images/Drip-System.png

[5] Van Delden S., SharathKumar M., Butturini M. et al. (2021) Current status and future challenges in implementing and upscaling vertical farming systems. *Nature Food, 9440956, 2(12).*

Ebb and Flow

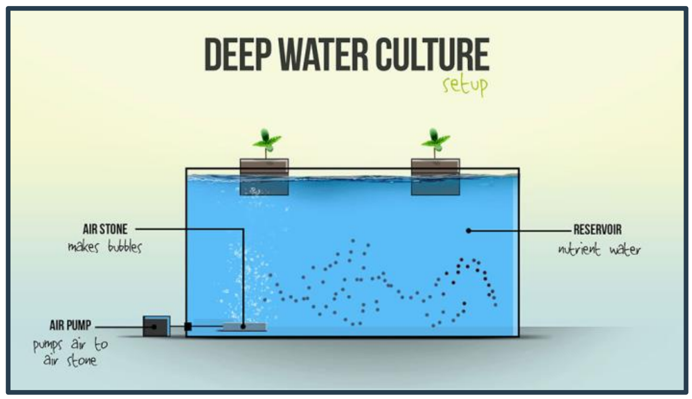
In ebb and flow systems (also known as flood and drain), plants are fed with nutrient-rich water pumped out of a reservoir below. The water is then returned via gravity to be reused in the cycle.



Source: https://greencamp.com/wp-content/uploads/2017/09/ebb-flow-system.jpg

Water Culture

In water culture hydroponics (also known as deep water culture), the roots of plans re continually suspended in nutrient-rich water. The 'deep' part of water culture comes from the concept that the plants are completely submerged in water at all points, as opposed to partially submerged (like in drip or ebb and flow methods).



Source: https://greencamp.com/wp-content/uploads/2017/09/deep-water-culture-system.jpg

Greenhouses

Although high tech indoor farming technologies have advanced significantly, greenhouses still make up approximately 50 percent of indoor growing installations.

Modern greenhouse designs were developed in the Netherlands in the mid 20th century, although historical records show greenhouses in Rome, Italy and Korea going back almost a thousand years. Greenhouses have been the dominant form of indoor agriculture for decades, particularly in the production of vegetables, flowers and ornamental plants.

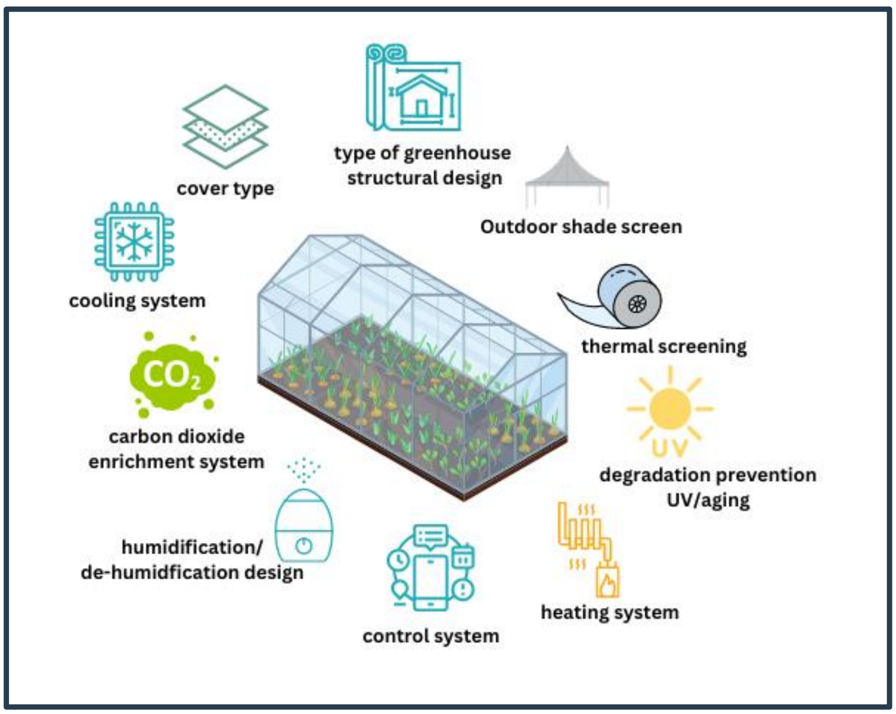
All greenhouse designs share the same common elements: growing takes place on one level, translucent cladding materials transmit natural sunlight, while climate control and irrigation equipment facilitate the growing of plants inside the greenhouses. Greenhouses can use soil-based or soilless horticulture techniques to grow plants. Modern greenhouses now usually have some form of CEA in their designs, such as artificial light to supplement sunlight during the winter months.

Greenhouses use natural light and work by harnessing solar energy, which comes in through its translucent panel material (glass, or polyethylene). Most wavelengths of solar radiation, except for long thermal infrared waves, enter the greenhouse and are converted from solar radiation to heat via the soil, plants, floor and other materials. The plants, soil and other materials then convert the solar radiation into longer wavelengths that are 'trapped' through the transparent panes, which results in heating the greenhouse. Since the heat becomes trapped, temperatures can stay relatively high, while also causing water to evaporate and lead to high relative humidity to assist in plant growth.

Greenhouse designs vary from low technology, low-cost and low productivity to high technology, high cost and higher productivity designs. They can range from sealed high-tunnels covered with polyethylene cladding, to large industrial-type structures built from steel with glass cladding.

It is important to note that indoor agriculture and horticulture using greenhouses in the north ranges from personal gardens and/or cheap grow tunnels, to community-based greenhouses and, in some cases, commercial-type greenhouses. This means that there is no one dominant design; greenhouses in the north come in a variety of designs and levels of complexity. Thus, a single greenhouse design will not meet the needs of Nunavummiut or Nunavut communities potentially interested in greenhouse crop production.

Generally, greenhouse design elements consist of the following:



Greenhouses can be classified in two main categories – open and closed systems. Open system greenhouses use natural ventilation as a medium of air exchange. Closed systems, on the other hand, rely on mechanical ventilation, which is the only means of air exchange. This means that the closed systems do not require any external air. Closed greenhouses offer superior control over the indoor air circulation, temperature and temperature gradients.

Greenhouse Type	Image	Description, Pros/Cons
High-tunnel Greenhouse	 https://www.rimolgreenhouses.com/sites/default/files/images/blog/Discovery2.JPG	• Low-tech/low-cost • Good for communities with limited skills in indoor farming • Low cost/low tech make this style good choice for northern farming operations • Low productivity due to low level environmental controls • Only extends growing season by ~1 month; year-round production not possible
Hoop Greenhouse	 https://www.buildmyowngreenhouse.com/images/1111111111.jpg	• Low-tech/low cost (generally less expensive than high-tunnel greenhouses • Can be easily disassembled and moved to new locations • Do not provide same level of weather protection as other designs • Are not considered permanent structures
Stand-alone Greenhouse		• Durable, double polyurethane covering and engineered steel structure • Range of tech options – from low tech soil-based to soilless production with CEA • Skills required vary with type of technology used
Gutter-connected Greenhouse	 https://ggs-greenhouse.com/sites/default/files/poly5.jpg	• Ideal for growing multiple crops, large scale farming operations • Capable of year-round production • High skill level required to utilize, could be difficult in the North • Superior air flow and temperature control • High tech and high cost

Chinese-style Solar Greenhouse /Passive Solar Greenhouse	 http://krisdedecker.typepad.com/.a/6a00e0099229e8883301bb08a0b7c8970d-pi	• Energy efficient (key consideration for northern regions) • Not many proven commercially viable models available • High capital costs
Geodesic Dome Greenhouse	 https://zipgrow.com/wp-content/uploads/2022/08/green-iglu.FB-3-1.jpg	• Extremely stable structures; stress is distributed over whole structure and no angular spaces for snow accumulation • Maximum use of sunlight; geodesic domes utilize sunlight at higher efficiency than standard greenhouses • Heat retention due to high heat retention – can be con for warmer climates but advantageous for the North

Controlled Environment Agriculture Market

The CEA market is a diverse industry, with many different facility types and technologies. Over half of the CEA market is still dominated by greenhouses, hydroponics (including aeroponics and aquaponics) makes up the other half of all indoor farms. Although 25 percent of indoor farms still use soil, they control their environment in a closed system using different set-ups. They vary from greenhouses, vertical systems, containers and sometimes basic hoop-style greenhouses.

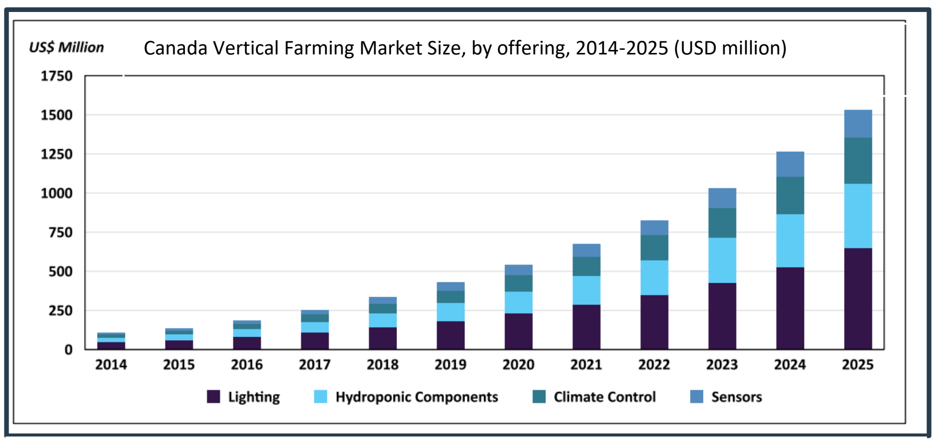
While there is wide variety in the types of CEA systems in operation, what they are able to grow economically remains similar. Most CEA farms grow leafy greens and herbs, while a minority grow tomatoes (16 percent as of 2017), which are dominated by large scale modern greenhouses in the southwestern US. While some fruits can be grown in greenhouses, growing them in VFS facilities remains a challenge. This is mainly due to high energy costs, which make growing them uneconomical. The energy to grow fruit producing vegetables can also be a limiting factor, with high costs per edible biomass. Energy costs are one of the most significant challenges for the industry, which make up about 25 percent of operating costs for VFS (but around eight percent for greenhouses.

Within the CEA space, the VFS sector (which excludes greenhouses) has risen in popularity with the advancement of LED growing lights. These lights use far less energy and emit less heat than other types of lights, and their costs have dropped significantly over the years. But energy costs remain a major barrier to the growth of the VFS market globally, mainly due to the cost of lighting and excess heat generated by the lights. These costs directly affect the economic feasibility of growing crops such as fruiting plants however herbs and leafy greens remain economically feasible.

Produce grown in CEA systems, and especially VFS is still more expensive than produce grown with conventional methods, even when shipping costs are accounted for. This is mainly due to higher energy and labour costs. For example, one study found that transportation costs for conventionally grown lettuce shipped from California to New York made up 67-70 percent of the landed cost, compared to just 12 percent for greenhouse and vertical farms. For a CEA farm, labour, management, energy and other operational costs account for over 80 percent of the total.

Despite the challenges, the CEA/VFS industry continues to grow at a steady pace. In 2017, the indoor farming industry in the US generated $848 million, growing at a rate of 3.4 percent. The revenue and scale of growth is largely due to the arrival of big market players, located in the southwestern US. These large farms grow crops in giant greenhouses and ship across the country and to some international markets[6].

The VFS sector within CEA is growing faster than all other types of hydroponics combined. The vertical farming industry grew from $3 billion in 2021 to $4 billion in 2022, with approximately 30 percent of the growth occurring in North America. Analysts predict that the market is set to grow at a compound annual growth rate (CAGR) of 26 percent to $21 billion by 2029. The predicted growth is the result of rising populations and the global demand for healthy and safe food[7,8]



Source: https://d3n8a8pro7vhmx.cloudfront.net/greenbelt/pages/12307/attachments/original/1623685363/GB_GrowthinFruitandVeg_REPORT_2021_E-ver_REV.pdf?1623685363

In Canada alone, $382 million (US dollars) was invested in vertical farming operations across Canada, with a CAGR above 20 percent. Over half of those investments were in containerized vertical farms (vertical farms set up in a shipping-like container) versus building based vertical farms.

[6] WWF (2020). Indoor soilless farming: Phase I: Examining the industry and impacts of controlled environment agriculture. Retrieved from: https://www.worldwildlife.org/publications/indoor-soilless-farming-phase-i-examining-the-industry-and-impacts-of-controlled-environment-agriculture

[7] https://www.foodincanada.com/features/vertical-farming-on-the-rise/

[8] https://jahaniandassociates.com/global-vertical-farming-market/

As of 2021, there were about a dozen commercial-sized vertical farms operating in Canada. One of the largest vertical farm operators is Elevate Farms, which can grow up to 454,000 kg per year of leafy greens including lettuce, arugula and basil in their 2,000 m^2 Welland, Ontario plant[9].

Although VFS has exciting potential, the industry is still new with many challenges to overcome. These challenges range from high capital costs and landed costs of grown produce, to high capital and energy costs, along with issues of scale.

Part 2 Agriculture in the North

Despite popular belief farming in Northern Canada is not new. It was home gardens in the Yukon that provided workers of the Klondike Gold Rush with greens and potatoes in the 1930s. Only after the Second World War and resulting fuel price declines, did a reliance develop on shipped produce (Nobel, 2013). In the Northwest Territories, small farms began appearing in the 1800s with the arrival of settlers, peaking around the time of the Klondike Gold Rush. Farms along the Yukon River, as well as in Dawson City and Mayo were producing substantial amounts of vegetables and hay until the mid 1950s. The decline of the horse-drawn carriage and rise of riverboats and road transportation, combined with declining populations post Gold Rush era led to a decline of farming in the region. Increased transportation infrastructure also facilitated this decline, as food could be imported at relatively low cost to the region[10].

The Hudson's Bay Company (HBC) also introduced farming and gardening in the Canadian Sub Arctic long before gardens sprouted further north. Archeological evidence has shown the former presence of gardens at Fort Albany, Moose Factory, Fort Severn, Fort York and Fort Churchill[11]. These gardens were set up for two main reasons – to counter the effects of scurvy and reduce the cost of shipping large amounts of food from England. Between 1670 and 1774, HBC policy mandated that gardening was to become a regular activity alongside all company posts[12] [13].

In the 1850's, the arrival of missionaries led to the expansion of garden plots in the North. These missionaries (who had experience in farming already) cleared and farmed the land; the produce was used to supplement the diets at missions, hospitals, and trading posts in the Canadian northwest[14].

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9 https://d3n8a8pro7vhmx.cloudfront.net/greenbelt/pages/12307/attachments/original/1623685363/GB_GrowthinFruitandVeg_REPORT_2021_E-ver_REV.pdf?1623685363

10 ROBINSON, S. (2010) Humble Dreams: An Historical Perspective on Yukon Agriculture since 1846. Northern Review, (32): 135-167

11 Avard, E. (2015). *Northern greenhouses: An alternative local food provisioning strategy for Nunavik* (Doctoral dissertation, Université Laval).

12 LEECHMAN, D. (1978) "I Sowed Garden Seeds." The Beaver, Winter 1970: 24-37.

13 HBC – HUDSON'S BAY COMPANY (2014) Our History - Business, Fur Trade, A Little Bit of Green: Gardening in Support of the Trade. http://www.hbcheritage.ca/hbcheritage/history/business/fur/a-little-bit-of-green-gardening-in-support-of-the-trade. Page consulted January 22, 2014.

14 Avard, E. (2015). *Northern greenhouses: An alternative local food provisioning strategy for Nunavik* (Doctoral dissertation, Université Laval).

In the early 1900s, the village of Fort Simpson had one of the largest missionary-run farms in the Northwest, where over 100 acres were brought under cultivation. Around the same time, the Oblates were regularly cultivating gardens and even built small greenhouses on the west coast of Hudson Bay, which lasted until the 1980s.

On the East Coast, in Labrador, the Moravian Missionaries also cultivated large gardens, where Inuit women regularly took part in gardening activities[15].

While it was largely settler society that introduced agriculture to the north, Northern First Nations have actively been involved in agricultural activities. For instance, a study by Loring and Gerlach (2010) stated that "for over a century, various forms of crop cultivation, including family, community and school gardens were components of the foodways of many Alaska Native communities." While Loring and Gerlach often present positive aspects of historical First Nations' farming initiatives, it is important to put into context that introduced agriculture in Indigenous communities was often part of a larger strategy of assimilation. Across several First Nation communities across Canada, people were forced to abandon traditional hunting and gathering practices in favour of Euro-Canadian forms of farming[16].

Conversely, Indigenous agricultural practices have developed independently of settler agricultural practices in certain First Nation communities across Canada. Evidence points to Indigenous people practicing agriculture in the Dakotas and Manitoba in the early 1400s, predating the arrival of Europeans. The 'Three Sisters' plants (corn, beans, squash) and also sunflowers, were the predominant crops that were grown along fields, which provided an additional source of fat and protein. In Canada, the Iroquois cultivated the 'Three Sisters' as the most notable example of farming in Indigenous cultures in Canada[17].

Following the history of farming in Northern Canada, the small gardens and farms that have been established over the decades (and in some cases centuries) also led to several greenhouses that were built across the Canadian North, and, specifically, Inuit Nunangat. These greenhouses, like the farms and gardens that came before them, were often constructed by missionaries or by HBC employees.

Its important to note that the scientific literature on northern indoor farming is extremely limited. The information for this report was mainly gathered through media sources, government information, institutional websites and through personal communication. This has led to a high-level understanding of the current situation in indoor farming in the North.

Secondly, it is important to consider that many indoor farming structures (including greenhouses, vertical farming units, and other potential structures/technology combinations) are likely missed due to the lack of current availability of such information.

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[15] Avard, E. (2015). *Northern greenhouses: An alternative local food provisioning strategy for Nunavik* (Doctoral dissertation, Université Laval).
[16] Gurney, R. M., Caniglia, B. S., Mix, T. L., & Baum, K. A. (2015). Native American food security and traditional foods: a review of the literature. *Sociology Compass*, *9*(8), 681-693.
[17] Friedrich, D. L. (2021). Vegetable farming, climate change, and food security in the Arctic. In *Justice and food security in a changing climate* (p. 2545). Wageningen Academic Publishers.

VFS in the Arctic

The renewed interest in arctic agriculture has led to several companies setting up vertical farming systems in communities across the Arctic. The majority of these systems are installed as containerized vertical farming units, utilizing retrofitted or customized shipping containers, or 'sea cans' as they are called in the North.

Below is a snapshot of some of currently operating systems across the Canadian Arctic by two companies. There are other similar VFS technologies and companies on the market, however only two are discussed below as an overview.

Growcer

Founded in 2019, The Growcer Inc. is a Canadian social enterprise that develops customized modular hydroponic farms, with the initial aim of being deployed in food insecure, remote communities across Canada. They have since expanded to partner with numerous schools, non-profits, businesses, and non-remote communities who see the value in locally grown produce[18].

Technology

Growcer uses hydroponic methods combined with automation to provide full control of environmental variables. Light, nutrients, temperature, humidity, carbon dioxide and water are monitored and adjusted in real time. This means that the company offers year-round, commercial farming regardless of outdoor weather conditions. Growcer's modular units are built as a turn-key solution, meaning they require minimal set up to being operational.

A Growcer VFS in Kugluktuk, Nunavut (Source: Growcer Presentation, 2022)

[18] https://www.thegrowcer.ca/

The company's systems are all grown in Canada. They report 95 percent less land use and 90 percent less water than traditional farming methods. In addition, the systems can be customized to northern climates and have been proven to be operationally effective in extreme temperatures of +/-40˚C.

Crops and Yield

Growcer's hydroponic systems allow operators to potentially grow over 140 different crop varieties. From seed to harvest, the average cultivation time is between 5-12 weeks, depending on the crop type.

Growcer's most common crops are:

- Lettuces
- leafy greens
- cultural crops
- herbs
- Asian greens
- microgreens

The total growing surface area of a typical container is 41.5 m^2 in the growing area and 1.5 m^2 in the seedling area. The yield potential is up to 2,624 planting slots, yielding more than 650 mature plants weekly.

Costs

The start up cost for one vertical farm is approximately $270,000 (CAD) plus installation and supplies.

Growcer - Investment Overview (one container farm)				
Growcer Farm	**Site Preparation**	**Installation, support, onboarding and training**	**Supplies**	**Ongoing support**
$270,000	Estimate varies based on local contractor(s)	$16,900	$7,470	$3,500

The operating expenses for one farm are broken down as follows:

Operating Expenses for 1 Growcer Farm	
Maintenance	8.7%
Depreciation and cost	12.5%
Software Subscription	6.7%
Growing Materials	12.5%
Utilities	11.5%
Labour	48.1%

Source: Growcer Presentation (2022).

Training

Growcer works with its clients throughout the project lifecycle. Once a sales contract has been signed, they provide the client with business planning, project planning, funding opportunities, site preparation as well as installation and training. Support is available once installation is complete, to facilitate operation throughout the life span of the farm.

Case Studies

Churchill, Manitoba

After floods washed out the railway connecting Churchill to the rest of the province, the Churchill Northern Studies Centre (CNSC) was looking at solutions to help grow local produce. Due to the rail line disruption, food prices spiked, and all goods had to be shipped via air.

The CNSC bought a Growcer system, which is now the only source of consistent local food. The unit was installed in November 2017 and produced 320-340 vegetables that were sold in the community. The yield increased to 450 during tourism season. The container has been growing produce in temperatures below -40˚C. Currently, the leafy greens sold to the community are below the all-in cost of shipped greens, at $3.99.

Kugluktuk, Nunavut

The Hamlet of Kugluktuk in Nunavut installed their Growcer system in February 2019. The project has yielded 12,000 lbs of produce annually since 2019. The Hamlet owns the system, and the daily operations of the container are managed by the school with students participating. Produce grown is sold to the local grocery stores and directly to community members. With changes in Hamlet staff and competing priorities, the system is currently not operational.

Kuujjuaq, Quebec

In 2018, the Nunavik community of Kuujjuaq, Quebec installed its Growcer system. The initiative is part of the Pirursiivik ("a place to grow" in Inuktitut) Project, which aims to make fresh produce more readily available in the community while promoting health and wellness.

The first produce was harvested in January 2019, which included lettuce and the traditional qunqulik plant (mountain sorrel). The produce is being sold at Newviq'vi, the local grocery store[19].

[19] Growcer presentation (2022)

ColdAcre

ColdAcre Food Systems designs and manufactures containerized vertical farming systems out of Whitehorse, Yukon. In addition, they also sell prefabricated systems along with their customized units.

Source: Inuvik VFS installed by ColdAcre. Source: ColdAcre (2022)

The company uses its own technology to operate Northern Canada's largest hydroponic farm, in Whitehorse, Yukon.

Technology

ColdAcre grows their crops via hydroponic methods utilizing a nutrient film technique (NFT), meaning the greens are fed via a constant flow of nutrients, using low-maintenance, long lasting magnetic drive pumps. Plumbing is done with PVC piping to make fixing and replacement as easy, cheap, and quick as possible.

For systems operating in Arctic climates, ColdAcre has made various modifications. For one, the heating and cooling system has been modified to utilize the outdoor temperatures to reduce costs and component wear and tear. The insulation has been increased for northern climates and all direct thermal bridging was terminated. In addition, lights with dimmers were selected to allow for power reduction for communities with high power costs. All of their system changes have been implemented and tested on their own commercial farm in Whitehorse, Yukon.

ColdAcre systems have galvanized steel racks which each hold five mature planting shelves and one nursery shelf. Each shelf uses NFT and high-efficiency LED all-spectrum light to grow the greens. These are fed using low maintenance long lasting magnetic drive pumps. The use of dehumidifiers maintains humidity around 70 percent. Specialized fans offer lateral and vertical airflow ensuring the plants do not get carbon locked. CO2 controllers automatically inject CO_2, while also controlling the dehumidifiers, HVAC, and dimming the lights[20].

ColdAcre offers a variety of containerized system models, however the most applicable to northern communities is their Model 16-AE. This system has a built-in arctic entrance which doubles as a processing room. This allows products to be grown, cleaned, stored, packaged, and distributed directly from the unit. It has the same amount of growing space as their Model 12, which can grow approximately 250 lbs per week if growing a mix of greens.

[20] ColdAcre (2022)

ColdAcre CEO Tarek Bos-Jabbar estimates that through their extensive training, clients can hit 75 percent of the estimated yield in the first year, increasing to approximately 90 percent in the second year of operations.

Like Growcer, and most containerized VFS, ColdAcre's systems are also a turn-key solution, requiring minimal set up once the unit is installed, and training completed. The system generally requires one to two full time personnel for operations.

Crops and Yield

The main crops currently produced by ColdAcre's systems are:

- Most varieties of lettuce
- Basil
- Mizuna
- Bok choy
- Herbs

ColdAcre can guarantee crop yields for their main crop varieties. In the next three to five years, the company expects to have root vegetables, fruiting vegetables, and most lettuce varieties successfully growing in their systems. In addition, ColdAcre has built an attached greenhouse unit which utilizes waste heat to grow tomatoes, cucumbers, peppers, potatoes, and carrots. The company is also exploring the potential of raising chickens/eggs in their systems.

Costs

ColdAcre's Model 6 (6 metre container farm) costs between $100,000 and $120,000, while a model 12 (12 metre) costs approximately $190,000. Shipping and site preparation costs run approximately $25,000.

Training

ColdAcre has created an in-depth training program to help facilitate capacity building, as this is one of the major challenges for successful operations of their systems in remote northern communities. The training is important for three main reasons:

1. It allows the operator to understand and visualize how to efficiently operate the system
2. The operator learns about the terminology, making all subsequent remote service calls and general questions more effective
3. Provides an opportunity to train new staff if someone suddenly quits or becomes ill

Training is provided in Whitehorse, which includes accommodations for the two-week period. While CEO Tarek Bos-Jabbar says that modifying system components is critical for successful operations in the North, the most crucial factor is human resources. Adequately trained staff are the largest factor in the successful or unsuccessful operation. As such, ColdAcre puts an equal focus on human resource development[21].

Solar Energy Option

ColdAcre has partnered with Solvest Inc. on some of their systems to integrate solar photovoltaic (PV) technology. Their system at the Kluane Lake Research Station was Canada's first completely off-grid system. It runs entirely on solar PV and battery storage for most of the year, with a generator providing power during the darkest months. For other systems, they have the potential to install solar PV on the roof of their containerized farms. This would reduce approximately 30 percent of the base load, and as such would not require any expensive battery systems. [22]

Greenhouses in the Arctic

A 2019 study identified there are 17 operational greenhouses across northern Canada with two of these in Nunavut (Iqaluit and Naujaat). From Iqaluit, to Kuujjuaq [23]and across the North, these greenhouses have yielded a variety of vegetables and herbs, including (but not limited to) carrots, tomatoes, peppers, and even potatoes and corn. Some operate solely with the assistance of volunteers, while others have full-time staff. And while most rely on fundraising and subsidies, they have all led to a greater sense of community and enabled crop growing at a community level.

There is extremely limited scientific literature on northern greenhouses. Additionally, no two greenhouses are the same and therefore reporting on crop yields and costs is not possible.

The following section summarizes some of the most well-known and currently operating greenhouse operations in the Canadian Arctic. These examples show that greenhouses are successful in the North and they have the potential to become a key element of a new northern food strategy.

Iqaluit, Nunavut

Greenhouse projects in Iqaluit date back until at least the 1960s, when a glass-covered greenhouse was constructed. Later, in 1976, a plastic-cladded greenhouse was constructed by the then Northwest Territories Department of Economic Development in partnership with the Manitoba

Source: https://iqaluitgreenhouse.com/

[21] ColdAcre (2022) correspondence with CEO Tarek Bos-Jabbar
[22] ColdAcre (2022) correspondence with CEO Tarek Bos-Jabbar
[23] CHEN, A., & NATCHER, D. (2019) Greening Canada's Arctic food system: Local food procurement strategies for combating food insecurity. Canadian Food Studies Vol. 6 No 1.

Greenhouse Research Project[24][25]. The greenhouse structure was prefabricated. In the end, it was plagued by project delays and improper planning; only small root crops and greens were harvested.

In 2001, local Iqaluit residents formed the Iqaluit Community Greenhouse Society (ICGS). The newly constructed greenhouse was made from polycarbonate cladding over a steel frame, covering an area of 90 m^2. As of 2012, it was still the most northern society-driven greenhouse above the treeline. It still functions as a community collective garden, where members of the ICGS participate jointly in hardening tasks.

The annual operational costs for the Iqaluit greenhouse is $6,000 which is mostly covered by donations and fundraising.[26]

Naujaat, Nunavut

Naujaat, Nunavut has a 1,300 ft^2 polycarbonate dome greenhouse installed in 2016. The dome structure means it can withstand winds of up to 110 km/hr and more than two meters of snow accumulation.

The greenhouse operates for about six months of the year and has a combination of raised soil beds and 1.5 m tall vertical hydroponic towers. The greenhouse has a large water tank that acts as a thermal mass to help keep the internal temperature between 20 and 25° Celsius. Produce grown includes leafy greens, carrots, turnips, potatoes, beans, beets, radishes and cauliflower. The produce is sold at farmers' markets and to the local food bank.[27] The project was spearheaded by the non-profit group Green Iglu.

The dome greenhouse cost about $160,000 to purchase and ship to Naujaat. The annual operating costs are about $17,000.[28]

Source: https://www.vice.com/en/article/ywg7kj/greenhouses-in-the-arctic-will-reduce-food-insecurity-in-canadas-north

Source: https://www.cbc.ca/television/higharctichaulers/igloo-shaped-greenhouses-are-growing-nutritious-affordable-food-in-canada-s-north-1.5365796

[24] WEBB, K. (1976b) End of two month report on Frobisher Bay Greenhouse. Report to Department of Economic Development and Tourism, Government of N.W.T., Yellowknife. 5pp.
[25] ROMER, M. (1987) Pond Inlet Gardens: A Report on the Design and Operation of a Solar Greenhouse on North Baffin Island, NWT, with Particular Reference to Economic Viability of Vegetable Production for Arctic Regions. Prepared for the Toonoonik-Sahoonik Co-op, Pond Inlet, NWT and Dept. Of Economic Development, GNWT.
[26] CHEN, A (2019) Greening Canada's Arctic food system: Local food procurement strategies for combating food insecurity
[27] WHITEHOUSE, J. (2018) Cold growth in northern climates. Greenhouse Canada
[28] MCGWIN, K. (2017) Can greenhouses take root in Nunavut? The Arctic Journal

Inuvik, Northwest Territories

Source: https://spectacularnwt.com//sites/default/files/styles/hero_desktop/public/attraction/gallery/2021-

The Inuvik Community Greenhouse is located in Inuvik, NWT and still boasts the title of being North America's northernmost greenhouse, which is located above the Arctic Circle (68.36° North). In 1998, the non-profit organization – Community Garden Society of Inuvik began plans for converting the decommissioned Grolier Hall Hockey Arena into a greenhouse. Most of the repurposed structure remained the same, save for the roof, which was replaced with polycarbonate glazing to let the 24-hour summer light to come in[29]. The retrofitted structure extends the growing season from May to October.

The 16,000 square foot structure is divided into two sections. The first is a 12,000 square foot garden on the ground floor, which holds seventy-four full size plots. Members pay a $25 fee per year and must complete 15 volunteer hours. The second part is a and a 4,000 square foot commercial greenhouse, where a variety of bedding plants and hydroponic vegetables (tomatoes, and English cucumbers) are produced. The revenues from the commercial operation go into covering the operation and management costs[30].

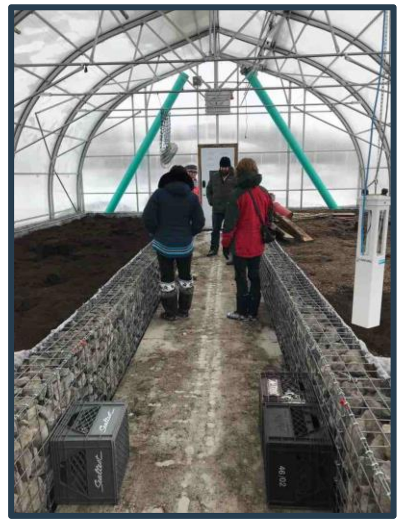
Carmacks, Yukon

The First Nation Reserve of Little Salmon/Carmacks which is two and a half hours north of Whitehorse, Yukon, has a community greenhouse. The facilities now include two greenhouses, a garden, potato farm and cold storage[31].

Source: https://www.yukon-news.com/wp-content/uploads/2017/06/YKN_LifeFR_localfood.jpg

[29] ICG – INUVIK COMMUNITY GREENHOUSE (2014) About the Inuvik Community Greenhouse. http://www.inuvikgreenhouse.com/index.php?p=1_7_FAQ
[30] MAHONEY, J. (2004) Hothouse flourishes as rink turns over new leaf. The Globe and Mail, July 12, 2004
[31] YUKON WELLNESS (2012) Greenhouse and Farm Operations, Carmacks. http://www.yukonwellness.ca/stories_greenhouse.php#.UubJOBAo5D8.

Kuujjuaq, Quebec



In Kuujjuaq, the largest community in the Nunavik Region of Quebec, boasts two community-led greenhouses, one which has been in operation since 1999. Both greenhouses have a combined total of 46 garden beds, which are distributed by a lottery system each year. The greenhouses are not artificially lit or heated, which limits the growing season to just 20 weeks a year[32].

Source: https://www.makivik.org/article/greenhouses-in-nunavik/

Other Indoor Farming Practices in the Arctic

While many northern growing operations can be neatly classified under greenhouse and VFS facilities, some follow a more holistic approach that utilizes a combination of agricultural and horticultural techniques including livestock production.

North Star Agriculture

North Star Agriculture is one such example of an agriculture development company that provides innovative food sovereignty solutions using a combination of technology and agricultural practices for northern communities. The company specializes in sustainable food production facilities across the Canadian North. Their mission is to ensure that northern, remote and Indigenous communities have an ability to plan, design, build and operate sustainable food production to secure their own food sovereignty through four pillars:

- A socially-minded approach
- Sustainability-first planning
- Innovative solutions for unique climates
- Integration of renewable resources throughout all projects

North Star's farming operations utilize a full suite of agricultural/horticultural methods, including outdoor farming/livestock production, greenhouses, VFS and aquaculture. North Star is developing VFS to complement their farming operations, in partnership with other organizations.

[32] For a more comprehensive analysis on greenhouses in the Arctic, please see the study by Ellen Avard: Avard, E. (2015). *Northern greenhouses: An alternative local food provisioning strategy for Nunavik* (Doctoral dissertation, Université Laval).

Case Studies

Na-Cho Nyak Dun First Nation, Yukon

Source: https://northstaragriculture.ca/nnd-farm/

As part of a comprehensive food strategy, North Star Agriculture worked with Na-Cho Nyak Dun First Nation in the Yukon to develop a working and teaching farm to increase access to healthy and nutritious food, grown in their own traditional territory. The ultimate goal was to provide community members with greater control over their food supply while also developing skills capacity.

The Na-Cho Nyak Dun First Nation acquired the 160-acre farm in 2018[33]. North Star Agriculture began renovations to the property in early 2020, which included renovations to the exterior gardens, greenhouse, stable, barn, coop and other structural components. Renovations to the greenhouse resulted in over 10 varieties of vegetables planted the following season, including cucumber, squash, corn, onions, tomatoes, swiss chard, lettuce, spinach, cauliflower, and various herbs.

Flat Creek Farm

Flat creek farm is Yukon's largest pasture-raised hog operation, located next to the Takhini River on 79 acres of land. North Star has been leading the development of the farm since 2015. The farm stared with 10 pigs in 2015 and has since expanded to a 200-pig operation in 2020. All pigs are sold to a Yukon-based meat distributor.

Arctic Indoor Farming Challenges and Opportunities

Incorporating indoor farming systems across Nunavut poses numerous challenges, especially if these systems are to function as part of an overall food sovereignty and food security solution. In reviewing the literature on indoor farming in the Arctic, along with corresponding with operators of systems across the territories, the following were identified as the main issues:

Arctic Climate and Extreme Weather

The arctic tundra brings with it sub-zero temperatures for much of the year, getting as cold as minus 40-60°C with the windchill. As a result, any indoor farming system, be it a greenhouse or VFS, must be constructed and customized to deal with these extreme temperatures. For greenhouses, their design must consider the prevailing wind direction and the position of the sun to maximize heat retention and

[33] https://northstaragriculture.ca/

energy efficiency.[34] [35] For VFS, containers need to be properly insulated to ensure maximum heat retention.

Snow accumulation on and around indoor farming structures must also be taken into account; high winds and blizzard conditions often create hard-packed snow drifts, which cause significant snow accumulation around structures.

Conversely, it is important to consider that in the summer months temperatures can often soar above 30°C inside greenhouses. This, combined with the effects of climate change, may mean shade curtains and proper ventilation systems for cooling greenhouses are needed in the summer months. For VFS, being able to dissipate heat from the LED lighting systems via proper HVAC technologies is a critical factor for success not just in the summer months, but year-round.

Growing Season

The number of days in the Arctic where the temperature remains above zero are considerably less than in southern latitudes. Even within Nunavut, there is considerable variation from east to west, and north to south. In Iqaluit, for example, daily mean temperatures are above zero Celsius for only four months of the year, while Sanikiluaq, the most southern Nunavut community, experiences above zero temperatures for six months (from May to October)[36][37].

Thus, colder mean monthly temperatures have the effect of shortening the growing season in a greenhouse. Growing seasons can be extended with the use of external heat inputs. This is not a limiting factor for VFS systems but applies to greenhouses.

In the long run, warming effects due to climate change will lead to an extended growing season, which will be an important consideration when designing new indoor farming systems.

Photoperiod

The photoperiod, or number of sunlight hours, is a critical consideration when it comes to designing greenhouses in the North. Overall, the days in Nunavut are much longer in the summer versus the dark season of winter. However, there is considerable variation in daylight hours across Nunavut. For instance, northern Qikiqtani Region communities such as Igloolik, Arctic Bay and Grise Fjord experience midnight sun in the summer along with periods of complete darkness in winter, while more southern communities such as Iqaluit, Rankin Inlet, and Kugluktuk in the west do not see the same variations during the year.

The summer daylight hours, therefore, are a major benefit to northern indoor farming operations in the North. The plentiful summer sunshine largely compensates for the shorter annual growing season. There

[34] Lamalice, A., Haillot, D., Lamontagne, M. A., Herrmann, T. M., Gibout, S., Blangy, S., ... & Courchesne, F. (2018). Building food security in the Canadian Arctic through the development of sustainable community greenhouses and gardening. *Écoscience*, *25*(4), 325-341.
[35] Avard, E. (2015). *Northern greenhouses: An alternative local food provisioning strategy for Nunavik* (Doctoral dissertation, Université Laval).
[36] Lamalice, A., Avard, E., Coxam, V., Herrmann, T., Desbiens, C., Wittrant, Y., & Blangy, S. (2016). Supporting food security in the Far North: Community greenhouse projects in Nunavik and Nunavut. *Etudes inuit. Inuit studies*, *40*(1), 147-169.
[37] Sanikiluaq weather data: https://www.wunderground.com/history/daily/ca/sanikiluaq/date/2022-2-5

are some varieties of plants that require periods of darkness for optimum growth, but these factors can be controlled using shading.

Lack of Local Soil

Good quality soil is another challenge for establishing greenhouse operations in Nunavut. This does not apply to the VFS under analysis, as they utilize soilless hydroponic methods. The soil in most Nunavut communities is sandy, with little organic matter. In some low-lying areas, organic matter has accumulated over years and forms a layer of dark black topsoil over the bedrock. If local soil is used, it must be modified to be more fertile.

In a 2016 study by Lamalice et al. looking at community greenhouses in the Arctic, the researchers used the Kuujjuaq greenhouse as a case study. In analyzing the local soil samples, the pH values of the soil were all below 5.2, meaning they were acidic. In contrast, the composts had a neutral to slightly alkaline pH, meaning they were suitable for common garden use. Soils that are acidic need to be limed for gardening purposes.

If soil in Nunavut communities was deemed inadequate, there are other options to consider. For one, shipping bulk quantities of soil for greenhouse operations from southern hubs may be necessary. This option would significantly increase the operating costs and could be a potential barrier to commercial greenhouse operation. Another option is to use compost from organic waste material already available in the form of food waste and other organic wastes in Nunavut communities. A combination of the two options would also be practical. VFS do not require soil, thus the lack of soil is not a limitation.

Crop Limitations

Greenhouse farming has traditionally been limited to the production of vegetables (lettuce, peppers, tomatoes, broccoli, carrots, corn, cucumbers and cabbage), flowers, herbs and small fruits, such as strawberries. However, greenhouses with CEA are able to extend the typical growing season, thereby allowing for a wider variety of crops to be grown.

Currently, VFS systems grow mainly herbs and greens, as they are the most economically feasible. Other crops are too energy intensive, and as a result, cost-prohibitive to grow. With more research and advancements in technology, other crops, such as fruiting vegetables, some fruits and potentially some root vegetables could be grown in VFS. Another challenge is the lack of pollinators, such as bees, required for some crops.

Financial Considerations

The costs associated with VFS and indoor farming in general are high, especially in the North. This is a result of the relatively high start-up costs, high transportation costs, and high costs of energy inputs. This makes it a challenge to achieve high productivity levels and price points of crops. All above mentioned companies in the space do offer financing/funding models and support to assist in bridging this gap. In addition, the utilization of alternative energy sources, such as solar or district heating, to reduce heating and energy costs are potential options to improve economic viability of northern indoor farming projects

Social Considerations

There are also many social concerns to overcome on the road to successful indoor farming operations in the North. For one, much training and capacity building is needed. Community project champions are a key factor in the long-term success of these facilities. In addition, these projects require community buy-in. There is an overall lack of cultural exposure to agriculture in the north, and initiatives around food sovereignty and food security are largely focused on traditional foods. Moreover, not everyone may want to purchase or eat leafy greens and herbs. On the other hand, Nunavummiut do buy these foods at their local stores. Being able to harvest locally produced crops would still serve Nunavut communities in providing nutritious and local food.

Recommendations

The variety of indoor farming technologies available means that there are options to choose from when planning infrastructure needs to support food sovereignty in Nunavut communities. Regardless of what options are chosen, these decisions must be done on a community level. Before these decisions are made, however, much legwork needs to be done regionally and Nunavut-wide to build capacity. Below are some recommended steps for communities, governments, institutions and organizations to take to advance indoor farming solutions in Nunavut.

1. Building Capacity – Education and Community Support

Indoor farming is not a traditional nor common food harvesting practice in Nunavut. As a result, many Nunavummiut likely do not know the benefits and opportunities that indoor farming technologies can bring in addressing food security in their communities. A natural first step then is to educate and inform the public on what indoor farming is, and how it can be utilized across Nunavut. This will require collaboration among all levels of government (municipal, territorial), along with support from Inuit Associations (including HTOs) and economic development corporations and NGOs. Working groups can be established as a first step to chart a plan of action. This capacity building should also address the barriers to adoption (ie funding, training, limits of growing crops), while also encouraging a holistic approach that takes into consideration a combination of technologies (both greenhouses and VFS). The success of this effort will only be realized when Nunavut's communities know, understand, and see both the benefits and challenges of installing and operating these systems.

2. Funding and Training Opportunities

As with any initial adoption of technologies, financial incentives are needed early on to help communities overcome the cost barriers of installation, operation and maintenance associated with indoor farming technologies. Supporting governments and organizations should work to identify available funding sources, as well as identify gaps in what is available for communities to access. There may be a need to develop new grants, subsidies, rebates and other financial mechanisms that are specific to indoor farming technologies. It will also be helpful to work with indoor farming companies already operating in the North, as they often help customers access various levels of funding.

All indoor farming companies contacted for this report provide training for their respective technologies. Beyond these opportunities, opportunities exist to provide education and training across Nunavut. This could range from creating new course modules at the college level, such as incorporating indoor farming technology training as part of Nunavut Arctic College's Environmental Technology Program, to sparking interest among youth through educational opportunities in schools. These programs should cultivate community champions who are willing to lead efforts in building and operating indoor farming infrastructure in their communities.

3. Ownership and Operations Structure

The ownership and operations structure of indoor farming facilities will vary from community to community. The majority of Northern indoor farming systems in this study are owned by First Nations and Inuit communities or non-profit organizations. For example, Inuvik's Community Greenhouse is run by the Community Garden Society of Inuvik, a not-for-profit organization formed in 1998 when the greenhouse began operating. Similarly, the Iqaluit Greenhouse is operated by the Iqaluit Greenhouse Society, which is also a non-profit organization. In contrast, Kuujuuaq's Growcer VFS is owned and operated by the Makivik Corporation, the organization which represents the Inuit of Nunavik, Northern Quebec. The type of ownership can also set the stage for who will be in charge of day-to-day operations.

Some examples of operational considerations that should be considered in the planning stages include:

- Is the proposed facility going to be run by volunteers or paid staff?
- Is there a way for youth to set up a structure where youth can be empowered to grow as community champions, while providing meaningful employment?
- Will there be membership fees for community members to have their own plots?
- Will the produce be sold direct to the consumer?

4. Community Specific Solutions

There is no one-size-fits-all approach to implementing greenhouse or VFS in Nunavut; there are advantages and limitations to both types of indoor farming. For example, while greenhouses with CEA technology may be able to grow a wider variety of crops, their utility is still limited to a short growing season in the North. VFS can grow produce year-round, but the commercial viability of crops is still limited largely to leafy greens and herbs. In addition, there is much diversity across Nunavut's communities in terms of population, climate and infrastructure needs. The first two recommendations should provide support for both types of indoor farming technologies in an unbiased way, so that all stakeholders are accurately informed of the benefits and drawbacks indoor farming technology can offer. Solutions should be tailored to suit community wishes and needs. An indoor farming solution that uses both greenhouse and VFS technology would be ideal, as they would complement one another and be able to provide a wider crop variety.

Conclusion

Advancements in agriculture and horticulture have led to a rapid rise in indoor farming techniques and technologies across the world. From modern greenhouses to VFS, these systems are making their way into Canada's North. Through CEA, environmental variables can be controlled with precision, allowing crops to be grown even in the cold, remote arctic climate.

Further advancements in Ag Tech will lead to overall cost declines for indoor farming systems including VFS, increasing their economics and attractiveness as potential solutions to addressing food security for northern regions, including Nunavut. These systems have the potential to shift some food production from the south to the community level, empowering Nunavut communities to take control of where their food comes from.

Several challenges remain, however. Costs still need to come down, and community buy-in must be there, along with community champions to ensure long-term success. Much capacity building also needs to be done to highlight both the opportunities and challenges. But many northern communities are already leading the way, like Iqaluit, Yellowknife, Kuujjuaq, and Inuvik (among others). These communities are utilizing both greenhouse and VFS technologies to help address the issues of food security and food sovereignty.

Despite the challenges, indoor farming holds potential in supporting food sovereignty and food security across Nunavut. Greenhouses (with CEA) and VFS are already operating in the north, with several companies looking to expand further into the territory. Nunavut organizations and communities to develop indoor farming solutions that cater to their specific needs. In many cases, it may make sense to combine VFS and greenhouse systems, allowing for the benefits of both to complement each other. These hybrid models are already being tried in northern communities, such as in Kuujjuuaq[38]. In addition, there is potential to explore the raising of livestock in communities, if they are willing; several individual-scale projects to raise livestock are already happening. More research is needed to accurately detail the challenges, opportunities, and feasibility of growing systems in the north. Equally as important is building the capacity amongst Nunavummiut to educate people on how indoor farming could potentially play a role in Northern food systems.

Modern problems require modern solutions. Indoor farming technologies may not be traditional ways of harvesting food, but they have the potential to enhance food sovereignty and empower Nunavummiut to grow their own food.

[38] https://www.makivik.org/kuujjuaq-hydroponic-container-growing-fresh-produce-in-nunavik/