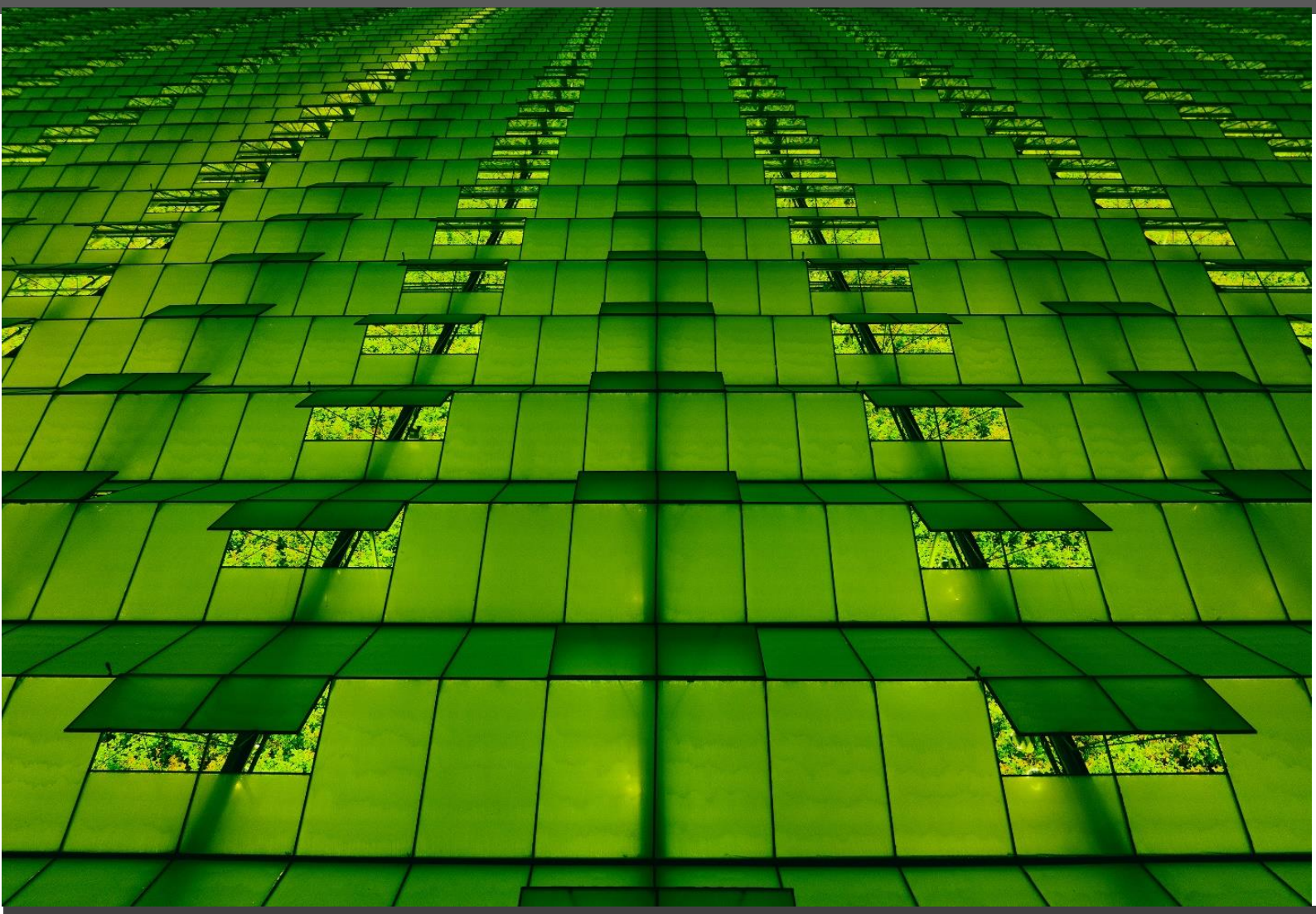

Case Study: Controlled Environment Agricultural (CEA) Systems

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A case study prepared for Remote controlled: The impacts of disruptive technologies in the Ontario agriculture sector

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About the Project

This case study is part of the *Remote controlled: The impacts of disruptive technologies in the Ontario agriculture sector,* which includes 48 key informant interviews with 52 key informants including agricultural industry experts, agricultural-related technology companies, and agricultural business experts to understand AgTech adoption in Ontario. For more information, please visit our project website.

Controlled Environment Agriculture Systems

Controlled Environment Agriculture (CEA) systems, also known as 'vertical farming' or 'indoor farming', combine technologies such as light emitting diode (LED) lighting technology, automated climate control and plant nutrient management, robotics, stacked or vertical growing container structures, and highly efficient building envelopes or growth chamber designs, to allow for agricultural production. These integrated CEA systems enable efficient indoor produce cultivation with less reliance on sunlight or land, or even completely without sunlight or soil.[i,ii] CEAs create sheltered mini-ecosystems that are often used in locations where field farming is not feasible or where there is a high susceptibility to risks from extreme weather events and pests. For example, CEA systems can be situated in food-scarce areas where outdoor field farming is unfeasible, such as cities and urban settings, colder climates, remote locations, or places without adequate soil.[iii]

CEA technologies allow for customization and automation of light, temperature, airflow, atmospheric gases, and humidity to create ideal growing conditions specific to individual crop requirements. Increasingly, artificial intelligence (AI), machine learning (ML), computer vision, and robotics technologies are used in CEA systems to automate agriculture processes, increase efficiency, and enhance productivity. This may include automated management of nutrient supply cycles, irrigation, and air flow in hydroponics, aquaponics, or aeroponics systems; assessment of crop growth quality; detection and control if weeds and pests; predictive insights for harvesting timing or disease diagnosis; and planting, pruning, and harvesting crops.[iv]

A Focus on Ontario

In Ontario, a number of initiatives have helped to spur innovation and the development of CEA system technologies. For example, Vineland Research and Innovation Centre's horticulture program focuses on applied engineering and commercialization opportunities for greenhouses and controlled environment agriculture, including data science, robotics, computer vision, and systems integration.[v] The program has established partnerships in the Niagara Region with local companies including AgricUltra Advancements, Bold Robotics, and Mycionics[vi]. Similarly, over the past ten years, the Robotics Institute at University of Guelph has developed the Guelph Intelligent Greenhouse Automation System (GIGAS), which includes a smart robot for harvesting indoor-grown tomatoes.[vii]

More recently, the Homegrown Innovation Challenge committed $33 million to generate solutions that extend the berry growing season in Canada.[viii] Several Ontario technology companies participated in the Homegrown Innovation Challenge. For example, Food Security Structures Canada (FSSC) FSSC has developed a vertical farming system that is engineered for ease of operation, maximum efficiency, and low operational costs to create advanced, high-yielding indoor environments for high-density cultivation.[ix] The system is designed to be easy-to-assemble, scalable, and sustainable. As part of the company's mission to help end

food security, FSSC has integrated the UNDRIP[1] and Truth & Reconciliation Commission's Call to Action #92 into their internal policies.[x] More specifically, the company's policy requires that projects are respectful of Indigenous communities and the company commits to providing these communities with equitable access and sustainable benefits from their projects. In Durham Region, Moduleaf, an autonomous indoor farming technology company, is developing mobile robots, autonomous monitoring, and real-time analytics for sustainable farming.[xi] Moduleaf has partnered with Feed the Need Durham, a regional emergency food distribution program, to explore how CEA and greenhouse technologies can be used to address food insecurity in Durham region.[xii] Elsewhere, AgriTech North is a social enterprise Beneficial-Corp (B-Corp) based in Dryden, Ontario, that is using emerging CEA technologies to grow fresh produce year-round to help resolve food insecurity in the northern parts of the province.[xiii]

Mushroom production is a segment of CEA systems that requires different or specially adapted technologies to address the unique characteristics of fungi cultivation. Because mushroom production is especially challenging compared to other crops, standardized agricultural production processes have only been established for certain species.[xiv] In Ontario, mushroom CEA systems companies Mycionics and Mycro Harvest are working to address these challenges by developing automation technologies that increase quality, consistency, and yield of mushrooms, as well as the potential range of mushroom species that can be grown commercially. Mycionics, which is co-located on a mushroom farm in Putnam, Ontario, produces robotic harvesting systems and smart farming technology to reduce manual labour while increasing food traceability and food-safety.[xv] Mycro Harvest, operating out of the University of Waterloo's Velocity Incubator, is developing AI-powered mushroom farm systems, with the goal of reducing the carbon intensity of mushroom production. These CEA systems solutions are intended to address labour shortages while enabling farmers to meet growing global demand for mushrooms. Table 1 provides examples of Canadian CEA systems companies.

[1] United Nations Declaration of the Rights of Indigenous Peoples

Table 1: Examples of Controlled Environment Agriculture Systems Companies Headquartered in Canada

Company	Year Founded	Headquarter Location	Description
Advanced Intelligent Systems	2013	Burnaby, BC	Advanced Intelligent Systems has created a set of customizable hardware and software, including robots for use in greenhouses and CEA operations.
Argus Controls	1984	Winnipeg, MB	Argus Controls produce automation solutions for precision control of climate, nutrients, and cultivation optimization in greenhouses and indoor growing environments.
AgricUltra Advancements	2017	Beamsville, ON	AgricUltra Advancements designs systems for maximizing facility production of indoor farms while minimizing energy inputs through multi-layer grow platforms, engineered inter-canopy management techniques, and advanced photobiology.
Bold Robotics	2017	Campden, ON	Bold Robotics offers custom machine design and engineering services for greenhouse and CEA automation solutions.
Canadian Climatrol Systems	1985	Surrey, BC	Canadian Climatrol Systems manufactures and supplies equipment and automation solutions for the greenhouses and CEA operations.
CanGrowHere	2020	Toronto, ON	CanGrowHere is working to produce Near Net-Zero energy smart facilities, with an integrated infrastructure platform to make year-round indoor food cultivation more accessible and profitable in Canadian climates.
Moduleaf	2022	Oshawa, ON	Moduleaf produces autonomous indoor farming technologies including robotics, AI, and ML to establish efficient growing environments that can provide consistent year-round production.
Mycionics	2014	Putnam, ON	Mycionics is an intelligent mushroom picking robotic automation system for mushroom cultivation in controlled environment agriculture settings.
Mycro Harvest	2023	Toronto, ON	Mycro Harvest's smart farm systems leverage low-cost automation powered by an AI-growing system.
NeuPeak Robotics	2019	Vancouver, BC	NeuPeak Robotics produces strawberry harvesting robotics.

Source: Created by authors based on company websites.

Impacts for Work & Rural Development

CEA systems can help mitigate and respond to climate impacts, while increasing agriculture productivity year-round.[xvi] CEA systems may also enable localized food production, enhanced biosecurity, and reductions in food transportation costs.[xvii] CEA systems also reduce the need for agrochemicals and large machinery,[xviii] while addressing local food security challenges and decreasing regional dependency on imported fresh produce.[xix,xx]

Below we outline some specific impacts for work and rural development, including: new markets, skills and job opportunities, diversifying agricultural production, addressing food insecurity, reducing environmental impacts, and creating a CEA innovation cluster.

New Markets, Skills & Job Opportunities

By making it possible to grow new crops in locations where it was not previously feasible, CEA systems may create opportunities for farmers to expand into new markets, develop new skills, and create new jobs in rural communities. For example, demand for mushrooms is increasing due to their importance in plant-based meat alternatives and for their use in sustainable bioplastics, polystyrene alternatives, and vegan leather products.[xxi] Interviewees noted the potential impacts that mushroom CEA systems might have on market, skill development, and job opportunities:

> *What that would mean for rural development is that there would be more jobs, more opportunities for not only labour positions, but higher skilled roles as well that are related to maintaining the technology. I think it would be extremely positive for rural development in the sense that it's an increase across the board as Canada takes its place as a leader in the production of these new specialty alternative materials. We're perfectly positioned right next to the U.S. with a ton of advantageous things like climate, because all of our systems are grown indoors. To be clear, that's why climate is advantageous. Also, certain price points like the Canadian dollar that make it advantageous to grow the product here versus in the U.S. So there's a ton of opportunity for regional expansion and economic and labour opportunities for rural areas* (Ag-Related Tech Company 16).

A number of interviewees also discussed how adopting robotics in greenhouses is helping to address labour needs because "*[…] folks don't want to work in a very hot greenhouse environment, very humid*" (Ag Industry Expert 4). A number of interviewees also noted how as a result of technology adoption in the CEA sector, there will be a shift in the skills needed. For example, Ag Industry Expert 3 argued,

> *[…] But the issue with the labour savings technologies is that […] it doesn't necessarily eliminate a job because workers are doing lots of jobs. So, you know, if you're in a greenhouse and you bought the robotic picker, those workers would still be needed to do packing. So that kind of thing* (Ag Industry Expert 3).

Diversifying Agricultural Production

Despite Canada's large land mass, only 7% of land can be used for farming.[xxii] Intense utilization of farmland can degrade its agricultural productivity over time.[xxiii] Faced with decreasing yields and increasing risks related to climate change, pests, and diseases, field farmers may adopt CEA systems on existing farmland to diversify their crops and create new income streams by expanding into new products and markets and extending their growing season.[xxiv] CEA systems may also encourage the development of urban agriculture, which has been shown to create a range of community impacts including access to food, improved diets, income opportunities, and green space.[xxv] One interviewee described this as follows:

> *Our vision is one in which farming in Canada changes, where it is not strictly a rural phenomenon, where there is more farming in and near cities, where there's more technology and science involved in food production. So one of the things that we're hoping is to democratize indoor farming, to make it something that does not require $10 or $15 million in capital to launch it. And that puts it closer into the reach of small family farms, as well as entrepreneurs who may not previously have thought of food production as something for them to get into* (Ag-Related Tech Company 20)

Addressing Food Insecurity

CEA can also help address food insecurity in remote, northern communities in Ontario. For instance, in 2018 the food basket cost[2] in Attawapiskat was $1,909.01, which is almost 125% more than Toronto's food basket cost ($849.60).[xxvi,xxvii] This cost difference is the result of many factors, including the inability to grow some crops and the high cost of shipping.[xxviii] Interviewees noted how CEA systems for indoor farming have the potential to reduce the cost of fresh produce in these communities, while increasing its quality and availability year round:

> *One of the things that we're really interested in, in terms of rural development, is getting these farms to food insecure rural areas. And we're looking right now, we've written some grants, and we're looking to partner with either remote or indigenous communities to try to get our technology, which is cutting-edge, leading technology for optimized growing, into some of the areas where there is no supply of local fresh food. And so if there was support for systems like to get those, because it costs a lot more to get, for example, a shipping container out to like Iqaluit to be able to grow out there. But we would like to see our technology deployed in places like that, because it's a small package that can deliver a massive amount of local fresh organic food* (Ag-Related Tech Company 16).

Likewise, another ag-related technology company working in controlled environment agriculture noted that their product is helping to address food insecurity and food quality issues in remote, Indigenous communities (Ag-Related Tech Company 14).

[2] The National Nutritious Food Basket is a survey tool used by various levels of government to assess and monitor the cost/affordability of eating healthy in Canada (Government of Canada, 2020).

Reducing Environmental Impacts

In 2021, the Canadian agriculture sector was ranked fifth among the nation's greatest GHG contributors.[xxix] CEA systems help provide opportunities for local food supply that can reduce the environmental impacts of long-distance transportation, thus contributing to emissions reductions.[xxx,xxxi] Furthermore, the use of agrochemicals in the agricultural sector contributes to land and water pollution.[xxxii] CEA systems can help farmers to reduce harmful inputs like pollutants and scarce inputs like water. For example, CEA farms use 99% less water than traditional farms, and much of the water can be reused.[xxxiii] Interviewees commented on how CEA systems can assist farmers in reducing inputs and the associated costs:

> *So, for example, you know, with traditional agriculture […] there is a significant amount of fresh water use that goes into these kind of growing operations. And you know, what happens is you're wasting or spending so much money on these utilities and stuff like that. You basically have to get bailed out every year because you can't make your profits back. So it's just becoming more unsustainable* (Ag-Related Tech Company 3).

Although indoor growing can lessen the environmental impacts of agriculture by reducing pesticides, using less water, and preventing fertilizer run-off, there are some potential environmental disadvantages as well.[xxxiv] For example, CEA systems can be energy intensive, which also leads to high operational costs.[xxxv] CEA system technologies are beginning to address this problem by using whole-system design approaches, real-time monitoring, and AI-powered optimization techniques that are expected to reduce total energy demand. For example, Ag-Related Tech Company 20 described their work to decrease CEA energy consumption:

> *One of the things that we are really focusing on is leveraging all of the energy resources we have, whether it's heat, cool, or light, and doing that in a way that the net result is a dramatically lower total consumption of energy required to produce a certain amount of food"* (Ag-Related Tech Company 20).

Establishing a Cluster in CEA Innovation

Interviewees discussed how the greenhouse sector in Ontario is growing at an "unprecedented rate" and with this growth they are also seeing "*[…] the information tech, the automation and robotics companies more and more interested in setting up more than just satellite locations in the region and the region is primarily Windsor-Essex"* (Ag Industry Expert 14). Ag-related technology companies also highlighted a number of partnerships and programs, both created and in development, in and near the region, including the Greenhouse Technician Program, which was launched in September 2023 at St. Clair College in Windsor, ON. The program was created in response to a shortage of skilled workers in the region[xxxvi] and is designed as a two-year program with students learning about the greenhouse sector through coursework, lab work, and experiential learning (e.g., greenhouse visits, placement).[xxxvii]

Future Considerations

A number of ag industry experts argued that over the next five years there will be more emphasis on greenhouses and more high-technology, including robotics, being integrated into these controlled environment systems. However, despite the purported opportunities and benefits of CEA, the adoption of CEA in rural areas is not without its challenges. One significant barrier to entry is the large start-up cost. The cost of CEA systems technology-related equipment requires large upfront investments especially in the initial stages.[xxxviii] And, there may be additional ongoing costs associated with energy use.

However, there are a growing number of government grants available for CEA initiatives. For example, SNAPP (Northern Ontario), Agri-Tech Innovation Cost-Share Program (OMAFRA), Sustainable CAP, and the Innovative Solutions Canada (ISC) program all provide funding to help build capacity in the sector.[xxxix,xl] In addition, while there are promising examples of Ontario cross-industry partnerships, experts continue to call for greater public and private sector investment in CEA development. Furthermore, there are calls to develop a stronger CEA ecosystem, comprised of technology developers, academics, investors, and farmers, in order to advance CEA innovation and promote the adoption of CEA systems for sustainable food production in the province.[xli]

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