



Executive Insights

Controlled Environment Agriculture: A Futuristic Fix for the Food System

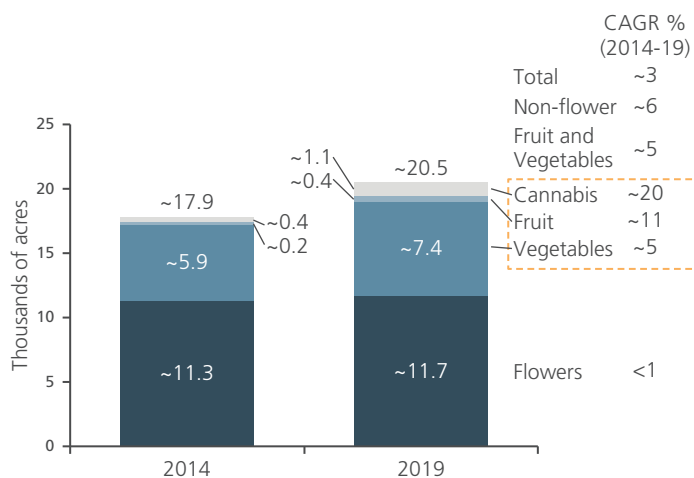
Indoor farming, also known as controlled environment agriculture (CEA), has been in existence since the first modern greenhouses were developed in the 19th century by French botanist Charles Lucien Bonaparte in Leiden, Netherlands. Over the years, greenhouses and other indoor growing approaches have evolved and proliferated.

Due to plentiful land and an agreeable climate, North America has primarily relied on conventional outdoor farming techniques for agriculture. Recently, however, there has been a surge of investment and growth in indoor farming, creating new opportunities in one of North America's oldest industries. The total acreage in the U.S. and Canada dedicated to indoor farming has seen ~5% growth per year for vegetables and ~11% per year for fruit from 2014 to 2019 (see Figure 1).

Against this backdrop, sharp-eyed investors and industry executives have taken note of a pocket of activity in the agriculture sector — one where a diverse group of innovators are taking a high-tech approach to produce farming. CEA creates sustainable, optimized growing conditions for crops while protecting them from pests or disease. It's part farm, part science lab, and wholly devoted to high-quality crop yields.

CEA can be used to grow a variety of things, including tomatoes, cucumbers, peppers, leafy greens (e.g., lettuce, kale, chard), herbs (e.g., basil, chives, mint, thyme), microgreens, strawberries and cannabis. Cucumbers and tomatoes were the earliest produce to be adapted to CEA, while strawberries are the most common of the fruits grown via CEA today.

Figure 1
Total greenhouse acreage in the US and Canada, by crop (2014-19)



Source: USDA Census of Agriculture (2017); Produce Grower; IndustryArc; Hortidaily; Cuesta Roble; Greenhouse Grower; USDA Floriculture Crops (2018); StatCan; The Packer; Agriculture and Agri-Food Canada's Statistical Overview of the Canadian Vegetable Industry (2018); Produce Blueprints; L.E.K. research and analysis

Controlled Environment Agriculture: A Futuristic Fix for the Food System was written by **Peter Walter** and **Rob Wilson**, Managing Directors, and **Shang Saavedra**, Engagement Manager, at L.E.K. Consulting. Peter and Shang are based in New York, and Rob is based in Chicago.

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Why now?

A few converging trends have contributed to the recent growth of CEA in North America. They include:

A challenging labor supply in key growing regions.

Immigration reform and minimum wage increases have cut into the labor supply for U.S. farmers, especially in growing-heavy regions such as California. A 2019 survey from the University of California, Davis, found that 56% of California farmers had trouble hiring the number of workers they needed in the previous five years, and 70% reported greater difficulty during 2017 and 2018.¹

Weather and climate change. Climate change is expected to fuel more unpredictable weather patterns that can be damaging to crops. California, for example, experienced persistent drought from 2011 to 2019, leading to rising water costs.²

Consumer trends. Consumer preferences are on the rise for produce that is sustainably grown, free of chemicals (e.g., pesticide-free) and locally sourced, and for fruit that is perfectly shaped. CEA has the ability to meet many of these needs. Many CEA-grown crops are chemical- and fertilizer-free, for example, and some vertical farms can use up to 95% less water than conventional farms.³

Retailers diversifying supply. Retailers are looking to source produce that can be available year-round, looks consistent and is more likely to be free of disease. CEA produce that has these characteristics can command premium pricing.

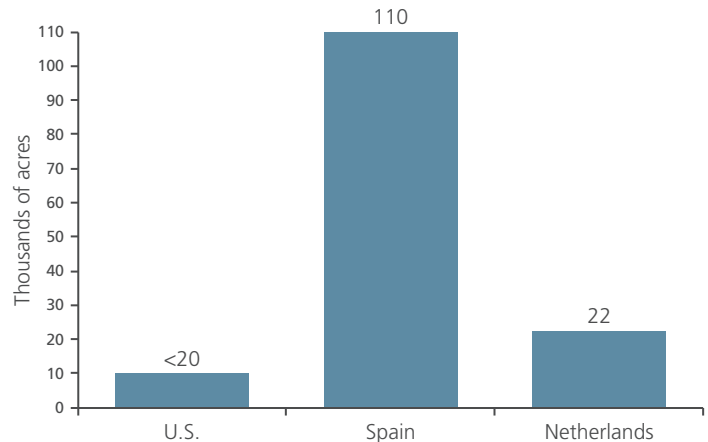
Technology enabling economical CEA. Advancements have occurred in multiple parts of the CEA ecosystem. This includes, for example, high-pressure sodium grow lights for year-round growing; diffused glass, which reduces stress on plants and provides even sunlight; high-pressure fogging systems to cool down greenhouses in hotter months; and more economical growing mediums such as basalt wool for growing tomatoes. These advancements are enabling CEA operators to reach and exceed a base threshold of economic viability.

Legalization of cannabis. Hemp is a legal cash crop throughout North America. Cannabis is legal throughout Canada and in 39 U.S. states. This, combined with a consumer interest in cannabidiol (CBD), has led to rapid market growth of about 38% per year since 2016.⁴ Cannabis is primarily grown using CEA.

CEA around the world

Spain, the Netherlands and Israel are global leaders in the adoption of CEA. The Netherlands is the third-largest vegetable exporter in the world (~\$8.2 billion in 2019), the U.S. is first at

Figure 2
Dedicated greenhouse farming acreage among top three vegetable- and fruit-exporting countries



Source: L.E.K. analysis of Statista, Wageningen University & Research, Ministerio de Agricultura, Pesca y Alimentacion, USDA, L.E.K. research

\$15.1 billion and Spain is second at \$9.9 billion.⁵ The Dutch have nearly eliminated the use of pesticides in greenhouse crops. They also make extensive use of advanced technology such as drones for monitoring crops and non-soil substrates for growing plants. While Spain's exports in vegetables and fruits are impressive in terms of volume, its CEA technologies lag those of the Dutch and the Israelis. Israel is a pioneer in agricultural technologies that benefit CEA — including drip irrigation for greenhouses and sensors that determine how much water, light and nutrition to deliver to each plant.

The U.S. remains the world leader in fruit and vegetable exports. Still, American farmers have fewer than 20,000 acres dedicated to CEA, trailing the Netherlands and Spain (see Figure 2). The upshot? In the U.S., CEA has significant runway for growth.

Growing technologies and trade-offs

CEA is a broad term. It refers to all indoor agriculture where certain aspects of the environment are controlled via technologies such as artificial light, hydroponics and aquaponics. In North America, L.E.K. Consulting estimates that ~95% of total CEA acreage is in greenhouses, but fully controlled indoor environments such as warehouses and containers have made inroads in recent years. Warehouses and containers fall in the category of vertical farms because of the way plants are stacked, and they are most commonly used for crops of limited height, such as leafy greens, microgreens and herbs. Table 1 offers a high-level comparison of greenhouses and vertical farms.

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Table 1
Greenhouses versus vertical farms

	Greenhouses	Vertical farms
		
Overview	<ul style="list-style-type: none"> Controlled structure that uses natural light during the daytime — typically via a glass or plastic ceiling Artificial light may be supplemented 	<ul style="list-style-type: none"> Fully enclosed environment that uses vertically stacked or vertically grown plants Only uses artificial light
Features	<ul style="list-style-type: none"> Degree of control varies greatly, from little control other than temperature to all aspects being controlled 	<ul style="list-style-type: none"> All aspects of environment are fully controlled Requires less land given vertical nature
Costs	<ul style="list-style-type: none"> Typically requires new builds — ranging from ~\$0.5M to \$3M per acre* Operating costs typically range from \$240K to \$1.5M per acre depending on the crop 	<ul style="list-style-type: none"> Requires very high capital expenditures of over \$10M per acre** Operating costs are ~1.5-2.5x of a greenhouse due to continuous lighting
Crops	<ul style="list-style-type: none"> Flowers Fruits (e.g., strawberries, raspberries) Vegetables (e.g., tomatoes, cucumbers, bell peppers) Leafy greens (e.g., lettuce, kale, chard) Microgreens Cannabis 	<ul style="list-style-type: none"> Leafy greens (e.g., lettuce, kale, chard) Microgreens Herbs (e.g., basil, chives, mint, thyme) Cannabis
Share of CEA acreage	~95%	~5%

*BrightFarms spent \$55M to build three greenhouses totaling 19 acres; AppHarvest spent \$28M to build a 63-acre greenhouse; Equilibrium Capital spent \$150-\$180M to build a 125-acre greenhouse asset

**AeroFarms has raised over \$100M to build 2.4 acres of vertical farms; 80 Acres Farms raised \$40M to build 3.4 acres

Source: Growcer; ZipGrow; Wired; L.E.K research and analysis

There is considerable debate in the industry about CEA's profitability, given the significant capital and operating expenses involved. According to the "State of Indoor Farming 2017" report, about half of indoor growing operations are profitable. By farm type, 75% of glass greenhouse farms are profitable compared to 50% of container-style farms and 27% of indoor vertical farms. By crop type, 67% of CEA tomato growers reported profitability, compared to 60% for microgreens, 45% for leafy greens and 17% for herbs.⁶

Looking ahead, the economics of CEA are likely to improve due to ongoing refinements that drive down per-pound production costs. Examples include additional automation to reduce manual labor costs, more efficient LED lighting and greater scale of operations. As data collection and analysis for precision farming improve, water and energy usage can see further declines while yields continue to improve. Some operators are looking to renewable energy as a way to reduce electricity costs.

Current landscape and key announcements

The North American CEA landscape is highly fragmented (see Figure 3). Vertical farms tend to focus more on vegetables, leafy greens, herbs and microgreens. Some of the larger greenhouse growers have differing portfolios of vegetables, leafy greens, herbs, microgreens and fruit, depending on their strategy. In terms of system, most growers focus on one type — either greenhouse or vertical farm.

Greenhouse operators

The greenhouse operator landscape in North America consists of a top tier of very large, vertically integrated players with multiregional operations, and then many smaller players. The large players include Mastronardi (which markets under the Sunset brand), Mucci Farms and AppHarvest. Mastronardi reports owning seven greenhouses (an estimated 300 acres) and having partnerships with/access to more than 5,000 acres of total

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Figure 3
North American CEA growers by business model type and product

NOT EXHAUSTIVE

	Vegetables, leafy greens, herbs, microgreens	Fruit	Cannabis
Greenhouses			
Vertical farms			

Source: Company websites; L.E.K. research and analysis

growing capacity (in Canada, the U.S. and Mexico). Mucci Farms owns and operates over 250 acres in Canada and partners with a network of 1,500 acres across North America. AppHarvest is in the process of expanding its total indoor growing space to more than 120 acres.

Given their larger scale per location, the large greenhouse operators tend to have geographically broad distribution reach, supplying retail grocery chains and foodservice customers regionally and/or nationally. By contrast, vertical farm operators tend to focus on more local off-take markets, enabling them to take advantage of the “locally grown” claim that many retailers and consumers value.

Vertical farms

Given the heavy capital investment required to build farms and current profitability challenges, most vertical farms have focused on significant fundraising as part of their growth strategy. Plenty has raised over \$500 million for a 2.2 acre (95,000 square feet) farm under development in Compton, California. AeroFarms raised \$238 million in funding and operates 2.4 acres (105,000 square feet) of total growing space in Newark, New Jersey,

with plans to build more. Shenandoah Growers expanded from greenhouses to vertical farms with a 1.4 acre (62,000 square feet) facility in Jefferson, Georgia. There are very few fruit and cannabis vertical farms, given the nascent state of the technology.

Retail partnerships

Many grocers in the U.S. already sell produce from CEA growers. Walmart carries BrightFarms salad kits and Houweling’s Group cucumbers. Costco sells greenhouse-grown romaine lettuce, tomatoes, cucumbers and peppers. At Target, Gotham Greens lettuce can be found.

Kroger was one of the first to launch a modular microfarm inside one of its banners in Seattle (two QFC stores), and Whole Foods even partnered with Gotham Greens in 2013 to build a vertical farm on top of a Brooklyn store. More recently, Plenty announced partnerships with Whole Foods (select Bay Area stores), Safeway (select Bay Area stores) and Albertsons (430 stores) in 2020. In April 2020, Publix unveiled a deal to carry lettuce and microgreens grown by Kalera, a vertical farm, in 165 stores.

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A sophisticated production method poised for takeoff

CEA adoption in North America is still in its infancy, with strong tailwinds for further growth over the next few decades. As advancements in technology enable further efficiency and productivity gains, the economic case for CEA is likely to only get stronger for crops that are well suited to these cultivation techniques. Long term, CEA will remain an important enabler of a reliable, economical and sustainable source of produce.

Endnotes

- ¹"Survey: California farms face continuing employee shortages," California Farm Bureau Federation, April 30, 2019
- ²"Drought in California," U.S. Drought Monitor, National Drought Mitigation Center, U.S. Department of Agriculture and National Oceanic and Atmospheric Administration
- ³"No pesticides and 95% less water — the indoor farming revolution," Hortidaily, May 24, 2018
- ⁴GreenWave
- ⁵ITC Trade Map
- ⁶"State of Indoor Farming," Agrilyst, 2017

About the Authors



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About L.E.K. Consulting

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