

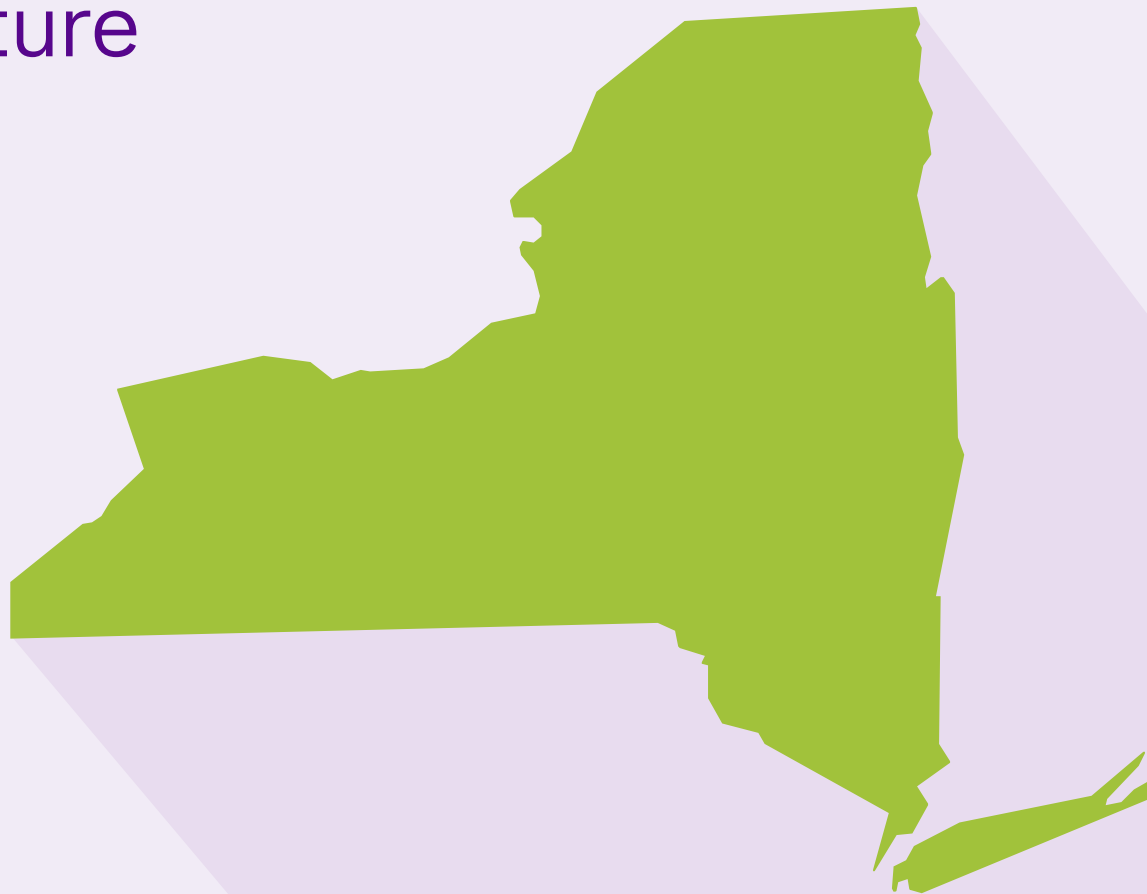
FoodMap NY

Leveraging Private-Sector Innovation
and Investment for Food Security

RESEARCH SPOTLIGHT REPORT

Controlled Environment Agriculture

November 2024



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Introduction

More than 44 million Americans experience food insecurity today, including more than 2.2 million people in New York State alone. Despite decades of government and philanthropic efforts, levels of food insecurity continue to rise, depriving millions of a decent quality of life, and costing our nation billions in preventable health care expenses.¹ In response to this crisis, federal and state leaders have called for private sector collaboration to improve food access and affordability; integrate nutrition and health; empower consumers to make, and have access to, healthy choices; support physical activity for all; and enhance nutrition and food security research.²

The NYU Stern Center for Sustainable Business, in partnership with Cornell University, and with the support of Mother Cabrini Health Foundation, sought to better understand where private sector interventions and investment could enhance food and nutrition security in New York State (NYS).

Research was conducted between April 2022 and May 2023 to assess current knowledge, efforts, and opportunities for private sector engagement in six focal areas:

1. Controlled Environment Agriculture
2. Supply Chain & Infrastructure
3. Healthy Food in Retail Environments
4. Food and Nutrition Assistance Programs
5. Food as Medicine
6. Food Finance

This report focuses on research and opportunities in the area of **Controlled Environment Agriculture (CEA)**. CEA encompasses a range of hydroponic growing practices, including indoor (vertical) farming, that are designed to optimize crop production and quality. By introducing a year-round growing system and making local production possible even in temperate climates, such as that of NYS, CEA holds significant potential to become a major part of the commercial agriculture system while improving access to locally grown produce.

Separate reports for each of the other areas are available here:

[view resources](#)

Defining the Opportunity

Controlled environment agriculture (CEA) refers to the practice of growing plants in a closed or partially closed environment, where environmental factors such as light, temperature, humidity, and CO₂ levels are carefully controlled and optimized for plant growth. This type of agriculture is often used to produce crops year-round, regardless of weather conditions, and can be especially beneficial in areas with limited access to arable land, water, and other resources.

CEA encompasses a range of growing systems, including soilless substrates, hydroponics, aeroponics, and aquaponics (combining fish and plants). A common theme of these systems is the ability to grow plants without soil but with precise control of the root zone and the capture/re-use of water and nutrients. There are also different types of CEA structures such as greenhouses and vertical farming systems (some of which are fully sunless, relying only on electrical light). Whether sunless or not, all high-tech CEA farms use supplemental lighting, temperature- and humidity-control systems (HVAC), and nutrient-delivery systems to maintain optimal growing conditions for crops.

CEA has several benefits over field agriculture, including reduced water usage, increased yields, and the ability to grow crops in urban areas, closer to consumers. But CEA systems can be expensive to set up and maintain, and they require significant technical expertise to operate effectively. Additionally, the high energy consumption associated with lighting and climate control systems can be a barrier to widespread adoption of CEA.

Because of these benefits, FoodMap NY is interested in looking into CEA as a potential strategy for addressing food insecurity in NYS. CEA can provide a reliable source of fresh vegetables, herbs, and fruit year-round, which is important in the Northeast, where traditional farming methods are limited by cold winters, short growing seasons, and limited access to arable land. CEA would also allow produce to be grown much closer to the end consumer, reducing transportation demands while providing the consumer with a fresher product.

We are exploring this space as an opportunity for private sector engagement, given the growing interest in locally sourced, sustainable, and healthy produce. CEA can help meet this demand. Additionally, CEA can be a way to create new jobs and economic opportunities in Upstate New York, particularly in rural areas where traditional farming may be less viable. As this chapter points out, however, CEA companies present specific challenges that will need to be considered.



Background

The Environmental Impact of CEA

Recently, experts have been examining the roles that CEA could play in the food system compared to other forms of agriculture. We looked at three representative studies that address CEA's environmental impacts.

First, Nicholson et al. 2020 assessed selected environmental outcomes of conventional field-based agriculture and compared these to representative CEA supply chains (greenhouses and plant factories).³ Specifically, they looked at the cost of production, cumulative energy demand, potential impacts of global warming, and water use per kilogram of leaf lettuce delivered to wholesale markets in New York City (NYC) and Chicago. While CEA uses around a tenth of the water required by field-based agriculture, the study's authors found that CEA supply chains have greater energy use and greenhouse gas emissions, primarily due to the energy required for lighting and HVAC. They conclude that "local" CEA supply chains for lettuce cannot be said to be more environmentally friendly than field-based production, even when field lettuce is shipped long distances.

Next, Stein 2021 compiled and synthesized over 50 studies on the effects of large-scale indoor farming on air, water, and soil.⁴ Stein hypothesizes that indoor farming (greenhouses and vertical farms) could significantly improve air quality through the conversion of open-field agriculture to forests. This is because food production that relies on open-field agricultural methods accounts for nearly 70% of the global atmospheric input of nitrous oxide (N₂O) and 40% to 45% of methane (CH₄). The study comes to a similar conclusion regarding water, as the reductions in water use are a key upside for indoor farms. Finally, Stein points out another principal benefit of indoor farming: the fact that no soil is used. Ultimately, the study highlights indoor farming's positive effects on air, water, and soil, although it does not mention energy requirements.

Finally, Bunge et al. 2022 conducted a review of peer-reviewed literature that assesses the sustainability performance of four different food systems.⁵ These include plant-based alternatives, vertical farming, food deliveries, and blockchain technology. They found that growing vegetables through vertical farms outperforms both open-field and greenhouse cultivation in terms of land and water usage, although the former does result in more greenhouse gas emissions. They also found that vertical farms are less efficient in terms of energy inputs, but the degree of environmental impact largely depends on the growing substrate, packaging material, and energy source.

CEA Financials

CEA operations often require large upfront costs, particularly production supplies, packaging, labor, structures, equipment, energy, and land. Energy costs often account for more than one-third of a CEA operation's total expenses. Another central cost element is the land, which consists of both production and non-production space (e.g., packing house and walk-in coolers, restrooms, administrative offices, parking). With field production, 67% to 70% of costs are due to packaging (including harvesting) and shipping, whereas for CEA these areas comprise less than 12%. On the other hand, labor and management, energy, and structures account for more than 80% of CEA costs, while transportation costs are minimal.

Nicholson et al. 2020 determined that total costs for CEA supply chains to provide lettuce to the Chicago and NYC metro areas are noticeably higher than lettuce sourced from field-agriculture operations—more than 150% of the costs of field-based production in the Salinas Valley of California.⁶ This is because the cost of electricity and land for CEA outweighs the much higher transportation costs for field-produced lettuce. Labor costs are also higher for CEA supply chains since additional labor is required for production. Furthermore, the administrative staff required to manage and market products is typically higher for CEA operations.

These findings suggest that greater productivity of CEA labor and utilities would be necessary for costs to be comparable to supply chains for field-grown lettuce. Companies will also need to choose locations strategically (such as peri-urban production outside of major cities) to optimize trade-offs between land and transportation costs. These findings are

backed by a November 2022 CoBank study. The bank determined that the break-even cost of production to grow and deliver greens for vertical farms is over \$3 per pound compared to a little over \$0.50 per pound for conventional outdoor farms.⁷ It concludes that cash flow has been impaired by high upfront investment and operational costs, consisting mainly of labor and huge energy expenses, along with the inability to capture premium pricing. As a result, CEA companies must also improve efficiencies in warehouse management and distribution rather than focusing solely on increasing productivity and quality of produce.

CoBank views industry consolidation as the ultimate outcome, where companies with sufficient funding to outlast competitors through extended periods of negative cash flow are the ones that will survive and eventually achieve profitability. Despite billions of dollars invested in indoor vertical farming in recent years, weak returns have been a significant impediment in attracting traditional types of financing, thus forcing vertical farms to rely on venture and private capital funding. For example, Wheatfield Gardens uses the commercial property assessed clean energy (PACE) program to finance its entire CHP (combined heat and power) system. PACE relies on borrowed capital to pay for the upfront costs associated with energy efficiency or renewable energy improvements, which is repaid over time via a voluntary tax assessment. This tool gives Wheatfield Gardens 30 years to pay back a \$1.8 million dollar loan at an interest rate of around 4–5%. CEO Paal Elfstrum sees this as a great funding source as other investors may require specific returns rather than focusing on the good that the company is doing.

Given the high cost of setting up CEA operations, we also researched alternative mechanisms for bringing together sectors and supporting new indoor agriculture businesses. An example of this can be found in community benefit agreements. A community benefit agreement (CBA) is a contract between community representatives and a developer. This written agreement benefits both parties as it guarantees certain benefits for the community, such as providing jobs for local workers and paying those workers a living wage, and ensures that the community will support (or at least remain neutral towards) the developer's project. An added benefit of a CBA is that its status as a private contract means that parties can incorporate new ideas and provisions outside the typical development deal to specifically address the community's wishes. However, there have been instances of developers misusing CBAs, so communities need to make sure that residents have a meaningful seat at the table during negotiations and the ability to actually enforce the final document.⁸

Plenty of opportunities exist to explore a CBA for CEA, especially given the higher number of CEA companies that are Certified B Corporations or otherwise committed to sustainability in their business models. In return for community support, which could drive a more efficient and expedited development process, coalitions could push companies for more local jobs as well as good deals on institutional purchasing of hyperlocal produce. For example, the CEA company could agree to sell a certain percentage of its crops at or below market prices to local schools, hospitals, or government offices. Many CEA farms are also moving to use solar panels to power their operations, so another possibility would be to either help build or subsidize solar panels for public buildings and open spaces. There are also opportunities to locate CEA operations near sources of waste heat (such as power plants, data server farms, or anaerobic digesters of organic waste). Given that there has yet to be a CBA involving a commercial CEA operation, communities could explore unique commitments that pertain specifically to their situation, such as developing partnerships with local grocery stores. This would be a win-win, as CEA companies would have steady demand for their products while communities would gain better access to healthy food that is grown sustainably.

Examples of CEA Solutions

80 Acres Farms

Overview

Founded by Mike Zelkind and Tisha Livingston in 2015, 80 Acres Farms is an indoor farming company focused on vertical farming, headquartered in Hamilton, Ohio.⁹ 80 Acres uses 100% renewable energy and claims it can produce more than 300 times the food of an ordinary farm per square foot while using 97% less water and zero pesticides.¹⁰

Funding

As of March 2023, 80 Acres Farms has raised \$275 million over the course of five funding rounds. These comprise a seed round in 2016 that raised \$10 million, a private equity round in 2019 led by Virgo Investment Group that raised \$40 million, a series-A round in 2020 that raised another \$40 million, and a series B-round in 2021 led by General Atlantic that raised \$160 million.¹¹ Most recently, FTX Ventures invested \$25M in January 2022. The company plans to use the capital to continue its expansion and product development.¹²

Status

As of January 2023, 80 Acres Farms operates eight indoor farms that use vertical farming systems to grow salad blends, herbs, tomatoes, and microgreens.^{13,14} Its produce is sold at over 600 retail and food-service locations, like Kroger, and it also utilizes an e-commerce channel. In January 2022, 80 Acres announced plans to build a new facility in eastern Boone County, Kentucky, which at the time of this writing is scheduled to open in the third quarter of 2023. The new farm is a 200,000-square-foot building located on 22-plus acres that will create 125 jobs, and it continues the trend of strategic location placements as the farm is close to its retail partners in Lexington and Louisville.¹⁵

At the start of 2023, 80 Acres appointed the U.S. branch of Siemens, a German industrial tech giant, to supply hardware and software to automate and scale its expanding U.S. operations. Siemens will also help finance the project, as 80 Acres' new infrastructure includes power distribution equipment, energy management and industrial automation software, and other edge and cloud computing systems. Among other developments, Siemens' R&D arm, Siemens Technology, hopes to leverage artificial intelligence and machine learning to develop an app that "optimizes software to identify irregularities, avoiding adverse conditions within the plants."¹⁶

Opportunities and Challenges

The continued growth of 80 Acres points to the potential of CEA even during periods of economic headwinds. The company's focus on strategic location placement allows it to strengthen connections with nearby retail partners as well as play the role of community partner, bringing good jobs to rural communities.

AeroFarms

Overview

Founded in 2004 by David Rosenberg, AeroFarms is a leader in the vertical farming industry. Based in Newark, New Jersey, the sustainable indoor agriculture company aims to transform the food system by improving the way farmers grow and distribute fresh produce.¹⁷ To accomplish this, AeroFarms uses the latest technology and research, such as a patented aeroponic growing system, to operate indoor vertical farms that use fewer resources, including land and water.¹⁸ At the same time, AeroFarms yields 390 times more per square foot annually when compared to traditional field farming.¹⁹ As a result of its environmental approach to agriculture, in February 2017, AeroFarms became the first indoor vertical farm to attain Certified B Corporation status.²⁰

Funding

AeroFarms has raised over \$200 million from 10 funding rounds since February 2010.²¹ These include a Series-B round in 2015 led by Wheatsheaf Group (now Grosvenor) that raised \$20 million, and a \$100 million round in 2019 that was led by Ikea's parent company, the venture capital arm of Ingka Group.²² Other members of AeroFarms' investor base include China's GSR Ventures, MissionPoint Capital, Middleland Capital, and AllianceBernstein.²³

In March 2021, AeroFarms announced plans to merge with Spring Valley Acquisition Corp, a special purpose acquisition company (SPAC), that was on its way to being publicly traded on the Nasdaq²⁴, in a deal that was valued at \$1.2 billion, and that was expected to raise around \$357 million in gross proceeds for the business.²⁵ In October 2021, however, both sides released a statement that they had "mutually agreed" to terminate the SPAC deal.²⁶ CEO Rosenberg claimed that it was "not in the best interests of [its] shareholders" to continue the transaction, and so AeroFarms still remains privately owned as of this writing.

But AeroFarms' funding does not solely come from investors with a business purpose. The company announced in February 2022 that it was kickstarting a multi-year research collaboration that would be funded by a \$2,112,454 grant from the Foundation for Food & Agriculture Research's (FFAR) Precision Indoor Plants (PIP) consortium.²⁷ Led by University of Florida researchers, AeroFarms will be working with experts at the University of California Riverside and Wageningen University to advance indoor growing of high-value tomatoes.²⁸ The ultimate goal is to determine ideal environmental conditions for consistently flavorful tomatoes while maximizing yield.²⁹

Status

At the moment, AeroFarms is expanding to the Mid-Atlantic, Southeast, and Midwest, with a new farm in Danville, Virginia, and another in the greater St. Louis area.³⁰ The Danville farm was announced in December 2019, and construction of the 136,000 square foot facility began in April 2021.³¹ Virginia Governor Ralph Northam announced 92 new jobs would be created in Danville-Pittsylvania County, where the farm began commercial operations in mid-2022.³² The location was strategically chosen to reach approximately 50 million people, who are located within a day's drive, and over 1,000 food retailers that are in close proximity.³³ Not only will this location allow AeroFarms to attain unmet market potential and build upon existing relationships with retailers like Whole Foods and Amazon, but the company is also targeting R&D partnership opportunities with nearby universities that have engineering and environmental sciences programs.³⁴

Meanwhile, in late 2022, the St. Louis Controlled Environment Agriculture Coalition selected AeroFarms to collaborate with the nonprofit World Wildlife Fund (WWF) in building a commercial indoor vertical farm in the St. Louis region.³⁵ At 150,000 square feet, it will be AeroFarms' largest farm to date, and the region of around 2.8 million people represents another excellent opportunity for the company, which deems the location a "gateway to food retailers throughout the broader Midwest."³⁶ Furthermore, the area has one of the world's highest concentrations of PhDs working in plant science and is home to more than 14,500 AgTech and bioscience jobs.³⁷ The exact location of the farm, the company's third, should be finalized by Q2 2022. By 2026, AeroFarms intends to have 16 farms, five of which will have 144 grow towers, instead of the 48 featured in its existing farms.³⁸

Opportunities and Challenges

WWF's recent collaboration with AeroFarms points to the growing interest in CEA as a way to reduce the climate impacts of traditional agriculture and bring people closer to their food, ultimately creating a more resilient and well-distributed food system. WWF's work in the St. Louis area will model innovations in energy savings for indoor farming, including repurposing existing energy assets and encouraging farms to co-locate for energy synergies.³⁹ This research has the potential to inform the evolution of CEA down the line.

AppHarvest

Overview

Jonathan Webb launched AppHarvest in January 2018.⁴⁰ The company grows non-GMO produce in large high-tech indoor farms that combine technology with conventional agricultural techniques. Its first greenhouse is based in Morehead, Kentucky, and the company plans to keep its operations in the Appalachian Region. This region, which spans from southern New York to northern Mississippi,⁴¹ enjoys a temperate climate and strategic proximity to major urban markets: Appalachian farms are roughly a one-day drive to approximately 70% of all U.S. households.⁴² AppHarvest became a Certified B Corporation in December 2019 and filed for an IPO in February 2021, becoming the first CEA company to go public in the U.S.⁴³

Funding

Revolution's Rise of the Rest Seed Fund led AppHarvest's seed round with an undisclosed amount in February 2018.⁴⁴ To build its first farm, AppHarvest raised \$82 million from Equilibrium Capital's Controlled Environment Food Funds in May 2019.⁴⁵ Around the same time, the company closed out a Series-A round led by ValueAct Capital's Spring Fund, which was joined by existing seed investors.⁴⁶ Then, in September 2020, AppHarvest announced plans to merge with Novus Capital, a NASDAQ-traded SPAC—a deal that was completed in February 2021.⁴⁷ The IPO raised close to \$475 million in gross proceeds, which included a \$375 million injection from existing and new investors like Fidelity Management & Research Company, Inclusive Capital Collective, and Novus Capital.⁴⁸ As a result, the company gained \$435 million in unrestricted cash that a spokesperson said would be used to "fund operations, including building additional high-tech controlled environment indoor farms, support growth and for other general corporate purposes."⁴⁹ AppHarvest later secured another \$91 million from Equilibrium Capital in July 2021 and the right to sell and issue up to \$100 million in shares of its common stock to B. Riley Financial in December 2021.⁵⁰

Status

In 2021, AppHarvest produced over 18 million pounds of tomatoes at its initial farm in Morehead. This generated over \$9 million in net revenue. Product was distributed to thousands of top grocery stores and restaurants, including grocery store chains like Kroger, Walmart, and Meijer.⁵¹ At the moment, all four of its farms are located in Kentucky, with the goal of establishing 12 operational farms by the end of 2025.⁵²

However, sales have been sluggish, and investor confidence has been low. AppHarvest hit a low in February 2023 as it missed projections for sales and the construction of its Kentucky greenhouses. As a result, the company had to unveil a plan to raise about \$40 million by issuing stock to cover its operating and capital needs through the end of the year. This caused its market value to fall to less than \$100 million by the second week of February, down from a high of \$3.7 billion following its IPO.

As of February 2023, AppHarvest was operating four farms that consist of 165 acres under glass. This includes two 60-acre farms for tomatoes in Morehead and Richmond; a 30-acre farm for strawberries and cucumbers in Somerset; and a 15-acre facility in Berea, where it grows salad greens.

Opportunities and Challenges

The rapid rise of AppHarvest presents several takeaways and lessons for similar ventures near NYS. A key factor of the company's success must be credited to its strategic location choices, which allow it not only to deliver fresh goods in a short amount of time, limiting spoilage, but also to save fuel on transportation, given how heavily the U.S. relies on imports. The country's imports have more than doubled over the past three decades, with 75% of U.S. fresh vegetable imports coming from Mexico.⁵³ Thus, starting a similar project near NYS could ameliorate several risks that were highlighted by the pandemic such as supply chain issues.

As of 2017, NYS had 6,866,171 acres in farming production, which is down from 7,183,576 in 2012.⁵⁴ The trend of decreasing land area suggests that farming must become more efficient since less land is being allotted to producing more food. CEA can provide one solution. Furthermore, NYS cropland on which all crops failed or were abandoned increased from 55,109 acres in 2012 to 161,150 acres in 2017 even though there was less total cropland.⁵⁵ The average size of a NYS farm was 207 acres in 2020, whereas AppHarvest's first farm was only 60 acres.⁵⁶ A CEA facility could continue to dedicate less land toward farming while producing more food and minimizing waste. Another major opportunity could be to use high-tech greenhouses to create good local jobs.

At this writing, AppHarvest has focused its production on tomatoes, although it is planning to start growing leafy greens and strawberries as well. According to the World Bank, tomatoes are the second most popular fresh market produce in the U.S. NYS' 2021 State Agriculture Overview does not provide data on tomatoes, and the New York Farm Bureau lists it as the state's 10th-most-produced agricultural product.⁵⁷ Given that CEA has proven its success in tomato growing, perhaps a similar project near NYS could bring a fresher version of in-demand produce to the state.

Key Learnings From Stakeholder Interviews

Our findings were necessarily limited by our small sample size. However, many stakeholders highlighted that CEA has served to increase access to healthy food options for those who can afford it rather than address food insecurity. For example, fighting food insecurity is not part of AeroFarms' explicit mission; CEO David Rosenberg believes that CEA companies cannot single-handedly solve the problem of food insecurity. Companies like AeroFarms primarily add fresh produce to the market, which does not tackle the economic root of the problem. Nonetheless, the foods they grow (largely greens) are certainly healthier than many options and priced at the same level as organics but with a better value proposition of being more nutrient dense, flavorful, and likely to be consumed due to their high quality. Today, AeroFarms' greens are sold not only by Whole Foods but also Walmart.

While increasing access to healthy food options does not address the bigger issue of poverty, which other organizations aim to do by tackling issues surrounding access, it could still make a dent in food insecurity in other ways. On top of building a larger presence in stores such as Walmart, AeroFarms has multiple community farm partnerships that work to alleviate food access issues by bringing its indoor vertical farming technology to local settings like schools, corporate cafeterias, and community centers. This offers students and adults the opportunity to participate in the full growing process, from seed to salad, and experience the benefits of hyper-local, sustainable food production.

These community farm partnerships aim to empower the next generation of scientists, chefs, and technologists to grow the best plants possible, which aligns with Rosenberg's hope that AeroFarms can "change behavior" surrounding food habits. Rather than providing more affordable healthy food options, his view of success is getting more people excited about eating healthy food by growing fresh, high-quality produce close to the company's consumer base. While not necessarily "food deserts," many of these areas face a lack of access to healthy local options, which AeroFarms could help address. AeroFarms hopes that the year-round access to fresh and nutritious leafy greens will push consumer preferences toward a healthier diet. To accomplish this, the company would welcome more government support for incentivizing corner stores and other small-box retailers to carry nutritious options.

Besides the price premium barrier to CEA's feasibility in addressing food insecurity, another obstacle is the shelf life of fresh produce. Aileen Randolph from the New York Farm Viability Institute cited many instances where people have declined to take free fresh food at local food banks due to its high perishability. As such, she urges CEA companies to consider who their target consumers are and what they would purchase. For example, Catherine Shick from FeedMore WNY, a Buffalo-based food bank, said that the organization has started using indoor techniques to grow its own food in addition to purchasing food from local farmers. As a result, the food bank received community input and modified its growing practices to produce more bok choy. This crop comes from two hydroponic container farms, or shipping containers, that are permanently stationed on the campus, and grow food 10 out of 12 months each year using LED lights and nutrients in a vertical growing environment. The 40-square-ft containers can grow the equivalent of what is produced across two to four acres—primarily leafy greens, but other crops can include radishes, herbs, and beans. While FeedMore WNY is not at a point where it can grow all of its own food for the community in these container farms, the latter have been a great addition. They demonstrate a potential scenario where CEA could be integrated with other strategies to address food insecurity.

Paul Sellew, who operates Little Leaf Farms, a greenhouse business in Massachusetts and Pennsylvania, was the most adamant of the stakeholders we interviewed about his belief that the CEA industry cannot be successful in its current model. His argument was that there is no lack of food in the market, and there are many good producers willing to sell; therefore, simply growing quality lettuce at its current cost will not be sufficient for breaking into the market. He sees no reason why businesses would not take advantage of the sun as a free resource in lieu of seeking an immense amount of funding to grow food in vertical farms. On a similar note, Louis Ferro of Empire State Greenhouses said that CEA shouldn't try to reinvent the wheel. He believes that good growing systems already exist, and that the focus should be on execution, not some novel technology.

Suggestions for Action

While CEA is expanding rapidly, several CEA companies (especially vertical farms) have recently failed. This could be correlated with the larger macroeconomic environment—i.e., venture capital requires quicker and higher rates of return (such as in the tech sector) than these inherently low-margin agricultural enterprises can offer. Given recession fears and rising interest rates in 2022 up until the time of this writing, some CEA companies have struggled to generate sufficient cash flow to support their capital-intensive projects. Lastly, a large benefit of indoor agriculture derives from environmental factors, relating to the absence of soil and water, yet the evidence on CEA's overall environmental benefit remains inconclusive due to the immense amount of energy it requires.

That said, CEA remains an interesting opportunity to pursue. CEA produces high nutrient dense fresh fruits and vegetables, critical for food and nutrition security, the “hidden hunger” or deficiency in intake of vitamins and minerals that are important for long-term health. But, currently, healthy produce comes at a price point that generally cannot compete with less nutritious but cheaper foods. The high costs of CEA must be brought down to help lower consumer prices for these foods.

Profitability could be improved by increasing energy efficiency, adopting renewable energy, automating certain functions (where helpful), and selecting locations where there is community support. Mid-tech greenhouses with a lower capital investment cost than vertical farms may be a good starting point. Ventures that produce cash crops (such as culinary herbs) as well as a greater portfolio of nutritious vegetables may be able to become both profitable and supportive of community food efforts. More research should be done on enabling technologies (e.g., low-cost automation, co-location to industries where waste energy can be used to heat greenhouses) as well as novel crops that address communities' unmet needs for diverse types of fruits and vegetables.

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