



Innovative Greenhouse Technologies for the Future

What is controlled environment agriculture?

By Robert Turner



Importing food threatens food security. Can innovative greenhouse technologies located in renewable energy locations reduce the risk?

As in many countries, the United States' food system has become dependent on multinational corporations that import food grown in faraway places. Since the early 2000s, food import costs have increased five times over – to a whopping \$18 billion annually. Of course, pineapples and kiwis come from locales with warmer climates, but we also import produce that can easily be grown in the U.S., including tomatoes, blueberries, and bell peppers, even during summer months. Domestically sourced produce comes mostly from drought-stricken California, which supplies one-third of the remaining vegetables consumed in the U.S. and three-quarters of fruits and nuts – but ever more precariously, as evidenced by almond and avocado failures in recent years.

This over-reliance on imports wasn't always the norm. During the early 1900s, nearly 40 percent of Americans still lived on farms, and most food was grown locally. To give an example: At the turn of the century, nearly all apples eaten in Iowa were grown in Iowa orchards (compared with only 15 percent today). The dramatic shift came after World War II, when Americans gained access to better refrigeration technology and a nationwide transportation network. By 2015, the proportion of food sales considered local had declined to 2 percent.

What is Controlled Environment Agriculture?

Are we destined for an import-reliant food system? A growing cadre of farmers who employ techniques collectively referred to as "controlled-environment agriculture" (CEA) is banking on a different destiny.

CEA includes heated greenhouses as well as soil-less hydroponic, aquaponic, and [aeroponic systems](#). In most cases, CEA means growing indoors with the aid of technology that allows farmers to maximize their influence over climatic conditions and resource inputs.

You might have seen news about so-called "[vertical farms](#)" popping up in former warehouses in North America, Asia, and Europe. Images show multihued grow lights encircling vertically stacked rows of vegetables, with robots busy plucking harvests at their precise peak. Seemingly futuristic, CEA companies may already be producing local food in a city near you.



Enthusiasts tout the promise of year-round food production closer to population centers, relinquishing reliance on foreign food imports and energy-intensive transport. CEA may also massively reduce water and chemical inputs while lowering carbon emissions. Given all these promised benefits, I wondered whether controlled-environment agriculture truly is a panacea. If so, what would a full-scale ag revolution mean for farmers navigating the transition?

Think Global, Eat Local

For insight, I met with Mike McConnell, a former U.S. Director of National Intelligence under two presidential administrations. “The U.K. is just nine meals away from chaos and food riots in the streets,” he said, referencing the shocking punchline from a 2008 study his office contributed research to. It showed that the United Kingdom depends on Spain and Italy (with their warmer climates) and the Netherlands (with its many greenhouses) for 50 percent to 80 percent of its food. At any one time, the U.K. had only “enough [food] on hand for nine meals before it’s gone. Now, I don’t think our situation in the U.S. is quite that dramatic, but a lot of our food comes from outside of our borders.”

McConnell’s focus at the time was on cybersecurity and threats to shipping networks. But contemplating supply chains quickly led to thoughts about food security. He worried about the global race to deliver organic soybeans from China and sliced zucchini from Turkey to a grocery store in Fargo, North Dakota. How many meals away from scarcity might we be? A big reason the U.S. has become so dependent on imported food simply comes down to cost. If a multinational food corporation can grow a pepper cheaper in Peru, then that’s what they’ll do; it’s business.

McConnell also acknowledged an exacerbating factor scientists agree on: Unpredictable weather already impacts food supply. "A warmer climate means two things: floods and drought," he said. "When that happens, crops fail. And when that happens on a global scale, mass migration becomes a strategic problem. There will be border wars. Countries will fight over water."

For myself, a small farmer already facing climate shifts along with farm-labor shortages and rising labor costs, I don't know how to prepare for more unpredictable weather while competing with \$10-per-day farm wages in Mexico. I believe localizing our food supply can offset challenges brought on by globalization. However, when I talk to people about local or regional food, many seem hung up on absolutes, thinking in terms of a wholesale alternative to corporate control of agriculture. For me, localizing doesn't mean eliminating trade – or absolute self-reliance. We can shift toward a more sustainable economy by producing and consuming most goods closer to home; companies, including those pioneering CEA, can be part of the shift. CEA's labor-saving automation and super-boosted yields per square foot could partially offset global economic pressures.

Dutch Greenhouse Technology

Next, I wanted to learn from a country attempting a better local-to-global balance, so I looked to the Netherlands. Only a bit larger than the state of Maryland, the Netherlands is the world's second-largest exporter of agricultural products by value – only behind the United States, which has 235 times its landmass. The Dutch achieved this by building on 400 years of trade relations, dedicating more than half its land area to agriculture and horticulture, and leaning into technological advances in both mechanized farming and transportation logistics.



What Are the Structures Used in Protected Agriculture?

As a longtime leader in greenhouse technology, the Dutch apply their know-how to other forms of controlled-environment agriculture. View Westland, a municipality considered the greenhouse capital of the Netherlands, from Google Earth satellite images, and you'll see a swath of glass. The region's climate-controlled farm complexes can each stretch for 175 acres or more. Mostly family-owned, these greenhouses use about a half-gallon of water to grow a pound of tomatoes (the global average is more than 28 gallons). CEA growers claim every acre in their greenhouses yields as much lettuce as 10 outdoor acres, cuts water usage by 80 percent, and reduces pesticides by over 95 percent. All of this is how a country located just 1,000 miles from the Arctic Circle became a leading exporter of heat-loving tomatoes, peppers, and onions.

More recently, the Netherlands earned the designation of being among the largest exporters of greenhouse buildings, infrastructure, and technology to the United States. Brands include KUBO, Prins, Dalsem, and Certhon. Greenhouse automation systems – the guts of the structures, including conveyor belts and computer-controlled environment systems – are supplied by Van der Hoeven Horticultural Projects and DutchGreenhouses.

Greenhouse Technology Companies in the United States

Tech upgrades aside, the Dutch way of growing is nothing new for the United States. At least 8,750 vegetable farms across the U.S. grow using greenhouses. One early pioneer is the Van Wingerden Greenhouse Company, located in Mills River, North Carolina. Founder Aart Van Wingerden started the company in 1972 after arriving from Holland. The Van Wingerden family still operates the company and has planted more than 650 acres in the greenhouses.

Yet, this success should not overstate the limited role CEA currently plays in the U.S.; only up to 2 percent of U.S. crops are currently grown in greenhouses or other controlled systems – signaling either exponential potential or a market simply not ready for this change.

CEA's economic viability recently came under scrutiny after the demise of some prominent companies, including Dutch company Glowfarms, U.K.-based Eider Vertical Farming, and the U.S. robotic-farming startup Fifth Season. Last year, two of the largest indoor vertical-farming companies in the U.S., AppHarvest and AeroFarms, filed for bankruptcy protections. Adam Bergman, head of AgTech investment banking at Citigroup, told Bloomberg that 2022 saw over \$1 billion in investment in vertical farming. In 2023, investments were under \$100 million.



So, what's the deal? The pitch for CEA seems a venture capitalist's dream: a way to grow crops that uses robots and artificial intelligence to conserve water, combat food insecurity, and save the environment. After investors have poured billions of dollars into CEA startups, pushing valuations into the upper stratosphere, the industry faces a harsh pendulum swing and profits remain elusive.

Food Versus Renewable Energy

Controlling environments requires large amounts of energy. Costs associated with heating glass- or plastic-covered greenhouses during winter can be enormous (summertime ventilation isn't cheap either). In sun-less systems, powering LED grow lights and round-the-clock ventilation is also expensive. The sheer scale of these operations compounds energy demands: A BrightFarms greenhouse complex in Etowah, North Carolina, is 280,000 square feet. Critics easily position CEA as a false solution that promotes food security at the expense of energy security.

These worries are valid. After all, the greenhouse industry flourished in the Netherlands largely because of cheap energy. But now, two years into Russia's war on Ukraine, Western Europe experiences volatile energy prices much like the rest of the world. However, I also challenge the outright dismissal of CEA by considering the potential for renewable sources to power operations.

Locating CEA systems near U.S. geothermal plants, as has been done in parts of the Netherlands, would be game-changing. Where geothermal isn't a viable energy source, we could site systems near solar or wind farms. Renewables change the whole equation.

Consider production efficiency in terms of yield per planting area – 10 pounds more lettuce per indoor acre than out. Some AgTech industry folks suggest the farmland saved from CEA could grow biofuels that can heat facilities in winter. Even if that doesn't quite pencil out, I know of a large Van Wingerden greenhouse in Charlotte that uses reclaimed wood for fuel, including recycled wood pallets and construction byproducts. If energy is the holdup, we have options.



Innovative Greenhouse Technologies for the Future

Even if renewably powered, CEA's ability to carve out a sizable, nationwide market share might still remain decades away if not for one other critical issue: water.

Especially for the western U.S., water insecurity is the factor defining agriculture's future. Even under the wettest scenarios, the U.S. "Fifth National Climate Assessment" projects decreasing summer soil moisture and reduced winter snow for the western plains into California. In other words, drought is here to stay. Colorado Gov., Jared Polis, speaking at a facility opening for CEA company Gotham Greens, summed up the challenge: "Unfortunately, without new technologies like Gotham Greens is deploying, Colorado won't have enough water to sustain the next generation of agriculture jobs or the industry that is a crucial part of the state's economy."

So, while some indoor greenhouses struggle, large outfits, including BrightFarms and Gotham Greens, are expanding, touting their ability to grow using 95 percent less water. BrightFarms has five new greenhouses scheduled to open in 2024, each of them covering 32 acres or more. Abby Prior, the company's chief commercial officer, believes, "The future of CEA is beyond promising. Similar to the momentum indoor-grown tomatoes experienced in the past, we believe that 50 percent of leafy greens nationwide will be sourced from indoor farms within the next 10 years."

I hope the U.S. will be strategic as CEA grows. If the country invited our own greenhouse revolution on a massive scale, we'd be wise to open the facilities near northern population centers, such as Chicago, New York, and Minneapolis. This strategy would reduce food miles, transport emissions, and supply risks, while delivering fresher food to stores a day after harvest, rather than a week later.

Which brings us to a final, glaring obstacle. For CEA to truly serve a local food economy, one that invests directly in local communities, the economics of these systems need to change. Upfront capital needs put CEA out of reach for many small farmers: A facility can cost \$12 to \$18 per square foot for the glass alone; a \$25-to-\$30-per-square-foot finished cost still excludes all the high-tech gadgets. Therefore, a 4-acre facility can easily top \$4 million to build, and a huge, high-tech facility like BrightFarms' new 35-acre project can easily top \$40 million. You've got to sell a lot of tomatoes to recoup that kind of investment.

Let's ensure small farmers can get into this business early, so the rewards of controlled-environment agriculture won't flow only to (you guessed it) large multinational food corporations.

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