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## **Why vertical farming just doesn't work**

**Vertical farms save water, prevent pesticide pollution and avoid extreme weather — but their Achilles' heel is their massive electricity use.**



**AeroFarms employees tend to baby kale in the company's New Jersey grow facility in 2019.**

**By Michael Grunwald**

Two years ago, an entrepreneur named David Rosenberg told me he was creating a new agricultural paradigm. His company, AeroFarms, had built the world's largest vertical farm in downtown Newark, and it was growing leafy greens with 99 percent less land and 95 percent less water than a traditional farm. It used no

pesticides. It allowed no runoff to escape into the environment. And it was de-risking the riskiest of human enterprises, deploying artificial intelligence, robotics, Big Data analytics, high-tech automation and club-vibe magenta LED lighting to create optimal growing conditions 24 hours a day, 365 days a year.

Rosenberg had positioned AeroFarms as a tech play, not an ag play, and when we spoke, he was preparing to take it public at a \$1.2 billion valuation. That was a lot of lettuce for a firm that had just started to sell salad, but it reflected the world's desperate need to grow more food with less environmental impact in an era of increasingly nasty droughts, storms and heat waves. The entire vertical-farming industry was booming at the time, offering an alluring alternative to the chaos of the outdoors.

The future is happening a lot faster than we expected," Rosenberg said.

Well, the future ended up happening a lot differently than he expected.

Aero Farms filed for bankruptcy in early June, citing "significant industry and capital market headwinds." Rosenberg stepped down as CEO. And the entire vertical farm boom has busted, with venture funding for the sector plunging 91 percent over the last year. Pioneers such as Orlando-based Kalera, Pittsburgh-based Fifth Season, Brooklyn-based Upward Farms, and Netherlands-based Future Crops and Glowfarms have gone bankrupt or shut down. Berlin-based Infarm, another industry leader, just laid off 500 workers, more than half its workforce.

It's not yet clear whether vertical farming is an overhyped, premature, expensive business model that can help change the world someday, or whether it's just a dumb and impractical idea. Its biggest immediate problem is that it's a ludicrous energy hog, because even though LEDs are way cheaper than they used to be, they're way more expensive than sunlight. I did some back-of-the-envelope math with one disillusioned investor, and we calculated that indoor farms like the one he had supported would require every megawatt of America's current renewable energy production to grow just 5 percent of America's tomato crop.



**An Upwards Farms grow facility in Brooklyn, NY. The company ceased operations in April, 2023.**

It's not even clear if indoor farming would be viable or scalable if it did solve its energy problems. Investors ranging from Google and Walmart to Bill Gates and Natalie Portman have also poured cash into horizontal greenhouses that deploy many of the same technologies that make vertical farms so exciting, while still using daylight to hold down energy costs. But industry darling AppHarvest, which was valued at \$3.7 billion after going public in 2021, has dropped 99 percent from that peak and is now flirting with bankruptcy as well.

This is a bummer, because feeding the world without frying the world is one of humanity's most urgent and massive challenges. By 2050, farmers will have to grow about 50 percent more food while using much less land and water and emitting much less carbon. As I wrote earlier this year, that means we can't turn up our collective noses at new food and agriculture technologies like meat or dairy substitutes engineered from plants or cells, or genetically modified or edited crops, livestock, bio-fertilizers or bio-pesticides. We might not need "all of the above," an

outdated energy slogan that's become more ideological than practical, but we'll probably need a lot of the above.

The problem will be figuring out how to make any of the above work at a reasonable cost on a global scale. The vertical-farming swoon is a reminder that technological solutions to the world's food and agriculture problems, while super-necessary, will be super-hard.

Outdoor agriculture has been around for 12,000 years, and it's a bit surprising that nobody's come up with a better way to grow food.

It's incredibly hard work to convert sunlight and soil into sustenance, especially for poor smallholder farmers in the developing world who lack tractors and planters and harvesters. It's also incredibly risky work. Crops get wiped out by droughts, floods and storms, by heat waves and cold snaps, by pests, weeds and diseases.

And farmers in wealthier countries create new problems when they fight back against Mother Nature, dousing their fields with chemicals that poison the air and the soil, fertilizers that pollute lakes and oceans, and irrigation water that sucks rivers and aquifers dry. But the 8 billion people on Earth need to eat, so agriculture keeps expanding its footprint at the expense of nature's footprint, bulldozing forests and vaporizing their carbon to grow more food.

What's so tantalizing about vertical farming is its potential to solve all those problems. It replaces backbreaking labor and diesel-fueled tractors with robots and automation. It replaces weather and winter with climate controls. It replaces nighttime with LEDs. It replaces pivot and drip irrigation with hydroponic and aeroponic systems that only provide the water plants need, a huge advantage in adapting to increasingly persistent droughts. As Vice President Kamala Harris pointed out after visiting vertical farming company Babylon Micro-Farms in Virginia this May, "Growing more food with less water will be one of the defining challenges of the 21st century."

Vertical farms also use much less fertilizer manufactured from natural gas than outdoor farms, and they don't allow any of it to escape into the environment in the form of nitrous oxide that boils the planet or runoff that degrades water bodies like the Great Lakes and the Gulf of Mexico. Birds can't poop on crops grown indoors, reducing the risk of food contamination. And vertical farms can be built near their customers, reducing spoilage as well as transportation costs and emissions.





The best thing about vertical farms is their potential to produce more food with less land, reining in agricultural sprawl in the same way high-rise apartment buildings rein in urban sprawl, freeing up conventional farmland for rewilding. AeroFarms has said it can produce 390 times as much greens per acre as outdoor farms; it turbo-charges plant growth by providing algorithmically optimized nutrition, lighting, temperature and humidity, enabling a harvest every two weeks instead of a few times a year. For scientists and agronomists searching for ways to avoid food crises and climate catastrophes, those kinds of turbo-charged yields are the Holy Grail.

For now, at least, energy costs seem to be a dealbreaker. It just takes too much electricity to replace the sun during the day and replicate the sun at night. Analysts have calculated that it would require five, 10 or many more acres of solar panels to provide the power for each acre of vertical farming. Maybe renewable energy will eventually become so abundant and cheap that investors won't care, but today's vertical farms pay too much for power to pencil out.

In any case, not even a zero-energy indoor salad-green farm could solve global agriculture's problems, because those problems aren't salad-green problems. They're not tomato problems or marijuana problems, either.

Two-thirds of global agricultural land is currently used to graze livestock, which is why more efficient ranching will be so vital for our future. Of the other one-third that supports crops, the vast majority grows grains, oils and other staples. Less than 0.2 percent grows lettuce, a global rounding error, and less than 3 percent grows fruits or vegetables.

The leafy greens produced by today's indoor farms are high-margin, low-calorie luxury items that have about as much to do with feeding the world as the Rolls-Royce Boat Tail has to do with transporting the world. Vice President Harris was correct when she told the crowd at Babylon Micro-Farms that "the kind of technology happening here can help feed millions of people," but agriculture needs to feed *billions* of people.

Until someone figures out how to grow rice, maize, wheat and other major crops indoors at a reasonable cost, indoor farming won't make much of a difference. My friend Ted Caplow co-founded BrightFarms, a hydroponic success story that raised more than \$200 million and built six huge greenhouses to grow greens close to cities. But Caplow was never happy with the company's limited ambition, and its leaders eventually forced him out.

"We were solving the lettuce problem, and I thought we might solve the strawberry problem," he told me. "But we were never going to solve the food problem."

David Rosenberg of AeroFarms told me he sympathized with Ted's concerns: "If you're not addressing the crops that feed most of humanity, you're on the fringes." He believed that AeroFarms would grow staple crops indoors in the medium term, but he was also trying to harness its technology to improve outdoor farming in the short term. The company's heavily automated and constantly monitored system was collecting more data and learning more about plant growth than any other farm in history, and Rosenberg had just forged a partnership with ag giant Cargill to use its data analytics and artificial intelligence to help cacao farmers in the developing world.

"We're unlocking the mysteries of plant biology," he told me in 2021. "We image every plant every day, so we can see when they're spotting and ripping and curling,

and we can figure out why. Every time we grow, we learn things that make us better farmers.”

In other words, AeroFarms wasn't just running a farm, or even a food factory marketed as a farm. It was running a lab, an institution of literally higher learning.

But it was still running a farm, and farming is still a tough business.

Many disruptive new technologies — the internet, virtual reality, artificial intelligence — follow a roller-coaster trajectory known in the tech world as the Gartner hype cycle.

The cycle begins after early movers prove the technology can work, thrusting the industry into a “Peak of Inflated Expectations” marked by investor exuberance and fawning media coverage. Then it fails to justify the hype, plunging into a “Trough of Disillusionment,” as the focus among investors and reporters shifts from its game-changing potential to its challenges with cutting costs and scaling up. Valuations crash. Startups fail. But survivors can make adjustments that lead them up the “Slope of Enlightenment,” as they start overcoming obstacles, and eventually to the “Plateau of Productivity,” when the industry matures and achieves mainstream adoption.

The indoor-farming industry believes it's now in a trough, like so many transformative tech industries before it. That's possible. But while indoor farming is a tech-enabled industry, exploiting some extraordinary wizardry, it's not really a tech industry. It's an ag industry. It grows physical products that must be cultivated, protected, harvested and transported. Food is not an app that can be distributed worldwide for no cost with a keystroke. It's atoms, not electrons.

Most farmers don't have to invent their tractors or irrigation systems, but that's essentially what vertical competitors like AeroFarms and big greenhouse players like Plenty, Gotham Greens and Bowery Farming are trying to do as they incorporate technology into their growing process. While it's awesome that AeroFarms can tweak its algorithms to make its arugula spicier or its spinach hardier, its success will depend on its basic ability to make stuff in a cost-effective way, not the coolness of the stuff it invents.

This is also the challenge facing alternative proteins, alternative fertilizers and other eco-friendly food-tech and ag-tech innovations. Take GreenLight Biosciences, a Boston startup that has adapted the RNA technology behind Covid

vaccines to produce bio-pesticides and bio-fungicides that can constipate potato beetles to death, eliminate the weird gray fuzz that ruins your berries in the fridge, and kill the parasitic mite that's wiping out the world's honeybees. GreenLight went public in early 2022 at a \$1.2 billion valuation, but none of its products have received approval from the Environmental Protection Agency yet, and last month, it was sold for just \$45 million.

The fake-meat industry has also struggled to live up to its hype. Beyond Meat's stock price has plunged 95 percent since 2019, when it had the biggest-popping IPO of the 21st century, and a bunch of major fast-food chains have stopped carrying its plant-based burgers. In 2021, a Berkeley startup called New Age Eats raised a \$25 million Series A round to build a factory that would grow pig cells into pork sausage, and announced that its goal was "to become the largest and most innovative meat company on earth" — not the largest cell-based meat company, the largest meat company. This spring, with its factory almost finished, New Age Eats shut down. The era when fake-meat companies were valued like tech companies, with market capitalizations as much as 100 times their paltry revenue, is probably over.

Still, I suspect the fake-meat industry will eventually make a big impact on global diets and land use. And while I'm less optimistic about the future of the indoor-farming industry, I can't be certain. I'm only certain that transforming the food and agriculture system that covers 12 billion acres and feeds 8 billion people will be brutally challenging. It will require a lot of work on a lot of solutions by a lot of scientists and entrepreneurs, and they'll require a lot of help from government. Congress is working on an enormous farm bill, and it should be pouring money into researching and deploying all kinds of innovations with the potential to increase yields, decrease emissions or shrink agriculture's footprint.

It actually would be great if vertical farms could solve the lettuce problem. America devotes about 375,000 acres to lettuce, which is about one of every 1,000 acres of U.S. cropland, but it amounts to one of every 2 acres that California farmers had to idle last year because of drought. The lettuce problem is a real problem that needs to be solved if we're going to feed the world and stabilize the climate.

But all of agriculture's bigger problems need to get solved, too — and they're not going to solve themselves.



