Vertical Farming 101: Everything You Need to Know

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A vertical farming system grows a diversity of salad greens in a basement of a converted bomb shelter in Dnipro City, Ukraine on Oct. 5, 2023. Narciso Contreras / Anadolu Agency via Getty Images

Quick Key Facts

- The global population is growing by 1% every year, and is projected to reach 9.8 billion by 2050. Vertical farming could provide a solution to cultivating enough food.
- Vertical farms can be built in many unconventional indoor spaces, including warehouses, skyscrapers, shipping containers, old industrial buildings and factories.
- Controlled Environment Agriculture (CEA) regulates temperature, humidity, lighting, water, nutrition and even carbon dioxide to create a perfect indoor microclimate for growing.
- Most vertical farms use hydroponic, aquaponic or aeroponic growing methods.
- Vertical farms use 95% less water and 99% less land than traditional farmland to create the same amount of food.
- Without pests or weeds threatening the success of crops, vertical farms are often 100% organic, using no pesticides, herbicides or synthetic fertilizers.
- High value, fast-growing crops like herbs, leafy greens, tomatoes and strawberries are among the most common crops grown on vertical farms.
- High energy usage, limited crop variety and the highly technical nature of vertical farming are some of the drawbacks of this method.

What Is Vertical Farming?

What if you could walk into your grocery store in February to buy fresh tomatoes, strawberries, herbs, and leafy greens — all fresh and locally grown in the middle of winter? With vertical farming on the rise, that might just become a reality.

The vertical farm Innovatus uses data-driven lettuce cultivation and tailor-made LED light recipes in Fuji City, Japan on Sept. 24, 2019. Jonas Gratzer / LightRocket via Getty Images

Vertical farming is pretty much exactly what it sounds like: a horticultural method of farming on vertical surfaces rather than horizontal ones. Vertical farms can be built in many indoor spaces, including warehouses, skyscrapers, shipping containers, old industrial buildings and factories. This highly precise method of farming utilizes LED lighting and smart growing systems to control factors like temperature, light, humidity, water, etc. in an enclosed space. It often employs other methods of farming as well, like hydroponics or concepts from other large-scale controlled agriculture operations.

History of Vertical Farming

Vertical farming as we know it is relatively new, but the concept itself is ancient. The Babylonian Hanging Gardens were built 2,500 years ago and remain one of the earliest examples of an advanced agricultural system that maximized space by growing upwards. The gardens were erected on vaulted terraces and likely were irrigated by a system of buckets and pullets that delivered water from the Euphrates River to a pool at the top. The Aztecs also used vertical farming

practices with chinampas: an agricultural system of growing plants on floating, marshy rafts suspended in lakes and rivers. The ground was too swampy for growing crops, so they covered these rafts with soil, and let the roots of the plants grow through the bottom of the rafts into the water. In the 1600s, French and Dutch farms grew fruits against cold stone walls. Even though th Northern European climate was too cold to grow most fruits, the stone captured the day's heat and released it during the night.

Flash forward to 1999. In a class led by Dr. Dickson Despommier at Columbia University, the modern vertical farm was conceptualized when the class sought solutions to feeding New York City using rooftop farming. In 2009, the first vertical farm was built in Singapore — Sky Greens farm had 100 towers to grow produce, each at 9 meters tall.

The Sky Greens Vertical Farming System in Singapore. Sky Greens

How Does Vertical Farming Work?

Controlled Environment Agriculture (CEA)

Vertical farms differ from conventional agriculture mainly in that crops are grown in highly regulated environments: a concept called Controlled Environmental Agriculture. This type of agriculture is c. .ned by its controlled approach to growing plants by manipulating the indoor environment to provide optimal growing conditions for specific plants. Temperature, humidity, lighting, water,

nutrition and even carbon dioxide are customized and monitored. CEA essentially creates a perfect

microclimate for growing — similar to a greenhouse environment, but much more exact. This method of farming has a lot of benefits — without the threat of flood, drought or other adverse and unpredictable environmental conditions, it allows for faster harvest cycles and predictable yields. It can also provide plants with the exact levels of nutrition, water and sunlight they need, wasting r resources in the process.

System Structures of Vertical Farming

In these controlled environments, advanced farming technologies also used outside of vertical farms are employed to cultivate plants. Hydroponic, aquaponic and aeroponic systems are the most commonly used system structures on vertical farms.

In **hydroponic farming**, plants are grown in a nutrient-rich aqueous solution. It's the most popular method of vertical farming for its efficiency and versatility, and the initial technology costs are lower than most other systems. This method isolates the nutrients and minerals in soil that are beneficial to plants and adds them directly to the water, eliminating the need for soil entirely. Hydroponics usually employs a soilless growing media to support a plant's roots while it grows — usually something like coconut coir, vermiculite, perlite, peat moss or rockwool.

The Growing Underground GU1 vertical subterranean farm uses hydroponic technology and LED lighting powered by renewable energy to produce fresh vegetables, in London, England on Sept. 29, 2020. Peter Dazeley / Getty Images

Aquaponic farming is similar to hydroponic, but uses water from fish tanks to support plant life. Water from the tanks contains nutrient-rich fish waste, which is then filtered and supplemented before being used by the plants. The water is oxygenated through this process and then sent back into the fish tank. Basically, there is a co-cultivation of both fish and produce by this method, each system benefiting the other.

In **aeroponic farming**, plants are provided with a nutrient-rich mist rather than water or soil. The plants grow on foam (which holds the plant in place), and the roots extend into a chamber filled with the mist. AeroFarms is one of the largest companies using this method, and successfully grows 550 kinds of vegetables.

Why Is Vertical Farming Beneficial?

There are notable environmental, economic and social benefits of vertical farming, all of which have contributed to its growth as a method of farming in recent years.

Requires Less Space and Land

You need a lot less space to create a vertical farm than a traditional farm, which requires huge swaths of fertile farmland to grow crops. In the last 40 years, we have lost more than 30% of arable land — that is, land that can be used for growing crops — to erosion and pollution, and are running out of land to meet the caloric needs of our growing population. Because of this massive need for space, farming is also the largest human cause of deforestation. Globally, 38% of land surface is used for agriculture. Razing ecosystems for farmland impacts biodiversity and the species that thrive there — rainforests especially are being cut down and replaced with monocultures, and more than half have already been destroyed. Vertical farming could present a solution to this crisis of space. By some estimates, 700 acres of farmland can be condensed into a supermarket-sized building with vertical farming.

Soil Health

In intensive, large-scale farming operations — particularly monocultures — soil is depleted of nutrients, and its microbiological diversity is damaged by synthetic fertilizers. Between one and six billion hectares of land are now considered to be depleted. Vertical farming sidesteps soil depletion completely, as most operations use no soil at all. In hydroponic vertical farming — which often us a soilless growing medium — no wait period is needed before growing again like most soil needs, allowing the farm to produce constantly without worrying about soil depletion.

Lower Water Consumption

We are in the middle of a water crisis, driven by climate change and our massive use of water for agriculture. Globally, 70% of water usage is attributed to agriculture. The megadrought in the western United States is in its 23rd year — but vertical farming has been identified as a way to relieve the intense pressure the drought places on farmers. Vertical farms use about 95% less water than traditional farms. Because they operate as a closed system, water can be recycled through the farm and reused. None is lost to evaporation, and water can be targeted directly at the roots so none is wasted. Crops grown on vertical farms also don't need as much washing before they are consumed, since they're grown in clean conditions.

Limited Chemicals

Soil on farms needs to be reinforced by organic and inorganic fertilizers over time as its nutrient

Although some vertical farms do utilize natural sunlight, most are highly dependent on LED lights to grow crops. There is some hope that electricity needs will fall in the future: according to Haitz's law — which measures the progress of LED technology — every decade, the efficiency of LED lighting systems improves by a factor of 20, so energy usage might fall on vertical farms in time. Renewable energy resources can also be utilized to provide electricity, although most vertical farms are still powered by fossil fuels. There is also an argument that renewable energy sources like solar and wind require large amounts of land, which could counteract the land-saving benefits of indoor farming.

Crop Variety

Unfortunately, not all crops are successful in vertical facilities. Leafy greens, herbs and small vegetables and fruits like tomatoes and strawberries are the most common and successful. These high value, fast-growing crops allow the enterprise to be more profitable, given the faster turnover. Root vegetables, for example, take much longer to mature, and aren't as profitable. Neither are ( )eal crops like wheat and corn that grow too tall to be stacked, so they cost much more than their conventionally grown alternatives.

There is also the question of whether indoor orchards are a future possibility, perhaps using dwarf varieties of common fruit trees. Some trees take a very long time to mature, however, which leaves them susceptible to diseases and bacteria in indoor environments.

Highly Technical Systems

Of course, given the highly technical nature of vertical farms, they are susceptible to technological issues. Power outages or other system malfunctions threaten the success of the farm — even a single issue with management of temperature, humidity, or lighting can hinder production. Farms must have highly trained people working on these specialized systems, and must be vigilant against water-borne pests or diseases, since they can spread quickly within the system once introduced.

Lack of natural pollination is another drawback of growing crops indoors. Even if bees are introduced, it's hard for them to navigate under the artificial lights. This is because many indoor farms use pink and purple lights — since plants are most successful when exposed to red and blue

wavelength light — but bees see differently from us and become disoriented. Workers therefore need to pollinate plants manually that require pollination to grow fruit.

Takeaway

Vertical farming has the potential to grow more food for a growing population, and can do so without the same environmental impact as traditional farming. It's not just a thing of the future, though — it's estimated that roughly 2,000 vertical farms are already operating in the United States. Aerofarms is one of the biggest names in aeroponic farming, and Bowery Farming based out of New York City is considered to be the largest U.S.-based vertical farming operation, and uses an AI operating system. Crop One and Farm.One are other big names in Boston and New York, respectively. Even the International Space Station has soilless systems growing cabbage, lettuce and kale in the cosmos. In 2021, vertical farming created a revenue of $3.4 million, and the industry is only expected to grow. By the year 2030, vertical farming companies are expected to grow by more than 25%, according to a 2023 study. So, maybe farm-fresh strawberries and tomatoes in February aren't too far off.

stores are depleted. When fertilizers are applied to traditional farmland, they often run off into nearby waterways, and the excess nitrogen and phosphorus can create "dead zones" in bodies of water. Vertical farming doesn't require these fertilizers, so there is no runoff into nearby communities.

Vertical farms also have little or no need for pesticides, since the controlled environment keeps pests from entering the space. One billion pounds of pesticides are used every year in the U.S, and have documented adverse effects on both ecosystems and human health — 10,000 to 20,000 farmworkers in the United States suffer from pesticide poisoning every year. Without soil, there's also no need for herbicides on vertical farms to target weeds. Thus, many vertical farms are inherently 100% organic.

Higher and More Reliable Yields

In all, vertical farms have much higher yields — as much as 10-20x per acre. Looking to the future, the effects of climate change will certainly impact the ability of farms to produce food, whether it be droughts, floods, higher temperatures or more frequent natural disasters. Because vertical farms aren't dependent on weather and seasons, they create perpetual harvests that are more dependable, so farmers don't have to worry about unpredictable losses in quite the same way. Furthermore, since temperature and other conditions can be regulated, they can produce seasonal crops all year round.

Food Access

Leafy plants farmed at Veggitech, a farming start-up utilizing agro technology and vertical farming techniques in Sharjah, United Arab Emirates on Sept. 25, 2023. As a desert nation with significant water scarcity, the UAE currently imports over 80% of its food. Andr DiCenzo / Getty Images

Food access is a growing argument for the expansion of vertical farms — particularly by bringing fresh, locally grown food to urban areas and food deserts, regardless of their environment.

With an estimated 80% of the world population living in cities by 2050, we will need to find a way to feed all of these people in areas where there is already very limited space for agriculture. The world population itself is projected to reach 9.8 billion by that year too, and food production will need to increase by 70% to feed a population of this size. In terms of acreage needed, this translates to an area roughly double the size of India. Given the small size of vertical farms, they can be built in existing spaces, including rooftops and other unconventional places available in cities. Growing fresh, healthy produce locally could make it more accessible and affordable to local people by eliminating the expensive shipping and storing processes of food that's transported from far away. The food itself tastes better and is of higher quality, too — since it hasn't been on the road or stc for weeks or months, the nutrients have had less time to deteriorate or for harmful bacteria like *E coli* to develop..

Reduced Emissions

Along with these opportunities for crop cultivation in urban areas, vertical farms make it possible to grow crops in places inhospitable to farming, like the Mountain West and glaciated parts of the Midwest. Therefore, out-of-season crops typically grown in warmer climates and shipped over long distances can instead be grown locally. This cuts down on the food miles attributed to a produce. Food miles — the distance that food has to travel before reaching consumers — accounts for about 20% of food system emissions. The food itself is also fresher, which means less food waste, and less rotting food producing methane in landfills.

Better Working Conditions for Farmers

Because there is less variability in vertical farming as opposed to outdoor agriculture, profits are more stable and therefore could mean better job security for workers. Workers aren't using heavy, dangerous farming gear that can cause injury, and aren't exposed to chemicals from pesticides and fertilizers, or diseases like malaria that are present on outdoor farms.

What Are the Potential Drawbacks of Vertical Farming?

While vertical farming presents exciting opportunities for the future, it also has its drawbacks — namely its high energy usage, limited crop variety and highly technical systems.

Energy Needs

The intense energy consumption of vertical farms is both an economic and environmental drawback. Given how dependent they are on electricity to function, indoor farms are highly vulnerable to fluctuating energy prices. They do, however, have control over when their "days" and "nights" fall, and can use electricity at times when it's cheaper. Not all places have access to reliable electricity either, making vertical farming a risk endeavor.

Title: The Future of Vertical Farming: Technical Objectives and Challenges

Introduction

As the world grapples with the increasing challenges of food security, resource scarcity, and environmental sustainability, vertical farming has emerged as a promising solution to address these issues. Vertical farming represents a revolutionary approach to agriculture that involves growing crops in stacked layers, often indoors, using advanced technology. This innovative method offers a range of technical objectives and challenges, with a focus on addressing shrinking water resources, reducing pesticide use, and shaping the future of employment in the United States and neighboring countries. In this document, we will explore these objectives and challenges in detail while highlighting the positive impact vertical farming can have on our future.

Technical Objectives

Water Efficiency:

- Reduce water consumption: Vertical farming systems aim to use significantly less water than traditional soil-based agriculture. Advanced hydroponic and aeroponic techniques optimize water usage by delivering nutrients directly to the plants' roots, minimizing wastage.
- Implement closed-loop systems: Recycling and reusing water within vertical farms can help mitigate the impact of shrinking water resources, ensuring a more sustainable approach to cultivation.

Pesticide Reduction:

- Develop integrated pest management (IPM) strategies: Vertical farms prioritize IPM techniques, such as biological controls and precision monitoring, to minimize the need for chemical pesticides.
- Implement strict hygiene protocols: Maintaining a controlled indoor environment reduces the risk of pest infestations, allowing for pesticide-free cultivation.

Energy Efficiency:

- Utilize LED lighting: Energy-efficient LED lights are employed to provide optimal light spectra for plant growth, reducing electricity consumption.
- Harness renewable energy sources: Integrating solar panels and other renewable energy technologies can further minimize the carbon footprint of vertical farming operations.

Crop Yield and Quality:

- Optimize plant nutrition: Fine-tuning nutrient delivery systems ensures that crops receive precisely what they need, resulting in higher yields and improved product quality.
- Develop crop-specific environmental controls: Tailoring the growing environment to each plant's specific requirements maximizes productivity and quality.

Challenges

High Initial Investment:

- Vertical farming systems often require significant capital investment in technology, infrastructure, and skilled labor. Overcoming this financial hurdle is a key challenge, particularly for small-scale farmers.

Energy Costs:

While LED lighting is energy-efficient, the energy demands of vertical farming can still be substantial. Finding cost-effective and sustainable energy solutions is crucial.

Technical Expertise:

Vertical farming necessitates a high level of technical knowledge in areas such as automation, hydroponics, and plant biology. Ensuring a well-trained workforce is essential for the industry's success.

Market Competition:

As vertical farming gains popularity, competition among producers may intensify. Maintaining profitability while meeting market demands poses a challenge for newcomers and existing players alike.

The Future of Employment

Vertical farming presents exciting opportunities for employment in the United States and neighboring countries. As the industry grows, so does the demand for skilled workers, ranging from agronomists and horticulturists to engineers and data analysts. These jobs are not only essential for the operation of vertical farms but also contribute to the broader agricultural technology sector.

In the next five years, we can expect to see a significant increase in employment opportunities within the vertical farming industry. This growth will not only provide jobs but also foster innovation and expertise in sustainable agriculture. As we move forward, it's important to invest in education and training programs to prepare the workforce for these emerging roles.

Conclusion

Vertical farming represents a promising solution to the pressing challenges of shrinking water resources, pesticide use reduction, and sustainable employment in the United States and neighboring countries. While it presents technical objectives and challenges, the potential benefits far outweigh the obstacles. By focusing on water efficiency, pesticide reduction, energy efficiency, and crop optimization, vertical farming can revolutionize agriculture and contribute positively to our future.

As we embrace this transformative approach to farming, we must also invest in education and research to overcome challenges, train a skilled workforce, and ensure the continued success of vertical farming in the years to come. The future of agriculture is vertical, and it offers a brighter, more sustainable future for us all.

January 26, 2024

Re. Responses to Questions and concerns regarding the following:

The City Commission did have a few questions for you; they are as follows:

- They asked if you could prepare a description of vertical farming for them. Please see attached

- What will the upgrades to the building be after it is purchased? Upon executed contract, the following will be engaged;

  1. Secure the space in all door and ancillary openings. Each of the eight (8) openings shall be secured by cement blocks including every horizontal space will be secured with re-rod and filled with cement.

  2. The clerestory windows at the north elevation of the space will be secured and also weather closure, the products and procedure shall be answered within the second quarter of 2024.

  3. The Vertical Farming system shall be commenced within the third quarter of 2024. The system shall be planned to provide for 2/3 of the space to be committed to Hop production, the balance to be potential retail as well as office space and storage.

  4. Hop and vegetable production is anticipated to commence in September 2024. NOTE: Production will be based upon the installation of the Robot systems, which are anticipated to commence within September 2024.

- Is the entity that will be using the building already prepared to move into the building when it is ready? Yes.. NOTE: The property note/ownership shall be in the name of the Corporation. To be provided to City Hall within the next two weeks.

Regards,

Parchment Vegetable Products, Inc.
2313753926