Can integrating IoT in vertical farming improve business viability?

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Reading time 17 mins

Key Points

- Vertical farming (VF) is a soil-less method of growing crops in stacked layers, often using controlled-environment agriculture to optimise resource use and produce food year-round in urban settings.
- Food can be grown in unconventional spaces (e.g., warehouses or containers) and uses up to 90% less water and 99% less land. VF uses no pesticides or fertilisers, so it is 100% organic, and some produce (e.g., leafy greens) grows 11 times faster than conventional farming.
- Early adopters and investors who hailed it as a revolutionary solution to feeding a rapidly growing urban population experienced significant setbacks and multiple challenges, e.g., high energy and labour costs, flawed business models, and difficulties in demonstrating profitability (there's a limited range of crops that can be grown using VF and costs of sale are significantly higher than conventional farming).
- Integrating IoT in vertical farming can help address these challenges: It reduces high energy consumption in key areas (e.g., LED lamps, air conditioning systems, dehumidifiers), helps to optimise resources better (e.g., smart irrigation systems reduce waste), and significantly improves sustainability when using renewable resources.
- Further incorporating complementary technologies (e.g. AI, computer vision, robotics, and blockchain) will improve efficiency and automation and decrease labour costs.
- Despite significant challenges, VF is not a failed concept, and the sector is still growing. It's essential to address the misconception that it can solve large-

scale food shortages when, in reality, it’s a niche market better suited as a complementary system to traditional farming that ensures the availability of seasonal produce throughout the year.

- In time, economies of scale will make smart power grids more accessible and VF technology more affordable – paving the way for increased innovation and new business models (e.g., cultivating medicinal plants and rare herbs where margins are higher).

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Last updated Oct 24, 2024

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Vertical farming (cultivating plants without soil in huge greenhouses), once hailed as a revolutionary solution to the challenges of feeding a growing global population, has seen several high-profile setbacks in recent years. Despite these challenges, vertical farming is not a failed concept—it offers real potential as a complementary method of food production. Agritech solutions such as IoT in

vertical farming could hold the key to re-opening more sustainable – and profitable – paths to food security

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How do vertical farming methods rank for sustainability?

Vertical farming is a sub-sector of controlled environment agriculture (CEA) that grows plants in vertical stacks indoors. It’s a highly precise method that uses no soil or sunlight and instead leverages LED lighting and intelligent growing systems to control factors like temperature, light, humidity, water, etc. The result is:

- The ability to farm in unconventional spaces (e.g., warehouses, shipping containers) and in urban areas would bring food closer to urban consumers and reduce transportation and logistics costs.
- Food production that requires approximately 90% less water and 99% less land than traditional farmland
- 100% organic produce. There are no pests or weeds to threaten the success of crops. Therefore, no pesticides, herbicides, or synthetic fertilisers are necessary.

- High-value, fast-growing crops such as herbs, leafy greens, tomatoes, and (some) berries can be produced all year round, reducing the need to import seasonal produce.
- Increased resilience to extreme weather conditions or supply chain disruptions.

There are three types of vertical farming methods: hydroponics, aquaponics, and aeroponics. Each has its advantages and disadvantages, as well as different implications for sustainability.

1. Hydroponic Vertical Farms

Plants are grown in nutrient-rich water instead of soil.

- Pros: It is water-efficient (uses up to 90% less water than traditional farming), allows for year-round production, and requires minimal space. Lettuce grown hydroponically grows 11 times faster than lettuce grown traditionally and produces half the amount of C02 gas emissions.
- Cons: It requires precise nutrient management, has high energy consumption due to artificial lighting, and is limited to specific crops like leafy greens and herbs.
- Sustainability Ranking: Moderate. Water conservation is a strong positive, but high energy consumption can offset environmental benefits.

2. Aquaponic Vertical Farms

Combines aquaculture (raising fish) with hydroponics, where fish waste provides plant nutrients.

- Pros: Closed-loop system that recycles nutrients, reducing fertiliser needs. Provides two products: fish and plants.
- Cons: Complex to manage, fish health can affect crop production and high start-up and maintenance costs.
- Crops: Leafy greens, herbs, and fish such as tilapia or catfish.
- Sustainability Ranking: High. The recycling of nutrients and dual food production system makes it highly sustainable but require more expertise and initial investment.

3. Aeroponic Vertical Farms

Plants are suspended in the air, with roots misted with nutrient solutions.

- Pros: It uses even less water than hydroponics, produces faster plant growth, and does not require soil.
- Cons: It requires specialised equipment and depends on a stable power supply and regular maintenance.
- Crops: Mostly leafy greens, herbs, and some root vegetables.
- Sustainability Ranking: Moderate to high. The minimal water usage is a huge plus, but the energy demands and technical expertise required can reduce sustainability.

One of the most significant critiques of hydro-, aero- and aqua-ponic systems is that there's no conclusive evidence that fruit, salad, and vegetable crops grown in soil-less systems are as healthy or contain the full array of nutrients (e.g., trace elements of selenium and iodine) as those grown in healthy soil. In addition, these systems operate within a typically industrial paradigm that prioritises economic considerations over all others. For example, an increased use of man-made materials such as plastic significantly impacts sustainability as a whole.

While each method offers unique benefits, they tend to cater to niche markets—growing primarily high-value, perishable crops like leafy greens rather than staple foods such as grains or potatoes. This leads to the misconception that vertical farming can solve large-scale food shortages when, in reality, it's better suited as a complementary system for producing seasonal produce year-round and reducing the reliance on imports.

Can integrating IoT in vertical farming address these challenges?

In addition to high investment, startup, and maintenance costs, vertical farms face the same challenges: High energy consumption (due to automation and irrigation systems, HVAC systems, artificial lighting, etc.), a dependency on technology – which has not yet matured – to work correctly (electricity cuts or irrigation system failures can cause significant damage); and risk of water or air-borne pathogens contaminating the entire system (vertical farms operate in a closed loop) requires precise management and technical expertise which further increases labour costs.

How can integrating IoT in vertical farming help?

1. Resource Optimisation

IoT sensors monitor real-time data on light, humidity, CO_2 levels, and plant health, enabling precision farming. This prevents the overuse of resources like water, nutrients, and energy, ensuring that every

input is used efficiently. For example, smart irrigation systems deliver water only when and where it's needed, significantly reducing waste.

2. Energy Efficiency

One of the biggest criticisms of vertical farming is its energy consumption, particularly for artificial lighting. IoT-enabled smart lighting systems use LEDs that adjust light spectrum and intensity depending on plant needs, minimising energy use. In some cases, renewable energy sources can power adaptive lighting and energy systems, lowering the carbon footprint further.

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3. Predictive Maintenance

Vertical farms can reduce downtime and avoid costly breakdowns by using IoT to monitor equipment performance—such as pumps, HVAC systems, and nutrient delivery systems. Predictive maintenance systems alert farmers to potential issues before they become critical, improving operational efficiency and preventing waste due to equipment failure.

4. Data-Driven Decision Making

IoT devices gather vast amounts of data, which can be used to optimise crop yields, reduce costs, and improve sustainability. Advanced analytics can predict the best conditions for each crop and adjust settings accordingly, creating an ideal growing environment that minimises waste and maximises productivity.

Which complementary technologies enhance IoT-enabled vertical farming?

IoT isn't the only technology driving the future of vertical farming. Artificial intelligence (AI), computer vision, robotics, and blockchain are also crucial in optimising production and reducing costs.

1. AI-Powered Crop Management

AI can analyse data from IoT sensors and other sources to predict crop performance, manage resources more effectively, and even create optimised "growing recipes" for different plant varieties. Machine Learning (ML) algorithms continually refine these recipes, leading to better crop yields and reduced resource usage. By incorporating AL and ML with IoT:

- Optimal settings for nutrient delivery, water flow, and light based on seasonal changes can be predicted.
- Based on sensor readings, cloud-based decision-making can identify potential deficiencies in nitrogen, phosphorus, and potassium#
- Due to real-time disease detection and diagnostic capabilities, farmers are more empowered to take preventive measures, safeguard crops, and maximise yield.

2. Robotic Automation

Robotics can take over labour-intensive tasks like planting, harvesting, and packaging, reducing the need for human labour and lowering production costs. Automated systems can work around the clock, increasing the efficiency of the entire operation. However, this also raises concerns about job displacement and the additional cost of re-training or upskilling existing staff.

3. Computer Vision for Crop Monitoring

Computer vision in agriculture is essential for monitoring plant health and development. Cameras and sensors, integrated with AI algorithms, can scan plants for early signs of disease, nutrient deficiencies, or pest infestations. By identifying problems in real time, computer vision enables precision intervention—treating only affected plants rather than entire sections—further reducing waste.

Additionally, computer vision can track plant growth rates, ensuring that each crop reaches optimal maturity before harvesting. This technology can also monitor crop quality, sorting out plants that don't meet standards, which improves overall product quality and consistency.

4. Blockchain for Supply Chain Transparency

Blockchain technology can track produce from farm to table, providing transparency and ensuring food is sustainably sourced. This could build consumer trust in vertical farming as a reliable source of fresh, high-quality produce.

CASE STUDY: Jones Food Company (JFC), Bristol, UK.

This UK-based company launched in 2017 and operates one of Europe's largest vertical farms. Its success, where many others failed, proves that vertical farming isn't simply a fad with no future.

- Actively supplies 3,000kg per week of fresh herbs to UK supermarkets, demonstrating commercial viability.

- Supplies 30% of the UK's cut basil.
- It uses solar energy to provide 15% of its power requirements, and newer facilities are being built to use 100% renewable energy.
- Each litre of water is cleaned and reused up to 30 times, thus reducing total water usage by up to 90%.
- Plants are seeded in recycled plastic bottles.
- Meets a growing demand for quality, fresh produce at an affordable price point.
- Builds turn-key vertical farms for other businesses.

A significant part of JFC's success is a result of leveraging a combination of technologies: Robots and AI systems feed data from the growing, germinating, and harvesting rooms into a machine learning program which uses that to optimise cultivation. Chief executive James Lloyd-Jones says: "We can export this technology around the world, like the Dutch exported their knowhow on greenhouses. The UK could lead in the export of this knowhow."

What can we learn from vertical farms that wilted instead of blooming?

In 2020, vertical farming startups in Europe and the US attracted billions in Venture Capital—the most ever in a single year. However, just a few years later, the boom was over, and many companies declared bankruptcy. These included Agricool (Paris, France), AppHarvest (Kentucky, USA), and the biggest global player, AeroFarms (backed by the Duke of Westminster's property firm Grosvenor and Abu Dhabi Investment Office).

'Easy money' in the form of funding and investment opportunities discouraged efficiency, and arising issues included:

- Flawed business models. Many businesses raised too much money without having viable business models or product/market fit studies and spent too much on sales and marketing.
- High inflation, labour, and energy costs. The EU estimates that indoor vertical farms spend around 60% of their revenue on electricity costs.
- Difficulties in demonstrating profitability. An analysis by US-based cooperative bank CoBank showed that vertical farming's breakeven cost of production per pound of leafy greens was approximately $3.07 compared to only $0.65 for conventional outdoor farming.

For startups and entrepreneurs looking to address food security and sustainability challenges through solutions such as IoT in vertical farming, a multi-faceted approach is necessary: Growing herbs and salads vertically and selling them to restaurants and supermarkets must be more scalable. The

primary revenue streams, as with the JFC case study, need to come from selling CEA products (e.g., growing towers and robotics) to end users (e.g. supermarkets) and developing compatible technologies adapted for vertical farming such as sensors, automation, computer vision and renewable energy.

Is there a future in vertical farming?

There is endless pressure to deliver significant returns in a short amount of time. Still, GT Thompson (House of Agriculture Committee) says that for vertical farming to supplement conventional farming sustainably, we need to take a long view of things. In time, economies of scale will reduce startup and implementation costs, thus reducing breakeven costs:

- As vertical farms grow in size and efficiency, their reliance on expensive grid electricity could be offset by investments in renewable energy solutions, such as solar and wind power.
- Advancements in energy-efficient lighting, like next-gen LED systems and more automated workflows using AI and robotics, will further cut operational expenses.
- Data-driven optimisation from IoT sensors and AI will allow vertical farms to maximise yields with less waste, improving profitability.
- New business models may focus on producing premium crops, such as medicinal plants or rare herbs, which have higher margins.

Second-wave innovators who learn from the mistakes the early adopters and first movers made are likely to be successful. IoT in vertical farming holds great promise but is not a one-size-fits-all solution to global food security.

Rather than viewing vertical farming as a silver bullet, it is more realistic to see it as part of a broader sustainable food ecosystem complemented by traditional farming, technological innovation, and intelligent resource management using renewable energy. With IoT and other technologies leading the way, vertical farming can become a critical tool in addressing food security challenges—just not the only one.

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Suggested reading

How to get a return on investment in IoT: Case studies of successful businesses

IoT in agriculture sustainability: Driving eco-friendly and yield-enhancing farming practices

IoT in UK smart grids: Powering a reliable and energy-efficient future

FAQ’s

Why is IoT important in vertical farming?

IoT is crucial in vertical farming because it enables real-time monitoring and control of growing conditions like light, humidity, and temperature. This ensures optimal conditions for crops, improving yield and resource efficiency. By automating processes, IoT reduces human intervention and helps farmers make data-driven decisions.

How does IoT improve sustainability in vertical farming?

IoT improves sustainability by monitoring resource use, such as water, energy, and nutrients, and ensuring they are used efficiently. Sensors and data analytics enable vertical farms to adjust conditions in real time, reducing waste. This leads to more sustainable production while conserving vital resources.

What role does AI play in vertical farming alongside IoT?

AI enhances IoT systems by analysing data from sensors and automating decisions, such as adjusting lighting or irrigation. This optimises crop growth and resource use, reducing operational costs. AI can also predict potential issues like disease outbreaks, allowing farmers to respond proactively.

Which crops are most commonly grown using IoT in vertical farming?

Leafy greens like lettuce, spinach, and herbs are the most common crops grown on vertical farms. These crops thrive in controlled environments and have short growth cycles, making them ideal for vertical farming. Other crops include strawberries and microgreens, although staple crops like grains remain impractical.

Why is vertical farming not suitable for staple crops?

Staple crops like grains and potatoes require more space and resources to grow than vertical farming systems can economically provide. The energy costs and technology needed to cultivate these crops are too high compared to traditional outdoor farming. As a result, vertical farming remains focused on high-value, fast-growing crops like leafy greens.

How can IoT help reduce the high energy costs in vertical farming?

IoT systems help reduce energy costs by optimising the use of artificial lighting and other energy-intensive processes. Sensors monitor the exact needs of plants, ensuring resources like light and heat are used only when necessary. By fine-tuning these conditions, IoT reduces energy waste and operational expenses.

What are the main types of vertical farming?

The three main types of vertical farming are hydroponics, aquaponics, and aeroponics. Hydroponics grows plants using nutrient-rich water, aquaponics combines fish farming with plant cultivation, and aeroponics grows plants with a misted nutrient solution. Each system has its pros and cons depending on resource availability and crop type.

Which vertical farming system is most sustainable?

Aeroponics is often considered the most sustainable vertical farming system because it uses 95% less water than traditional farming and requires no soil. However, it also demands advanced technology and high energy usage for misting and monitoring systems. Hydroponics and aquaponics can also be sustainable with efficient resource management.

Why do vertical farms struggle to be profitable?

Vertical farms struggle with profitability due to high energy costs and the need for expensive technology. The controlled environments require significant investment in lighting, ventilation, and IoT systems, which can be difficult to offset by selling produce. Additionally, many crops grown in vertical farms are still seen as premium products with limited market appeal.

How does IoT help vertical farms monitor plant health?

IoT systems use sensors to continuously monitor plant health by tracking conditions like nutrient levels, temperature, and humidity. This data allows farmers to detect early signs of disease or stress, enabling timely interventions. By providing real-time insights, IoT helps maintain plant health and improves overall yields.

When did the vertical farming bubble burst, and why?

The vertical farming bubble burst in 2022 due to the unsustainable business models many farms were using. High energy costs, inflation, and difficulties in achieving profitability contributed to the collapse of several startups. Many vertical farms could not compete with traditional farming’s lower costs for staple crops.

What are the limitations of IoT in vertical farming?

The main limitations of IoT in vertical farming are the high initial setup costs and the need for specialised technical skills to operate and maintain the systems. Additionally, IoT relies on robust infrastructure, which can be costly and complex to integrate with renewable energy solutions. Despite these challenges, IoT can significantly increase productivity when used effectively.

Who can benefit from IoT in vertical farming?

Urban farmers, agritech startups, and large-scale agricultural companies can all benefit from IoT in vertical farming. It provides a solution for producing fresh, local produce in cities with limited space. Consumers also benefit from year-round availability of sustainably grown produce with fewer food miles.

How does IoT improve water efficiency in vertical farming?

IoT systems monitor water usage and ensure that only the necessary amount is delivered to plants at the right time. This precision irrigation reduces water waste, which is particularly important in water-scarce environments. By controlling water distribution, IoT also helps maintain optimal growing conditions without over-saturating plants.

Which vertical farming companies are using IoT effectively?

Companies like AeroFarms, Bowery Farming, and Infarm are leading the way in using IoT to optimise vertical farming operations. These companies use IoT sensors and AI to monitor plant growth, automate environmental controls, and improve resource efficiency. Their success demonstrates the potential of IoT to make vertical farming more viable.

What are the humanitarian implications of IoT in vertical farming?

The use of IoT in vertical farming may lead to job displacement due to automation and reliance on robotics. However, it also creates opportunities for upskilling workers in fields like data science, AI, and agritech maintenance. As vertical farming grows, the demand for technical expertise could open up new career paths in sustainable agriculture.

Why is IoT considered essential for scaling vertical farming?

IoT is essential for scaling vertical farming because it allows farmers to automate and optimise processes that would be difficult to manage manually on a large scale. It provides real-time data that improves decision-making and resource allocation. Without IoT, the complexity of managing vertical farms would limit their scalability.

How does IoT help reduce waste in vertical farming?

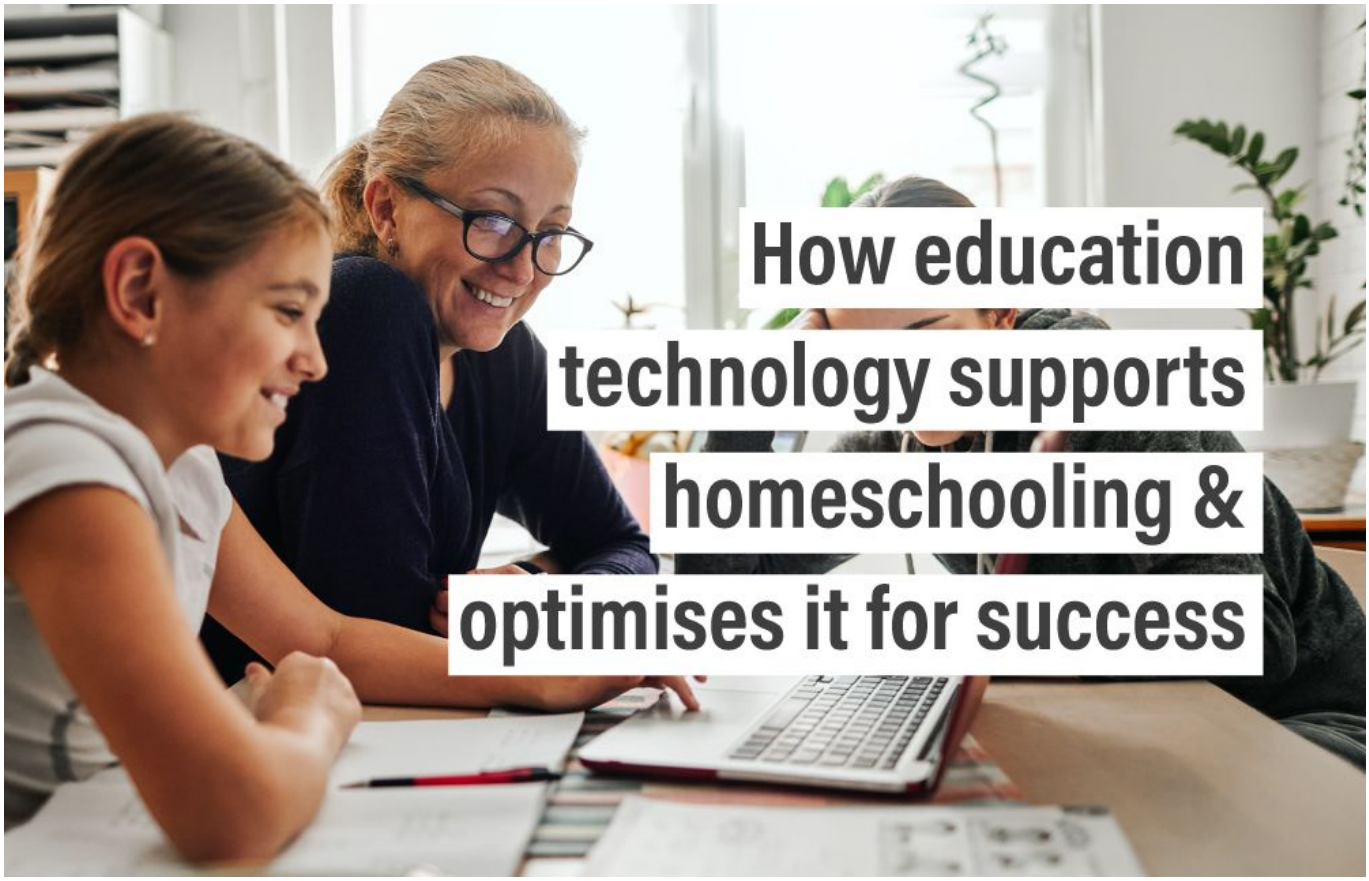
IoT helps reduce waste by precisely monitoring the conditions plants need to thrive, such as water, light, and nutrients. This ensures resources are used efficiently and less produce is lost due to over- or under-watering, poor lighting, or nutrient imbalances. IoT also helps identify underperforming plants early, allowing targeted intervention.

What is the future of IoT in vertical farming?

The future of IoT in vertical farming is likely to involve even greater automation, data-driven optimisation, and integration with renewable energy sources. As technology advances, costs will decrease, making vertical farming more economically viable. IoT, combined with AI and robotics, will play a key role in scaling sustainable, local food production.

How can IoT help reduce labour costs in vertical farming?

IoT helps reduce labour costs by automating tasks such as monitoring plant health, controlling environmental conditions, and adjusting nutrient levels. This reduces the need for manual labour and allows fewer workers to manage larger vertical farming operations. By streamlining processes, IoT also improves productivity, further lowering labour expenses.



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