WHITE PAPER

Efficient ventilation, air conditioning and automation

Vertical farming: From a trend to future technology

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Vertical Farming

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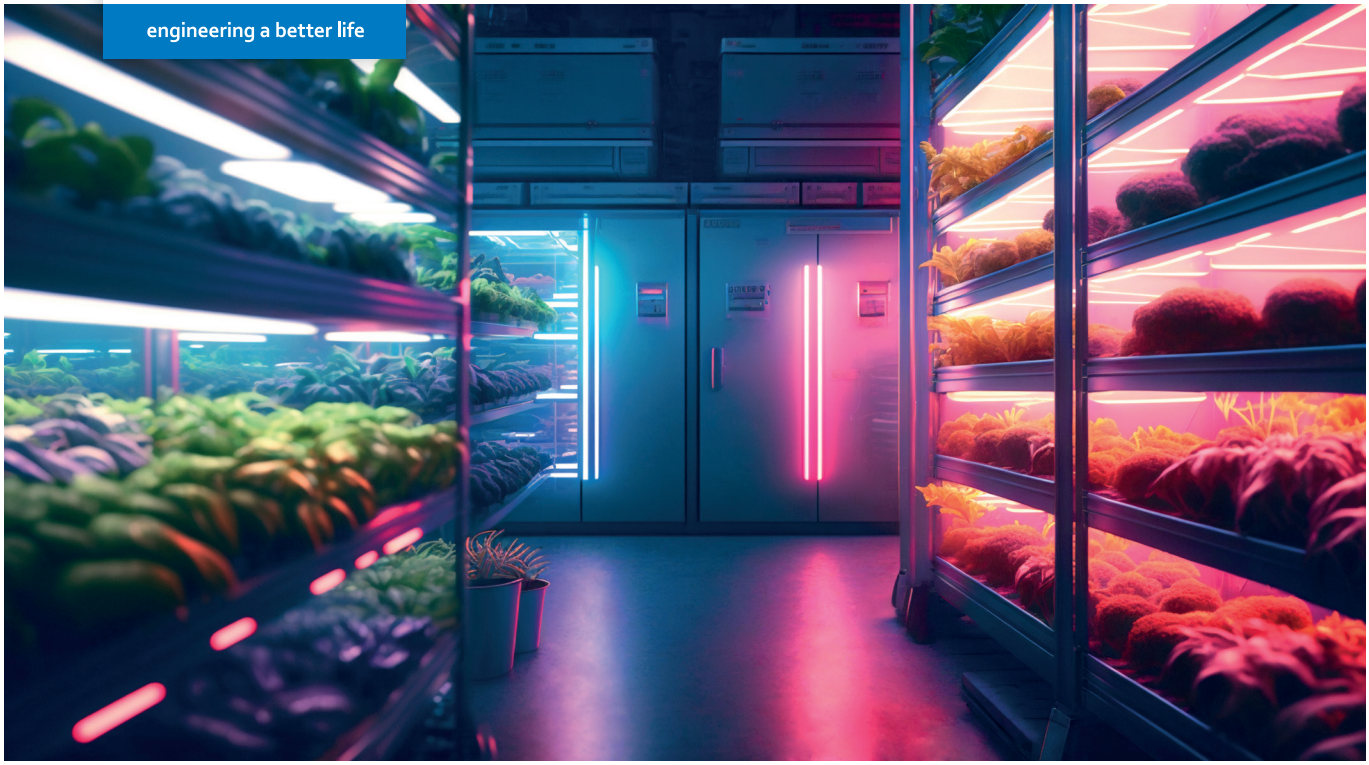

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1. Executive Summary

The global population is constantly increasing. For this reason, the challenge of not having enough cultivated land for agriculture is a growing issue. By 2050, two-thirds of the population will live in the city. Urbanization is forcing society to take action. In addition to increasing urbanization, reduced agricultural space in particular is becoming a serious problem. Every year around the world, around three million hectares of agricultural land are lost to soil degradation and conversion for various development purposes, which in turn reduces harvest yields. The vertical farming method could be one answer to the problem. Vertical farming involves growing plants using vertical structures in a controlled environment, which maximizes production and efficiency over minimal space. Based on the circular economy and hydrocultures, it is mainly plant and animal products that are grown in buildings throughout the year and in greenhouse conditions.

1.1 Future technological opportunities

Nowadays, daily life is being influenced by digitalization in many areas. The Internet of things (IoT) supports the development of smart farming. Modern greenhouse management systems adapt air conditioning, nutrient solution or irrigation control. Thanks to vertical farming technology used for plant cultivation, up to 90 percent of the water used can be saved with closed circuits. The protected cultivation ensures undisturbed growth without adverse weather conditions. The products can be grown and distributed close to the consumer. Technical raw materials are produced without any impact on the environment. No transport is required from far away areas or other countries. Transportation time and costs are reduced. In view of urbanization, this is a way to shift agriculture to cities, using only a fraction of the area that would be otherwise required. Since the plants are grown without a substrate and in a controlled environment, pesticides do not need to be used. Pests do not reach the plants through the closed systems in the first place, and resources are saved.

Advantages of Vertical Farming at a glance

- Advantages of Vertical Farming at a glance
- water consumption can be saved by 90 percent undisturbed growth
- short delivery routes
- space saving due to vertical farming
- no use of pesticides
- Saving of resources
- yield increase
- Handling after harvest

2. Design and function

Vertical farming includes many different methods and systems. Each method has challenges, requirements and advantages. The methods that have become most widespread are hydroponics, aeroponics and aquaponics.

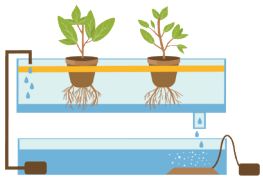
2.1 Hydroponics

Hydroponics refers to the „earthless" cultivation of plants. A simple hydroponic system consists of two levels. The plant is located on the upper level, while the lower level consists of a nutrient-rich water reservoir. The nutrient solution includes, nitrogen, phosphate, potassium, and more. There are circulating and non-circulating systems, also known as active and passive hydroponic systems. They differ mainly in terms of their structure and complexity. Both systems have in common that the media composition is checked regularly. Passive systems usually operate without electricity, pumps or other technical components and, due to their low effectiveness, are not suitable for use in a vertical farm.
In the circulating systems, the nutrient salts and minerals contained in the water are continuously and evenly distributed. The water is pumped from the reservoir to the plant roots at regular intervals and is enriched and fed with oxygen depending on the needs of the plant (see Mathur, Muthukumaraswamy 2022:159). The hydroponics method is already being used in greenhouses to grow vegetables and medicinal plants in controlled conditions (see Burger 202:55). Hydroponics is a relatively low-maintenance technology, is not a very labor-intensive cultivation method and delivers good yield.

2.2 Aeroponics

Aeroponic cultivation methods are active hydroponic systems. The main difference between hydroponics and aeroponics is that hydroponics uses an earthless medium, as described, while aeroponics is a cultivation method without a substrate (see Mathur, Muthukumaraswamy 2022:160). In this process, the roots hang completely free in the air and are sprayed with an aerosol that is a mixture of nutrients and water. Plants that are grown according to this method are sprayed or misted with the required amounts of water (see Mathur, Muthukumaraswamy 2022:160). Aerosols are mixtures of liquid or solid particles in gases. In this case, the aerosol is an atomized nutrient solution in the air (see Hempel 2014:7). The particle size is key for the system's success, because it affects the plant's root performance. NASA's research showed that a particle size of five to 50 µm is optimal (see Miller 2009). The plants take in the drops using their hair root systems. High-pressure nozzles or sprinklers are used to nebulize the nutrient solution and bring it to the roots as a kind of vapor, which causes them to grow faster (see Burger 2020:55). 95 percent less water is consumed than would be required in conventional agriculture.

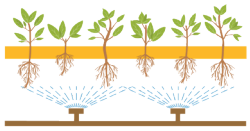
Hydroponics



ADVANTAGES HYDROPONICS:

- Cultivation in soilless medium
- flexible location
- fast growth and high yields
- efficient nutrient consumption

Aeroponics



ADVANTAGES AEROPONICS:

- regional food production
- low labor input
- low water consumption

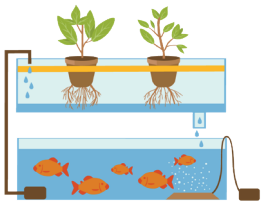
2.3 Aquaponics

The production of a vertical farm does not have to be limited to vegetarian food. In practice, there is already a process that combines plant and fish farming, called aquaponics (see Burger 2020:60). Aquaponics is a hybrid biosystem that integrates aquaculture and hydroponics. The symbiosis of plant and fish saves many resources (see Beer 2022:134). In this method, nutrient-rich waste from fish basins is used to fertilize hydroponic production beds (see Mathur, Muthumaraswamy 2022:160). In „conventional" fish farming, nutrient-rich water is disposed of via a sewage treatment plant, which is costly. In aquaponics, the water is used as a liquid fertilizer. Aquaponics consists of three elements: the fish farm, the filter system and a growth bed for plants (see Beer 2022:134). The hydroponic beets act as biofilters and remove chemical compounds, such as nitrates and ammonia, from the fish water. This offers a decisive advantage because, if fish are kept in an aquaculture, five to 15 percent of the water must be changed every day, otherwise there will be too much nitrate, produced by fish metabolites (see Burger 2020:60). The treated water enters special embedded areas for the plants (see Beer 2022:134). The plants can utilize the carbon dioxide emitted by the fish using photosynthesis, extract energy from them and produce oxygen in return. Once the plants have absorbed the nutrients, the water returns to the fish container, and the water is purified and enriched with oxygen (see Beer 2022:134). The result is an almost closed system that consumes very little water and can be reused in resources, such as nutrients, water, heat and electricity (see Burger 2020:61).

2.4 Light recipe

In addition to special requirements for nutrient supply, the variety of plants also creates different lighting requirements. Whereas smaller vertical farms can often draw on a lot of natural sunlight, large vertical farms are usually operated entirely without sunlight. As a result, plant growth is controlled with artificial light (see Beer 2022:133). The advantage of grow lamps is that the light spectrum can be adapted and tailored to the needs of the plants being cultivated. Different wavelength ranges in the spectrum have different effects on plants. The growth lamps' LED spectrum ratios can be adapted depending on the type of plant being cultivated, the stage of cultivation and the photoperiod required by the plants (see Mathur, Muthukumaraswamy 2022:162). Plants need sunlight for photosynthesis to generate energy and to produce healthy ingredients, called the secondary process. There are complex compounds in the plant's leaves. Chlorophyll a and chlorophyll b absorb red and blue light from the sun for photosynthesis (see Mathur, Muthukumaraswamy 2022:162). This is why blue and red light is primarily emitted when supplying plants with LED lamps. The mixture of different wavelengths creates a light composition that successfully imitates the daylight and the daily rhythm (see Gabot 2022). Appropriate light recipes can be used to influence whether the salad is „softer" or more „crunchy". According to Agrilution, there have been experiments for rocket that enable up to double the amount of vitamin C by changing the light formulations with a higher blue content (see Agrilution o.D.). Currently, one of the biggest challenges is in light technology. The LEDs' high energy consumption means high energy costs. High-performance fans are in demand to avoid the formation of hot spots and enable safe and cost-effective operation.

Aquaponics



ADVANTAGES AQUAPONICS:

- decentralized food production
- closed system
- groundwater is not polluted

3. Solutions for vertical farming

3.1 Ventilation and air conditioning

Plants can only grow optimally at precisely controlled temperatures, relative humidity and ventilation. Fans are used around the clock in a vertical farm, for example for LED cooling to avoid hot spots, for central air supply and for their distribution. They provide the plants with an air supply matching their needs. They withstand temperature changes, high humidity and UV radiation.

There are different concepts for ventilation and air conditioning. Suitable heating, ventilation and air conditioning is required to guarantee optimal conditions for plant growth, and the system has a significant impact on the energy consumption of the farm.

Tunnel ventilation pushes the air through the building. However, central ventilation units installed on roofs are also common, as is providing the plants or floors with a targeted air supply via pipe and hose systems, which also have to be supplied with a fan to supply the air.

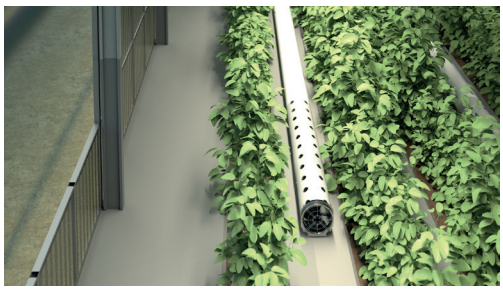


Image 1

Different fans are required here: compact axial fans move high air flows of up to 65,000 m^3/h and operate reliably even at high back pressures of up to 1,500 Pa. They are therefore particularly suitable for the tunnel supply. A comprehensive range of accessories enables further modifications to be made, such as guard grills. It is possible for the power supply to be 5 to 110 VDC or 11 to 480 VAC. Centrifugal fans are particularly impressive at high back pressures up to 5,200 Pa. Their air flow rates are up to 30,000 m^3/h. They are available with forward or backward-curved blades and in a scroll housing or as freewheel fans. Versions with an external rotor motor in the impeller are also compact and therefore require little installation space in the ventilation units usually installed on the roof. The power supply provided is 6 to 72 VDC or 85 to 480 VAC. Compact fans have proven their worth for air conditioning in supermarket cabinets, for ventilating individual shelves and for cooling LEDs. They also operate at a high level of energy efficiency, have various types of protection designs and contribute towards economical operation in this indoor farming concept. In addition, an intelligent air conditioning solution uses waste heat to operate the dehumidification mode, using reheating and internal heat recovery. In combination with a heat pump, the HVAC system can process the waste heat generated by the cooling units in the LED lighting, for example, and feed it back into the building. This enables the efficiency and energy requirements of the entire farm to be optimized.

Image 2

Image 1
Tunnel aeration provides a targeted air supply to the plants.

Image 2
Both axial fans (top of picture) and centrifugal fans (bottom of picture) are in demand and required in indoor farming applications.

3.2 Drive technology

The different farming concepts involve a wide range of work processes and therefore depend on high-performance drive systems. Many different work processes in vertical farming increase the complexity of goods handling. However, the efficient automation of logistics processes offers great potential for savings. In this way, decentralized drive solutions reduce costs for transport or handling systems. This ranges from automated product handling with autonomous driving vehicles to conveyor belts and access control systems. The ArgoDrive driving/steering system from ebm-papst combines propulsion and steering functions in one drive unit, consisting of motor, transmission, omnidirectional steering, sensors and all the necessary connections. This makes it possible to move large loads with a total vehicle weight of up to two metric tons. All of this relies on good control characteristics and precise positioning.

Image 3

Reliable, compact and highly dynamic drive systems that withstand strong loads are required to open and close barriers, gates and windows, for example. System solutions play a crucial role here and flexible, reliable drive systems with a high degree of networking are indispensable. Based on many years of experience, ebm-papst offers a modular drive system of system solutions for this field, consisting of motor, transmission and electronics; in terms of transmissions, both planetary and angular gearboxes.

Transporting plants (e.g. by means of assembly line systems) can also be implemented with existing solutions. The optimal design of these solutions is strongly influenced by the topology of the vertical farm and the arrangement and design of the cultivation spaces.

3.3 Production monitoring

Robotics and automation are increasingly being used in the context of automated indoor cultivation. For a high-yield harvest, the conditions for growth must be continually monitored to initiate targeted changes or quickly eliminate problems if required. ebm-papst helps with this using its digital services. Sensors and hubs ensure that all necessary and meaningful data is mapped digitally, whether it is the status of technical systems or monitoring air and water quality. This enables all data on air conditioning, nutrient supply or lighting to be captured and visualized in real time. For example, using an app, it is also possible to test settings or automatically receive current messages on a cell phone. The specially developed cloud applications provide the appropriate information and control options to optimize production and make it economical and sustainable.

Image 4

Image 3
ArgoDrive drive/steer system from ebm-papst

Image 4
Process automation in the production cycle of a vertical farm

4. Cultivation options

Herbs and vegetables are grown. The farms are currently used primarily for low leafy vegetables such as salads, spinach, mustard plants, bok choy, red beets and the herbs or berries mentioned previously. Basic foods such as wheat, potatoes, corn or rice are less suitable for cultivating in multistory buildings due to the height and need for soil.

4.1 Side note: Building a vertical farm – a project for ebm-papst trainees

The trainees at ebm-papst are also thinking about the future and focusing on the megatrend. The budding mechatronics engineers and electronics technicians researched and built everything themselves, from the composition of the nutrient solution to monitoring and evaluating the temperature and humidity, and harvesting the plants. Herbs and vegetables are grown for the canteen in a glass cube. The company's own axial fans ensure an optimum air supply. The coordinated components enable an optimum climate and are tailored to the needs of the individual plants. Special LED strips ensure the necessary light, while an automated control system regularly supplies the plants with a nutrient solution.

To enable the processes to be automated in future, the Energy Scouts have installed a smart gateway to monitor and analyze the crop cycle. This transmits data, which the trainees can use to optimize the processes and achieve the best harvest results.

Image 5

Image 5

In the ebm-papst canteen in St. Georgen, the trainees have already successfully put their Vertical Farm into operation.

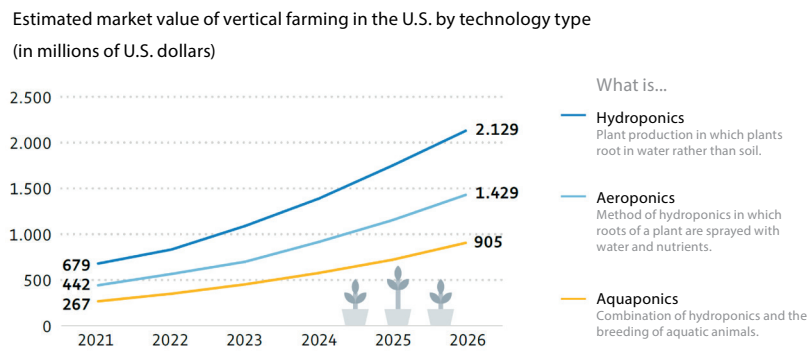


Image 6: By 2026, the vertical farming market in the U.S. is expected to grow to more than $4.4 billion.

5. Conclusion

Vertical farming is an emerging and important technology for the future of the food supply. Market forecasts for the coming years show promising growth rates. By 2026, the market for vertical farming in the USA, for example, is expected to grow to over 4.4 billion dollars. In addition to being able to produce plants all year round, its environmentally friendly operation is particularly noteworthy. Precisely adapted temperatures, humidity values and airflow are essential for creating an optimal environment for the plants. For this purpose, the growth conditions must be continuously monitored using process automation. Fans are in use around the clock in a vertical farm. Depending on the type and design of the vertical farms, there are different concepts for ventilation and air conditioning. The system has a significant influence on the efficiency and energy consumption of the farm and plant growth. In addition to tunnel ventilation, central ventilation units and tube and hose systems are primarily used. The various farming concepts also depend on high-performance drive systems. Automating the logistics processes also offers great potential for efficiency. Here, the range stretches from automated product handling with autonomous driving vehicles, to conveyor belts and access control systems.

About ebm-papst

The ebm-papst Group, a family-run company headquartered in Mulfingen, Germany, is the world's leading manufacturer of fans and motors. Since it was founded in 1963, the technological leader has set international industry standards with its core competencies in motor technology, electronics, digitalization, and aerodynamics. ebm-papst offers sustainable, intelligent, and tailor-made solutions for virtually every requirement in ventilation and heating technology.

In the 2022/23 financial year, the Group generated turnover of EUR 2.540 billion. It employs just under 15,000 people at 30 production sites (including in Germany, China, and the U.S.) and in 50 sales offices worldwide. ebm-papst sets the benchmark in almost all sectors, such as ventilation, air conditioning and refrigeration technology, heating technology, information technology, mechanical engineering, intralogistics, and medical technology.

References

Agrilution (o. D.): Magazin: Spannende Artikel zu Vertical Farming | Agrilution, [online] https:// de.agrilution.com/magazin/sonnenlicht-vs-led [abgerufen am 15.01.2023].

Mathur, Tanishi/Arumugam Muthukumaraswamy (2022): Intelligent Manufacturing and Energy Sustainability: Proceedings of ICIMES 2021, New York, Vereinigte Staaten: Springer Publishing.

Burger, Kathrin (2020): Super-Food für Wissenshungrige!: Warum wir essen, was wir essen, 1. Aufl. 2020, Springer.

Hempel, Johann (2014): Untersuchungen zu Wurzelstützstrukturen in aeroponischen Systemen am Beispiel von Lactuca sativa, Masterarbeit, Hochschule Dresden.

Miller, Frederic P. (2009): Aeroponics. Hg. v. Agnes F. Vandome und John McBrewster. Beau Bassin, Mauritius: Alphascript Pub.

Beer, Jonas (2022): Europäischer Klimaplan: Mit konkreten Lösungen zurück ins Gleichgewicht, FinanzBuch Verlag.

Gabot (2022): Vertical-Farming: Mit moderner LED-Technik möglich, [online] https:// www.gabot.de/ansicht/vertical-farming-mit-moderner-led-technik-moeglich-415121.html