AEROFARMS' VERTICAL FARMING: THE FUTURE OF FARMING?

AeroFarms LLC (henceforth referred to as AeroFarms), co-founded in the USA by Ed Harwood, David Rosenberg, and Marc Oshima, was the world's largest vertical farming company. The company had a mission to transform agriculture by developing environmentally responsible farms throughout the world, especially in urban areas.[1] AeroFarms' vertical farms, based on aeroponics technology, were not affected by climate change. The plants did not require soil or sunlight for growth but thrived on nutrient-rich water and LED lights. Leveraging data analytics, the company was able to cultivate superior quality crops than conventional farming, with 95 percent less water and zero pesticides.[2] As it minimized usage of natural resources, Aerofarm was selected as one of the finalist for World Economic Forum Ecolab Award for Circular Economy Enterprise.[3] Apart from environmental contributions, Aerofarm was believed to also resolve the food crisis globally.

According to international trade experts, as trade tensions between countries like China and the USA increased, food security was threatened across several countries that depended on the import of food. The co-founders of AeroFarms believed that their aeroponics technology-based vertical farms could contribute toward achieving indigenous food security goals through urban, local, and in-house farming.[4] Demand for vertical farms globally was increasing, as shown in detail in **Exhibit 1**.

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[1] AeroFarms: Our Story. (n.d.). Retrieved from https://aerofarms.com/story/

[2] This Farm of the Future Uses No Soil and 95% Less Water. (July 5, 2016). Retrieved from https://aerofarms.com/2016/07/05/farm-no-soil-95-less-water/

[3] AeroFarms leads circular economy movement, heads to Davos. (Jnaury 18, 2016). Retreived from https://aerofarms.com/2016/01/18/aerofarms-leads-circular-economy/

[4] A Path to #ZeroHunger. (October 16, 2018). Retrieved from https://medium.com/@AeroFarms/a-path-to-zerohunger-6d456c247051

AeroFarms particularly established itself in urban areas close to the market. This not only reduced transportation costs compared to conventional farming but also shortened product-to-market cycle time to a few hours, compared to a few days in conventional farming. They could thus offer fresh and locally produced crops. These features were much appreciated by consumers, who were increasingly conscious of health and sustainability.[5] Rosenberg, co-founder and CEO of AeroFarms, commented on food security and environmental sustainability, stating, "Cities have a lot of mouths to feed. We have population growth, urbanization, and we need better ways to feed humanity that are sensitive to the environment. Vertical farms are one of many solutions."[6]

AeroFarms was, however, criticized by experts for producing more carbon emissions than traditional farming, owing to the use of LED lights.[7] The viability of the company's business model was also questioned by critics. A high level of capital expenditure had resulted in the extinction of several vertical farm startups, like Google's Alphabet X, within a few years of inception. AeroFarms was also criticized for its claim to be solving the world's food problem while it offered only salad greens and no high-calorie grains.[8]

AeroFarms had received US$238 million from venture capitalists across the world by July 2019 but then faced challenges receiving additional funds. New legislation released in January 2019 by Donald Trump, President of the USA, enhanced government authority to block international

[5] Bereznak, A. (April 11, 2017). The future of agriculture is happening in cities. Retrieved form https://aerofarms.com/2017/04/11/future-agriculture-cities/

[6] Garfield, L. (March 15, 2016). Inside the world's largest vertical farm, where plants stack 30 feet high. Retrieved from https://www.businessinsider.com/inside-aerofarms-the-worlds-largest-vertical-farm-2016-3

[7] Blaustein-Rejto, D. (Jnauary 30, 2018). Don't count out vertical farms. Retrived from https://thebreakthrough.org/issues/food/vertical-farms-raise-yields-but-what-about-emissions

[8] Marston, J. (January 3, 2019). Why vertical farming won't Grow without more data. Retrieved from https://thespoon.tech/why-vertical-farming-wont-grow-without-more-data/

venture capitalist funding in American startups. Commenting on funding, Rosenberg stated, "The nature of the business means that we are always in capital raising mode."[9] Analysts also believed that rising nationalism and tougher foreign-investment rules could challenge capital movement.[10] Amidst these challenges, could Rosenberg make aeroponics and data science-based vertical farming the future of crop cultivation? Can he create a profitable and sustainable business model to solve the world's food problem? How can he combat the capital requirements and energy challenges associated with vertical farming?

ORIGIN & BACKGROUND OF THE COMPANY

In 2003, Harwood, then a professor at Cornell University's College of Agriculture and Life Sciences, invented a new cloth material made of recycled water bottles, which could be used to hold plants grown through an aeroponics system.[11] In this system, plants were grown suspended in the air with the entire body of the plant held by a special cloth. No soil was used to hold the root of the plants; instead, special nutrient-laden water was continuously sprayed on the roots. Harwood patented his invention and formed a company called Aero Farms System. However, Harwood could not commercialize his invention.[12]

In 2011, Rosenberg, who was in the business of waterproof concrete, and Oshima, a marketer in the food and restaurants industry, observed the inefficiencies associated with traditional farming.

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[9] Burwood-Taylor, L. (December 14, 2015). AeroFarms 'Always in Capital Raising Mode' as Vertical Farming Group Raises $20m. Retrieved from https://agfundernews.com/aerofarms-always-in-capital-raising-mode-as-vertical-farming-group-raises-20m5157.html

[10] Chon, G. (June 4, 2019). Breakingviews - U.S.-PRC tensions upend tech funding supply chain. Retrieved from https://www.reuters.com/article/us-usa-china-breakingviews/breakingviews-us-prc-tensions-upend-tech-funding-supply-chain-idUSKCN1T52JO

[11] Ryan, K. J. (June 14, 2017). The future of farming may not involve dirt or sun. Retrieved from https://www.inc.com/kevin-j-ryan/aerofarms-disruptive-25-2017.html

[12] Ibid.

Sensing an opportunity, Rosenberg and Oshima started researching new systems of farming. In this process, they came across vertical farming and Harwood's invention. They offered Harwood a cash infusion in his company in exchange for letting them join Aero Farms System as co-founders; Harwood agreed.[13] Rosenberg and Oshima introduced a new business model for the company, optimizing the growing process by using data and selling the produce directly. Harwood, Rosenberg, and Oshima started buying old buildings, such as a paintball center and a club, and began converting them into vertical farms. [14]

In 2015, Aero Farms System became AeroFarms, with Harwood as the Chief Science Officer, Rosenberg as the CEO, and Oshima as the Chief Marketing Officer. The company intended to set up vertical farms in towns and cities across the globe to meet food requirements in the future.[15] By July 2019, there were 130 employees associated with AeroFarms.

The patented technology that Harwood held provided the perfect conditions for growth and cultivation of healthy plants with a new level of precision and productivity as well as minimal environmental impact and minimal risk.[16] Farming through the use of precision technology was considered the future of farming. Experts called it "Farming 4.0," citing its benefits of high production efficiency with low CO_2 emissions.[17] According to Oshima, AeroFarms aeroponics

[13] Ryan, K. J. (June 14, 2017). *op. cit.*
[14] Ibid.
[15] Peters, N. (April 4, 2019). Will Vertical Farming solve the world's growing ecological and human crises? Retrieved form https://www.themanufacturer.com/articles/will-vertical-farming-solve-the-worlds-growing-ecological-and-human-crises/
[16] We are transforming agriculture. (n.d.). Retrieved from https://aerofarms.com/
[17] Lamborelle, A., & Álvarez, L. F. (November 7, 2016). Farming 4.0: The future of agriculture? Retrieved from https://www.euractiv.com/section/agriculture-food/infographic/farming-4-0-the-future-of-agriculture/

system was "390 times more efficient in terms of land usage than an equivalent traditional farm."[18] It took 12–14 days for baby leafy greens, like kale and lettuce, to grow at AeroFarms' facility, compared to 30–45 days in traditional farms. Fast growth of plants implied not only faster supply of produce but also faster prototyping; the company could experiment with different techniques for plant growth and within a few days observe the results and adjust.[19]

In a typical climate-controlled AeroFarms facility, plants were placed in trays stacked 30 feet high rather than being held in soil. LED lights were used instead of sunlight and sprinklers were used to fertilize the plants. Employees, whom AeroFarms called farmers, wore coverall suits, rubber gloves, and hairnets while monitoring the facilities.[20]

Between 2010 and 2019, AeroFarms received US$238 million from seven rounds of funding (by venture capitalists) and one grant (from Foundation of Food and Agricultural Research, USA) (see **Exhibit 2** for funding information). The company received US$100 million in funding in July 2019 for the purpose of rapidly expanding across four different continents and its home country and to explore new types of crops.[21] US expansion was meant to cover areas such as Camden, New Jersey, Southern New Jersey, and Buffalo, New York. AeroFarms constructed vertical farms in urban areas that were not typically known for agriculture, like Newark, New Jersey, which was also the global headquarters for the company. The 69,000-square-foot warehouse in Newark was the world's largest vertical farm facility; it produced two million pounds of leafy greens each

[18] Fitzpatrick, A. (March 21, 2019). This airline is working with the world's largest 'vertical farm' for fresher in-flight meals. Retrieved from https://aerofarms.com/2019/03/22/this-airline-is-working-with-the-worlds-largest-vertical-farm-for-fresher-in-flight-meals/
[19] Fitzpatrick, A. (March 21, 2019). *op. cit.*
[20] Garfield, L. (March 15, 2016). *op. cit.*
[21] Marston, J. (July 9, 2019). Vertical farming heavyweight AeroFarms raises $100M in fresh funding. Retrieved from https://thespoon.tech/vertical-farming-heavyweight-aerofarms-raises-100m-in-fresh-funding/

year.[22] AeroFarms focused on locations in the USA that had once been industrial spaces that were adversely impacted by the global outsourcing of manufacturing.[23] AeroFarms converted these industrial spaces into warehouses for their modular farms.

BUSINESS POTENTIAL OF AEROFARMS

In the light of increased trade wars between countries like the USA and China, experts recommended considering new methods of food production to improve domestic food security.[24] Food security was a challenge not only due to trade wars but also due to increasing population globally. According to the Food and Agricultural Organization of the United Nations, the world population was projected to reach nine billion by 2050; in the same period, the amount of available arable land was expected to decrease to only one-third of the amount available in 1970.[25] In the USA, 35 percent of food was imported, and on average, food travelled 2,000 miles over two weeks to reach grocery shelves.[26] Oshima believed that AeroFarms was improving domestic food security by promoting local produce irrespective of climate conditions. Their urban locations enabled them

[22] Garfield, L. (March 15, 2016). *op. cit.*

[23] Yuan, L. (May 9, 2018). How AeroFarms is designing a new playbook for the future of agriculture. Retrieved from https://aerofarms.com/2018/08/13/how-aerofarms-is-designing-a-new-playbook-for-the-future-of-agriculture/

[24] Jenkins, A. (September 10, 2018). Food security: vertical farming sounds fantastic until you consider its energy use. Retrieved from https://theconversation.com/food-security-vertical-farming-sounds-fantastic-until-you-consider-its-energy-use-102657

[25] Stark, K. (March 24, 2019). Economic Viability of Vertical Farming: Overcoming financial obstacles to a greener future of farming. Retrieved from https://blogs.nicholas.duke.edu/env212/economic-viability-of-vertical-farming-overcoming-financial-obstacles-to-a-greener-future-of-farming/#_ftn1

[26] Karp, D. (March 13, 2018). Most of America's fruit is now imported. Is that a bad thing? Retrieved from https://www.plugandplaytechcenter.com/resources/indoor-vertical-farming-new-era-agriculture/

to be in the vicinity of local consumers and hire local employees[27] (see **Exhibit 3** for details on the market value of vertical farming across different parts of the world in 2015). In 2014, when Washington, D.C., passed the D.C. Urban Farming and Food Security Act, the ability of AeroFarms to expand in urban areas and offer locally grown food eased. The act promoted "urban farming and food security in DC by establishing incentives to encourage the use of privately-owned land for urban farming and community gardens."[28]

Climate change was also expected to increase drastically in the following decades, so more instances of intensifying heat stress, droughts, and damage to ecosystems were likely to hinder the ability of growing crops through traditional means. Farming experts expected vertical farms like AeroFarms, through their use of a climate-controlled environment and aeroponics system, to be least affected by climate change, which posed severe challenges to traditional farming practices.

LEVERAGING DATA ANALYTICS

Data analytics were a key aspect of AeroFarms' crop cultivation strategy. The company's vegetable growing trays collected approximately 30,000 data points on aspects such as temperature, humidity, CO_2, and oxygen levels. Data scientists from universities, such as Harvard and MIT, analyzed the metrics in real-time with the help of machine-learning software. With this information, they determined how future crops would grow.[29] With data, the scientists optimized the algorithms (also known as growing algorithms) of 250 different plant types, such as kale, arugula, and mizuna.

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[27] Chang, J. (June 30, 2017). Marc Oshima, AeroFarms: Helping a Food Desert Flourish [Q&A]. Retrieved form https://www.specialtyfood.com/news/article/marc-oshima-aerofarms-helping-food-desert-flourish-q/

[28] DC Urban Farming and Food Security Act of 2014. (February 4, 2014). Retrieved from https://www.dcgreens.org/dc-urban-farming-and-food-security-act

[29] Garfield, L. (March 15, 2016). *op. cit.*

Once the best way to grow the green leafy vegetables was known to the company, it was replicated every time. By adjusting the algorithms, AeroFarms scientists were able to tailor the produce, such as making the plants sweeter or boosting levels of vitamin A. They were also able to cut growing cycle times and remain unaffected by fluctuations in seasons or climate.[30]

AeroFarms partnered with Dell Inc., to explore how the Internet of Things and data science could help maximize the growth of greens. Since tastes and textures were determined by the plant's growth conditions, such as temperature changes, humidity, and PH,[31] Dell Inc. helped AeroFarms appropriately use sensors to track information at virtually every step of the growing process, from seeding to germination to growing to harvesting and finally packaging. This information was sent wirelessly to servers so that it could be closely analyzed to improve taste, texture, color, yield, and nutrition metrics for its crops.[32] Rosenberg stated, "How we organize and manage that data, it's incredibly important." "When you have that as your lens, in looking at a business, you see problems in different ways and solutions come and get prioritized in different ways. That's OK." "That information will be critical for automating vertical farming processes to the point where they can be commercialized more 'meaningfully.'"[33]

Dell Inc. also helped AeroFarms employ special cameras to track the spectral conditions of the growing trays and of the lighting technologies. When something unusual was detected, an alert with images was sent to a tablet computer. These images were consequently analyzed to solve the problem. Rosenberg stated, "We have this fully connected farm." "That enables us to both manage

[30] Yuan, L. (May 9, 2018). *op. cit.*
[31] Schnaidt, P. (January 9, 2018). IoT takes root in the farm of the future. Retrieved from https://www.iotsolutionprovider.com/agriculture/iot-takes-root-in-the-farm-of-the-future
[32] Clancy, H. (May 10, 2018). Why data is an essential nutrient for AeroFarms crops. Retrieved from https://www.greenbiz.com/article/why-data-essential-nutrient-aerofarms-crops
[33] Ibid.

the farm as well as take information from the farm and send it to the right people to make the most of that data."[34]

At AeroFarms, specialists from horticulture worked in teams with engineering, food safety, data science, and nutrition experts. This gave AeroFarms the capability to understand plant biology in an unprecedented manner. The company also worked with top tastemakers and chefs, such as David Chang, and leading researchers at research universities, such as Cornell and Rutgers, as well as the Foundation for Food and Agriculture to deeply understand cultivation of the most nutrient-dense and flavorful leafy greens on the planet.[35] According to reports, the lettuce produced by AeroFarms was extremely tasty with an explosion of spicy and sweet flavor. [36] Oshima stated, "It's a type of control and precision you can't ever get out in the field."[37] Emphasizing the company's global ambitions, he stated, "It's not just plants." "At the end of the day it's about nourishing communities. It's how we can build these responsible farms in major cities all over the world."[38] AeroFarms sold its produce to local supermarkets under the brand name "Dream Greens."[39]

AEROFARMS CHALLENGING TRADITIONAL FARMING

AeroFarms' production capacity was approximately 10 times greater than that of a typical 1,300-acre farm in New York.[40] Leafy vegetables like lettuce from traditional farmers usually did not

[34] Clancy, H. (May 10, 2018). *op. cit.*
[35] AeroFarms named to Fast Company's 2019 Most Innovative Companies. (February 20, 2019). Retrieved from https://aerofarms.com/2019/02/20/aerofarms-named-to-fast-companys-2019-most-innovative-companies/
[36]Garfield, L. (March 15, 2016). *op. cit.*
[37] Fitzpatrick, A. (March 21, 2019). *op. cit.*
[38] Bereznak, A. (April 11, 2017). *op. cit.*
[39] Clancy, H. (May 10, 2018). *op. cit.*
[40] Garfield, L. (March 15, 2016). *op. cit.*

reach the shelves of major supermarkets until five to seven days after harvest, as they were grown on farms located hundreds of miles outside urban areas. AeroFarms, on the other hand, grew vegetables within 15 miles of urban areas like Manhattan and delivered the batches immediately after they were harvested. In the USA, the company partnered with organic wholesalers, like Farmigo Inc., and sold its lettuce across grocery stores in New York at a price comparable with organic lettuce.[41] Urban farming drastically reduced transportation costs due to local farming practices. This was expected to eliminate fluctuations in wholesale produce prices that varied with fuel prices.[42] Furthermore, AeroFarms used 95 percent less water and 50 percent less fertilizer than most traditional conventional farms, and as the greens were cultivated in a controlled indoor environment, they were not exposed to pests, eliminating the need for pesticides.[43]

IMPEDIMENTS TO GROWTH AT AEROFARMS

Crop variety

Danielle Nierenberg, co-founder of Food Tank, a nonprofit organization in the USA, was skeptical about the growth potential of vertical farms. She claimed that vertical farms "will never grow enough to feed cities." However, Nierenberg believed that vertical farming had the potential to create a new type of urban green space.[44]

AeroFarms excelled in leafy greens. However, green leafy vegetables were not sufficient as a meal by themselves, especially in terms of food security where high calorie grains were more

[41] Ibid.
[42] Stark, K. (March 24, 2019). *op. cit.*
[43] Garfield, L. (March 15, 2016). *op. cit.*
[44] Wong, V. (March 3, 2017). Inside the computerized lettuce factory of the future. Retrieved from https://www.buzzfeednews.com/article/venessawong/the-computerized-lettuce-factory-of-the-future

important.[45] Although Rosenberg agreed with this issue, he emphasized the role of aeroponics technology. He stated, "Vertical farming won't solve all the world's problems in feeding humanity, but it is certainly part of the solution." Oshima further added that AeroFarms was considering growing other crops, like berries, peppers, and cucumbers. He said, "Our lens is on how we can transform agriculture around the world."[46] Oshima added, "We can grow anything, but we focus specifically on short-stem leafy greens and herbs. It allows us to ensure a high level of quality and consistency and replicate that year-round."[47] AeroFarms intended to experiment with other fruits and vegetables in the future.[48]

Vertical farming required large upfront costs due to higher real estate values per square meter in urban centers as well as infrastructure requirements for plant growth. In 2015, AeroFarms building costs were estimated to be US$39 million for two acres of farm land in the urban area of Newark, while an acre of land for vertical farming in Iowa was available at an average cost of less than US$8,000.[49] Furthermore, as LED lights substituted for sunlight in vertical farms, one 37-story vertical farm facility required a net total of 3.5 GWh of electricity (i.e., 3.5 million kilowatts of electricity, enough to power 3.5 million homes in the USA for an hour); this cost about US$6 million a year.[50] According to a report by Agrilyst Inc., a cultivation management platform, "With

[45] Marston, J. (January 3, 2019). *op. cit.*
[46] Wong, V. (March 3, 2017). *op. cit.*
[47] Clayton, C. (May 2, 2016). Urban farming goes high-Tech. Retrieved from https://www.dtnpf.com/agriculture/web/ag/news/farm-life/article/2016/05/02/aerofarms-seeks-change-model-indoor
[48] Garfield, L. (March 15, 2016). *op. cit.*
[49] Is the world's largest vertical farm worth the cost? (July 7, 2016). Retrieved from https://www.charleskochinstitute.org/blog/is-the-worlds-largest-vertical-farm-worth-the-cost/
[50] Stark, K. (March 24, 2019). *op. cit.*

less conventional financial sources available to indoor farmers for both capital and operational expenses, as well as higher operational costs, it takes growers a long time to realize profits."[51]

Funding

As AeroFarms relied on venture capital funding, venture capitalists participated from different parts of the world, such as GSR ventures from China, Wheatsheaf group from the UK, ADM capital from Hong Kong, Inka group from the Netherlands, and Missionpoint capital investors from the USA. However, in January 2019, Donald Trump, the US President, signed new legislation that expanded the government's ability to block foreign investment in US companies, irrespective of the investor's country of origin. [52] After this nationalistic legislation, investments from Chinese venture capitalists in American startups came to a halt and venture capitalists from several other countries also faced problems in funding startups.[53]

High Energy Consumption

Owing to high capital requirements, vertical farming, like conventional farming, required subsidies from the government. Without this, the low prices of conventional farming could make vertical farming unattractive for consumers. Under the Agriculture and Food Research Initiative Competitive Grants Program designed by the United States Department of Agriculture, vertical

[51] Cosgrove, E. (January 3, 2018). Access to capital is biggest challenge to indoor farms – Report. Retrieved from https://agfundernews.com/indoor-farming-report-agrilyst.html
[52] Somerville, H. (January 7, 2019). Chinese tech investors flee Silicon Valley as Trump tightens scrutiny. Retrieved from https://www.reuters.com/article/us-venture-china-regulation-insight/chinese-tech-investors-flee-silicon-valley-as-trump-tightens-scrutiny-idUSKCN1P10CB
[53] Ibid.

farming was listed as a Program Area Priority for further study and potential implementation, reflecting the possibility of further funding.[54]

Analysts like Scott Beyer, who worked in the area of free-market policy, criticized the subsidy that New Jersey and the city of Newark gave to AeroFarms, given the poor economics and environmental impact of vertical farming.[55] According to Louis Albright, director of Cornell University's Controlled Environment Agriculture program, vertical farms generated 10 times more carbon footprint than traditional vegetable farms due to the use of LED lighting.[56]

AeroFarms acknowledged the drawback of the high energy requirement and stated they were trying to address that problem. They hired Roger Buelow, the former chief technology officer of Energy Focus, an LED lighting company. Roger efficiently designed AeroFarms' customized LED lighting system. Oshima claimed, "That allows us to be much more energy efficient than anything else out there."[57] According to the US Energy Information Administration, between 2012 and 2014, LED lighting became 50 percent more efficient. By 2020, it was expected that with the decline in price of LED-based lighting, efficiency would further increase by 50 percent.[58]

Talent Acquisition

According to Dickson Despommier, a microbiologist and professor emeritus at Columbia University, the biggest challenge for vertical farming companies was to find the right talent. He

[54] Stark, K. (March 24, 2019). *op. cit.*
[55] Beyer, S. (April 9, 2015). Newark subsidizes A crackpot idea: Vertical farming. Retrieved from https://www.forbes.com/sites/scottbeyer/2015/04/09/newark-subsidizes-a-crackpot-idea-vertical-farming/#706c262e114d
[56] Garfield, L. (March 15, 2016). *op. cit.*
[57] Ryan, K. J. (June 14, 2017). *op. cit.*
[58] Garfield, L. (March 15, 2016). *op. cit.*

said, “The biggest issue is finding people who are qualified. Growers in particular are very hard to find. Who’s training them? The answer is, very few places.” In the US, the University of Arizona, University of California, Davis, and the University of Michigan were among the few institutions that offered courses in vertical farming.[59] At AeroFarms, talent was an even more critical issue as they leveraged Harwood’s patented growing medium. Oshima stated, “No one has direct experience with this.” Once AeroFarms found suitable candidates, it trained them on the company’s more than 100 best operating procedures.[60]

COMPETITION

AeroFarms was the largest vertical farm company in the world, with the highest revenues and annual production of any vertical farming company[61] (see **Exhibit 4** for competitor comparison). The company had nine farms, including seven farms in the USA and one each in Saudi Arabia and China. Oshima stated, “From day one, this has been about having an impact around the world.” AeroFarms aimed to have 25 farms by 2022.[62] The company also differed from other vertical farming companies in cost effectiveness. For instance, other vertical farm growers used rock wool as a substrate for holding the roots of plants in place and disposed of it after growth for sanitary reasons. AeroFarms used a proprietary replacement, a cloth made from recycled water bottles, which could be cleaned and reused. Oshima stated, “It’s a cloth we developed—we have patents on this stuff. We simply wash the cloth after every harvest, so we have a (bacteria/fungi) kill step

[59] Ryan, K. J. (June 14, 2017). *op. cit.*
[60] Ibid.
[61] Ibid.
[62] Ibid.

there, and then reuse that."[63] AeroFarms had patents and trade secrets for its vertical farming techniques, and it kept the expertise in-house, which helped them to ensure data safety. They had more than 280 different standard operating procedures on managing a farm.[64] Irrespective of the location of the farm, in Newark or Dubai, AeroFarms had the ability to observe and monitor crop cultivation process in real-time.[65] The data and knowledge gathered from the vertical farms helped AeroFarms globally, regardless of location or geography.[66]

A number of promising vertical farm operations had failed in the past. In 2015, Google's Alphabet X abandoned its automated vertical farm project, as it couldn't grow staple crops like grains with vertical farming techniques. VertiCrop, founded in 2011, declared bankruptcy within three years.[67] Chicago-based startup FarmedHere shut its operations in 2017. For every company like AeroFarms, there were others who could not survive for various reasons, such as operational costs and failure to break even. As these small companies failed, Paul Gauthier, an associate researcher at Princeton involved with the Princeton Vertical Farming Project, stated, "A lot of the small companies have something to tell, and we should hear their story."[68] Oshima explained that AeroFarms had a goal to be at least cash flow positive.[69] Vertical farming on average took seven years to show signs of profitability.[70]

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[63] Kloosterman, S. (March 15, 2018). AeroFarms pursues world's highest-producing indoor farm operation. Retrieved from https://vegetablegrowersnews.com/article/aerofarms-pursues-worlds-highest-producing-indoor-farm-operation/
[64] Yuan, L. (May 9, 2018). *op. cit.*
[65] Ibid.
[66] Kloosterman, S. (March 15, 2018). *op. cit.*
[67] Garfield, L. (March 15, 2016). *op. cit.*
[68] Marston, J. (January 3, 2019). *op. cit.*
[69] Clayton, C. (May 2, 2016). *op. cit.*
[70] Cosgrove, E. (January 3, 2018). *op. cit.*

Apart from aeroponics-based vertical farming, which AeroFarms used, aquaponics systems and hydroponic systems were also believed to be a solution for food cultivation in cities (see **Exhibit 4** for the definitions of different vertical farming technologies). Commercial farms, like Gotham Greens in New York and Lufa Farms in Montreal, used hydroponic systems to grow plants. Given the success of such projects, experts believed this could pose a threat to the AeroFarms aeroponic system of vertical farming (see **Exhibit 5** for details on the market value of vertical farming in the USA based on type of technology).

MARKETING PARTNERS

Although AeroFarms supplied salad greens to restaurants, corporate dining, and schools, their biggest customers were retailers, including US retailers such as ShopRite, Whole Foods, Seabra Foods, and Fresh Direct.[71] In 2019, Singapore Airlines announced their "farm-to-plane" partnership with AeroFarms.[72] In-flight meals were traditionally not enjoyable, as ingredients often needed to be shipped hundreds or thousands of miles from farms to airports, which impacted their freshness. AeroFarms was in proximity to Newark Liberty International Airport, and leafy greens grown in its facility were made available to Singapore Airlines within hours of harvest, making meals onboard aircraft fresher and tastier**.** Singapore Airlines' culinary experts were specifically interested in AeroFarms' bolder, spicier greens, which could help overcome passengers' dried-out palates in airplane cabins.[73] The airline saw the AeroFarms partnership as a way to further differentiate itself in the crowded aviation world. James Boyd, Vice President of public relations

[71] Chang, J. (June 30, 2017). *op. cit.*
[72] Fitzpatrick, A. (March 21, 2019). *op. cit.*
[73] Ibid.

in Singapore Airlines, stated, "Food is an area where we can stand out." Singapore Airline included AeroFarms' greens in soy poached chicken, a garden green salad, and heirloom tomato ceviche.[74]

Customer feedback suggested that AeroFarms' unique approach was working. According to Oshima, customers' "palates [had] been woken up again." Chang appreciated AeroFarms' greens so much that he not only invested in the company but also joined its board of advisors.[75] Marcus Samuelsson, the youngest chef to have a 3-star rating from The New York Times, partnered with AeroFarms as the primary provider of greens for his Newark, New Jersey, restaurant, Marcus B&P.[76]

AeroFarms, however, had challenges in appealing to consumers as an "organic" food. Consumers believed that "organic" implied not adding any synthetic chemicals to grow the crop. However, the USDA did not define whether vertical farming produce would qualify as organic. Accordingly, AeroFarms did not have that USDA-certified organic seal.[77] Oshima stated, "We actually think we're really good stewards of the environment and of the soil in particular because we're allowing it to heal. There's no carbon release because we're not tilling. There are a lot of benefits to what we are doing because we are growing indoors." "…USDA would say they have not kept up with technology. We think that's a dialogue and designation that's going to evolve."[78]

AeroFarms also developed an early relationship with the Newark School District, which not only purchased leafy greens from the company but also taught students about its operations and

[74] Fitzpatrick, A. (March 21, 2019). *op. cit.*
[75] Cox, O. (July 23, 2018). AgTech firm AeroFarms maximizes production and efficiency while producing tastier "Lifestyle Greens." Retrieved from https://aerofarms.com/2018/08/14/agtech-firm-aerofarms-maximizes-production-and-efficiency-while-producing-tastier-lifestyle-greens/
[76] Ibid.
[77] Clayton, C. (May 2, 2016). *op. cit.*
[78] Ibid.

agriculture. Oshima stated, "It's cool. Here in Newark we teach sixth-graders about how to be a farmer."[79]

THE ROAD AHEAD

The global vertical farming market was expected to reach a size of US$12.77 billion by 2026.[80] However, limitations on crop varieties and high initial investments restrained this market growth. Commenting on the potential of their business, Rosenberg stated, "We are at a major inflection point globally as we think about the challenges of increasing population and urbanization, loss of fresh water and arable land, worker welfare, food safety, and food security, and AeroFarms is uniquely positioned to address each of these areas with proprietary growing technology and unmatched growing history and expertise." AeroFarms was contracting with new retailers on an almost weekly basis.

According to Henry Gordon-Smith, founder of Agritecture Consulting, big vertical farms like AeroFarms had difficulty being profitable as they were highly capital-intensive.[81] AeroFarms did not disclose its financials but claimed that after many challenges, they turned a profit in 2019.[82] Consumers preferred organic food, a label that the AeroFarms brand lacked. Because of this, Rosenberg believed that consumers needed to be educated, stating, "You have to trust the consumers to make an educated decision." He believed that consumers were very open to greens

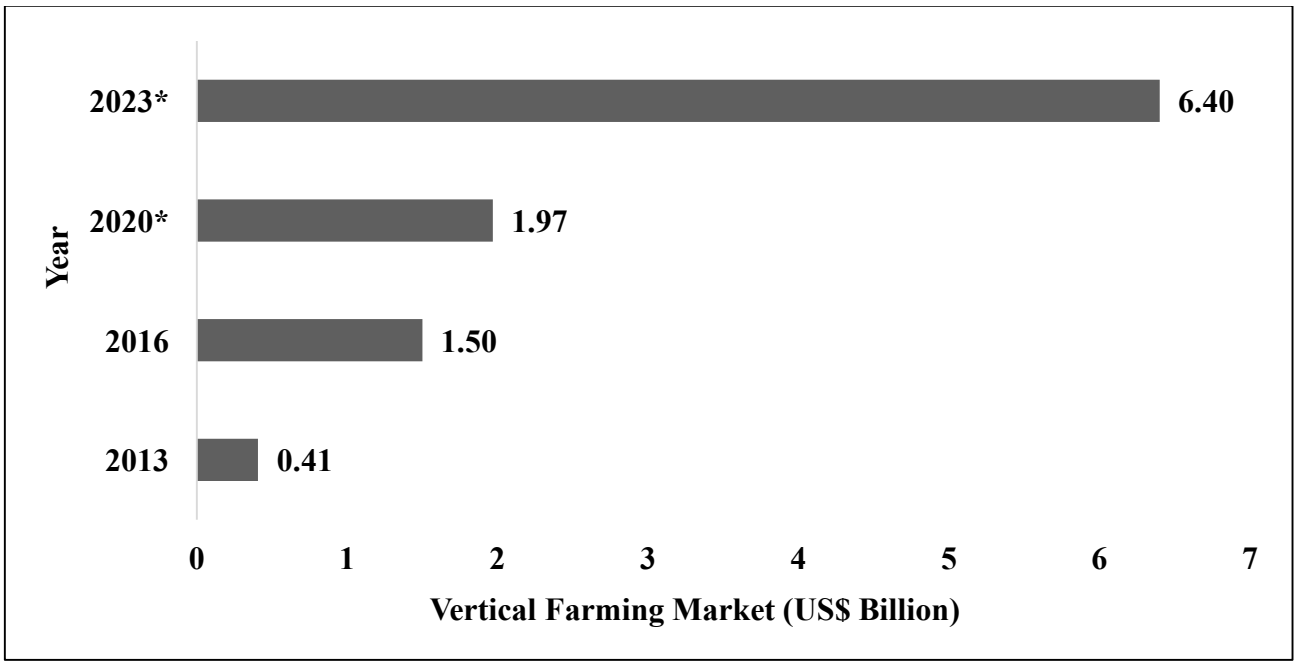
[79] Ibid.
[80] Projected vertical farming market worldwide in2018 to 2026 (in billion U.S. dollars). (August, 2019). Retrieved from https://www.statista.com/statistics/487666/projection-vertical-farming-market-worldwide/
[81] Michel, J. (February 25, 2019). Tech connection boosts New York vertical farmers. Retrieved from https://www.thejakartapost.com/life/2019/02/25/tech-connection-boosts-new-york-vertical-farmers.html
[82] Fortdao, L., & Terazono, E. (July9, 2019). AeroFarms raises $100m as investors rush to indoor farms. Retrieved from https://www.ft.com/content/cac48190-9d8a-11e9-9c06-a4640c9feebb

from vertical farms when they were educated that this method carried the benefits of less water and no pesticides. [83]

Paul Gauthier, a Princeton University plant researcher, believed that for vertical farmers to be successful, they needed to develop more protein-rich offerings.[84] Rosenberg, on the contrary, believed in focusing their data science-based business model only on greens and vegetables for better utility of space year round. Amidst these challenges, could Rosenberg mold consumers' interest in vertical farming-based cultivated crops? Can Rosenberg meaningfully solve the world's food problem without cultivating high calorie-based proteins and grains? What should he do to make vertical farms the future of crop cultivation?

[83] Robots and better business models: How the world's growing population can learn to feed itself. (September 5, 2019). Retrieved from https://fortune.com/2019/09/05/sustainable-food-farming/
[84] Michel, J. (February 25, 2019). *op. cit.*

Exhibit 1. Projected Vertical Farming Market Globally (2013- 2023) (US$ Billion)



Source: Projected vertical farming market worldwide from 2013 to 2023 (in Billion U.S. dollars). (June 23, 2017). Retrieved from https://www.statista.com/statistics/487666/projection-vertical-farming-market-worldwide/

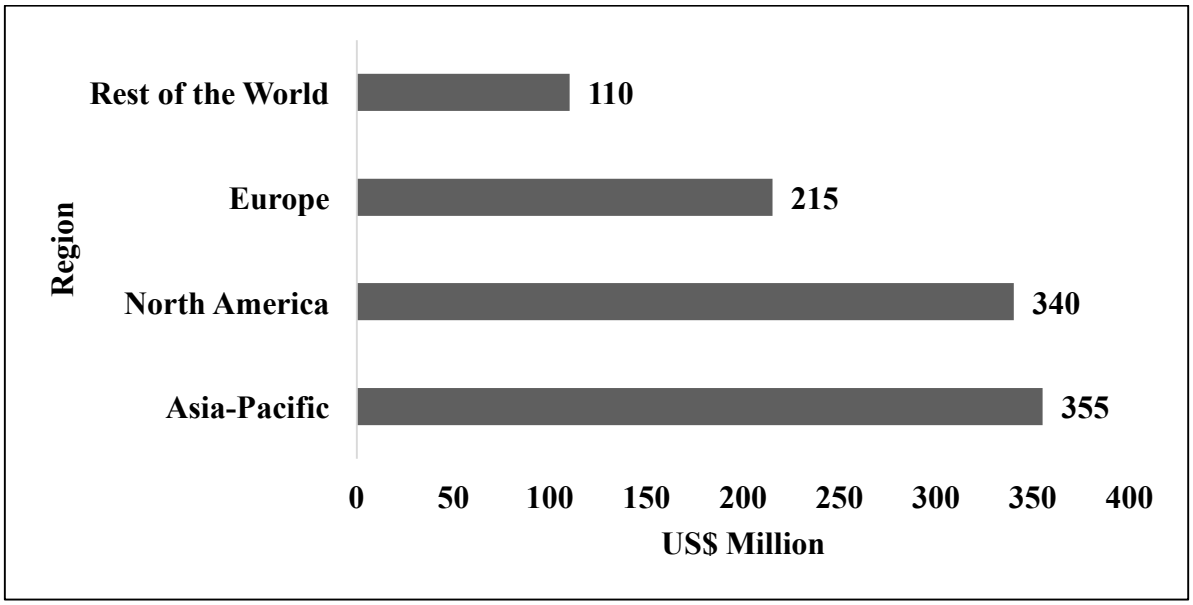
*= Estimated value

Exhibit 2. AeroFarms: Funding Rounds (2010-2019) (US$ Million)

Date	Funding Round	Money Raised (US$ Million)
February 8, 2010	Seed Round	0.5
February 17, 2010	Series A	5
October 31, 2014	Venture Round	36
December 10, 2015	Series B	20
May 3, 2017	Series C	35
September 8, 2017	Grant	1
October 30, 2017	Series D	40.5
July 8, 2019	Series E	100

Source: Overview: AeroFarms. (August 1, 2019). Retrieved from https://www.crunchbase.com/organization/aerofarms#section-overview

Exhibit 3. Market Value of Vertical Farming (Region-wise) (2015) (US$ Million)



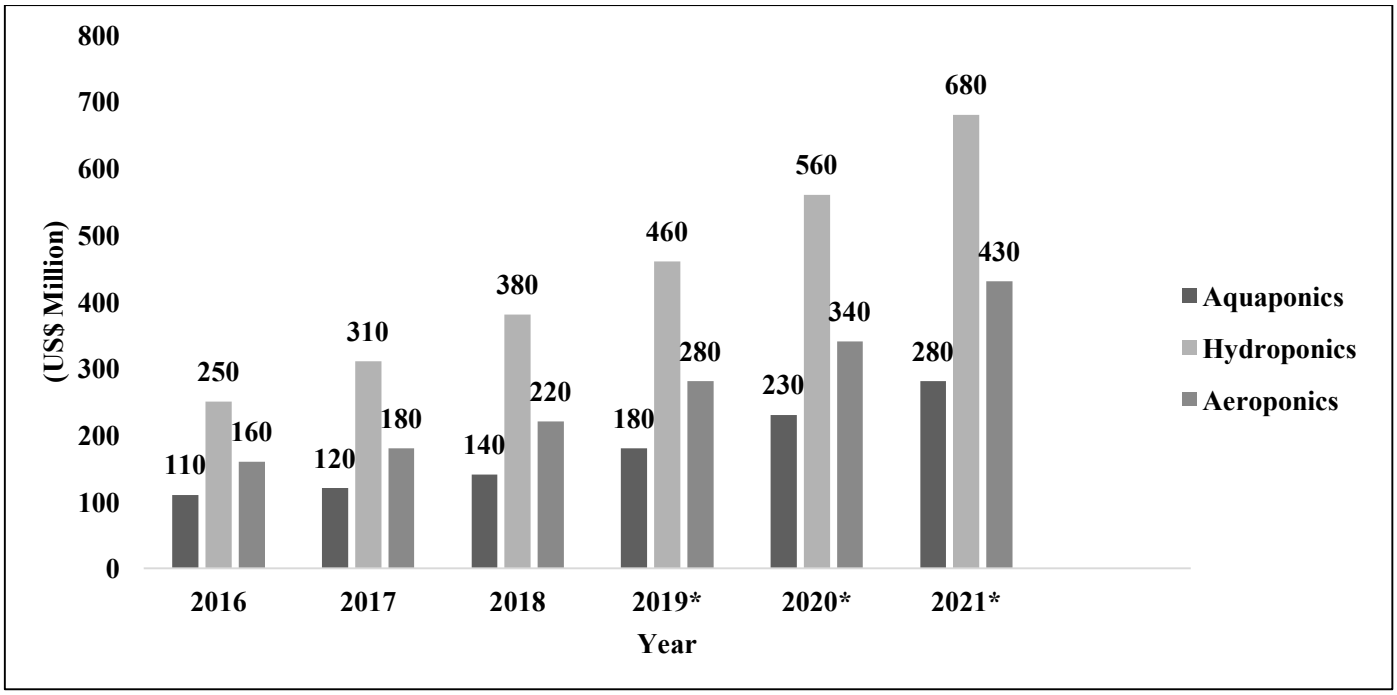
Source: Market value of vertical farming worldwide in 2015, by region (in Million U.S. dollars). (October 6, 2017). Retrieved from https://www.statista.com/statistics/752410/projection-vertical-farming-market-worldwide/

Exhibit 4. Competitors of AeroFarms (2019)

Company	Number of Employees	Total Funding (US$ Million)	Revenue (US$ Million)	Vertical Farming Type	Definition
AeroFarms LLC	130	238.0	50.0	Aeroponic	In the aeroponic system in roots of plants hang in the air and a sprinkler system sprays the roots with nutrient-rich water.
Bowery Farming Inc.	85	117.5	5.0	Hydroponic	In the hydroponic system roots of plants remain submerged in a continues flow of nutrient-rich water.
Plenty Inc	50	226.0	5.0	Hydroponic	
Gotham Greens Farms LLC	135	42.9	105.0	Hydroponic	
BrightFarms Inc.	120	113.9	11.5	Hydroponic	
Lufa Farms	35	5.0	7.0	Aquaponic	A combination of both hydroponics and aquaculture (which is farming of fishes) is known as aquaponics. Fish poop into the water they live in making the water high in nitrogen, an essential nutrient for plants. Plant roots absorb nitrogen from the water, purifying it and leaving it clean enough for fish to live in.

Source: Overview: AeroFarms. (July 1, 2019). Retrieved from https://www.crunchbase.com/organization/aerofarms ; Overview: Bowery Farming. (July 1, 2019). Retrieved from https://www.crunchbase.com/organization/bowery-farming-inc ; Overview: Plenty. (July 1, 2019). Retrieved from https://www.crunchbase.com/organization/see-jane-farm#section-overview ; Overview: Gotham Greens. (July 1, 2019). Retrieved from https://www.crunchbase.com/organization/gotham-greens ; Overview: BrigthFarms. (July 1, 2019). Retrieved from https://www.crunchbase.com/organization/brightfarms Overview: Lufa Farms. (July 1, 2019). Retrieved from https://www.crunchbase.com/organization/lufa-farms ; AeroFarms's competitors, revenue, number of employees, funding and acquisitions. (July 1, 2019). Retrieved from https://www.owler.com/company/aerofarms ; Heather (May 9, 2018). What's the difference: Hydroponics Vs. Aquaponics Vs. Aeroponics. Retrieved from https://originhydroponics.com/hydroponics-vs-aquaponics-vs-aeroponics/

Exhibit 5. Market Value of Vertical Farming in the USA by Technology Type (2016-2021) (US$ Million)



Source: U.S. vertical farming market value 2013-2024, by technology. (September 28, 2018). Retrieved from https://www.statista.com/statistics/752429/market-value-of-vertical-farming-in-the-united-states-by-technology/

*= Projected value for the year