What is the cost structure in vertical farming?

Ömer Özgün Üngüder, 27523, Oemer-Oezguen.Uengueder@hsrw.org, Mohammed Abdullah, 27830,
Mohammed.Abdullah@hsrw.org, Jiajun Chen, 27775, Jiajun.chen@hsrw.org
Communication and Information Engineering - Hochschule Rhein-Waal

***Index Terms*—Vertical Farming, Interdisciplinary Project, Cost**

I. Cost structure in vertical farming

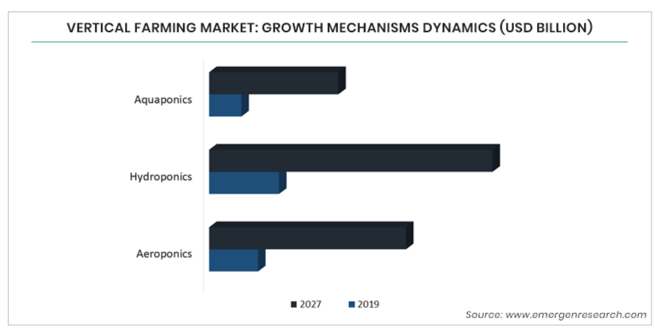
Increasing population, climate change,over-utilisation of cultivable land, security of food quality, water shortage, and other challenges are heavily weighing on the current conventional agricultural system. A disrupting new sustainable system is needed to be able to sustain the world's 10 billion population when it tops out at the end of this century. One of the potential solutions to this that can be implemented currently is vertical farming (VFing), which is growing impressively, correlated with the rise of technological innovation and business opportunities. New VFs are incipient worldwide, with an increasing amount of capital investment. This paper aims to develop a VF business framework that creates an overall better understanding of the VF industry from a research and business-like perspective.

Currently worth £3bn, the global market for vertical farming is growing by 20% a year and is forecast to reach a staggering $11.7bn by 2027, according to Emergen Research's report published in 2020. With the Asia pacific region being the dominant force in the VF market as expected from the higher population density. The profitability of a VF enterprise is grounded in the shift in public preferences towards vertical farms cultivated organic foods, first and foremost, as being perceived as more nutritious, healthier and safer. As the rising incidences of chronic diseases has driven the consumer space towards healthier foods as a trend. A keynote worth highlighting is that 64% of vertical farms in the VF business space is occupied by the shipping container segment. It is therefore possible to derive from the business perspective, that these container platforms offers the highest profit margin for projects with a moderate investment, as they provide advantages such as a high level of endurance in extreme weather conditions, ease of transportation, low use of water and most importantly cost effectiveness, is unmatched when compared to other forms of VF platforms, with the example being repurposed industrial buildings as the next most common form of VF platform that requires a far higher maintenance budget per square meter.

"From spectrum waveform analysis to nutrient analysis, there are so many different elements that come into the mix. If you're given the wrong advice, not only is your vertical farm not going to be profitable, you'll risk a lot of investment going down the pan," warns Craig Price, director of operations at Light Science Technologies, a UK based company that supplies fully integrated technology solution for all Controlled Environment Agriculture (CEA) applications. [1]

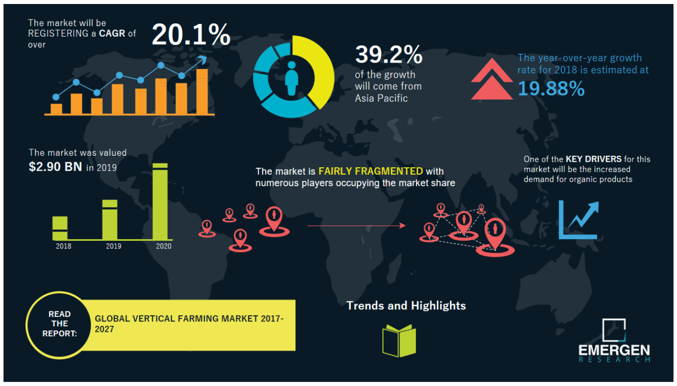
II. Capital expenditure (capex), operational expenditure (opex) and yield

The right balance between these three components is required for a VF enterprise to generate a sustainable profit. Capital expenditures are purchases of significant goods or services that will be used to improve a company's performance in the future. Capital expenditures in the industry of vertical farms would consist of the costs to pay for the plant to house the vertical farm, and equipment costs such as machinery, Building improvements, Computers and Vehicles. While the opex would consist principally of the monthly incurring expenditures such as rent of the location and wage of salaries of specialist labor, as the more automated a vertical farm is, the higher the costs of select specialists that provide their manual labor inputs. The bare minimum requirement to generate a positive net profit and ROI would mean the VF enterprise must aim to maximize the yield output of the organic foods to offset the two aforementioned cost categories. The previous advantages stated with the shipping container platform would ensure the operational costs saved being carried over and immediately reinvested into cutting edge LEDs and sensors to improve the yield generated by the farm to the highest quality possible, as a direct way to increase the profit margin.



However, more opportunities to fine tune a vertical farm with experimental technology for higher profit margin arsies when there's a high amount of capital investments. This became possible when existing players in the farming and tech industries expand into the VF market with preexisting supply chains, thus negating the need to search for distributors and consumers of their product when they already have a farm to table business cycle established, this is something the more modest capital startups do not have a luxury to afford right from the beginning. Giant indoor farming company BrightFarms, which supplies US grocery retailers with packaged salad greens, recently secured $100m funding, including capex to support its expansion plans, while vertical farm startup Infarm attracted $100m investment in June 2019. And California-based Plenty raised $200m in 2017, while managing to attract backers which include Amazon boss Jeff Bezos.

III. Future developments to increase profit margins



Vertical farming would already be in a further stage of development from greater investments if they were capable of growing all types of vegetables, fruits, and even cereal grains – which is the major cash crop. The focus is currently on high-value, rapid-growing, small-footprint crops (e.g. lettuce), which is limiting[2]. In terms of high-density food composed of carbohydrates, current day crop production in the VF industry cannot provide sufficient calories to meet the standard diet. Vertical farms are enclosed systems, which is mostly seen as a positive aspect, but on the other hand, there are no insects for pollination of the crops. Alternatively, pollination is possible by hand, but requires high amounts of manual labor[2]. Further challenges for the VF industry are the need to constantly improve the level of efficiency and profitability. These aspects can only be achieved by improving the multi-disciplinary knowledge via support largely by academic and technological research, action research, innovation, and investment in large-scale VFs. Still, as of today, the required amount of energy is in conflict with the principles of sustainable food production[2], [3]. One step to combat this problem is the development of new energy-efficient LEDs. Additionally, assembling a qualified team to fully operate a VF can also be a challenge. Successful operations usually require a high level of requisite knowledge and expertise from what could truly be described as making the project interdisciplinary, e.g. plant scientists, microbiologists, mechanical engineers, and electrical engineers, all with even more distinguishable practical knowledge of VFing[4].

IV. How to calculate the cost

According to Shao[5], There are 5 steps to calculate the total capital cost.

A. Step 1

In the first step, the land acquisition cost is calculated.

B. Step 2

Calculating the construction cost. In one equation:
Construction cost = Structure cost + Finishing cost + Appliance cost
The structure cost means what kind of material will be used in the building of the farm. For example, concrete, steel, brick, etc.
The finishing cost includes the finishing work of the ceiling, floors, walls, columns, doors, windows, etc.
The appliance costs include various appliances needed for the vertical farm, for example, electrical engineering appliances, water supply, drainage, gas supply, fire control, HVAC system, intelligent systems, lifts, etc.

C. Step 3

This step includes the costs for the system. In one equation:
System cost = Grow light cost + Growing area cost + Germination and clean cost + Water and nutrient cost + Food processing cost + Waste management cost + Renewable energy cost

Growing area systems include cooling system, vent door, air circulator, testing equipment, growing supplies, CO_2 enrichment, insect protection, etc.
Water and nutrient systems include smart controllers, accumulator tanks, water processing system, piping system, etc.

D. Step 4

This step includes other construction costs, reserve funds, loan interests and initial working capital.

E. Step 5

The last step is to calculate all the costs described above.
Total Capital Cost = Land Cost + Construction cost + System cost + Other construction cost + Reserve fund + Loan Interest + Initial Working Capital

Additionally, the annual operating cost can be calculated as,
Operating cost = Growth Lights Bill + Environmental controls bill + Misc. Energy Bill + Water Bill + Seed cost + Nutrient cost + Personnel Cost + Maintenance cost + CO_2 cost - Reduction from renewable energy

References

[1] "Is vertical farming profitable?" [Online]. Available: https://lightsciencetech.com/is-vertical-farming-profitable/
[2] J. Birkby, "Vertical farming," jan 2016.
[3] F. Kalantari, O. M. Tahir, R. A. Joni, and E. Fatemi, "Opportunities and challenges in sustainability of vertical farming: A review," *Journal of Landscape Ecology*, vol. 11, no. 1, pp. 35–60, jan 2018.
[4] T. Kozai, "Why led lighting for urban agriculture? in led lighting for urban agriculture," pp. 3–18, 2016.
[5] Y. Shao, T. Heath, and Y. Zhu, "Developing an economic estimation system for vertical farms," *International Journal of Agricultural and Environmental Information Systems*, vol. 7, apr 2016.