Economic Development Committee

City of Leavenworth Conference Room
3:45 PM – 4:30 PM
October 11, 2022

Members:
Clint Strand*
Marco Aurilio
Anne Hessburg

Staff:
Selby / Lilith

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Agenda Items:

1. Indoor Farming (35 minutes) – Chelan Douglas Regional Port Authority
2. Housing Deed Restriction Options – Indeed update (10 minutes)

Future Agenda Items:

1. UGA Analysis Update
2. Net Zero Leavenworth - Options/Alternatives for driving
   a. Review of Parking Committee discussion
   b. Front Street Closure Update
3. Industry Recruitment Considerations – Childcare
4. Industry Recruitment Considerations - Recreation Related
5. Industry Recruitment Considerations - Light Manufacturing & Live-work units
6. Net Zero Leavenworth – Recycling/Composting, Residential & Commercial
7. Net Zero Leavenworth - Solar programs (commercial & residential)
8. Net Zero Leavenworth - Options/Alternatives for driving

**Chairperson*
Audio recording available upon request for 90 days

PROJECT OVERVIEW

Quest Site Solutions (Quest) is assisting a food company with location analysis for **greenhouse** operations. Guided by core values of sustainability and community, the company strives to be an exemplary corporate citizen and grows **non-GMO produce utilizing hydroponic methods that are free from pesticides and herbicides**. Capacity in the pacific northwest of the United States is needed to serve current and future clients with high-quality fresh produce. The company has requested that its identity be kept **confidential** at this point in time. Correspondence regarding this project should use the code name – **Project Alfred**.

The project objective is to identify a viable site for climate-controlled greenhouse operations. Project Alfred is seeking a location within a 2-hour drive of population centers that has compatible surrounding land uses and access to a highway network. Utility infrastructure must be in place at the site or be able to be extended by 3rd Quarter 2022.

The initial phase of the project will entail an approximately 180,000 square foot greenhouse and a 30,000 square foot support facility (total of 210,000 square feet). Three potential future phases could each add an additional 180,000 square foot greenhouse and expansion of support facilities, for a potential total growing space of 720,000 square feet and an overall facility footprint of approximately 840,000 square feet at full buildout.

CAPITAL INVESTMENT AND EMPLOYMENT

The capital investment for the initial phase of the project will be approximately **$25 million**. The three potential future phases could increase capital investment by an additional $25 million each, for a potential total capital investment of $100 million.

Project Alfred is planning to hire approximately **50-55 employees** for the initial phase, including approximately 40-45 hourly employees and 10 salary employees. The three potential future phases could each add an additional 10-15 hourly employees, for a potential total employment of 80-100 at full buildout.

PROJECT SCHEDULE

Prescreening deadline	**November 18, 2021**
Full proposal response due	**November 30, 2021**
Notification of selection for virtual site visits	December 2021
Quest virtual site visits	**January 2022**
Notification of selection as Finalist Location	February 2022
Final property investigations and incentive negotiations	1st Quarter 2022
Selection of preferred location	2nd Quarter 2022
Facility construction begins	4th Quarter 2022

UTILITY SPECIFICATIONS

Utility capacity and reliability is critical. Service requirements are listed in the table below. Required service for Phase I must be able to be in place by 3rd Quarter 2022.

Utility	Phase I (initial operations)	Each Additional Phase (future expansions)	Total Requirement (Phases I, II, III, and IV)
Electric	5250 amps connected load, 4800 kVa preferred, 24 hr/day, 7 days/week	Each additional phase will add up to, but not exceed, the Phase I requirement	Total requirement will not be more than quadruple the Phase I requirement
Natural Gas	Min. pressure 2.0 psig Avg. use 22 MMBTU/day Peak use 110 MMBTU/day	Each additional phase will add up to, but not exceed, Phase I requirement	Total requirement will not be more than quadruple the Phase I requirement
Water	42,000 gallons per day	42,000 gallons per day	Total requirement will not be more than quadruple the Phase I requirement
Sewer / Effluent	20,000 gallons per day	20,000 gallons per day	Total requirement will not be more than quadruple the Phase I requirement
Telecom	Fiber preferred 500 Mbps required	Fiber preferred 500 Mbps required	Fiber preferred 500 Mbps required

ENVIRONMENTAL AND LAND USE CONSIDERATIONS

The facility ventilation system will draw in and circulate outside air throughout the greenhouse. Surrounding land uses, and air quality from the uses, must be compatible with growing fresh food. Additionally, sunlight is critical for the greenhouse operations, therefore the site must not be located where it will be shaded by surrounding structures.

MINIMUM CRITERIA

- Site must be at least **25 acres**, with a minimum of **20 contiguous and developable acres.**
  - **Preference is for 30+ acres** that can accommodate multiple phases, with a total **building footprint of up to 645-feet x 1,300-feet.**
- Site must be available for sale and a purchase price specified.
- Site must be within 25 miles of an Interstate or four-lane highway and be accessible via roads that meet U.S. DOT standards for tractor-trailer access (80,000 lbs., etc.).
- Site must be within a 1.5-hour drive of a commercial service airport, preference for < 1 hour.
- Site must be zoned appropriately or be able to be rezoned for intended use within 60 days after selection as a finalist location.
- Site must be able to be permitted for construction to begin in 4th Quarter 2022.
- All utility infrastructure must be in place at the site or have planned right-of-way access identified and a plan for providing utilities clearly demonstrated (including schedule and cost). All utility extensions must be able to be completed by 3rd Quarter 2022.

PRESCREENING PROCESS

Quest will be prescreening sites on a rolling basis through November 18th and determining the properties for which we will request a full proposal. This is a required step in the process and ensures that proposal efforts are focused on sites that meet or have the potential to meet the project specifications and minimum criteria.

To submit a site for prescreening, email a description of site characteristics, property real estate flyer (or link to internet listing) and/or available maps by 8:30 pm eastern on November 18th. Feedback will be provided a rolling basis; therefore, early submittal is encouraged.

REQUEST FOR PROPOSAL (APPLICABLE TO SITES THAT PASS THE PRESCREENING)

Quest is seeking detailed information on sites that pass the prescreening process. This step in the site selection process enables a thorough desktop evaluation of sites and infrastructure to determine the locations for virtual site visits. Information provided should be as detailed as possible in order for Quest to fully understand the property characteristics and infrastructure.

Please submit the following required information for each site in the order listed:

1) Completed Site and Community Questionnaire
2) Transportation map (include highways and commercial airports within 60 miles of site)
3) Aerial photograph with site boundaries identified and site dimensions labeled
4) Topographic map with site boundaries identified
5) FEMA floodplain map with site boundaries identified
6) Ownership map / tax map with site boundaries identified
7) Easements and right-of-way map(s) with site boundaries identified
8) Deed indicating property ownership and legal description of property boundaries (if the site is comprised of multiple parcels, provide documentation for each parcel)
9) Documentation of property availability (property listing, option agreement, or letter of commitment to sell) with a purchase price specified
10) Map(s) illustrating the current zoning for the property and surrounding area with site boundaries identified
11) Copy of the zoning ordinance.
12) If a rezoning will be required, provide a letter detailing the rezoning process and timeline.
13) Copy of the industrial park covenants and restrictions (if applicable)
14) Map of nearby businesses (include a legend that lists facility operations)
15) Utility infrastructure map(s) with property boundaries identified that clearly indicates location and size of the following:
    a. Power lines and substation(s)
    b. Gas lines
    c. Water lines
    d. Sewer lines and lift station(s)
    e. Telecommunications infrastructure

Please submit the following requested information for each site if available:

16) Phase I (and/or Phase II) environmental study and/or all documentation of the present environmental conditions and any past remediation conducted on the site
17) Geotechnical assessment report
18) Wetlands delineation map and report
19) Endangered species investigation report
20) Archeological and historical investigation report

SUBMISSION INSTRUCTIONS

For sites that pass the prescreening process, please submit all proposal information electronically no later than Tuesday, November 30th at 3:30 pm eastern.

Information submitted should adhere to the following guidelines:

- Submit items in the order listed above and as a separate file for each item. The file name for each item should correspond to numbering listed. For example, the file name for the topographic map (#4 on this list) should read “4 – Topographic Map.”

- All maps should show a title, a scale, a directional arrow, clear boundaries of the site, and a date. Hand drawn maps are not acceptable.

- All letters must be on the appropriate letterhead and include a date and a signature.

Project Green PNW Campus

Company Description:

Project Green PNW Campus features an agricultural company expanding their food production capacity to support demand in the Pacific Northwest. This U.S. based multi-farm operator focuses on cultivating living roots produce in greenhouses using hydroponic and climate control growth methods. The development of this site would support demand for products in Washington, Oregon, Idaho and Utah. Examples of produce include; living red/butter lettuce products and packaged lettuce mixes (i.e. romaine, and spring mix).

The company is looking for Greenfield sites with utilities (electricity, gas, water and sewer) available on-site. As part of the development strategy, the company will focus on building new greenhouses and support buildings in parcels rather than . The total size when built out would incorporate up to 40 acres in total. Sites should reflect an ability to purchase and develop parcels where possible. The company would like to where possible use renewable energy sources, additionally due to operations the service reliability is an important consideration to sites. If available, please provide information regarding energy mix, options for renewable energy use, and electricity service reliability. Proximity to freeways/highways is preferred, transportation is mainly road based.

Jobs, Capex & Timeline

Total Employment:

Employment per Development	Land Development Increments* + Timeline
15	Minimum 3-6 acres (Year 1)
25 (adding 10 new jobs)	6-12 acres (Year 2-3)
50 (adding 25 jobs)	9-12 acres (Year 5-7)
100 (adding 50 jobs)	15-24 acres (Year 5-7)
	Total space needed: 40 acres

***** the company will build in 3 – 6 acres increments depending on market demand but expect up to 40 acres will be required to cover needs.

Job creation: Breakdown example of 25 positions & wages.

- Professional: 4 ($140k salary est.)
- Technical/Skilled: 8 ($30 an hour)
- Semi-skilled: 7 ($21 an hour)
- Unskilled: 6 ($16 an hour)

Capital Expenditure: Depending on each phase of development. Example, phase 1 ≈ $15-18 million, phase 2 $8-10 million. Potential of $23-28 million, more capex as later phases are developed.

Timeline: Site Tour: 3 month (December 2021 if possible) | Site Selection: 6 months (Q1 2022)
Groundbreaking: June 2022 | Operational: June 2023

Project PNW Campus	**Preferences/Specifications**	**Notes**
Site preference	Greenfield w/ utilities connected. 24-40 acres, zoned, graded	Plus if graded and pad ready with utilities available. Company will develop 6 acre parcels over time. Access to interstate, no rail service need anticipated.
Electricity	800 kWH peak demand in winter (80,000 kWH per month)	Falling power demand in warmer months. Please provide information regarding service reliability, due to operations the company needs to ensure stable power supply.
Natural Gas	40,000 thermos per month	Interested in potential biogas options.
Water	5000 gallons per day	
Sewer	TBD	
Truck	10-20 per day	

Please consider the following for site submission:

- Are there options for a multiphase project that could ensure long-term local growth? (The company would like to be able to develop 6 acre parcels at a time, with an option of up to 24 acres and potentially up to 40 acres).
- Highlight of regional workforce, particular focus on the agriculture sector and computer skills needed to work greenhouse facilities/hydroponic systems.
- Access to transportation and key markets such as Seattle, Portland, and Boise. The company provides produce to retailer around the region.
- As a reminder: service reliability for electricity is critical for business operations, please include this in your site submissions if available.

Please include a brief cover letter/executive summary addressed to “Project PNW Campus”. Cover letter and or executive letter should focus on regional advantages, and workforce availability.

Due Date: November 10th at 5:00pm.

WIKIPEDIA

Vertical farming


Vertical farming in Singapore

Vertical farming is the practice of growing crops in vertically stacked layers.[1] It often incorporates controlled-environment agriculture, which aims to optimize plant growth, and soilless farming techniques such as hydroponics, aquaponics, and aeroponics.[1] Some common choices of structures to house vertical farming systems include buildings, shipping containers, tunnels, and abandoned mine shafts. As of 2020, there is the equivalent of about 30 ha (74 acres) of operational vertical farmland in the world.[2]

The modern concept of vertical farming was proposed in 1999 by Dickson Despommier, professor of Public and Environmental Health at Columbia University.[3] Despommier and his students came up with a design of a skyscraper farm that could feed 50,000 people.[4] Although the design has not yet been built, it successfully popularized the idea of vertical farming.[4] Current applications of vertical farmings coupled with other state-of-the-art technologies, such as specialized LED lights, have resulted in over 10 times the crop yield than would receive through traditional farming methods.[5]

The main advantage of utilizing vertical farming technologies is the increased crop yield that comes with a smaller unit area of land requirement.[6] The increased ability to cultivate a larger variety of crops at once because crops do not share the same plots of land while growing is another sought-after advantage. Additionally, crops are resistant to weather disruptions because of their placement indoors, meaning fewer crops are lost to extreme or unexpected weather occurrences. Because of its limited land usage, vertical farming is less disruptive to the native plants and animals, leading to further conservation of the local flora and fauna.[7]

Vertical farming technologies face economic challenges with large start-up costs compared to traditional farms. In Victoria, Australia, a "hypothetical 10 level vertical farm" would cost over 850 times more per square meter of arable land than a traditional farm in rural Victoria.[5] Vertical farms also face large energy demands due to the use of supplementary light like LEDs. Moreover, if non-renewable energy is used to meet these energy demands, vertical farms could produce more pollution than traditional farms or greenhouses.

Contents

Techniques

Hydroponics


Indoor Hydroponics of Morus, Japan

Hydroponics refers to the technique of growing plants without soil.[8] In hydroponic systems, the roots of plants are submerged in liquid solutions containing macronutrients, such as nitrogen, phosphorus, sulphur, potassium, calcium, and magnesium, as well as trace elements, including iron, chlorine, manganese, boron, zinc, copper, and molybdenum.[8] Additionally, inert (chemically inactive) mediums such as gravel, sand, and sawdust are used as soil substitutes to provide support for the roots.[8]

The advantages of hydroponics include the ability to increase yield per area and reduce water usage. A study has shown that, compared to conventional farming, hydroponic farming could increase the yield per area of lettuce by around 11 times while requiring 13 times less water.[9] Due to these advantages, hydroponics is the predominant growing system used in vertical farming.[1]

Aquaponics


Aquaponics with catfish

The term *aquaponics* is coined by combining two words: *aquaculture*, which refers to fish farming, and *hydroponics*—the technique of growing plants without soil.[10] Aquaponics takes hydroponics one step further by integrating the production of terrestrial plants with the production of aquatic organisms in a closed-loop system that mimics nature itself.[1][10] Nutrient-rich wastewater from the fish tanks is filtered by a solid removal unit and then led to a bio-filter, where toxic ammonia is converted to nutritious nitrate.[10] While absorbing nutrients, the plants then purify the wastewater, which is recycled back to the fish tanks.[1] Moreover, the plants consume carbon dioxide produced by the fish, and water in the fish tanks obtains heat and helps the greenhouse maintain temperature at night to save energy.[10] As most commercial vertical farming systems focus on producing a few fast-growing vegetable crops, aquaponics, which also includes an aquacultural component, is currently not as widely used as conventional hydroponics.[1]

Aeroponics

The invention of aeroponics was motivated by the initiative of NASA (the National Aeronautical and Space Administration) to find an efficient way to grow plants in space in the 1990s.[1][11] Unlike conventional hydroponics and aquaponics, aeroponics does not require any liquid or solid medium to grow plants.[12] Instead, a liquid solution with nutrients is misted in air chambers where the plants are suspended.[12] By far, aeroponics is the most sustainable soil-less growing technique,[12][1] as it uses up to 90% less water than the most efficient conventional hydroponic systems[1] and requires no replacement of growing medium.[12] Moreover, the absence of growing medium allows aeroponic systems to adopt a vertical design, which further saves energy as gravity automatically drains away excess liquid, whereas conventional horizontal hydroponic systems often require water pumps for controlling excess solution.[12] Currently, aeroponic systems have not been widely applied to vertical farming, but are starting to attract significant attention.[1]

Controlled-environment agriculture

Controlled-environment agriculture (CEA) is the modification of the natural environment to increase crop yield or extend the growing season.[13] CEA systems are typically hosted in enclosed structures such as greenhouses or buildings, where control can be imposed on environmental factors including air, temperature, light, water, humidity, carbon dioxide, and plant nutrition.[13] In vertical farming systems, CEA is often used in conjunction with soilless farming techniques such as hydroponics, aquaponics, and aeroponics.[13]

Aeroponically-grown chives

Types

Building-based farms

Abandoned buildings are often reused for vertical farming, such as a farm at Chicago called "The Plant", which was transformed from an old meatpacking plant.[15] However, new builds are sometimes also constructed to house vertical farming systems.

Shipping-container vertical farms

Vertical farm in Moscow[14]

Recycled shipping containers are an increasingly popular option for housing vertical farming systems.[1] The shipping containers serve as standardized, modular chambers for growing a variety of plants,[1] and are often equipped with LED lighting, vertically stacked hydroponics, smart climate controls, and monitoring sensors.[1] Moreover, by stacking the shipping containers, farms can save space even further and achieve higher yield per unit area.

Deep farms

A "deep farm" is a vertical farm built from refurbished underground tunnels or abandoned mine shafts.[16] As temperature and humidity underground are generally temperate and constant, deep farms require less energy for heating.[16] Deep farms can also use nearby groundwater to reduce the cost of water supply.[16] Despite low costs, a deep farm can produce seven to nine times more food than a conventional farm above ground on the same area of land,[16] according to Saffa Riffat, chair in Sustainable Energy at the University of Nottingham.[17] Coupled with automated harvesting systems, these underground farms can be fully self-sufficient.[18]

History

Initial propositions

Dickson Despommier, professor of Public and Environmental Health at Columbia University, founded the root of the concept of vertical farming.[3] In 1999, he challenged his class of graduate students to calculate how much food they could grow on the rooftops of New York. The students concluded that they could only feed about 1000 people.[4] Unsatisfied with the results, Despommier suggested growing plants indoors instead, on multiple layers vertically.[4] Despommier and his students then proposed a design of a 30-story vertical farm equipped with artificial lighting, advanced hydroponics, and aeroponics[19] that could produce enough food for 50,000 people.[4] They further outlined that approximately 100 kinds of fruits and vegetables would grow on the upper floors while lower floors would house chickens and fish subsisting on the plant waste.[4] Although Despommier's skyscraper farm has not yet been built, it popularized the idea of vertical farming and inspired many later designs.[4]

Implementations

Developers and local governments in multiple cities have expressed interest in establishing a vertical farm: Incheon (South Korea), Abu Dhabi (United Arab Emirates), Dongtan (China),[20] New York City, Portland, Los Angeles, Las Vegas,[21] Seattle, Surrey, Toronto, Paris, Bangalore (India), Dubai, Shanghai, and Beijing.[22] Around US$1.8 billion were invested into startups operating in the sector between 2014 and November 2020.[2]

In 2009, the world's first pilot production system was installed at Paignton Zoo Environmental Park in the United Kingdom. The project showcased vertical farming and provided a solid base to research sustainable urban food production. The produce is used to feed the zoo's animals while the project enables evaluation of the systems and provides an educational resource to advocate for change in unsustainable land-use practices that impact upon global biodiversity and ecosystem services.[23]

In 2010 the Green Zionist Alliance proposed a resolution at the 36th World Zionist Congress calling on Keren Kayemet L'Yisrael (Jewish National Fund in Israel) to develop vertical farms in Israel.[24] Moreover, a company named "Podponics" built a vertical farm in Atlanta consisting of over 100 stacked "growpods" in 2010 but reportedly went bankrupt in May 2016.[25]

In 2012 the world's first commercial vertical farm was opened in Singapore, developed by Sky Greens Farms, and is three stories high.[26] They currently have over 100 nine-meter-tall towers.[27]

In 2012, a company named The Plant debuted its newly developed vertical farming system housed in an abandoned meatpacking building in Chicago, Illinois.[15] The utilization of abandoned buildings to house vertical farms and other sustainable farming methods are a fact of the rapid urbanization of modern communities.[28]

In 2013 the Association for Vertical Farming (AVF) was founded in Munich (Germany). By May 2015, the AVF had expanded with regional chapters all over Europe, Asia, USA, Canada, and the United Kingdom. This organization unites growers and inventors to improve food security and sustainable development. The AVF focuses on advancing vertical farming technologies, designs, and businesses by hosting international info-days, workshops, and summits.[29]

In 2015 the London company, Growing Underground, began the production of leafy green produce underground in abandoned underground World War II tunnels.[30]

In 2016, a startup called Local Roots launched the "TerraFarm",[31] a vertical farming systems hosted in a 40-foot shipping container, which includes computer vision integrated with an artificial neural network to monitor the plants; and is remotely monitored from California.[32] It is claimed that the TerraFarm system "has achieved cost parity with traditional, outdoor farming"[33] with each unit producing the equivalent of "three to five acres of farmland", using 97% less water[34] through water recapture and harvesting the evaporated water through the air conditioning.[35] The first vertical farm in a US grocery store opened in Dallas, Texas in 2016, now closed.[36]

In 2017, a Japanese company, Mirai, began marketing its multi-level vertical farming system. The company states that it can produce 10,000 heads of lettuce a day—100 times the amount that could be produced with traditional agricultural methods because their special purpose LED lights can decrease growing times by a factor of 2.5. Additionally, this can all be achieved with 40% less energy usage, 80% less food waste, and 99% less water usage than in traditional farming methods. Further requests have been made to implement this technology in several other Asian countries.[5] As of 2021, Bowery Farming is the largest indoor vertical farming company in the United States.[37]

Advantages

Efficiency

Traditional farming's arable land requirements are too large and invasive to remain sustainable for future generations. With the rapid population growth rates, it is expected that arable land per person will drop about 66% in 2050 in comparison to 1970.[5] Vertical farming allows for, in some cases, over ten times the crop yield per acre than traditional methods.[6] Unlike traditional farming in non-tropical areas, indoor farming can produce crops year-round. All-season farming multiplies the productivity of the farmed surface by a factor of four to six, depending on the crop. With crops such as strawberries, the factor may be as high as 30.[38]

Vertical farming also allows for the production of a larger variety of harvestable crops because of its usage of isolated crop sectors. As opposed to a traditional farm where one type of crop is harvested per season, vertical farms allow for a multitude of different crops to be grown and harvested at once due to their individual land plots.[39]

According to the USDA,[40] vertical farm produce only travels a short distance to reach stores compared to traditional farming method produce.

The United States Department of Agriculture predicts the worldwide population to exceed 9 billion by 2050, most of which will be living in urban or city areas. Vertical farming is the USDA's predicted answer to the potential food shortage as the population increases.[40] This method of farming is environmentally responsible by lowering emission[41] and reducing needed water. This type of urban farming that would allow for nearly immediate farm-to-store transport would reduce distribution costs and shorten produce travel time.

In a workshop on vertical farming put on by the USDA and the Department of Energy[42] experts in vertical farming discussed plant breeding, pest management, and engineering. Control of pests (like insects, birds, and rodents) is easily managed in vertical farms because the area is so well-controlled. Without the need for chemical pesticides the ability to grow organic crops is easier than in traditional farming.

Resistance to weather

Crops grown in traditional outdoor farming depend on supportive weather and suffer from undesirable temperatures, rain, monsoon, hailstorm, tornado, flooding, wildfires, and drought.[43] "Three recent floods (in 1993, 2007 and 2008) cost the United States billions of dollars in lost crops, with even more devastating losses in topsoil. Changes in rain patterns and temperature could diminish India's agricultural output by 30 percent by the end of the century."[44]

The issue of adverse weather conditions is especially relevant for arctic and sub-arctic areas like Alaska and northern Canada where traditional farming is largely impossible. Food insecurity has been a long-standing problem in remote northern communities where fresh produce has to be shipped large distances resulting in high costs and poor nutrition.[45] Container-based farms can provide fresh produce year-round at a lower cost than shipping in supplies from more southerly locations with a number of farms operating in locations such as Churchill, Manitoba, and Unalaska, Alaska.[46][47] As with disruption to crop growing, local container-based farms are also less susceptible to disruption than the long supply chains necessary to deliver traditionally grown produce to remote communities. Food prices in Churchill spiked substantially after floods in May and June 2017 forced the closure of the rail line that forms the only permanent overland connection between Churchill and the rest of Canada.[48]

Environmental conservation

Up to 20 units of outdoor farmland per unit of vertical farming could return to its natural state, due to vertical farming's increased productivity.[49][50] Vertical farming would reduce the amount of farmland, thus saving many natural resources.[22]

Deforestation and desertification caused by agricultural encroachment on natural biomes could be avoided.[51] Producing food indoors reduces or eliminates conventional plowing, planting, and harvesting by farm machinery, protecting soil, and reducing emissions.[38]

Traditional farming is often invasive to the native flora and fauna because it requires such a large area of arable land. One study showed that wood mouse populations dropped from 25 per hectare to 5 per hectare after harvest, estimating 10 animals killed per hectare each year with conventional farming.[52] In comparison, vertical farming would cause nominal harm to wildlife because of its limited space usage.[7]

Problems

Economics

Vertical farms must overcome the financial challenge of large startup costs. The initial building costs could exceed $100 million for a 60 hectare vertical farm.[53] Urban occupancy costs can be high, resulting in much higher startup costs – and a longer break even time – than for a traditional farm in rural areas.

Opponents question the potential profitability of vertical farming. In order for vertical farms to be successful financially, high-value crops must be grown since traditional farms provide low-value crops like wheat at cheaper costs than vertical farms.[5] Louis Albright, a professor in biological and environmental engineering at Cornell stated that a loaf of bread that was made from wheat grown in a vertical farm would cost US$27.[54] However, according to the US Bureau of Labor Statistics, the average loaf of bread cost US$1.296 in September 2019, clearly showing how crops grown in vertical farms will be noncompetitive compared to crops grown in traditional outdoor farms.[55] In order for vertical farms to be profitable, the costs of operating these farms must decrease. The developers of the TerraFarm system produced from second-hand, 40-foot shipping containers claimed that their system "has achieved cost parity with traditional, outdoor farming".[56]

A theoretical 10-story vertical wheat farm could produce up to 1,940 tons of wheat per hectare compared to a global average of 3.2 tons of wheat per hectare (600 times yield). Current methods require enormous energy consumption for lighting, temperature, humidity control, carbon dioxide input and fertilizer and consequently the authors concluded it was "unlikely to be economically competitive with current market prices".[57]

According to a report in *The Financial Times* as of 2020, most vertical farming companies have been unprofitable, except for a number of Japanese companies.[2]

Energy use

During the growing season, the sun shines on a vertical surface at an extreme angle such that much less light is available to crops than when they are planted on flat land. Therefore, supplemental light would be required. Bruce Bugbee claimed that the power demands of vertical farming would be uncompetitive with traditional farms using only natural light.[58][59] Environmental writer George Monbiot calculated that the cost of providing enough supplementary light to grow the grain for a single loaf would be about $15.[60] An article in the Economist argued that "even though crops growing in a glass skyscraper will get some natural sunlight during the day, it won't be enough" and "the cost of powering artificial lights will make indoor farming prohibitively expensive".[61] Moreover, researchers determined that if only solar panels were to be used to meet the energy consumption of a vertical farm, "the area of solar panels required would need to be a factor of twenty times greater than the arable area on a multi-level indoor farm", which will be hard to accomplish with larger vertical farms.[5] A hydroponic farm growing lettuce in Arizona would require 15,000 kilojoules (4.2 kWh) of energy per kilogram of lettuce produced.[62] To put this amount of energy into perspective, a traditional outdoor lettuce farm in Arizona only requires 1100 kJ of energy per kilogram of lettuce grown.

As the book by Dr. Dickson Despommier *The Vertical Farm* proposes a controlled environment, heating, and cooling costs will resemble those of any other multiple story building.[63] Plumbing and elevator systems are necessary to distribute nutrients and water. In the northern continental United States, fossil fuel heating costs can be over $200,000 per hectare. Research conducted in 2015 compared the growth of lettuce in Arizona using conventional agricultural methods and a hydroponic farm. They determined that heating and cooling made up more than 80% of the energy consumption in the hydroponic farm, with the heating and cooling needing 7400 kJ per kilogram of lettuce produced.[62] According to the same study, the total energy consumption of the hydroponic farm is 90,000 kJ per kilogram of lettuce. If the energy consumption is not addressed, vertical farms may be an unsustainable alternative to traditional agriculture.[62]

The energy requirements of vertical farming lead to significant land use to provide the energy. For every acre of crops grown via vertical farming, 5.4 acres of solar panels would be required to supply the energy via solar power.[64] Thus in practice, vertical farming may require more land than traditional farming, not less.

Pollution

There are a number of interrelated challenges with some potential solutions:

- Carbon emission: A vertical farm requires a CO_2 source, most likely from combustion if colocated with electric utility plants; absorbing CO_2 that would otherwise be jettisoned is possible. Greenhouses commonly supplement carbon dioxide levels to 3–4 times the atmospheric rate. This increase in CO_2 increases photosynthesis at varying rates, averaging 50%, contributing not only to higher yields but also to faster plant maturation, shrinking of pores, and greater resilience to water stress (both too much and little). Vertical farms need not exist in isolation, hardier mature plants could be transferred to traditional greenhouses, freeing up space and increasing cost flexibility.

- Crop damage: Some greenhouses burn fossil fuels purely to produce CO_2, such as from furnaces, which contain pollutants such as sulphur dioxide and ethylene. These pollutants can significantly damage plants, so gas filtration is a component of high production systems.
- Light pollution: Greenhouse growers commonly exploit photoperiodism in plants to control whether the plants are in a vegetative or reproductive stage. As part of this control, the lights stay on past sunset and before sunrise or periodically throughout the night. Single story greenhouses have attracted criticism over light pollution, though a typical urban vertical farm may also produce light pollution.
- Power needs: If power needs are met by fossil fuels, the environmental effect may be a net loss;[65] even building low-carbon capacity to power the farms may not make as much sense as simply leaving traditional farms in place while burning less coal. Louis Albright argued that in a "closed-system urban farming based on electrically generated photosynthetic light", a pound of lettuce would result in 8 pounds of carbon dioxide being produced at a power plant, and 4,000 pounds of lettuce produced would be equivalent to the annual emissions of a family car.[54] He also argues that the carbon footprint of tomatoes grown in a similar system would be twice as big as the carbon footprint of lettuce. However, lettuce produced in a greenhouse that allows for sunlight to reach the crops saw a 300 percent reduction in carbon dioxide emissions per head of lettuce.[54] As vertical farm systems become more efficient in harnessing sunlight, they will produce less pollution.
- Ventilation: "Necessary" ventilation may allow CO_2 to leak into the atmosphere, though recycling systems could be devised. This is not limited to humidity tolerant and humidity intolerant crop polyculture cycling (as opposed to monoculture).
- Water pollution: Hydroponic greenhouses regularly change the water, producing water containing fertilizers and pesticides that must be disposed of. Spreading the effluent over neighboring farmland or wetlands would be difficult for an urban vertical farm, while water treatment remedies (natural or otherwise) could be part of a solution.

See also

- Arcology
- Development-supported agriculture
- Folkewall
- Foodscaping
- Green wall
- Pot farming
- Terrace (agriculture), Terrace (gardening), and Terrace (building)
- Urban horticulture

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