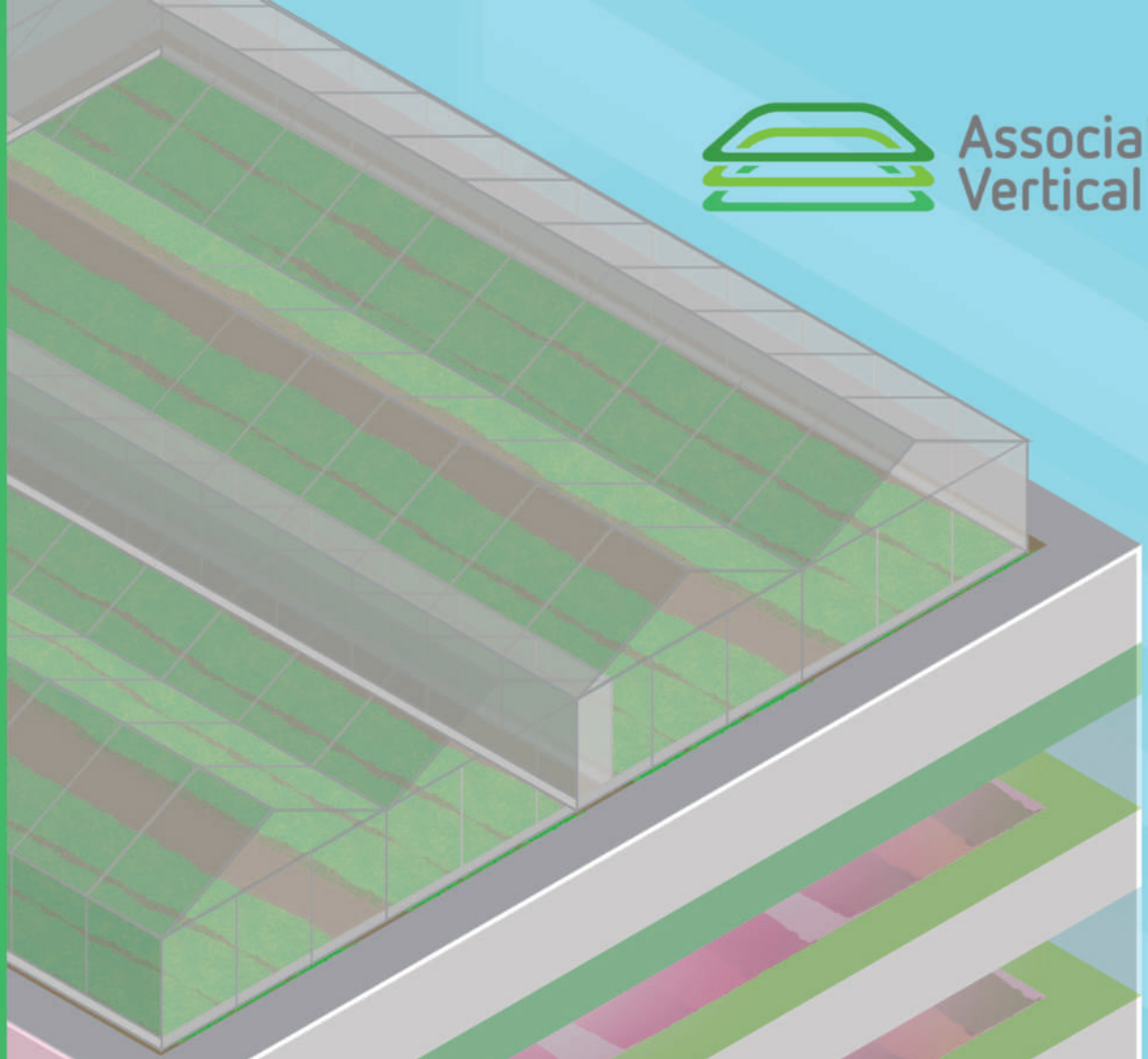

Association for Vertical Farming

THE STATE OF VERTICAL FARMING

SEPTEMBER 2016

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The Association for Vertical Farming e.V. founded in 2013, is an independent nonpartisan organization committed to educating the public – and influencing the public discourse – on global vertical farming issues. The Association for Vertical Farming e.V provides summits, workshops, newsletters, a forum and other sources of information and networking for industry leaders, policymakers, academics, and other experts to speak to its members and the public on these issues.

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Inert medias, SOP content requiring sterilization and sound cultural control.

Michael M. W.

TOP PHOTO: Vydrofarm by HydroGarden BOTTOM PHOTO: METRO Group (Source: Infarm/Merav Maroody)

INTRODUCTION

Authors: Howard Brin, Vincent Fesquet

Today's conversations about vertical farming deal almost exclusively with food production. After all the key advantages of vertical farming are to grow healthy, pesticide-free crops all year round at very high and very predictable rates of yield. However, the authors of this report believe that this is only the beginning. Vertical farming can also be used for waste water management and recycling, innovative local food distribution and business models, air quality measures, reducing greenhouse gas emissions, education, as well as playing a potential role in novel health, nutritional, and pharmaceutical applications.

Before we can begin expanding the conversation about vertical farming, we need to establish a common language that includes global industry events and definitions that can be applied to vertical farming and controlled environment agriculture (CEA). That is the first purpose. From there, the authors intend to share the state of the industry based upon the most current information available to date and expand the conversation into new opportunities and areas of possibility for vertical farming globally.

Based on survey results from the Association for Vertical Farming (AVF) members, the definition of vertical farming is the practice of producing food in vertically stacked layers, vertically inclined surfaces and/or integrated into buildings. The modern idea of vertical farming uses CEA technology. CEA facilities use environmental control (humidity, temperature, gases, etc.), fertigation[1], and potentially artificial control of light (as a supplement in the case of a rooftop greenhouse, or as a unique light source in pure indoor farming conditions).

In the current state of the industry employing a qualified workforce is one of the main challenges in the private sector. Vertical farming CEA facilities use a diverse team of experts from different backgrounds that include growers, horticulturalist, mechanical, biological and electrical engineers, architects, data scientists, food safety experts, etc. This report looks at CEA education programs and degrees in schools, universities and private companies worldwide. It posits the next steps needed to develop the next generation of vertical farmers.

As the industry continues to educate and search for qualified vertical farmers, cities will have to cope with urban regulations to foster industry development. We analyzed architecture and urban regulations, and shed light on how Singapore, New York City and Paris are adapting to urban regulations as well as various programs that support vertical farming and their respective city sustainability objectives.

We point out how cities and various programs can provide funding or support for vertical farming companies. However, for any enterprise to enter the vertical farming industry, it is crucial to have a sound business proposition and understand how to survive and scale in local markets. We address and analyze finance and business models and provide a roadmap for entrepreneurs.

Vertical farming technologies are not limited to food production. An important and generally under-reported production method for medicinal products is vertical farming. Plant-made pharmaceuticals may create the opportunity to produce biologically active molecules at a low-manufacturing cost. We outline what are plant-made pharmaceutical products and production advantages used for recombinant protein pharmaceutical production. We were careful to include data on the use of medicinal plants in various regions of the world. With medicinal plants used widely in Asia, we chose to highlight current business opportunities for vertical farming beyond food. We also mention market opportunities and novel applications in the biopharming space, that is, using plants to manufacture novel biological agents, which has been difficult to imagine before the rise of new CEA and low cost genetic engineering technologies. However, this report will not address medicinal marijuana developments despite market growth in operational facilities that use CEA technologies.

One main purpose of the white paper is to evaluate global developments and document the regional specificities of the vertical farming industry, as driven by bottom-up (private sector-led) and/or top-down (government-led) initiatives in each region. This report identifies in specific regions how the building up of vertical farming can also promote adjacent industries (e.g., semiconductor and LED lighting industry in Taiwan). As the industry grows within each

[1] Fertigation is the injection of fertilizers, soil amendments, and other water-soluble products into an irrigation system.

country there will be champions, survivors and failed enterprises.

Media coverage in the West and Asia reports on the scale, size, methods, models and production capabilities of vertical farms, and provides insight on the amount of operational units and trends. Although actionable data to support decision makers is limited, we assess and provide an analysis of current operational facilities and provide forecasts of overall industry trends. In the face of insufficient data and a lack of proven models, we nevertheless hope throughout the course of this report to offer the reader a complete view based on the information currently available.

This study has its caveats. As already indicated above, in the industry there is no aggregated data source, and this is the role we are attempting to fulfill. Throughout the course of the report we compiled available data from public sources and government documents, as well as from more than 30 interviews we conducted to demonstrate and forecast the development of the industry. This is one of the first attempts to describe the global vertical farming industry; moving forward we will be in a position to go deeper and add material to the study. In short, our findings indicate that before we envision vertical farms as tools for our cities, first we need to remove remaining administrative constraints, improve the training of the workforce, encourage competition, enhance business models and attract investors.

WHAT DOES A VERTICAL FARM NEED?

> *Grower experience and training. Far too many participants in this industry have far too little actual crop production knowledge and/or experience.*
>
> **Joe S.**

TOP PHOTO: Texas A&M Agrilife Research Center BOTTOM PHOTO: Teens for Food Justice

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EDUCATION

Authors: Jeffrey Landau, Howard Brin

A condensed history of agriculture can be summarized in several agricultural revolutions. First was the Neolithic Revolution[1] (around 10,000 BCE), where human cultures transitioned from the hunter-gatherer lifestyle to settlements and agriculture. Thereafter came the Arab Agricultural Revolution (700-1100)[2], the British Agricultural Revolution (1750-1800s)[3], the Scottish Agricultural Revolution (1700s-1800s)[4], and the Green Revolution (1930s-1960s).[5] These revolutions transformed and shaped human migration and agricultural processes. Centuries of knowledge and practice were perfected to seed, grow and harvest crops. Skilled farmers were the backbone of civilizations. In the 21st century, we face a rapidly growing population paralleled with a declining amount of arable land. This global issue has prompted the AgTech movement and has given rise to a new type of farmer - an urban farmer, a vertical farmer.

Agricultural Education

The development of modern technology and education created agricultural degree programs that met the needs of the 20th century farmer. These programs have produced highly skilled recruits for traditional agriculture companies but the 21st century farmer will have to move forward and learn new skills. A growing trend among the vertical farming industry is the need for talented and highly knowledgeable candidates with transferable skills geared toward agricultural technology. In an urban context, the industry requires more than the 20th century farmer - it requires engineers, horticulturists, data scientists, HVAC specialists, plant scientists and more, all with the knowledge and understanding of CEA. CEA is a combination of horticultural and engineering skills that optimize crop production, crop quality and production efficiency.[6] The urban farmer is also confronted with specific logistics and distribution downstream activities.

Today's society is experiencing agriculture and technology in a vastly new way. Our present actions as educators in agriculture will continue to shape our food security and infrastructure for decades to come. Agricultural education addresses the current and future concerns that humanity faces including: disease-stricken crops, prolonged droughts, harsh winters, natural disasters and climate change. The study of CEA has taken root in many schools and universities worldwide to address these issues as the world faces the loss of arable land. To further this progression of agriculture, today's universities will need to adapt and incorporate new focused tracks on vertical farming into their programs for the new urban and vertical farmer.

Grade School Programs

Introducing agriculture must start well before university level. In the USA, incorporating vertical farming applications into Science, Technology, Engineering and Mathematics (STEM) education and curriculum choices, would allow students to apply their STEM education to innovative ideas and projects. Teaching the fundamentals and basics of agriculture, horticulture and urban farming at the grade-school level opens the door for students to pursue a career path that is in dire need of young professionals. In Europe, EUROPEA[7] is working with a network of more than 1,000 vocational schools and institutions to develop programs within agriculture, horticulture and forestry.[8]

In Kameoka, Japan, traditionally a farming community that served Kyoto, elementary schools from 3rd to 6th grade (approximately 9- to 12-year olds) have incorporated vertical farming technology and applications in their textbooks. Spread Co. Ltd. ("Spread"), a Japanese vertical farming company, is collaborating with the board of education in Kameoka as a part of these efforts.[9] It is unknown if national Japanese textbooks at the elementary to high school

[1] Bocquet-Appel, Jean-Pierre. "When the World's Population Took Off: The Springboard of the Neolithic Demographic Transition." Science 333.6042 (2011): 560-61. Print.

[2] Watson, Andrew M. "The Arab Agricultural Revolution and Its Diffusion, 700–1100." J. Eco. History The Journal of Economic History 34.01 (1974): 8-35. Web. 2 Jan. 2016 <https://www.jstor.org/stable/2116954?seq=1#page_scan_tab_contents>

[3] Richards, Denis, and Wray Hunt. An Illustrated History of Modern Britain, 1783-1980. Harlow, Essex, England: Longman, 1983. Print.

[4] Whyte, Ian, and Kathleen A. Whyte. The Changing Scottish Landscape, 1500-1800. London: Routledge, 1991. Print.

[5] Hazell, Peter B.R. "The Asian Green Revolution." IFPRI Discussion Paper 00911 (2009): n. p. Web. 3 Jan. 2016. <https://core.ac.uk/download/files/153/6257689.pdf>

[6] Albright, Louis DeMont. Environment Control for Animals and Plants. St. Joseph, MI: American Society of Agricultural Engineers, 1990. Print.

[7] EUROPEA is an association working for the development of vocational education and training (VET) in the European green sector. This sector covers a wide field of professions within agriculture, horticulture, and forestry.

[8] "About EUROPEA." EUROPEA. EUROPEA, n.d. Web. <http://europea.org/about/>

[9] Price, J.J.Video conference interview. 22 Jan. 2016. Spread Co Ltd. See interview on pg. 45.

levels are also dedicated to youth vertical farming education and practicum. While in the USA, there has been a growing trend in elementary schools adopting agriculture education programs in their classrooms (e.g. hydroponics).

There are several student-led programs across the USA that have incorporated agriculture into their curricula. The National FFA Organization (Future Farmers of America) is an inter-curricular student organization that aims to develop students' leadership, personal, and career skills through agricultural education. The National FFA Organization follows a three-component model for educating students: classroom and laboratory instruction (contextual learning), supervised agricultural experience (work-based learning) and student leadership organizations.[10] In New York City (NYC), Teens for Food Justice (TFFJ), a non-profit that collaborates with local schools works with students by helping them to study the technology, science and business of indoor hydroponic farming, and gain experience growing produce inside their schools, and the skills needed to serve as health and nutrition ambassadors.[11]

At Jefferson Elementary in Hawaii, USA, the grade school is incorporating hydroponics into their curriculum. With a grant from Rotary Club of Honolulu Sunset, the school was able to purchase 20 hydroponic kits. Principal Garret Zakahi aims to embed sustainable practices into the school's STEM curriculum.[12]

A prime example of a comprehensive agricultural science program can be seen at Maize High School in Kansas, USA. Maize High School consists of about 1,300 students in grades 9 - 12. The agriculture program is spearheaded by science teacher Jay Super. With 20 years of teaching experience, he has started and developed the agriculture focused Career and Technical Education (CTE) program. The motivation behind this program is to raise awareness of where food comes from and to teach students how to grow their own food.[13]

These are only a few examples of how school systems are beginning to promote urban agriculture. The National FFA Organization is a model for other schools to follow as an example of promoting agricultural education in secondary schools. Further analysis is needed of secondary schools' agricultural education programs in Europe, Asia, South America and Africa to better understand the progress being made outside the USA.

University Programs

North America

Higher education systems in North America currently offers numerous degrees in CEA and horticulture. An increase in demand for CEA specialists has driven the academic community to invest more resources into new programs, hire new professors and offer new courses. This investment has been beneficial in furthering the future development of our food infrastructure but still lacks vertical farming-specific programs that will teach our students the skills needed to advance the industry. With the rise of vertical farming and the demand for these skilled professionals, now is the time for academia to develop new programs for the future of our food infrastructure.

> "The demand for university educators continues to increase, as knowledge and experience of the plant science, engineering, marketing, and agricultural production practices are required for effective implementation of CEA as a significant complement to field agriculture in the food chain. Responding to the national demand for CEA requires university level education and training. Witness the expansion of CEA programs at North Carolina State University, Michigan State University and most recently at the University of Florida…. The result of consumer demand for fresh, healthy, and locally grown vegetables, and the marketplace response to this pressure, new greenhouse food crop production is expanding and in 2014 it was estimated to contribute $11.7B to the production food chain. Moreover, continued CEA technological innovations have attracted ever growing Investments in 'AgTech' from $2.4B in 2014 to an expected $4B in 2015."
>
> - Gene Giacomelli, Professor and Director of CEAC at University of Arizona

Universities such as the University of Arizona, Cornell University, Michigan State University (MSU), Massachusetts Institute of Technology (MIT), Texas A&M AgriLife, and the Ontario Agricultural College have been leading the way in CEA education and research. These programs in North America are teaching students the skills they need to join the vertical farming industry.

The University of Arizona offers courses tailored to CEA that will directly contribute to the vertical farming industry. Courses can be viewed online at the University of Arizona's Controlled Environment Agriculture Center (CEAC) website.[14] The CEAC has ongoing research in their lunar greenhouse through NASA's Steckler Space Grant, Advanced Sensing

[10] "FFA Mission & Motto." FFA Mission & Motto. National FFA Organization, n.d. Web. 4 April 2016. <https://www.ffa.org/about/what-is-ffa>
[11] "The TFFJ Mission." Teens for Food Justice. Teens for Food Justice, n.d. Web.7 April 2016. <http://www.teensforfoodjustice.org/about-us/about-tffj/>
[12] "Sustainability Takes off at Jefferson Elementary." Hawaii DOE | Sustainability Takes off at Jefferson Elementary. Hawaii State Department of Education, n.d. Web. 7 April 2016. <http://www.hawaiipublicschools.org/VisionForSuccess/SuccessStories/Schools/Pages/Sustainability-takes-off-at-Jefferson-Elementary.aspx>
[13] Super, Jay, Personal phone interview. 4 Feb. 2015. Maize High School. See interview on pg. 18
[14] "UA Courses | Controlled Environment Agriculture Center." Controlled Environment Agriculture Center. The University of Arizona, n.d. <http://ceac.arizona.edu/>

and Climate Control Lab for Sustainable CEA Systems, Controlled Environment Plant Physiology and Technology Lab and in the South Pole Growing Chamber.

Cornell University's CEA centre provides numerous resources and workshops for its students. The Cornell University CEA program actively conducts research for all aspects of commercial-scale vegetable crop production. This research focuses on CEA, lettuce, tomatoes, spinach, lighting, marketing, temperature control and energy. The Cornell CEA program has published two Grower's Handbooks to the public: lettuce[15] and spinach.[16] These guides are excellent resources for individuals to learn about the seed-to-harvest cycle of these greens.

Dr. Erik Runkle is one of the leading Professors in the Department of Horticulture for Michigan State University. Dr. Erik Runkle's floriculture program focuses on the environmental physiology of ornamental herbaceous plants. Alongside this, MSU is researching lighting applications in floriculture crop production, greenhouse environment for energy conservation management, growth and development of herbaceous perennials, and plant growth regulators on greenhouse crops. MSU has in-depth and comprehensive programs for those looking to obtain an undergraduate or graduate degree from an accredited university.[17]

The MIT Media Lab Open Agriculture Initiative, run by Director Caleb Harper, develops hardware and software for sensor-controlled hydroponic and aeroponic agriculture systems. Through their Food Computers, Caleb Harper and his team are experimenting with innovative growing techniques and recipes to optimize food infrastructure.[18] The team aims to openly share their food computers and plant recipes online for all to access. The MIT Media Lab is also in partnership with Indoor Harvest to design and build a high-pressure aeroponic watering system as part of MIT Media Lab's "Changing Places" research.[19]

Dr. Michael Gould of Texas A&M is the Director of the Texas AgriLife Research Center and Extension Center in Dallas. One of his initiatives is the Food 3.0 project, integrating plant science with renewable energy and CEA technologies, dramatically increasing the sustainability and yields of urban food production systems to help meet the world's food needs in the 21st century. The Food 3.0 project has three objectives: eliminate production losses, reduce non-renewable inputs, and optimize plants for low-input production.[20]

In Canada, the Ontario Agricultural College (OAC) at the The University of Guelph has dedicated multiple research facilities for CEA. The Controlled Environment Systems Research Facility and Space and Advanced Life Support Agriculture program conducts intensive research and development for space and closed-environment related activities. This is done in partnership with Intravision Group, a bio-light and systems integration company working with new technologies for production of foods and plant-made pharmaceuticals.[21] Research topics include multispectral LED arrays, antibody engineering for greenhouse protection, indoor air bio-filters, and green roof research.

Asia

Countries such as mainland China, Taiwan, Japan, and South Korea support vertical farming infrastructure through R&D, operations and education. Although there is a substantial amount of work being done to incorporate vertical farms into Asia's food infrastructure, governments, institutions and universities will need to do more. They can consider integrating training and educational programs to develop and progress the future food infrastructure needed to feed Asia's rapidly growing population of 4.4bn.[22]

Mainland China

Since 2002 Mainland China has made significant developments in vertical farming R&D projects through state-controlled research institutions. It was not until 2013 that state-sponsored research initiatives have started to add agricultural universities as part of programs to research vertical farming related technologies.

The first group of state-sponsored R&D projects began in the 2000s, and focused on hydroponics using artificial lighting. The R&D teams were led by Professor Yang Qichang. In 2013, the central government set the policy of "industry regurgitation-feeding agriculture"[23] and added vertical farming into the national "863 Program". The 863 Program is a central government-level policy research initiative to close technology gaps betwen mainland China and foreign countries. The focus is the adoption and advancement of technologies in various sectors to assure mainland

[15] Brechner, Melissa, and A.J Both. Hydroponic Lettuce Handbook. Ithaca: Cornell Controlled Environment Agriculture, n.d. PDF.
[16] Brechner, Melissa, and David De Villiers. Hydroponic Spinach Production Handbook. Ithaca: Cornell Controlled Environment Agriculture, n.d. PDF.
[17] "Degree Requirements." MSU Horticulture. Michigan State University, n.d. Web. <http://www.hrt.msu.edu/degree-requirements/>
[18] "Farming for the Future." Open Agriculture. MIT Media Lab, n.d. Web. <http://openag.media.mit.edu/>
[19] "MIT CITY FARM." Indoor Harvest. Indoor Harvest, 2013. Web. <http://indoorharvest.com/blogs/projects/56681221-mit-city-farm>
[20] Gould, Michael. "Urban Food Production." Urban Food Production. Food 3.0, n.d. Web. <http://food3point0.com/>
[21] "Bio." Intravision Group. Intravision Group, n.d. Web. 8 April 2016. <http://www.intravisiongroup.com/about-me-shift/#bio>.
[22] "Asia Population (LIVE)." Population of Asia (2016). WorldOMeters, n.d. Web. 2 June 2016. <http://www.worldometers.info/world-population/asia-population/>.
[23] As the Chinese government had until recently put more weight on developing industry at the cost of other domains, including environment and agriculture, it is now calling for the accelerated development in these less advanced domains with the assistance of industry private players.

China's financial independence from other countries' foreign technologies. With this policy, selected universities and institutions receive funds to research and optimize vertical farming technologies.

Through the 863 Program in 2013, the Ministry of Science and Technology funded the National High Science & Technology Project on Intelligent Plant Factory Production with USD 8m to be used between 2013 and 2017. The Chinese Academy of Agricultural Sciences (CAAS) is the main organizer, with 15 other universities, institutions and companies involved. The project is led by Professor Yang Qichang as Chief Scientist.

As a part of the National High Science & Technology Project many universities have been tasked to focus on specific research initiatives. For example, Zhejiang University was chosen to concentrate on "Research on Artificial Lighting Plant Factory Technology Integration", and to aid research a vertical farming facility was built in 2013 covering 800 sqm (8,611 sqft) in Changxing, China to grow lettuce. In the same year, Nanjing Agricultural University became responsible for the "Research on Application of Semiconductor Lighting in Plant Tissue Culture". Although universities are now involved in R&D projects focused on technologies for vertical farming, it is unclear if the R&D projects under the 863 Program will provide faculty at universities the resources and skills to develop vertical farming degree programs and/or vocational schools in mainland China's higher education system. Nonetheless, research efforts are paving the way to develop advances in technology for the vertical farming industry.

Taiwan

In Taiwan, education and research have primarily been driven by Professor Wei Fang of the Department of Bio-Industrial Mechatronics Engineering at National Taiwan University (NTU).[24] Wei Fang has been widely recognized as the "father" of vertical farming in Taiwan. His area of research is broad and includes: environmental control of bio-systems, simulation and optimization, aquacultural engineering and phytomation, ion selective sensors, LED spectra for particular purposes, fuel cells, and technologies related to cost reduction and quality improvement of crops, facilities, and systems.

In 2010, the Institute of Agriculture at NTU formed a cross-disciplinary research team to engage in research, education and promotion related to vertical farms in Taiwan with financial support from NTU, the Council of Agriculture (COA), the National Science Council (NSC), and the Ministry of Education. NTU has started weekend training courses on "Plant Factory Applied Technology" since 2012. Attendees have included employees and senior managers from a broad spectrum of industries. National Taiwan University of Science and Technology (NTUST) opened two courses on aquaponics in 2014 with the building of an aquaponics rooftop demonstration farm.

Japan

As one of the leading nations in the vertical farming industry, several universities in Japan are focused both on research projects and developing the next generation of skilled workers. The following are three universities engaged in research and education.

At the Tamagawa University Research Institute in Tokyo, The Biosystems & Biofunctions Research Center focuses on environmental conservation, increased food production and stable energy supplies. The research center is working on four big issues: developing a novel agricultural production system using optical semiconductor devices, photomorphogenesis research in plants, developing a plant cultivation system in space, and developing herbicides using natural products and microorganisms.

The Center for Environment, Health and Field Sciences ("Center') at Chiba University aims to promote fundamental and applied research on science and technology related to environment, health, urban environmental horticulture and field sciences. This facility works in coordination with undergraduate and graduate schools at the Chiba University. The Graduate School of Horticulture conducts education and research in natural sciences, cultivation, plant breeding, biotechnology of bio-resources, landscape design and engineering, human health and welfare, environmental science for sustainable cities and nature conservation, food system studies, and environmental and development economics.

The Center was founded in April 2003 with 15 academic members and over 50 associate academic members belonging to various scientific fields within Chiba University. Attached to the Center is the Kashiwanoha Kampo Clinic of Chiba University, founded in June 2004, as well as the Kashiwanoha Acupuncture Clinic of Chiba University, founded in November 2006. The Center has three horticultural experimental stations in Kashiwa, Atagawa and Numata.

India and Singapore

India has limited education and training programs for CEA. In order to address this, CEA certification curricula must be introduced at Indian agricultural science institutions. A leading hydroponics researcher for over 20 years has been Dr. GL Bansal, a professor of plant physiology at CSK HP Agricultural University in Palampur, India. Dr. GL Bansal grows

[24] Department of Bio-Industrial Mechatronics Engineering. National Taiwan University. n.d., Web. 10 May 2016. <http://bime.ntu.edu.tw/main.php>

peppers and tomatoes hydroponically and has delivered several lectures on hydroponics and vertical farming.

Extracurricular activities focusing on hydroponics and urban farming should be made available at primary and secondary school levels in private schools, where funding is more available than for government schools. A further in-depth analysis of India's agricultural programs is needed to better understand the agricultural environment.

Currently, CEA and agriculture programs are non-existent in Singapore. Polytechnic schools have limited programs and horticulture curriculums focus on landscape architecture; leaving interested students (and farmers) with nearly no access to education.[25] One option is at Ngee Ann Polytechnic from Senior Lecturer Gregory Chow. As part of his research activities, he is finding ways to develop hydroponic cultivation and aquaponic systems for vertical farming. As an island city-state, Singapore is in an ideal location to create and develop an urban agriculture and CEA program, with the limited amount of land it occupies to further increase its food security.

Europe

Europe is currently at the forefront of greenhouse and agricultural technologies. With Dutch universities leading the way, Europe is in a prime position to lead vertical farming by bringing their CEA knowledge and agriculture experience together with technology and innovation.

HAS University, located in 's-Hertogenbosh, Netherlands, has a small but ambitious horticulture program, training approximately 50-70 students per year, with a small portion interested in indoor vertical farming. Senior Lecturer Jasper den Besten at HAS University hopes for an increase in interest and discussion of vertical farming. This increased interest would allow HAS University to establish an indoor vertical farming bachelor's degree.[26]

Wageningen UR is a collaboration between Wageningen University and the DLO foundation[27]. The urban agriculture program at Wageningen UR aims to develop several different areas: design and research of new concepts for urban land use, connecting community and public organizations with citizens and business owners, creating space for urban agriculture, and evaluating current and future projects to advise policy makers and business partners. Seppe Salari, a student at Wageningen University, described the program as having enthusiastic, resourceful and knowledgeable professors.[28]

At Nottingham Trent (NT) University, Professor Lu Chungui is a leading researcher in sustainable agriculture. Professor Lu Chungui's goal is to investigate resource use efficiency in particular nutrients (e.g. N, P) and energy (LED lighting) use efficiency in both soil and soilless growing systems. NT's other research includes: sustainable urban agriculture through innovative vertical farming, innovative energy saving and climate control systems for greenhouses, LED lighting to regulate plant growth and development, and systematic functional analysis of nitrogen/phosphate use efficiency in crops.[29]

Non-Accredited Programs

Those seeking to advance their agricultural skills can participate in numerous public courses offered by various companies within the industry, which also aim at developing the nascent industry and promote their solutions. Companies including CropKing, Farmtek, Brightbox, and Bright Agrotech offer several training modules to teach future farmers. These courses offer individuals a great opportunity to learn from experienced professionals without having to return to an academic institution.

[25] Lionel Wong. Phone interview. 3 June 2016. UpGrown Farming Company. See interview on pg. 30.
[26] den Besten, Jasper. Phone interview. 25 Jan. 2016. See interview on pg. 16.
[27] The DLO Foundation is the legal entity within Wageningen University and Research Centre (Wageningen UR) that contains the applied research institutes.
[28] Salari, Seppe. Phone Interview. 28 Jan. 2016. Wageningen UR
[29] "About NTU - Staff Directory." Nottingham Trent University. Nottingham Trent University, n.d. Web. 10 Jan. 2016. <https://www.ntu.ac.uk/apps/staff_profiles/staff_directory/185546-2/26/chungui_lu.aspx>
[30] "Grower's School." Cropking. Cropking, n.d. Web. <https://www.cropking.com/catalog/grower%E2%80%99s-school>
[31] "CEA Learning Center." FarmTek. FarmTek, n.d. Web. 5 Jan. 2016 <http://www.farmtek.com/farm/supplies/>
[32] "Upstart University: Learn How to Start Your Own Farm." Upstart University. Bright AgroTech, n.d. Web. 5 Jan. 2016. <https://university.upstartfarmers.com/>
[33] "Growing without Daylight (SPOC)." HAS Kennistransfer & Bedrijfsopleidingen. HAS Hogeschool, n.d. Web. 5 Jan. 2016. <http://www.haskennistransfer.nl/growing-without-daylight-spoc>

Company	Program	Description
CropKing[30]	Introductory grower workshop	A two-day program that teaches the fundamentals of controlled environment vegetable production systems.
FarmTek[31]	Hydroponics & aquaponics school	A three-day school teaching participants the latest in growing, CEA, guest speakers and more.
Bright Agrotech[32]	Upstart University	A 15+ course covering basics of growing techniques, business and financial planning, and market research.
Brightbox[33]	Working with daylight-free multi-layer cultivation Cultivation without daylight Plant Physiology Business Management for Horticulture	Brightbox is an initiative of Botany, HAS University of Applied Sciences and Philips Lighting, in close collaboration with the Province of Limburg. This collaborative offers several courses specializing in indoor agriculture and business. All courses are located in 's-Hertogenbosch, Netherlands.

Table : Non-Accredited Programs offered internationally

Conclusion

A vertical farm will employ a diverse team of experts that come from different backgrounds. Teams would include mechanical, biological, and electrical engineers, data scientists, nutrition and food safety experts, growers and horticulturists. To further agriculture and technology, universities and private enterprises will need to create programs incorporating plant science into engineering, business, marketing, logistics, distribution and architecture programs. Engineers will need to understand how plant physiology effects design and equipment choices. Business managers will need to understand plant life and harvest cycles.

The industry needs a vertical farming educational track that can streamline the skills needed to own, run and operate a vertical farm. A vertical farming track under a horticulture, engineering, business, or architecture degree would create exceptionally skilled talent that would have the opportunity to profit well from vertical farming operations.

Students should know both the business and operational sides of vertical farming. Topics such as market analysis, operational management, labor modeling, marketing, determining price points, logistics and distribution are key components that all vertical farms utilize. Programs that aim to incorporate these fundamentals to their studies will produce top-notch talent.

The starting point for CEA, vertical farming, and urban agricultural education should start before higher education. Incorporating these skills and lessons into secondary schools would create new opportunities for students to pursue following their graduation. Building international bridges of knowledge between America's STEM education policy, Europe's EUROPEA project, Japan, Taiwan and mainland China institutions are essential components in furthering the agricultural education of our students and the global workforce.

HAS University

Interviewee: Jasper den Besten, Senior Lecturer, HAS University
Interviewer: Howard Brin, Association for Vertical Farming

Educating the future

Senior Lecturer Jasper den Besten at HAS University has been working in the applied research and education department for almost 35 years, focusing on CEA greenhouse technology and plant breeding. In 2009, Jasper den Besten began indoor vertical farming R&D in collaboration with PlantLab. Despite limited operational know-how and case studies, the partnership discovered in an indoor controlled environment an operator can easily produce 3x more leafy greens compared to a high-tech CEA greenhouse. Based on the findings, Jasper den Besten decided to dedicate research on indoor vertical farming cultivation systems and LED lighting, with the end goal to educate future vertical farmers.

As a beginning to the education process, Jasper den Besten and HAS University (in collaboration with industry partners) launched an online educational course “Growing Without Daylight”. The courses range from cultivation systems to photosynthesis, but a main focus is on LED lighting technology applied in indoor vertical farms.

The need for students interested in vertical farming technologies

At HAS University’s horticulture program, each year there is approximately 50 - 70 students, but only a small portion are interested in indoor vertical farming. The students primarily come from the Netherlands and have a background in traditional farming or greenhouses, with ambitions’ to take over their family's conventional farm or greenhouse. An additional option is to find a commercial job at a greenhouse, farm or seed company. This prevents HAS University from establishing a bachelor degree course on vertical farming, but hopefully in the coming years interest will increase and discussions will steer towards creating a focused indoor vertical farming discipline. Jasper den Besten said if trends signal an increase in indoor vertical farming, there is the possibility to develop a program.

Photosynthesis vs LED efficiency improvements

According to Jasper den Besten, there is a need to improve LED lighting efficiencies but it is not entirely the most logical advancement at this point for indoor vertical farms. The LED lighting industry has already achieved almost three micromoles per/w and LED energy to light conversion is approximately 60%. There is the possibility to reach 70%. However, to achieve these improvements, high capital investments are required to develop completely different LED lights to make them more efficient.

Instead of the industry devoting improvements primarily on LED Lighting, Jasper den Besten believes it is beneficial to focus more on increasing efficiencies in the photosynthesis process of plants. At the moment photosynthesis efficiency is only 4%, but if we are capable of increasing plant photosynthesis efficiency, the effects would eclipse LED lighting. Jasper den Besten mentioned over the past five years it was possible to raise the production from 200 to 300 grams per sqm / day and it may be possible to harvest 400 grams per sqm / day by optimizing light capture through smart spacing systems and different lighting recipes for different growth stages.

Texas A&M AgriLife Research Center

Interviewee: Dr. Mike Gould, Director, Strategic Initiatives, Texas A&M AgriLife Research Center - Dallas
Interviewer: Howard Brin, Association for Vertical Farming

Staying alive is different than staying healthy

Dr. Mike Gould throughout his career has touched upon several issues in his decades of research. In terms of the food and supply value chain, it can be broken down to two parts: calories and nutrition. The Western world tends to consume more calories than nutrition, which has partly been caused by the current agricultural system that operates primarily to increase yields and transportation of food, rather than nutritional optimization. On the other hand, in the developing world more people eat to stay alive – and agriculture tends to be more local but with lower yields that are generally not as nutritious.

For vertical farming there is immense opportunity. Similar to any emerging industry, the technological developments by consumers and regulators are less understood. As people become more conscious of their food, undoubtedly there will be a way to add more value by increasing nutritional content of each product. There needs to be a way to cascade this issue.

If we figure out how to produce food in CEA, there will be a dramatic increase in yield per space, but also with a need to decrease the energy requirements. As we increase yield per space, decrease energy requirement and focus vertical farming market foods to have higher nutritional content, any given food system will have better control of the value chain. This is applicable to both the developed and developing worlds.

To innovate is to find solutions

The cannabis industry is a politically sensitive topic, but putting political arguments aside, taking a sensible look at the development of the industry speaks truth to what vertical farming can accomplish in a shorter period of time. In the USA, for example, the cannabis industry was able to innovate indoor plant growth with limited options: zero federal grants, university research, legalized lab testing and limited published literature; and without annual conferences for the academic and private sectors. Despite its limitations (and operating through trial and error), cannabis innovators took cannabis plants indoors and over time reduced the size of the crop, and simultaneously increased the "nutritional" content (15x fold) and yields.

It is possible this can also be applied to food production. The cannabis industry spent approximately 50 years without all of the scientific tools available to them. Undoubtedly, there was an incentive driving these advancements - market demand and being a very high valued crop. Although food production does not demand the same price points as cannabis, incentives such as understanding the nutritional content of food and production location, will help drive advancements for vertical farming food production. Fortunately, unlike the cannabis industry that generally operates underground, food production is capable of using the abovementioned tools.

Texas A&M AgriLife Research Center

As a research organization, the Texas A&M AgriLife Research Center is not focused on improving areas where activity by private and commercial entities create incremental improvements such as LED lighting and CEA systems. Research instead concentrates on the fundamental part of any cultivation system, plants. At Texas A&M AgriLife Research Center scientists are engaged in developing plant technology to optimize growth within indoor climates, which is the ability to dwarf plants and increase nutritional content, and with the purpose to be developed for practical purposes.

Think outside the box

Dr. Mike Gould proposes the vertical farming industry should move from designing systems that focus on only stacking layers in 2D space. The industry will stagnate if entrepreneurs continue to copy business models that are only making incremental changes. There needs to be advancements in plant breeding and engineering lights that are organized into 3D spaces. The entities that are capable of making these changes will advance the industry and possibly become a supplement to food systems.

Maize High School

Interviewee: Jay Super, High School Teacher, Maize High School
Interviewer: Jeffrey Landau, Association for Vertical Farming

USA high school students taking the lead to build hydroponic systems

Maize High School located in Maize, Kansas, USA, consists of about 1,400 students in grades 9 - 12. In 2013, the high school's district received funding from the State of Kansas and Kansas Farm Bureau to start an agriculture education program. Following the start of this program, Maize High School received donations from Sedgwick County Farm Bureau, Cargill, and several individuals. Science teacher Jay Super, a 20-year veteran educator that started and developed the agriculture-focused Career and Technical Education (CTE) program, spearheads the agriculture program.

The initial goal was to procure and apply hydroponic systems available in the market, but Jay Super explained that eventually the students began to create their own systems made from PVC piping. He observed students developed a real interest where food comes from, how it is produced and processed, and the science and technology behind it. Jay Super sees students take a keen interest in obtaining information on both sides of the story related to agriculture reports.

Hydroponics agriculture program

The motivation behind the program derived from two ideas: raising awareness of food provenance and having students grow their own food. The program was designed to incorporate three levels of the CET education process: introduction, technical and application. The introductory level introduces students to the importance of agriculture, which covers a broad understanding of the various applications of agriculture and the numerous career opportunities within the industry. The technical level goes in-depth regarding plant sciences. This includes horticulture and food science classes. At this level, students investigate, research, and evaluate plant production, processing, distribution, selection and packaging. The application level gives students the opportunity to learn basic financial practices involved with running and maintaining an agriculture operation. This level includes an accounting class that covers the principles and procedures in running an agriculture business. On top of this, students are encouraged to take an agriculture-based internship or focus on an agriculture specific design project. The program has been a great success among students, faculty and parents.

In order to provide strong fundamental knowledge on controlled environmental agriculture production, Jay Super is looking to expand the program and create a permanent greenhouse onsite for students to use as a lab and resource. The hope is to bring on more faculty to facilitate teaching and create an agriculture, greenhouse and hydroponics focused mechanics class that will allow students to critically solve and engineer new devices for use. Jay Super noted students are encouraged to design their ideas, which will hopefully include vertical systems. With help from the National FFA organization Jay Super hopes to raise funds to further develop and expand his Ag-Science program.

WHAT DOES A VERTICAL FARM NEED?

Educate individuals and companies for open-source policy and spreading the lesson learned. Innovation and capabilities are the accelerators of this new endeavor, not patents.

Yishai N.

TOP PHOTO: UrbanFarmers AG BOTTOM PHOTO: Intravision Group AS

2

ARCHITECTURE AND URBAN REGULATIONS

Progressing Towards Sustainable Cities

Authors: Vincent Fesquet, Howard Brin, David Murayama

In the 2000s early renderings of vertical farms made by architects and designers were first imagined and designed as utopian-inspired skyscrapers. Although creative and appealing the renderings far exceed technical and financial feasibility. In the late 2000s and early 2010s more practical designs were created. For example, Plantagon designed a model through a tronconic building shape using a conveyor belt system for plant harvesting, and BrickBorn Farming imagined a fully enclosed building using artificial lighting. The two projects went into implementation details, but have not been built or operational. But around the same time and when *The Vertical Farm: Feeding the World in the 21st Century* by Professor Dickson Despommier was published, vertical farms began to emerge and operational developments started to occur.

There has been a gradual increase in numbers of rooftop greenhouses and indoor vertical farms, but operating at a scale on a city-by-city level, based on urban regulations and financial viability. However, this is now beginning to change; and cities are starting to adapt and interpret urban regulations to foster industry development. In this chapter we look at architecture and urban regulatory constraints related to vertical farming, and follow by looking at how Singapore, New York City (NYC) and Paris are supporting vertical farming initiatives as a part of their sustainability objectives.

Architecture and urban regulations

Indoor vertical farms

The main concerns of indoor vertical farms using artificial lighting in relation to architecture are load and operational facility use specifications, particularly fire safety compliance and electrical hazards. There are many architecture and urban regulatory constraints shared between indoor vertical farms and rooftop greenhouses, and as such, we focus on rooftop greenhouses.

Challenge: finding commercial space

The urban regulations adapted to rooftops and warehouses are in relation to the specific needs of a rooftop greenhouse and indoor vertical farming commercial activity. Finding proper space for both types of operational facilities is challenging. For prospective rooftop greenhouse locations, cities have initiated and implemented GIS mapping to find ideal rooftop flat space, but finding proper space (particularly for commercial sites) is difficult. The main issue lies in the need to cope with regulations in terms of access, security and use, which is not possible to analyze with only GIS mapping. If any entity wants or needs to build a project on a rooftop, they will have to deal with building construction codes and urban regulations in terms of height and the ability to build additional surfaces.

In general, cities have to adapt and / or interpret urban regulations to foster agriculture. Zoning will have to reinterpret and permit for vertical farming activities within the city, and rooftop use through the ability to build greenhouses in excess of building height limits. A few cities have taken the first steps to adapt local codes to promote rooftop farming, which includes greenhouses.

NYC, for example, in 2012 as an initiative to increase sustainability throughout the city, the New York City Council adopted the Zone Green Text Amendment. One amendment involved regulation changes on industrial, commercial and school buildings for rooftop greenhouses. The zoning amendment change allows for rooftop greenhouses to be exempt from floor area and height limits, and the rooftop greenhouse must not exceed 7.62 m (25 ft) in height. The zoning change, however, prohibits rooftop greenhouses to be located on top of buildings that contain residences or sleeping accomodations.[1]

As for Paris, rooftop space has been identified as suitable for rooftop greenhouse use and a review process has been initiated on urban regulations to allow for vertical farming on rooftops in excess of building heights. This should be

[1] New York City Government. Department of City Planning. Zone Green (N 1201132 ZRY) Enacted by the City Council: 4/30/2012. New York City, Department of City Planning. April 2012. Web. 16 April 2016. <http://www1.nyc.gov/assets/planning/download/pdf/plans/zone-green/adopted_text_amendment.pdf>

effective in August 2016. Paris has also launched in 2016 the Parisculteurs[2] initiative, which provides plans and load resistance characteristics for various sites for project development. Romainville, an eastern suburb of Paris, adopted in 2013 new city planning rules allowing for new zoning and the ability to introduce farming activities within the city and to provide the opportunity to erect rooftop greenhouses for farming purposes. The greenhouse may exceed the building's height by a maximum of 7 m (22.9 ft).[3,4]

Rooftop and façade greenhouse facilities

There is a growing trend of rooftop and façade greenhouses appearing in cities and particularly in the West on various type of buildings from schools to supermarkets. The use of thick façades for food production purposes (e.g., Vertical Harvest in Jackson Hole, USA) is a pioneering use of form and function. Apart from an aesthetic change and production purpose, the use of a *thick* façade greenhouse could be viewed as the first development of Building-Integrated Agriculture (BIA).

No matter the type of growing technique used (open-air or CEA greenhouse), facilities face the same initial issues after finding proper space: load resistance and access. In the case of rooftops, access is critical and should have a dedicated area to avoid usage conflicts. Critical points also include the ability to deal with technical equipment obstructions on rooftops and regulatory compliance, which are not directly related to production purposes including: elevator, staircase and HVAC fittings, fire safety, security and food safety.

Rooftop access and load resistance

The first two issues that need to be addressed for rooftop greenhouses are space access and load resistance. Rooftops need to cope with regulations in term of access, security (including fire protection) and use (e.g. ability to have employee access), and with architectural aesthetics and labor code in the case of commercial activities. Rooftop load resistance is measured and dealt with according to the type of technique envisioned. This is dependent on the thickness of substrate. Growing beds may range between 240kg / sqm (15 cm thick) over 600kg / sqm ahead of 40cm of growing substrates. On average for aquaponics fish tanks, it will require criteria more than or equal to 800kg / sqm of load resistance.[5]

As for hydroponics technique load requirements, ebb and flow and deep water culture (DWC) rafts may have requirements ranging between 50kg to 250kg / sqm, while nutrient film technique (NFT) require the least load resistance. An area within the facility may need to be designed to gather and store water and fertigation.

The respect of load capacity is very important, as damage resulting from misuse related to load resistance capacity may trigger insurance issues. It is important to include that any operational facility on a rooftop will need to adapt and ensure rooftop waterproofing.

Interviews conducted with industry players related to both load resistance and waterproofing indicate that technical solutions exist and are not an issue unless load resistance capacity is dramatically different from the requirements of the envisioned operations. This is thus an arbitrage between the technical solution and the cost of implementation.

The next step: regulation and certification

As a project progresses and issues with urban building regulations are settled, the next step is coping with proper food production and distribution regulations: Good Agricultural Practices (GAP), local hygiene regulations and veterinary authorizations. In some rare cases related to aquaponics, the ability to grow certain fish species will need to be first authorized by proper authorities.

Interviews from operators indicate that on a country-by-country basis, administrative processes are more or less easy to manage. Operators should understand all local regulations in order to scale operations beyond an R&D platform.

Enlarging sites and lowering investment costs

In order to enlarge sites and lower investment costs, different routes can be explored.

Building-Integrated Agriculture (BIA). The development of vertical farming projects on existing buildings will benefit the positive impact of a rooftop or façade greenhouse. This is performed in a bio-climatic approach to lower building

[2] See detailed information at www.parisculteurs.paris/fr/sites/

[3] See detailed information about Romainville urban regulations (PLU) at www.ville-romainville.fr

[4] Romainville Village. L'agriculture urbaine: à Romainville. Romainville, n.d. Web. 8 Feb. 2016.<www.parisculteurs.paris/fr/sites/>. The "tour maraichère" project is a vegetable greenhouse tower promoted by the village of Romainville as a vertical farming project. An architectural competition was held in 2015 and is now seeking financial sponsors.

[5] Based on a fish tank minimum height of 80cm (approximately 31 inches)

energy waste. As for new buildings, at the design phase BIA and bio-climatic approaches can be promoted and taken into consideration. This in order to dramatically lower initial set-up costs, in comparison to existing building adaptation.

Farm removability. The removability of an indoor vertical farm or rooftop greenhouse is an effective cost consideration. The installation of a "plug and play" and / or modular system would allow the operator to move an indoor vertical farm or rooftop greenhouse to a separate site.

Growing techniques. An operator can install artificial lighting and optimize growing techniques to improve crop yields, and employ the ability to operate using a smaller rooftop size and implement 3D farming.

Vertical farming as part of city sustainability agendas

The world is becoming rapidly urbanized, and every decade cities around the world grow at a faster pace. Since the last few decades, cities have not only grown in quantity but in density, reaching significant sizes that we now call megacities, which are populations of more than 10mil. The reason for rapid urbanization is simple. Cities are our most important creation as they are the pillars of society around the world.

As many other studies and publications have mentioned before, the urbanized world accounts for more than 50% of the world's 7.2bn people, and it is predicted to rise to 80% by 2050. With this booming trend, cities represent approximately 75% of economic output and 80% of energy consumption and also greenhouse gas emissions. Although cities are our most important economic engines and highest quality-of-life domains, city migration trends are generating a wide variety of ecological, infrastructure and socio-economic challenges that represent major barriers for urbanized areas to grow into truly sustainable cities.

In order to continue and ensure a prosper and sustainable future, cities and urban centers need to act now, if they have not already. To make this effort a reality, public leaders, the market and most importantly society as whole will need to become agents of sustainability and adopt practices to cope with solving environmental, social and economical problems that are growing.

The great stream of people coming into the cities is affecting the most essential components of cities' infrastructure and resources: water and energy supply, food demand, waste management, sewage systems, transport networks and land appreciation to name a few.

Singapore, NYC and Paris are promoting and / or support pioneer programs related to urban agriculture and vertical farming. We report on cities with a wide range of geographical coverage to better understand how different cultures, financial stability, resources and weather conditions, are tackling the same problem and integrating vertical farming in their sustainability agendas.

Singapore, the Garden City

Singapore is one the most advanced and wealthy cities in the Asia-Pacific region. Its service-based economy and infrastructure have become sophisticated in the past few decades.

When it comes to sustainability and urban planning, Singapore has created a highly comprehensive eco-friendly agenda that will take the city towards the next level of sustainability. Harnessing on its most distinguished strengths, technology and innovation, the city has focused its full agenda into "intelligent city infrastructure" that includes detailed plans and exceptional incentives to attain its goals set by 2020 and 2030, according to the Ministry of National Development. The government has committed SGD 1.5bn to support a wide variety of its programs within the Sustainable Singapore Blueprint program 2015.[6]

One of the biggest drivers making Singapore into an innovation and technology hub, is its support for entrepreneurs and business. In 2013, Singapore became the world's most business-friendly regulatory environment for new ventures.[7] Without going in too much detail about their regulations, it is important to mention that the country has great flexibility and incentives when it comes to trading, taxation and business operation overall. This nurturing environment is crucial in maintaining economic competitiveness and welcome new technologies and businesses such as vertical farming.

[6] Panaech, Simarn. "Govt commits $1.5b for new plants to create a more sustainable future for S'pore". Asia.One. Nov. 2014. Web. 7 Jan. 2016. <http://news.asiaone.com/news/singapore/govt-commits-15b-new-plans-create-more-sustainable-future-spore>

[7] "Singapore Continues to be Most Business-Friendly Economy in the World, Philippines among the Top Ten in Improving Business Regulation". The World Bank. October 2013. Web. 7 January 2016. <http://www.worldbank.org/en/news/press-release/2013/10/28/singapore-business-friendly-economy-world-philippines-top-ten-improving-business-regulation>

Going vertical

One major challenge for the city is its dependence on external food sources. Singapore imports around 90% of its food supplies from over 30 countries.[8] The region only can take advantage of approximately 101.1 ha (250 acres) for food production.[9] This creates a vulnerable environment for Singapore when it comes to short supply and transportation pricing. As a countermeasure, in 2014 the government increased agriculture production quotas in order to promote productivity. This change also came with a SGD 63mil[10,11] agriculture productivity fund pledge to encourage the expansion and adoption of new technologies in the sector. With real-estate prices at a premium, vertical construction seems like the most viable way as the city has started to experiment with rooftop gardens and vertical farming.

Although it is not clear if the agriculture productivity fund pledge has been allocated to vertical farming companies, there have been positive changes in government policy to support industry growth. The Agri-Food and Veterinary Authority (AVA), the government body responsible for functions such as food safety, food supply, promotion of agro-technology and farm licenses, announced in June 2016 that agricultural land tenders will increase from a 10-year lease to a 20-year lease. This is to support investment in high-tech farming techniques (e.g. vertical farming) and allow farmers to obtain value from investments in automation.[12] Overall, it appears there are positive changes on the part of the Singaporean government to support industry growth particularly in regards to optimizing land use.

Obtaining a farm license

Obtaining a farm license in Singapore begins with an application to the AVA. If a farm including a vertical farm has received a farm license, the entity is technically considered a commercial farm.[13] There are seven vertical farms reported that have received a farm license ranging from vegetable to crab production.[14] The city-state has highly strict zoning laws because of its well-planned and efficient land-use by the government. The AVA requires operators to explain key points in their application process for a farm license that entails technologies used, categorization (industrial vs. farming), type of organization and economical benefits.[15]

In Singapore Agriculture Zoning falls under classification S-1, which includes hydroponics and aquaculture farms. However, it is not clear if aquaponics and aeroponics techniques fall under this category and are permitted to operate in Singapore. This is not uncommon in many other cities around the world, and it is unclear if both outdoor and indoor hydroponic and aquaculture techniques are permitted.[16]

Innovative companies

One of the world's first commercial vertical farms, Sky Greens, was built 22.5 km (14 miles) from the city's central business district. The company claims it can produce 182.5 tons of produce per annum (10 times more than traditional farming). Their produce varies over 10 types (Chinese cabbage, spinach, kai lan, etc) of high quality, flavorful and safe vegetables at a higher yield than traditional methods. This high-tech farm uses its proprietary low carbon hydraulic system called "A Go-Gro" consisting of 6 m (19.6 ft) tall towers that only need approximately 60 sqm (645.8 sqft) to be installed. The technology and operation of the towers are based on a close-loop system that greatly increases efficiency; low amounts of water and energy, reusing waste, and proximity to a distribution center for low cost in transportation and fresh consumption.[17] The company not only intents to sell it produce but also its technology to other players and countries.

There are a few factors that are making Sky Greens successful. First, the business venture is supported by the Singapore government. An additional advantage is the region's weather conditions; the country benefits from year-round natural heating and sunlight, convenient temperature and its location in the designated area of Singapore's

[8] Pao, Maureen. "Urban Farms Build Resilience Within Singapore's Fragile Food System". National Public Radio. Aug. 2014. Web. 10 Jan. 2016. <http://www.npr.org/sections/thesalt/2014/08/20/341623536/urban-farms-build-resilience-in-singapore-s-food-system>

[9] Krishnamurthy, Ravindra. "Vertical Farming: Singapore's Solution to Feed the Local Urban Population". Permaculture Research Institute. July 2014. Web. 20 June 2016. <permaculturenews.org/2014/07/25/vertical-farming-singapores-solution-feed-local-urban-population/>

[10] SGD 63mil is approximately USD 46.8mil (1 SGD ≈ USD 1.34)

[11] Capik, Cori. "Singapore Opens S$63 Million Fund for Farmers". AgFunder News. Sept. 2014. Web. 10 Jan. 2016. <https://agfundernews.com/singapore-opens-s63-million-fund-farmers.html>

[12] Wei, Aw Cheng. "Helping farmers maximise yields". Straits Times. June 2016. Web. 26 June 2016. <http://www.straitstimes.com/singapore/helping-farmers-maximise-yields>

[13] Wong, Lionel. Phone interview. 3 June 2016. UpGrown Farming Company. See interview on pg. 30.

[14] Singh, Bryna. "Vertical farms on the rise in land scarce Singapore". Straits Times. July 2016. Web. 11 July 2016. <http://www.straitstimes.com/lifestyle/farming-on-the-up-and-up>

[15] Agri-Food & Veterinary Authority of Singapore. Starting a Farm. June 2015. Web. 20 April 2016. <www.ava.gov.sg/explore-by-sections/farms/land-farms/starting-a-farm>

[16] See Singapore's zoning interpretation chart at: https://www.ura.gov.sg/MP2008/ims/TABLE%201%20-%20Zoning%20Interpretation.htm

[17] Chow, Lorraine. "World's First Hydraulic-Driven Vertical Farming Produces 1 Ton of Vegetables Every Other Day". EcoWatch. Sept. 2015. Web. 1 Feb. 2016. <http://ecowatch.com/2015/09/11/sky-greens-vertical-farm/>

agro-technology park. Although weather conditions in Singapore may help vertical farming business developments, new companies are testing fully enclosed vertical farms to supply local consumers. One of the first companies to test this model is the start-up Sustenir Agriculture (Singapore) Pte Ltd is ("Sustenir").

Sustenir occupies a total growing surface area of 688 sqm (7,405 sqft), but currently only uses half for kale production. The growing system designed by co-founder Benjamin Swan is a modular patented NFT hydroponic technology equipped with a linear HVAC system and LED lighting.[18] The company's approach to competitiveness is to produce high-value kale products that can compete with imported kale products (in Singapore kale is considered 'exotic') that have higher price points in the market.[19]

Local market size

As mentioned above, local reports claim there are seven licensed vertical farms in Singapore. In an interview with Lionel Wong, Founding Director of UpGrown Farming Company, he mentioned there are also a handlful of vertical farms at the R&D stage that are in the process of receiving farm licenses. The Singaporean vertical farming market appears to be poised for growth and expected to double in the following six months.[20]

New York City

NYC is the largest city in the USA and a well known epicenter for international business, arts, media, research, technology, education and architecture. NYC has an innumerable amount of buildings and an impressive infrastructure to carry the city's high density population.

NYC is aware of several challenges (climate change, population growth, infrastructure decay and evolving economy) that it needs to tackle in order to ensure economic prosperity, high quality of life and overall success. For these reasons, the NYC Mayor's Office of Sustainability and Mayor's Office of Reovery and Resiliency have developed and are monitoring the implementation of the OneNYC Plan.[21] The plan focuses on fours areas: sustainability, growth, equity and resiliency, while engaging city residents, city agencies, public and business leaders to create higher synergies.

NYC is focusing on embracing gardens and urban agriculture. The city government has increased the support by modifying laws and integrating gardening in school programs and community centers. These initiatives are related to OneNYC objectives, regarding their plan to promote healthier communities, embrace disease prevention diets, increase resilient food systems and improve food access to New Yorkers. The city presents in the OneNYC report that it will support commercial ventures in urban farming and more specifically vertical farming.[22] The city and to an extent New York State is beginning to pay attention and support vertical farming through various initiatives to foster industry growth.

Shaping eating habits through school and education

If we can see a glimpse of what future consumers will demand, it will be higher quality of produce and more fresh and nutritious food that are aligned with their diets and values. The emergence of urban agriculture caught the attention of the Brooklyn Borough President Office, which has invested USD 2mil in urban agriculture education to bring hydroponics into classrooms.[23] The Manhattan Borough President Office (MBPO) also views schools with alternative agriculture programs as a channel to help children understand the value of food and education. The

[18] Khew, Carolyn. "High-tech farmers cropping up: Local farmers using high yield methods to ramp up Singapore's food production capabilities". Straits Times. March 2016. Web. 6 April 2016. < http://www.straitstimes.com/singapore/high-tech-farmers-cropping-up>

[19] Laing, Callum. "Martin Lavoo, Co-founder of Sustenir". The Asian Entrepreneur. June 2015. Web. 3 Feb. 2016. <http://www.asianentrepreneur.org/martin-lavoo-co-founder-of-sustenir/>

[20] Wong, Lionel. Phone interview. 3 June 2016. UpGrown Farming Company See interview on pg. 30.

[21] The City of New York. Mayor's Office of Sustainability. One New York: The Plan for a Strong and Just City. New York City: Office of Sustainablity. April 2015. Web. 17 Feb. 2016. <http://www1.nyc.gov/html/onenyc/index.html>

[22] Ibid.

[23] Brooklyn Borough President Office. BP Adams Unveils "Growing Broolyn's Future," $2 million Urban Farming Education Initiative Bringing Hydroponic Classrooms to a Dozen Brooklyn Schools. New York City: Brooklyn Borough President Office. Nov. 2015. Web. 7 May 2016. <http://www.brooklyn-usa.org/bp-adams-unveils-growing-brooklyns-future-2-million-urban-farming-education-initiative-bringing-hydroponic-classrooms-to-a-dozen-brooklyn-schools/>

MBPO has committed USD 1mil for the fiscal year 2017 Discretionary Capital Funding for urban agriculture programs focused on hydroponics and aquaponics. The MBPO is looking to find ways to utilize urban plots, hydroponic labs, community gardens and greenhouses, which will start with funds allocated to classrooms.[24] The MBPO is determined to forge urban agriculture as an initiative to improve food quality and health, build stronger communities, provide education opportunities and create environmental and economic incentives.[25]

Students at the Food and Finance High School in Manhattan are working in research laboratories operated by the Cornell University Cooperative Extension program to provide education in hydroponics, aquaculture and aquaponics. Students learn to obtain hands-on CEA growing experience, and about food and nutrition while developing skills for the CEA industry.[26]

Compliance issues: permits and authorizations

As the industry has developed in NYC, urban and vertial farming companies and non-profits have difficulty being completely compliant with regulations since various government agencies oversee agriculture. In order to take an additional step to integrate urban agriculture and vertical farming as viable industries, one main point of contact that represents the industry should be created to help support industry growth. As an example, the City of Atlanta in the southern USA has created an Urban Agriculture Director role to take responsibility with these issues.[27] In an interview with the City of Atlanta's Urban Agriculture Director, Mario Cambardella, he explains how the new role is being developed.

Urban rules: zoning law changes

Overall, urban agriculture zoning rules in NYC are fairly permissive. The barriers lay more in the shortfall of incentives rather than policy and zoning laws.

As mentioned above, to encourage the development of rooftop greenhouses, the NYC City Council adopted the Zone Green Text Amendment in 2012 to alleviate prior constraints that prevented opportunities for rooftop greenhouses. Although the text amendment has lifted previous restrictive zoning laws for rooftop greenhouses, there are still limitations preventing rooftop greenhouses to be on buildings that contain residences or sleeping accommodations.[28] As for indoor vertical farms, it is not clear how Floor-Area-Ratio and additional urban regulations will be interpreted for re-adapt warehouse models. This will need to be clarified as more companies start revitalizing these spaces throughout NYC.

Land availability in NYC

Based on a recent study by The Urban Design Lab at Columbia University, an area reaching up to 2,023 ha (5,000 acres) has been identified that can be used for urban agriculture in NYC. The sites' characteristics could vary widely, needing different strategies and approaches in order to be utilized for agriculture activities.

There is no question NYC has a vast number of underutilized rooftop space. The high density of buildings does not only provide space, but also an ideal location to distribute produce to its high-density population. Urban agriculture can benefit from the already implemented infrastructure (transportation networks, proximity to merchants and consumers, access to capital and community support) to more efficiently distribute produce, decrease costs and time, while providing a great boost for vertical farming and technologies.

Funding opportunities

As for public funding, in New York State opportunities are available for companies applying clean tech energy efficient projects and CEA technologies. There is also an option to receive energy rebates from the local utility company.

Funds are provided by the New York Green Bank for clean tech energy efficient projects. As vertical farming in the finance world is considered a high risk capital investment and there still appears to be no clear track record to develop a financial ecosystem, one option is possible through the New York Green Bank. There are guidelines for technologies that are eligible for financing: renewable energy resources, energy efficient resources, and other type of clean energy

[24] Manhattan Borough President Office. Borough President Issues Plan to Expand Urban Agriculture. New York City: Manhattan Borough President Office. 2015. Web. 7 April 2016. <http://manhattanbp.nyc.gov/html/news/releases-april2015.shtml>

[25] Manhattan Borough President Office. How Our Gardens Grow: Strategies for Expanding Urban Agriculture. New York City: Manhattan Borough President Office. 2015. Web. 7 April 2016. <http://manhattanbp.nyc.gov/downloads/pdf/GardenReport.pdf>

[26] Kulshrestha, Kritika. "Cornell staff advise NYC urban farmers: Urban farming introduces children and adults to the value of green spaces". Morning AgClips. Oct. 2015. Web. 10 May 2016. <https://www.morningagclips.com/cornell-staff-advise-nyc-urban-farmers/>

[27] See interview with City of Atlanta Urban Agriculture Director Mario Cambardello on page 29.

[28] New York City Government. Department of City Planning. Zone Green (N 1201132 ZRY) Enacted by the City Council: 4/30/2012. New York City: Department of City Planning. April 2012. Web. 16 April 2016. <http://www1.nyc.gov/assets/planning/download/pdf/plans/zone-green/adopted_text_amendment.pdf>

projects.[29] Although vertical farming is not specifically mentioned, the New York Green Bank will take proposals on a case-by-case basis and consider financing for New York State projects.[30]

The New York State Energy Research and Development Authority (NYSERDA) recognizes CEA as a potential technology to increase local food production and significantly reduce greenhouse heating loads on rooftops. NYSERDA in early 2016 provided USD 1mil in funding for Gotham Greens's third rooftop greenhouse facility in NYC, to help cover CEA-related technologies in the facility, and conduct research on insulation and energy costs for rooftop greenhouses in NYC.[31] NYSERDA sees the investment as part of building a sustainable future for residents of New York.

The local utility company in NYC, ConEdison, provides energy efficiency rebates for horticulture lighting installations. The energy rebates administered by Lockheed Martin[32] for ConEdison have partially strict requirements for the different standard commercial qualifiers (e.g., Energy Star, DLC). There are limitations to these rebates, and ConEdison has a 'tool' to calculate rebates. The rates are limited to a one-year payback and take into account a few factors a part of an indoor farm and rooftop greenhouse facility.

There are additional NYC and New York State funding opportunities for vertical farming entrepreneurs in NYC from providing payment for workforce development and education.

Moving forward

NYC has a relative high density of vertical farming companies. The city is home to well-known vertical farming companies that consists of both rooftop greenhouses and indoor vertical farms that use hydroponics, aeroponics and aquaponics. There are currently four commercial scale CEA vertical farms in NYC[33] and a handful at the R&D stage. The local market is also supported by indoor farming related software, hardware and consulting companies.

NYC is striving to become a leader in sustainability and has begun to recognize urban and vertical farming are a part of the solution. There are city and state funding opportunities and other programs available to develop workforce skills and the city is positioning itself as one of the leaders in vertical farming. As the industry grows in NYC, comprehensive education and job training programs for CEA need to be implemented along with a vertical farming focused incubator to educate not only growing techniques but also the business of vertical farming (e.g., logistics, distribution, sales and marketing).

Paris

The future of sustainability will be decided by cities, and one of the cities setting up programs to support these initiatives is the city of Paris. The 2050 Paris Smart City project commissioned by City Hall is envisioning a city applying renewable energy technologies to drastically decrease the city's greenhouse gas emissions by 75% in 2050.[34]

France as a whole has begun to provide guidelines and a prospective to the nation's regional development through the Master Plan for the Ile de France Region (Schéma Directeur de la Région Ile de France) (SDRIF) to foster sustainable food supply as one of its objectives. However, it is mainly related to farmland protection and agro-ecological development. There does not seem to exist a true food planning strategy and the inclusion of urban agriculture and / or vertical farming plans. The extent of a so-called plan is through the Direction Régionale et Interdépartementale de l'Alimentation de l'Agriculture et de la Forêt en Ile de France (DRIAFF), which developed a booklet to address points that urban agriculture projects in the Paris regions should follow.

Urban regulations

In Paris, urban regulations are under review and actionable by August 2016, with one of its many goals to create a new set of urban regulations to foster rooftop productive use, which includes greenhouses (rooftop production greenhouses will not be accounted for building height limits). For now rooftop greenhouse projects are suspended

[29] NY Green Bank: A Division of NYSERDA. "RFP No.1 – Attachment B: Illustrative Guidelines for Eligible Investments". New York: Albany. n.d. Web. 10 April 2016. <http://greenbank.ny.gov/-/media/Files/FO/Current-Funding-Opportunities/RFP-01/RFP-1-ATT-B.pdf>

[30] NY Green Bank: A Division of NYSERDA. Investment Strategy. New York: Albany. n.d. Web. 10 April 2016. <http://greenbank.ny.gov/Approach/Investment-Strategy#tech>

[31] New York State Energy Research and Development Authority. "Governor Cuomo Announces Opening of New Gotham Greens Greenhouse Facility in Queens: Company's Newest 60,000-Square-Foot Facility To Triple the Amount of Fresh, Local Produce It Provides to New York City's Tri-State Customers". New York State: NYSERDA. Feb. 2016. Web. 9 May 2016. <http://www.nyserda.ny.gov/About/Newsroom/2016-Announcements/2016-02-02-Governor-Cuomo-Announces-Opening-of-New-Gotham-Greens-Greenhouse-Facility>

[32] Lockheed Martin. "Lockheed Martin Managing Con Edison Commercial and Industrial Energy Efficiency Programs". March 2011. Web. 18 April 2016. <http://www.prnewswire.com/news-releases/lockheed-martin-managing-con-edison-commercial-and-industrial-energy-efficiency-programs-117533018.html>

[33] Rooftop greenhouse companies are the only known commercial scale vertical farms in NYC: Gotham Greens operates three sites and Sky Vegetables one. Our assessment is not inclusive of seasonal open-air rooftop greenhouse (e.g. Brooklyn Grange). It should be mentioned AeroFarms is based in Newark, New Jersey but supplies NYC.

[34] Lynch, Gerald. "Paris as a Green and Sustainably Future City is Even More Beautiful". Gizmodo. Jan. 2015. Web. 2 Feb. 2016. <http://gizmodo.com/paris-as-a-green-and-sustainable-future-city-is-even-mo-1680372218>

until the new set of regulations are enacted.

GIS inventory of urban agriculture and vertical farming potential

GIS mapping on Paris city area was performed to collect an inventory of potential rooftop space for urban agriculture production. It was estimated a total of 22ha (54.3 acres) of at least 1,000 sqm (10,763 sqft) or more was evaluated as potential space. The mayor of Paris has outlined an objective to have 100ha (247 acres) of green roofs that includes 33ha (81.5 acres) dedicated for food production by the end of 2020. To push forward this objective, in 2015 various events were organized by Paris City Hall, and additional initiatives to showcase sustainable green projects included school gardening, living wall food producers and permit concepts. Some of it has recently materialized through the Parisculteurs initiatives.[35] About 20 rooftops have been allocated to welcome urban agriculture projects.

Grower status: permits and authorizations

While the DRIAAF booklet covers various fields in urban agriculture, vertical farming as a new topic is not fully addressed within the booklet, and similar to Singapore and NYC, start-ups will have to initiate and experiment as codes are adapted for vertical farming activities. For now, vertical farming entrepreneurs, especially with commercial purposes, can initiate dialogue with DRIAAF officers to evaluate on a case-by-case basis constraints related to agricultural production (hygiene, electrical hazards, etc), capacities and authorizations and optimal system set up.

In order to produce vegetables, farm facilities will need to comply with phyto-sanitary measures and be affiliated with the Mutualite Sociale Agricole (MSA).[36] Then depending upon whether product transformation is contemplated, farm facilities may also have to comply with specific rules associated with produce and growing systems.

Access to funding: subsidies

In Paris, an urban grower can benefit from subsidies related to agriculture activities and / or other incentives. However, this is dependent on the legal structure chosen to implement projects. Such choices to be made influence tax treatments (e.g. VAT, corporate tax, etc).

As for public funding, growers have options to access funds related to the Programme d'Investissements d'Avenir (PIA)[37]; an EUR 47bn[38] budget designed to finance innovation, strengthen productivity, R&D and companies competitiveness. Within this program, a specific fund called Projets Agricoles et Agroalimentaires d'Avenir (P3A) funded with EUR 120mil[39] over a 3-year period, is set up to develop the future of agriculture and agri-food industries. A specific section, "2I2A" (Volet compétitif "Initiatives innovantes dans l'agriculture et l'agroalimentaire) with a budget of EUR 10mil[40] is designed to develop innovative agriculture and food initiatives. For now, projects may receive up to EUR 200k[41] to cover a maximum 50% of the project expenses.

Access to technology

Entrepreneurs and growers engaged in R&D and small scale projects are supported by different public organizations that can provide assistance on technical support and expertise. The Institut Technique de l'Horticulture (ASTREDHOR) and its regional networks can provide technical advice on projects. ASTREDHOR, for example, has developed research programs such as the APIVA project focused on aquaponics. An additional organization designed to support food production sites is ARRDHOR – CRITT Horticole, which concentrates on growing techniques irrespective of the farm location, or of whether the project is ground-based, indoor or rooftop.

Education

In Paris, dedicated urban agriculture education programs are available within school and universities. AgroParisTech (Paris Institute of Technology for Life, Food and Environmental Sciences) has recently developed courses to address urban agriculture developments. The courses include to a limited degree an observatory of urban agriculture developments including vertical farming. The courses are partly sponsored by Vinci, a building and infrastructure construction group. Through the T4P project, an innovative research project on rooftop production, AgroParisTech students can develop open-air vegetable growing tests on school rooftops to observe potential pollution issues and study the principles of circular economy.[42]

[35] "Les Parisculteurs. 46 Sites for Urban Agriculture and Revegetation!". France: Paris. n.d. Web. 12 Feb. 2016. <www.parisculteurs.paris/fr/sites/>
[36] English name: Agricultural Social Mutual Fund
[37] English translation: Investments Program for the Future
[38] ≈USD 53.2bn
[39] ≈USD 136mil
[40] ≈USD 11.3mil
[41] ≈USD 226k
[42] T4P: innovative research projects on Productive Parisian Roofs. INRA Science & Impact.

Vertical farming projects in Paris

The commercial vertical farming scene in Paris is in the very beginning stages of development. There are currently two commercial rooftop hydroponic greenhouse projects: Toit Tout Vert (construction permit under instruction), and a project in the Parisian suburb Romainville called Tour Maraichère.[43] At the moment there are no known pure indoor farming enterprises operating in Paris, apart from the startup Agricool that is testing strawberry production in a shipping container.

What happens next?

There is a willingness to promote urban agriculture within Paris and the nearby region, which includes vertical farming. The potential for commercial vertical farming facilities relies more on new building infrastructure with the intent to build a rooftop greenhouse. The lack of sizable rooftop space limits the capability of establishing commercial facilities.

Urban regulations are currently being modified to give the opportunity to develop projects. At the moment, the first commercial projects will have to deal with the code adaptations as the city experiences the various challenges of commercial-scale vertical farming projects.

[43] "L'agriculture urbaine: a Romainville". Village of Romainville Press Release. n.d. Web. 20 Feb. 2016 <http://www.ville-romainville.fr/sites/default/files/documents/Dossier%20Presse%20tour%20maraich%C3%A8re.pdf>

City of Atlanta

Interviewee: Mario Cambardella, Urban Agriculture Director, Mayor's Office of Sustainability, City of Atlanta
Interviewer: Howard Brin, Association for Vertical Farming

City of Atlanta, USA: Mayor envisions urban agriculture as a future market

In 2015, the City of Atlanta passed an urban agriculture ordinance to support and encourage the local urban agriculture industry. This was in order to address city laws that prevented urban farmers from obtaining business loans and operating with compliance issues.

Mayor Kasim Reed created the Urban Agriculture Director position to support the emerging industry and meet requirements related to policy, funding and general support. The City of Atlanta chose Mario Cambardella, a Masters' graduate of Landscape Architecture and Environmental Planning and Design, the former owner of Urban Ag Inc, a landscape architecture company focused on food production. The new Urban Agriculture Director is in position to support planning, design, policy (technical expertise) and the growth of the urban agriculture industry in Atlanta.

Goals for year one as Urban Agriculture Director

Housed in the Mayor's Office of Sustainability, Mario Cambardella stated an Urban Agriculture Director needs to ensure and support the vision of a top-tier sustainable city, that is inclusive and promotes cultural heritage with an accessible healthy and local food network. He urges communities help define the Urban Agriculture Director role and be a source of information to recognize where obstructions lie. As a first step he is engaged in community outreach and discussing urban agriculture policy (green procurement policy) and formulating agendas with food vendors, growers, composting organizations, Georgia Power and Army Corps of Engineers, etc. As Urban Agriculture Director, he wants to be a source to help local companies and non-profits with grant opportunities to secure funding for their projects.

One of the first challenges is to determine how permitted use and zoning can be properly interpreted within existing codes for vertical farming and rooftop greenhouses. The development of these projects compels cities to take a whole new look at mix-used buildings. In Atlanta urban agriculture on a commercial scale is considered industrial, and to address this issue, his office is working with the Director of the Office of Planning to assist with guidelines on permitted use and zoning. The importance is to make sure they are ahead of developers and that barriers do not exist when they apply for these type of projects.

Task force to support CEA

In 2016, the City of Atlanta created a task force to look at safety considerations for CEA, with the goal to look at policies to support CEA. Mario Cambardella stressed that the City of Atlanta wants to support the development of CEA, but there needs to be careful considerations in terms of policy that makes these type of environments safe.

What does an Urban Agriculture Director want from the industry?

Vertical farm and rooftop greenhouses need to inform Urban Agriculture Directors' issues related to public safety and health, fire hazards and water discharge (if water is channeled into the storm-water system and its effects). Mario Cambardella is confident urban agriculture is a key to a sustainable city, but in order to understand the principles of urban agriculture, hydroponic and aquaponic growers, they have to be vigilant about public safety, health and welfare.

UpGrown Farming Company

Interviewee: Lionel Wong, Founding Director, UpGrown Farming Company
Interviewers: Howard Brin, Association for Vertical Farming
David Murayama, Analyst, Association for Vertical Farming

Agriculture education and vertical farming perception in Singapore

Agriculture and farming in not a mainstream career for most Singaporeans. Lionel Wong said Singapore's education system from primary school to higher education for agriculture and related subjects are typically not available to students to learn or major in. The extent Singaporeans have access to agriculture education is to receive a horticulture diploma, which are focused on landscape architecture. This restricts Singapore's ability to educate and develop skills for homegrown farmers. Unfortunately, new and aspiring farmers in Singapore have very limited access to industry jobs in agriculture, farming and CEA.

Despite the lack of formal education, in Singapore vertical farming is leading to new urban farming innovations. There has been positive responses from consumers, and increasingly more vertical farming startups due to recognition of the high-quality produce. For the time being, vertical farming produce is typically for the higher end market segment.

Operating with diversified business models

The vertical farming industry is small, but growing rapidly in Singapore. Commercial vertical farms are involved in producing vegetables, fish, crabs and other types of food products. There are also many small operations at the R&D stage improving their produce, systems and overall business model.

In Singapore, there is high interest in vertical farming largely due to food security issues. This is partly responsible for the increase in vertical farming companies. To survive as a viable business in Singapore, companies need to have a diversified business model. With high labor and land lease costs, vertical farms are not just growers, but also technology developers. It is common to generate revenue from both selling farm produce and farming solutions. Lionel Wong hopes as the industry grows in Singapore and public perception starts to become more aware of vertical farms and their produce, vertical farming businesses will become more viable and scale. This is starting to become possible with decrease in equipment costs, and more importantly, growing support from the Singaporean government.

Government support and policies (city-state system)

Lionel Wong mentioned Singapore has become an economic region for technological breakthrough and a front-runner in innovation. The government provides financial support for a wide range of technological companies and projects proposing or pursuing a technology breakthrough. Singapore continues to attract innovative companies into the country / region - to use Singapore as a business hub, innovation development center, export base and marketing platform.

The government is helping lead Singapore's urban farming revolution. There are new government-led initiatives that promote the emerging vertical farming movement, which interlinks with Singapore's sustainability agenda priorities to become a more self-reliant country. For example, recently the government has extended farm-land leases in certain locations to 20-years. The AVA has been helpful by offering R&D and industry support, grants and assisting companies with strong networks.

Overall, the growing support and encouragement by the Singapore government is positive for vertical farming in the country, which will foster scalability and increase public awareness. This support can serve as a role model / case study for implementing vertical farms in cities worldwide.

Sky Vegetables

Interviewee: Adam Sorota, Executive Vice President, Sky Vegetables
Interviewers: Howard Brin, Association for Vertical Farming
Vincent Fesquet, New'rban View

Sky Vegetables: a building integrated agriculture rooftop greenhouse

Sky Vegetables is a 740 sqm (8,000 sqft) NFT rooftop hydroponic greenhouse above the Fresh Plaza – Arbor House affordable housing complex in The Bronx, New York City. The Platinum LEED certified building totaling 4,560 sqm (48,000 sqft) was designed with the anticipation of a rooftop greenhouse and is possibly one of the first projects to be a focused BIA project. Sky Vegetables benefits from a dedicated elevator and lobby, and storm drain water is collected in the basement and recirculated back into the greenhouse. The design also has placed greenhouse boilers in the basement, which are separated from the housing heating system.

Based on the unique nature of the project, there is zero rent to be paid, and instead a Common Area Maintenance fee. The Sky Vegetables project was able to come to fruition partly because of the landlord benefiting from tax credits. The landlord has been partially responsible for financing Sky Vegetables. According to Adam Sorota, their team has invested over USD 2mil into the Sky Vegetables pilot project, and since the beginning they understood the financial constraints of a small greenhouse. For more than two years it has been necessary to trial extensively to be in a position to collect data and prove the business model.

The importance of first running a test format

The rooftop greenhouse was built as a test format to acquire technical knowledge and prove the concept. It was also NYC's willingness to test this concept on top of a mixed-used residential building. The trial and error has been integral to the team to refine implementation and operational constraints. Adam Sorota noted some of the major obstacles Sky Vegetables has dealt with respectively from operations to implementation: 1) GAP certification process, sanitation, growing knowledge and calculating an affordable rooftop greenhouse size to support a full time grower and proper distribution; and 2) proper dimensions and design of the heating system. He added the two most difficult aspects is growing consistently and distribution and if they would have directly implemented a large rooftop greenhouse format, by now they would have financial hardships. The test format allowed Sky Vegetables to pool a team of experts to deal with the issues they have faced since its inception.

Sky Vegetables trials has put them in a confident position to implement commercial formats to investors for a larger rooftop greenhouse. The Sky Vegetables team is looking for USD 4mil investment to build and operate a 4,500 sqm (48,000 sqft). The rooftop greenhouse will have two pods that are each a minimum size of 2,230 sqm (24,000 sqft). Current expansion plans include to build in NYC, Boston, Maryland and potentially Chicago.

Optimal harvest yields and distribution

During peak seasons Sky Vegetables, which only uses natural light, is able to produce 200 to 250 cases[1] of fresh leafy greens 49 weeks per year. They are currently growing Genovese basil, Upland watercress, Wild arugula and at times Baby Bibb lettuce, dill and cilantro. The fresh produce is sold to 20 supermarkets including Whole Foods. As a part of their business model Sky vegetables is also trying to reach end-consumers.

[1] According to Adam Sorota, each plant weighs approximately 5oz per plant and each case has 12 plants.

WHAT DOES A VERTICAL FARM NEED?

> *There are many areas for optimisation of systems themselves, but the major barrier to uptake is still the relatively high capital costs associated with new enterprises. Smaller enterprises cannot garner the large profits that are possible with efficiencies of scale.*
>
> **Rhydian B.D.**

TOP PHOTO: ECF Farmsystems. BOTTOM PHOTO: Spread Co Ltd

3

FINANCE AND BUSINESS MODELS

Authors: Vincent Fesquet, Howard Brin

Growers and operators of vertical farming projects pursue very different objectives. The farm facility may be built and operated for research, lifestyle, social, educational or commercial purposes. The main objective of the farm, as well as the structuring choice of open-air vs. CEA, will have a deep impact on its size and economics, which can range from a few sqm (sqft) dedicated to educational activities to large indoor vertical farms with commercial objectives. The financial key to any farming project is the quantification of capital expenditures ("capex") required to build and operate the site. Depending on the growing system (and sometimes surfaces dedicated to host events), techniques and building adaptation or creation, capex may range from approximately USD 1,000 / sqm (USD 93 / sqft) and up to USD 4,000 / sqm (USD 372 / sqft).[1]

The following section will concentrate on commercial farms and CEA, which mainly imply the use of a greenhouse and natural lighting, or the use of artificial lighting for plant growth within a building or a warehouse.

Rooftop greenhouse and natural lighting

In the case of a ground, rooftop, or façade based greenhouse, initial capex is high. These costs include the greenhouse, HVAC, and climate management systems[2], and if required, supplementary artificial lighting. However, capex can vary from one project to the other depending on the following factors.

Rooftop greenhouse. On rooftops, greenhouses will have to conform to building construction rules and labor codes, and therefore greenhouse capex for rooftops will be much more important compared to ground-based projects. In the case of a fully equipped hydroponic rooftop greenhouse, studies[3] and desktop analysis indicate a minimum investment ratio of USD 1,000 / sqm, or about three times the costs compared to ground based greenhouses. The only data point below USD 1,000 / sqm that we have been in the position to obtain is related to Lufa Farms (Montreal, Canada), which is reported to have experienced greenhouse implementation costs of USD 861 / sqm (USD 80 / sqft) for its first rooftop hydroponic greenhouse.[4] A rooftop greenhouse can reach much higher costs depending upon the need for building adaptation.

Rooftop building adaptation. Increased set-up costs are required by dedicated access, load capacity and structure reinforcement, waterproofing and security. Additionally, aquaponics rooftop units may require higher capex due to the load of fish tanks' load and additional processes.

Vertical growing techniques. Sophisticated vertical growing techniques and conveyor belts are used to handle plants and increase growing surfaces (e.g. Sky Greens in Singapore or Vertical Harvest in Jackson Hole, USA).

In this category, growers and operators tend to agree[5] that the required minimum rooftop greenhouse size has to be greater than 1,200 / 1,500 sqm (12,900 / 16,150 sqft) in order to manage at least two different climates[6], with pure hydroponic incumbent players willing to set up bigger operations to benefit from scale effect.

The evolution of the rooftop greenhouse expansion experienced by Gotham Greens provides an interesting example in this respect. The company based out of NYC began operating its first 1,393 sqm (15,000 sqft) rooftop greenhouse in 2011. Over the years it has added three additional sites with the most recent in 2015 expanding to a new 7,000 sqm (75,350 sqft) rooftop greenhouse on top of the second-floor rooftop of the Method Products manufacturing factory in Chicago, USA. The scale of operational facilities provides improvements in operations and decrease in set-up costs

[1] Kozai, Toyoko, et al. Plant Factory – An Indoor Vertical Farming System for Efficient Quality Food Production. London: Elsevier. 2016. Print.
[2] Initial capex costs also include harvesting equipment, packaging equipment, cleaning equipment and to some extent automation equipment; although at the current stage of development, vertical farming units do not apply the same level of sophisticated automation as ground based greenhouses operations.
[3] Agriculture and Agri-Food Canada. The Union of Quebec Greenhouse Growers., La Serriculture Sur Les Toits en Milieu Urbain : Perspectives de Développement Dans le Contexte Québécois. Québec: SPSQ 31. May 2013. Web. 12 March 2016. <https://www.agrireseau.net/Economie-et-Gestion/documents/Rapport%20Serriculture%20Urbaine_Final.pdf>
[4] For further analysis on Lufa Farms, see Alvarez, Jose B., Robert Mackalski, Annelena Loeb, and Lisa Mazzanti. Harvard Business School Case 514-008. Lufa Farms. Oct. 2013. Print.
[5] Interviews conducted with rooftop greenhouse operators
[6] According to growers, climate zone management require a minimum 600 sqm (6,458 sqft). Therefore, a minimum 1,200 sqm (12,916 sqft) provides potentially two different warm and cold areas for different crops.

relative to production.

Options to finance capex

There are three options for owner-operators of rooftop greenhouses to consider: 1) investment by grower, 2) investment by a third-party in exchange for rent or lease, and 3) investment by the owner of the building and rent of the rooftop greenhouse to the growers.

Investment performed by the grower. The grower performs the investment through equity and bank loans. Depending upon the city and / or country, the grower may receive subsidies.

Investment is performed by a third party in exchange for a lease or rent. The most advanced and sophisticated growers propose lease contracts to third-party investors, or rooftop owners, in order to amortize the cash investment over a long period of time. It helps reduce start-up costs and operations to fund the annual costs of the rooftop greenhouse.

Additionally, renting of greenhouses that have been developed by incumbent industrial players may also be used. This type of financing is still subordinated to the ability to remove efficiently (at a low cost) the greenhouse and equipment from a rooftop, and also to current market depth. Further technical developments have to come to an effective "plug and play" concept, allowing the operator to move the rooftop greenhouse from one place to the other. This principle has been demonstrated in other industries, such as solar panel equipment. These schemes would allow for the possibility of an equipment rental market.

Investment is performed by the owner of the building that rents or leases the rooftop greenhouse to growers. An owner of a host building needs to be convinced of the marketing and program advantage associated with the promotion of a rooftop greenhouse facility, the ability to benefit from the bio-climatic insulation and / or energy savings associated with a converted rooftop. UrbanFarmers AG ("UrbanFarmers"), for instance, is promoting its activities through a value proposition for the owner of its rooftop.[7]

In any case, the ability for the grower to avoid financing the upfront cost of the rooftop greenhouse is an important factor.

As in the case of UrbanFarmers, the new 1,500 sqm (16,150 sqft) rooftop aquaponics greenhouse, in the Hague, Netherlands, which required an approximate USD 3.052m[8] investment, is reported to be "led by a Dutch municipal investment fund and a private Swiss investor".[9] In the case of the 740 sqm (8,000 sqft) rooftop greenhouse operated by Sky Vegetables on top of the Fresh Plazza – Arbor House housing complex in NYC, the project was catalyzed by tax credit benefits for the landlord.[10] As a result, the landlord has partially financed the associated operation.

Indoor vertical farms

As far as artificial lighting as the main light source is concerned, two schemes can be envisioned: 1) farm units implemented in existing underutilized buildings, and 2) buildings erected for the purpose of indoor vertical farms, or as otherwise known in Asia, plant factories using artificial lighting (PFAL).[11]

In the case of artificial lighting used within a building, capex is lowered since there is no need to invest in a greenhouse. Instead, investments concentrate on CEA equipment: artificial lighting, HVAC and humidity management and stacking fixtures, among other items. Compared to greenhouses, farm removability from an indoor environment is easier to handle, but production is less diverse and predominantly limited to vegetative crops, such as leafy greens and microgreens. Production constraints in these systems include current stacking techniques, artificial lighting and related growing recipes developments.

Projects where preexisting containment infrastructure is not available may also include start-up costs associated with construction. In a recent study[12], investment costs are reported to be close to USD 4,000 / sqm (372 / sqft). With such high start-up costs, yields and value-added products are all the more important.

[7] See for further explanations: https://urbanfarmers.com/wp-content/uploads/2015/09/RZ_UFA-RoofTF_A4_12-4_EN_LT06a1.pdf

[8] UF secures full financing of Eur 2.7m to build UF002 De Schilde – Europe's largest commercial rooftop farm project in The Hague, NL. 2015. Web. 17 April 2016. <https://urbanfarmers.com/wp-content/uploads/2015/09/15709_UF-Press-Release-UF002-De-Schilde_draft-AG-1.pdf>

[9] Graber, Andreas. Video conference interview. 22 Jan. 2016. UrbanFarmers AG. See interview on pg. 83.

[10] Sorota, Adam. Video conference Interview. 12 Jan. 2016. Sky Vegetables. See interview on pg. 31.

[11] Chinese and Japanese languages commonly use the term "植物工厂"; a direct translation in the English language is plant factory

[12] Kozai, Toyoko, et al. Plant Factory – An Indoor Vertical Farming System for Efficient Quality Food Production. London: Elsevier. 2016. Print. Note that calculations are based on land area in Japan and a facilities benchmark that includes 15 tiers and a vertical distance between the tiers of 50cm. Investment costs are subject to change per sqm based on land prices and facility design.

Rental costs

Finding proper space for rooftop greenhouses is a key success factor for growers and the question of rent paid for the rooftop or building space is a well-kept secret in the industry. Fortunately, growers may benefit from the willingness of some building owners to help develop the industry, and as the industry develops rents will have to compare with other programs and / or equipment (e.g. solar panels in case of rooftops). Within the industry, some such as UrbanFarmers clearly state that a rooftop greenhouse is a good way to monetize incremental space for the landlords and utilize the space as marketing scheme.

As for indoor vertical farms, in Western countries growers are mainly using buildings of low-value (former warehouses and brownfield factories, unused underground tunnels and underutilized spaces) in places where other activities might be difficult to promote and the cost of land is relatively cheap. However, it is still important to understand that space used to grow plants cannot compete with the profitability of buildings hosting housing, offices or other programs. Investments to build indoor vertical farms would be difficult to amortize unless high-value vegetables were sold at a very expensive price, and furthermore, stacking and automation will need to improve further while growing equipment costs (LED lighting, HVAC systems, etc.) decrease.

Business models segmentation

The majority of start-up projects are run by new-comers in the grower business, apart from a few vegetable wholesalers and distributors that have started and operate vertical farms. The latter companies benefit from in-house integrated logistics capabilities, and therefore their distribution cost is marginal. Leaders with these capabilities include Ecco Jaeger in Bad Ragaz, Switzerland[13], and Trade Group with its subsidiary Spread in Kyoto, Japan, which operate rooftop greenhouse and indoor vertical farms, respectively.

Irrespective of the lighting source, companies involved in the vertical farming industry for commercial purposes fall into different categories. We have identified three main business model categories in the vertical farming industry.

Turn-key farm solutions and services. They are twofold:1) players that provide commercial systems and small farm systems providers (B2B), or 2) home farm providers (B2C) including home appliances and to some extent small kitchen devices.

Engineering, Procurement and Construction (EPC) service businesses are commercial turn-key farm providers that present a variety of solutions to their clients including design, construction, installation, maintenance and management assistance, but are not dedicated to operating the farm. Under most circumstances, there is a need to demonstrate the viability of the concept through test formats. This is the case of ECF Farmsystems GmbH ("ECF") based in Berlin, Germany. The company operates a flagship aquaponics farm to demonstrate its technical ability to build aquaponic systems. In this case, the company will not run the units set up for clients, although they may provide training and consulting services.

In the small farm modular systems category[14], B2B models (e.g. InFarm) or B2C models provide farms as growing appliances (or even furniture); systems are sold outright, and the company may provide seed capsules and devices to maintain system operations. One may ask what type of system can be modeled as furniture? Home farms integrated as furniture include the Grove Ecosystem from Grove (Sommerville, USA) or Agrilution's Plant Cube™ (Munich, Germany).

Sales of vegetables and fish. As growers demonstrate the viability of commercial units and roll over the concept, they are able not only to access debt financing but also potentially to license and sell farms. As an example Spread is planning to expand abroad through partnering and licensing.[15]

Sales of systems (including lighting). They tend to set up flagship farms to demonstrate the relevance of their products and solutions (e.g. Keystone Technology's showrooms) or offer assistance and research center facilities (e.g. Indoor Harvest's CLARA project and Philips GrowWise Center) to help growers.

The importance of expressing the right company position and choice of business model will drive investors' interest and approach in a company's business model and technologies. While providers of systems (and to some extent turnkey solution providers) may be viewed as AgTech, the sale performed is rather limited to one-time, apart from maintenance services, and these companies face a market depth that is still in its infancy. On the other hand, farm units intended to sell vegetables will potentially enjoy stable and recurring cash flow. Their model is presumably closer to infrastructure than AgTech, although they face an inherent risk related to living production.

[13] Ecco Jaeger implemented a turnkey aquaponics rooftop farm from ECF Farmsystem GmbH in Berlin, Germany.
[14] We exclude here small B2C home appliance devices
[15] Price, J.J. Skype conference interview. 27 Jan. 2016. Spread Co Ltd. See interview on pg. 45.

As we concentrate on growers, business models and organizations will be different depending upon the targeted customers such as restaurants, grocery stores, supermarkets or end-consumers, and whether products are harvested and / or transformed, or the assortment is completed by other peri-urban farms. Interviews conducted tend to highlight that a mass distribution strategy tends to require larger commercial units, which in turn concentrate on fewer products. FarmedHere is an example of a business model that concentrates on targeted value-added products sold through supermarkets.

Customer	Relationship	Distribution	Transformation[16]	Assortment Completed [17]	Company Example
Supermarket chain	Contracts with products on shelf	No	Y or N[18]	No	FarmedHere
	Shop in shop – corners	Yes, to end customer	Y or N	No	n.a.
Groceries and restaurants	Spot sale or contract	Yes	Y or N	No	Gotham Greens
End consumers	Baskets – no choice	Dropping points or end customers	Potential	Y or N	n.a.
	Baskets – pick & choose[19]	Dropping points or end customers	Potential	Y or N	Lufa Farms
	Corner market	Yes	Y or N	Y or N	ECF flagship farm and market

Table: Typology of commercial farm model positioning

Each model has pros and cons, and requires thorough analysis of the market place and competitive landscape. Supermarkets may bring multi-year contractual security, which might be monetized over time; while products chosen as an internet pick-and-choose may help build a community and allow to capture a higher part of the value chain, but increase distribution costs.

In the current state of the market, vertical farming product pricing tends to be higher than conventional supermarket products. This reflects both the amortization of the investment, energy costs and the marketing ability to deliver ultra-fresh, healthy and traceable products. To shrink the price gap will depend upon an operation's ability to increase yields further through new techniques and lower investment costs.

In the market today, the vast majority of indoor vertical farms concentrate on leafy greens. These farms tend to focus on supermarket, grocery and restaurant distribution channels. Rooftop greenhouse farms have a wider product assortment, which allows them to target end consumers directly.

[16] Transformation may help to avoid waste and lengthen shelf life.

[17] Assortment of vertical farm products that are supplemented by peri-urban grower products. The farm is therefore also collecting products to provide a wider basket proposal potentially including transformed products such as dairy, meat and bread, in order to move towards a "one-stop shop" food concept. Products may be sold through basket subscription or pick and ordered via internet.

[18] Depends upon the number of products which are sold to supermarkets. Some growers who concentrate on few products offer transformed products such as basil vinaigrette created and distributed by FarmedHere or ready mix salads such as Gotham Greens "Endless Summer Mix" as examples.

[19] Pick and choose gives consumers more flexibility but implies a well-run internet ordering platform and strong logistics from harvesting to basket filling, while pre-formatted may be easier to handle under a subscription concept.

A comparison of rooftop greenhouses vs indoor vertical farming is presented below:

Farm type	Rooftop greenhouse	Indoor warehouse model	Container	Small / home farm[20]
Lighting	Mainly natural	Artificial	Artificial	Natural and artificial
Removability	-	+	++	+++
Diversity of production	+	-	-	-
Scalability	+	++	-	n.a.
Investment cost (envelope and equipment)	High	Low: existing unused buildings High: dedicated building	Low	n.a.
Energy costs	Low	High	High	n.a.
Potential benefit for the host building	BIA; bio-climatic approach	n.a. [21]	n.a.	n.a.
Distribution channels	Wide ranging from supermarkets to end consumers	Supermarkets, restaurants, groceries	Restaurants, groceries	Internet and over the counter
Ability to serve different objectives	++	-	-	-
Challenges	Initial investment cost and finding proper space	Energy cost and to some extent finding proper space	Scalability	Services

Rooftop greenhouses and indoor vertical farm (in this case readapted warehouse) models benefit from different key success factors. Rooftop greenhouse operators will try to lock rooftop spaces as fast as possible, while indoor vertical farm operators, for whom finding proper space is probably easier, will need to rollout their concept and establish distribution contracts as first market movers.

Key financial metrics

Business model economics are sparsely shared, so early stage vertical farming endeavors find it difficult to predict normative gross profit and EBITDA margins. Nevertheless, while start-up costs are high, operational costs generate interesting gross profit and EBITDA margins. EBITDA margins are very dependent upon growing techniques used and business models chosen[22]. This is the Return on Investment ("ROI") that needs to be strengthened to help finance the industry. Furthermore, as it has occurred in other emerging industries, tax incentives and government subsidies may help to attract investors and develop the industry.

Interviews with companies ranging from rooftop greenhouses to indoor vertical farms have shown that growers tend to believe that ROI should be between 8 and 12 years. Exceeding this figure becomes a business decision not rooted in pure economic reasoning.

Products and technique developments that enhance grower business models

Higher-value products. These types of products include transformation such as spring salad mixes. The value to end-consumers may help improve the profitability of the operations. In Japan, Keystone Technology Inc. is an example of a company that targets LED system developments "to arouse the potential capacity of vegetables"[23] through light and nanometer research. As a part of this research, Keystone Technology is looking to increase folic acid concentrations in vegetables and develop products with anti-oxidant properties for anti-aging.

Technical improvements. Technical improvements are needed to enhance profitability; from the ability to truly link the vertical farm HVAC system to the building, to lowering the costs of artificial lighting and the design of true vertical production systems. As an example, Indoor Harvest in Houston, USA, is developing efficient HVAC systems and fixtures, which include advanced plumbing for aeroponics, and layered LED lighting systems to enhance efficiency and ease assembly for multi-tier installations.[24]

[20] This model addresses the objective to allow end consumers grow their own produce and / or aromatics. Investment costs for the end-consumer is not very high, although cost per vegetable produced is high. Interestingly, Metro Cash & Carry has on trial one in its retail stores in Berlin, Germany a small turnkey farm purchased from InFarm to animate its fresh produce section. The project can be viewed as the future of the end consumer supermarket experience; the first attempt to develop growing corners on-site, which is similar to the introduction of bakeries decades ago. In addition to this model, Inno-3B in Quebec, Canada, (Saint-Pacôme, Québec) will provide leafy greens on growing gutters within a supermarket, to be directly picked up by customers.

[21] The potential benefits of an indoor vertical farm are not directly related to the host building but rather to its program.

[22] Desktop analysis demonstrates labor is the main cost for a rooftop greenhouse. As for indoor vertical farms the main costs are labor and energy costs. The workflow (especially harvesting and packaging) and labor costs associated with the distribution strategy retained (B2B or B2C) need to be carefully assessed, as undervaluation may stifle profitability, and therefore, arbitraged in the light of product assortment, growing techniques used and potential automation, as well as density of the catchment area.

[23] Miwa, Chika. Video conference interview. 13 Feb 2016. Keystone Technology Inc. See interview on pg. 43.

[24] Skyes, Chad. Phone interview. 15 Dec. 2015. Indoor Harvest Corp. See interview on pg. 91.

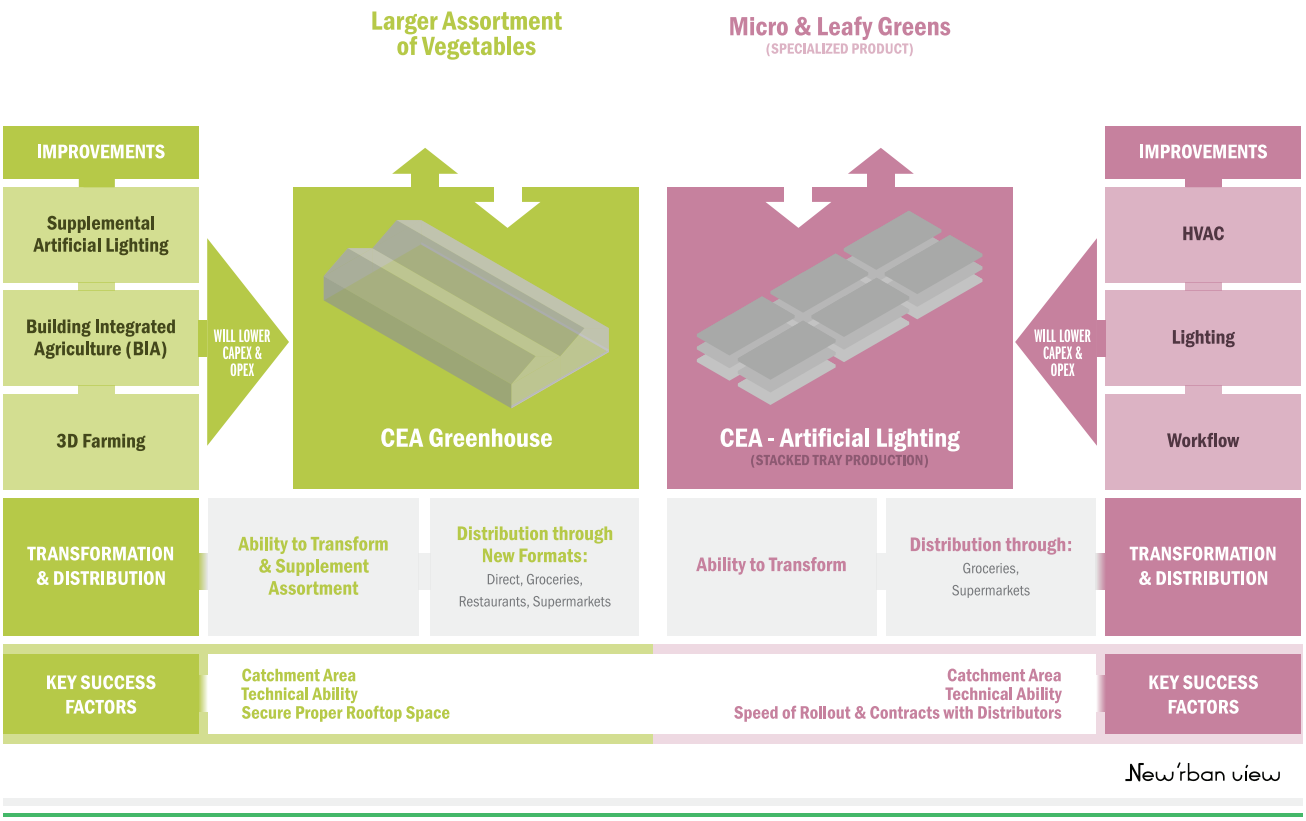
Building Integrated Agriculture. BIA designs will mitigate building adaptation costs. As rooftop design and uses for greenhouses will be anticipated as part of the design phase of a building, the cost of adaptation for load capacity, management of emerging items and rooftop access will not be necessary. The future use of the building waste heat will also save greenhouse energy costs, enhancing profitability. Depending upon geography, growers may benefit from subsidies to further research BIA.[25]

3D farming. Based on the difficulty of finding large proper space, the ability to increase growing surface vs. floor surface is a critical point. Today, most rooftop greenhouses enjoy a limited difference between growing surface and floor surface (the majority use single-layer production systems), and many growers, such as UrbanFarmers[26], believe proper 3D farming technology is key, especially as greenhouse heights offer interesting perspectives in this respect. The Toit Tout Vert rooftop greenhouse project in Paris, France, works on such solutions. Nevertheless, so far, apart from a few rotating conveyor automats in Asia (e.g. Sky Greens) or North America (e.g. Affinor Growers and Vertical Harvest), the offer of 3D farming techniques is still to be developed.

The following chart summarizes business model segmentation and developments.

SELLING PRODUCTION

Business Model Segmentation



Investors

Generally, AgTech investment has been growing rapidly over the past few years, reaching unprecedented volumes. Globally speaking, private equity is showing increased interest for AgTech investments, with a total investment volume reported by banks and media-targeting investors to be close to USD 4bn in 2015, from USD 2.4bn in 2014.[27]

It is, however, very difficult to get consistent numbers attributed to investments made in vertical farming start-ups. Moreover, Western countries are better covered by investor media than Asian and other non-Western nations. VC and private equity are not the main standards of investment in Asian countries: Japan and mainland China primarily rely on large companies, families and national and local government support. Similarly, Singapore and Hong Kong fall somewhat under this same category, which explains the lack of investor media reporting on these type of investments. As such, we will not comment on these numbers. It is worth highlighting that the vertical farm investment category

[25] See below NYSERDA funding to Gotham Greens for its Queens, New York City rooftop greenhouse
[26] Graber, Andreas. Video conference interview. 22 Jan. 2016. UrbanFarmers AG. See interview on pg. 83.
[27] Burwood-Taylor, Louisa, et al. "Annual Investing Report – Year in Review 2015." AgFunder. 16 Feb. 2016. Web. 29 March 2016. <https://agfunder.com/research/agtech-investing-report-2015>

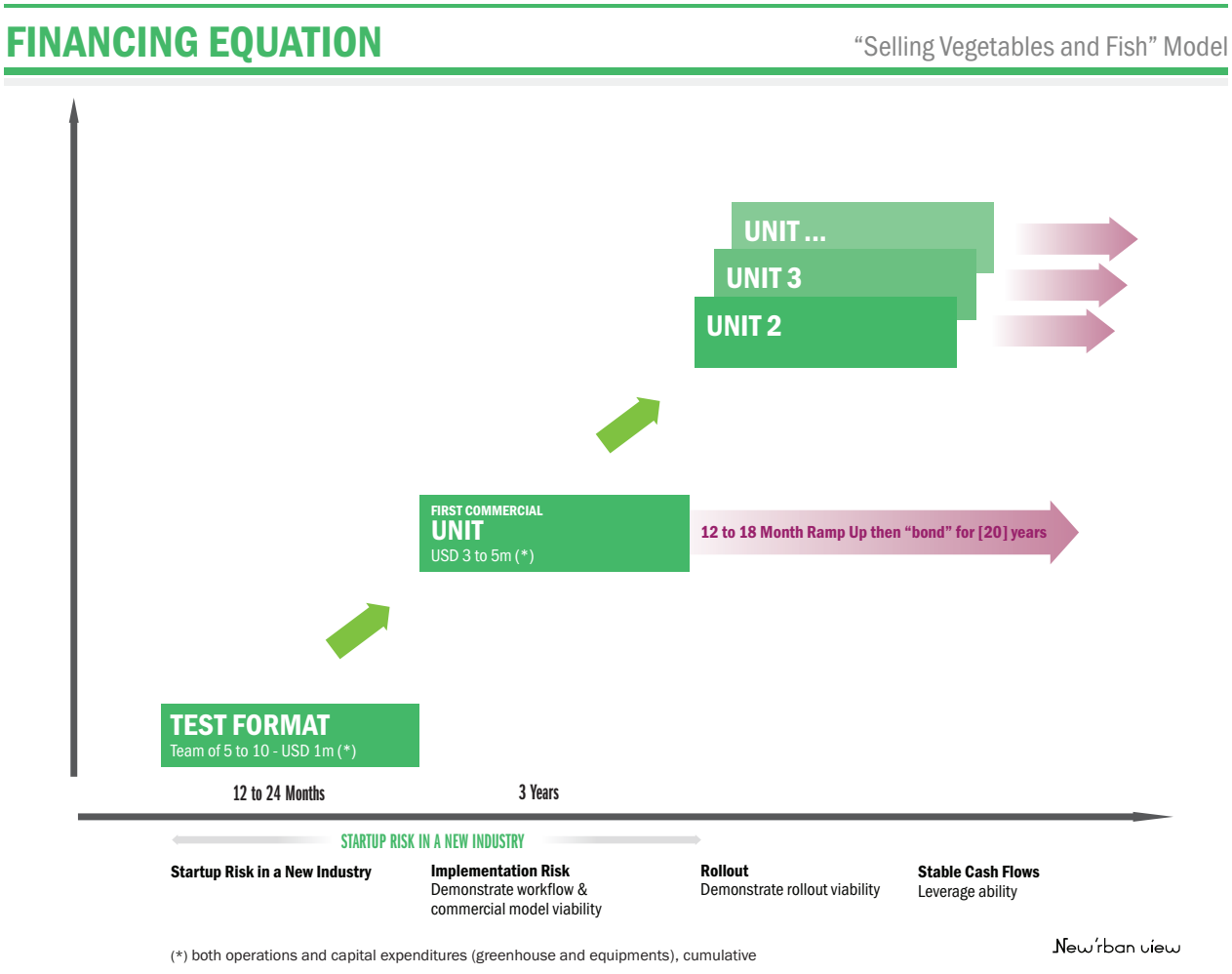
accounts for a very small portion of AgTech investments[28], which is approximately USD 50mil in 2015. As far as operational facilities are concerned, vertical farms cannot promise AgTech valuation multiples[29], for now.

Here the vertical farming operational facilities market should be distinguished from the vertical farming equipment market. Interestingly, some market research firms announced very important developments in vertical farming equipment.[30]

On a project basis, investments are meaningful and significant investments have been made over time to develop vertical farms. Paul Hardej, one of the founders of Farmedhere, mentions that the company raised approximately USD 15mil[31]; and in public sources it is reported Aerofarms has raised USD 20mil as of December 2015[32], and Gotham Greens has raised an estimated USD 30mil since inception.[33] Alongside equity, projects also try to raise debt financing. In this respect, the ability for the project company to obtain proper guarantee from a parent company of size or any governmental body helps. As an example, Spread in Japan was able to raise debt financing through proper guarantees given by its parent company Trade Group in order to develop its Vegetable Factory™.

As vertical farmers look for funds, operational proof-of-concept over a few sqm (sqft) dramatically helps to demonstrate the technical ability of the team before raising cash to develop a first commercial farm. On average, it appears to require approximately three years for start-ups to open their first commercial format and between USD 3mil and 5mil in capital expenditures in order to do so. The roll-out of the concept is then ready to start after technological aspects are fine-tuned and funding is secured.

The following chart provides a view of a grower's operational development over time and investment needed, based on case studies.



[28] It does not take into account investments performed in companies providing equipment and systems. It only refers to vertical farms selling vegetables and companies selling turnkey vertical farms.

[29] Valuation multiples such as EBIDTA multiples reflect forward value expectations of investors. In AgTech potential breakthroughs or market potentials allow investors to value companies operations at higher levels than growers.

[30] An Acute Market Reports study dated April 2015 mentions a vertical farming market, mainly lighting to reach USD 2bn by 2020, while MarketsandMarkets mention in its January 2016 study, "Vertical Farming Market by Functional Device, Growth Mechanism and by Geography – Global Forecast to 2020", a global vertical farming market projection including equipment to reach USD 3.8bn by 2020.

[31] See interview with Paul Hardej / FarmedHere on page 47.

[32] Kolodny, Lora. "AeroFarms Raises $20 Million for High-Tech Urban Agriculture." Wall Street Journal. 2015. Web. 14 March 2016. <http://blogs.wsj.com/venturecapital/2015/12/10/aerofarms-raises-20-million-for-high-tech-urban-agriculture/>

[33] Burwood, Taylor. "3 Big Challenges for Indoor Agriculture." AgFunder News. 2015. Web. 12 March 2016. <https://agfundernews.com/3-big-challenges-for-indoor-agriculture4864.html>

As projects are replicated and businesses mature, growers find economies of scale. In an interview with Spread's Global Marketing Manager, J.J. Price, he predicts the company will save 25% of its initial costs per lettuce head on their new facility The Vegetable Factory™ in comparison to their original facility, the Kameoka Plant.[34]

Investors follow concept developments

As players roll out their farms and concepts through new farms, existing investors have been seen to reinvest. For example, BrightFarms[35] secured a further USD 13.7mil series B in 2015[36], having raised over USD 30mil from inception. Spread announced that its new Vegetable Factory™ represents a further USD 14.5mil to 18mil investment (¥1.6bn to 2bn[37]), including cost of R&D and testing. In the interview section of the chapter, Spread provides insight on its business model and new facility.

Where to look to raise capital?

Angel, Seed, VC and Ag Funds. Sources of funding often sought by founders include Angel investors, investors in Seed and Venture Capital Tech, and the agriculture fund industry. AgFunder is an interesting platform providing opportunities for large institutional investors and small and individual accredited investors to invest in various types of agricultural companies, including indoor vertical farms.

Crowdfunding. In addition to Seed and Venture Capital fundraising options, crowdfunding can be an option for companies to raise capital. Vertical farming companies have launched successful crowdfunding campaigns to raise capital for their operations and products. Grove Lab[38] executed a six-city USA fundraising campaign, while Freight Farms[39] and Growing Underground[40], have successfully raised funds through crowdfunding to start or develop their businesses.

An example of a project funded from various parties is the Vertical Harvest[41] project in Jackson Hole, USA. The project was financed through a combination of public funds, bank loans, corporate sponsors, Seed funds, and more than 240[42] individuals who pledged funds ranging from USD 100 to USD 1,000.

Impact funds and cooperative bodies. Due to the nature of investment criteria of impact funds, they should also be attracted by the vertical farming model. Cooperative bodies involved in the agriculture industry are also reported to review vertical farm developments[43] and may invest at some point.

Grants and subsidies. In the USA, vertical farming projects developed in areas focusing on revitalization may benefit from public funding, tax credits and grants to foster employment. This is the case with Aerofarms: the company received USD 9mil in public funding, tax credits and grants to develop its vertical farm in Newark, USA.[44] More recently, in January 2016, it was announced that FarmedHere obtained preliminary approval of a USD 400k state tax rebate to develop a 5,575 sqm (60,000 sqft) vertical farm in Louisville, USA.

As previously mentioned, rooftop greenhouse projects are also gaining traction because of their energy saving advantages. Gotham Greens benefited from public funds including USD 1mil from the New York State Energy Research (NYSERDA) to develop its newly operated 5,575 sqm (60,000 sqft) rooftop hydroponic greenhouse in NYC.

In Asia, there has been, and will continue to grow substantial support from national and local governments to support the development of vertical farming. For instance, in mainland China, the Investment Association of China[45], which is

[34] Price. J.J. Telephone conference interview. 27 Jan. 2016. Spread Co Ltd. See interview on pg. 45.
[35] According to the AVF vertical farming definition mentioned in the introduction, BrightFarms is not technically considered as a vertical farm, as BrightFarms greenhouses are built on the ground in urban areas. It is, however, an interesting case.
[36] Manning, Laura. "Greenhouse Company BrightFarms Closes Series B on $13.65m." AgFunder News. 2015. Web. 19 March 2016. <https://agfundernews.com/greenhouse-company-brightfarms-closes-series-b-on-13-65-million5026.html>
[37] McCurry, Justin. "Japanese firm to open world's first robot-run farm." The Guardian. 2016. Web. 18 March 2016. < http://www.theguardian.com/environment/2016/feb/01/japanese-firm-to-open-worlds-first-robot-run-farm>; and J.J. Price. Skype conference interview. 27 Jan. 2016. Spread Co Ltd. See interview on pg. 46.
[38] According to Crunchbase.com, among the USD 4.42mil raised up to 31 Dec 2015, USD 412k has been raised through crowdfunding platform Kickstarter. <https://www.crunchbase.com/organization/grove-labs>
[39] Use of Kickstarter. 479 backers, USD 30,975 raised to construct the first production unit. <https://www.kickstarter.com/projects/488253196/freight-farms-grow-fresh-food-in-any-environment/posts/157191>
[40] GBP 243k raised through crowdfunding platform Crowdcube on top of £750k to start operations. Note that a recent news article mentioned £600k raised through crowdfunding. <https://www.fginsight.com/news/underground-farm-harvesting-food-for-london-restaurant-trade-11485>
[41] Hudson, Danny. "Vertical Harvest Urban Farm by E/YE Design Under Construction." Designboom. 2015. Web. 12 Jan. 2016. <www.designboom.com/architecture/eye-design-vertical-harvest-in-jackson-2-28-2015/> Note it is reported construction costs of USD 3.6m.
[42] "Pledge Members". Vertical Harvest. 2016. Web. 24 April 2016. <http://verticalharvestjackson.com/the-greenhouse/
[43] This point has been mentioned in interviews, although for obvious reasons we cannot be more specific.
[44] Larson, Chris. "VCs, Financiers Show Growing Interest in Urban Farming." CleanTechIQ. 2016. Web. 24 April 2016. <http://cleantechiq.com/2016/01/vcs-financiers-show-growing-interest-in-urban-farming/>
[45] "The Investment Association of China Will Launch a RMB 20bn Modern Agriculture Fund – First Phase of the Plant Factory Investment Program." China Securities Journal. Jan. 2015. Web. 28 April 2016. Web. <http://stock.jrj.com.cn/2015/01/20043418729821.shtml>

administered by the National Development Reform Commission (NDRC) has recently launched a RMB 20bn[46] "Modern Agriculture Industry Fund" focused on high-tech agriculture. This fund will provide monetary assistance for vertical farming initiatives on a case-by-case basis.

Large companies involved in equipment and lighting provide support. They may assist in developing technologies, supporting research efforts or investing. Kubo, the Dutch greenhouse manufacturer invested in Lufa Farms. Lighting manufacturers are particularly involved as Philips, GE, Panasonic or Toshiba have all bought into indoor vertical farming projects.[47]

Challenges to the increase of investments

Due to the capital intensive nature of vertical farming and the current infancy of the industry, it is still difficult for vertical farming growers to raise money and find proper financial investors. The traditional Seed and early stage investors that are willing to take implementation risks see their return expectations capped by the stable cash flow and limited growth characteristics of a vertical farm operation. While these characteristics may attract "infrastructure" or "utilities" types of investors who value long term stability, the risk of growing vegetables is very different from that of infrastructure businesses. Expansions and rollout of concepts, as well as financial schemes, such as Opco / Propco[48], or the aid of asset based financing will help, but the financial investment community still needs to get used to vertical farming business, metrics and credit risks.

[46] ≈USD 3.046bn (USD 1: RMB 6.56)

[47] For further infomration see Philips City Farming and Illumitex interviews on pages 82 and 92, respectively.

[48] Investments or Properties and operations are located into different vehicles, PropCo and Opco respectively. Propco rents its assets to Opco. This scheme has been implemented in various capex intensive industry, such as the hotel industry. Propcos might be then sold to real estate investors.

ECF Farmsystems GmbH

Interviewee: Nicolas Leschke, CEO and Co-founder, ECF Farmsystems
Interviewers: Howard Brin, Association for Vertical Farming
Vincent Fesquet, New'rban View

ECF Farmsystems: a passively connected two-loop aquaponics system

ECF Farmsystems GmbH ("ECF") is a Berlin-based consulting, planning and construction company that operates a 1,800 sqm, (19,375 sqft) ground based aquaponics farm. The farm includes a 1,000 sqm (10,763 sqft) ebb and flow hydroponics greenhouse with an attached 200 sqm (2,152 sqft) marketplace dedicated to selling its products. The farm has been operating since April 2015 as a unit dedicated to test and demonstrate ECF's ability to offer consulting and EPC[1] services (e.g. turnkey aquaponics farms). The project required a total investment of EUR 1.6mil investment, according to Nicolas Leschke. The system produces 30 tons of fish and approximately 30 tons of vegetables per annum, although as noted by Nicolas Leschke, a precise tonnage is difficult to assess due to the variety of vegetables grown. The company works with tilapia, carp and pikeperch, and grows a wide range of crops, including watermelons, pineapples, tomatoes, eggplants, peppers and leafy greens.

The ECF aquaponics systems is a passively connected two-loop system: aquaculture next to hydroponics. Nicolas Leschke explained a two-loop system helps manage water criteria (pH) and fine-tune growing parameters for each system. This is impossible in a pure one-loop aquaponics system when there is a compromise to be made between fish and vegetables. Artificial lighting has only been used for propagation but will soon be phased into a leafy green compartment first with traditional lighting and then LEDs. This move is opportunistic thanks to the development of a partnership with an artificial lighting manufacturer, otherwise it would not have been made due to high LED lighting equipment costs. Nicolas Leschke added 70% of the fertilizer needed for vegetables are produced by the fish, and the products are grown pesticide-free using proactive and organic pest control methods. Moreover, fish feed is organic and zero antibiotics are released into the system. However, a roadblock for its products is the fact that in the EU, aquaponics cannot be certified organic despite the products being "organic".

The first turnkey solution established in Switzerland

ECF developed in 2015 for Ecco Jaeger, a fruit and vegetable wholesaler in Switzerland, its first turnkey aquaponics unit. It is a 1,500 sqm (16,200 sqft) aquaponic rooftop farm on top of a refrigerated warehouse. The 1,000 sqm (10,763 sqft) greenhouse benefits from waste heat of the ground floor cooling units. The building had been designed to receive an additional storey, and therefore, both the project cost (approximately EUR 1.4mil including the system) and operational costs were lowered. This farm is one of the very first examples demonstrating the interest of BIA on investments and operations. Nicolas Leschke added product distribution may be well integrated in the future to the existing distribution channels of the company.

Each project is specific, each market is different

Nicolas Leschke describes three phases for a project: 1) customer preliminary discussions to recognize a feasible business case, 2) detailed project documentation, and 3) planning costs and construction phase. ECF recommends to target an 8- to 12-year return on investment and 12% to 15% EBITDA margins for an economically viable project.

Each project is specific and also depends upon the country. Due to different price positioning and cost of food, Switzerland may allow for smaller systems and direct distribution. In Germany, which enjoys lower food prices, larger units are required and distribution through supermarkets may be more cost effective. In any case a farm system would be difficult below 1,000 sqm (10,763 sqft).

[1] EPC – engineering, procurement and construction business type.

Keystone Technology

Interviewee: Chika Miwa, Manger of Overseas Business Promotion, Keystone Technology
Interviewer: Howard Brin, Association for Vertical Farming

Turnkey solution provider developing value-added products

Keystone Technology ("KST") based in Yokohama, Japan, was established in 2006 by its Founder, President and CEO, Seiichi Okazaki. The company is a full-service turnkey indoor vertical farming solutions company that designs, manufactures and installs fully equipped LED lighting cultivation systems, and assists clients to develop sales channels, marketing and branding. KST is focused on the need for an agriculture solution to solve and secure four main factors of production: quantity, quality, harvest time and price. KST has six full-time employees and one part-time employee.

Since 2006 the development of KST cultivation systems have been aided by subsidies from three Japanese government bodies and a JV partnership with AGRI Oh Inc. According to Chika Miwa, as a turnkey farm solution provider, showrooms have been built at two locations: Shin-Yokohama and Yokohama, in order to showcase KST's products as viable indoor food production systems. The Shin-Yokohama showroom invested by KST and AGRI Oh Inc is wholly designed and developed by KST, and the said showroom has a total investment of USD 439,387 (JPY 50mil). The additional showroom located in Yokohama has been solely designed, constructed and invested by KST; the total investment is USD 175,778 (JPY 20mil).

KST has designed DFT cultivation systems that are 2.1m (width) and 2.5m (height) units with proprietary water-cooled LED lighting. The systems use an air-pump to absorb air in water, which results in high to nearly max dissolved oxygen. The LED lighting systems use red, green and blue lights that can be controlled independently depending on the needed light color combination for each stage of plant growth. The units are ideal for space with a ceiling height of 3m, in order to maintain low energy costs and sustainability optimization.

The KST flagship cultivation system, AGRI-OH V (five), can produce up to 9,000 heads of lettuce per annum / unit, and the most optimal plant growth efficiency rates excluding lettuce are rocket salad, basil, dill and swiss chard. In addition to optimal plant growth, KST is developing cultivation systems for higher value-added products. For example, since 2014 KST has been collaborating with Yokohama City and a Kobe University professor to increase folic acid[1] (vitamin B) concentrations in vegetables. KST is also developing products with anti-oxidant properties (rich in polyphenol) for anti-aging, and are in the R&D phase to increase ascorbic acid in vegetables and to reduce nitrate nitrogen (NO3) in vegetables.

Challenges moving forward

Over the years KST has made good use of its financial portfolio arrangements. However, as a small company with limited human resources, the company is limited operationally to take on multiple projects at any given time. In Japan, financing through VCs and institutional investors is not a model commonly practiced, and instead KST is looking to receive investment from government or well-established companies. The focus is for further system development, R&D to control functional components / biosynthesis regulation, and assistance to reach an audience abroad for company expansion.

[1] Folic acid is a vitamin of the B complex, found especially in leafy green vegetables. Folic acid helps to synthesize and repair DNA and RNA, to aid rapid cell division and growth, produce healthy red blood cells, and important for pregnant women to prevent major birth defects for a baby's brain or spine.

Edenworks

Interviewee: Jason Green, CEO and Co-founder, Edenworks
Interviewers: Howard Brin, Association for Vertical Farming
Vincent Fesquet, New'rban View

From rooftop greenhouse to indoor warehouse

Edenworks is a startup originally involved in rooftop farming using complete CEA operations. However, in early 2016, confronted with the difficulty of building on rooftops coupled with the inherent execution risks of new construction (delays, cost overruns, etc.) in dense urban environments, no matter how many times projects have been launched, the team has recently put aside the rooftop greenhouse concept for an indoor warehouse approach. This change, which is the result of a deep industry teardown exercise, is rendered possible by the increasing efficiency and falling costs of LED lighting. Instead of an investment in a greenhouse structure, CAPEX is made in LED lighting systems which potentiate higher produce yield than sunlight and offer a better return on investment. As mentioned on Edenworks' new website, indoor vertical farming offers "no ups or down with the weather. Same price, same availability year round".

The company's mission is to operate sustainably, and therefore, the choice of aquaponics was commanded by a willingness to operate a closed-loop system – not just recirculating - in a sustainable manner and foster protein (fish) production. The closed-loop aquaponics 74 sqm (800 sqft) R&D facility in Brooklyn, New York, which was primarily a two-tier greenhouse that has been adapted to a vertically stacked vertical farm design that reflects Edenworks' change of model, to prove technology and cultivation techniques. Today, Edenworks' business model is to sell leafy greens, microgreens, and fish (tilapia) directly to grocery stores, in contrast to its early days, selling to early adopters at restaurants and foodservice companies. This approach is often used by start-ups and test formats since it is easier to handle than retailers' procedures and volume requirements, according to Jason Green. Currently, the team is 10 professionals and has raised approximately USD 1.3mil through VC, Angel investors, friends and family, but Jason Green has stated he is constantly looking for additional funding to increase capabilities and scale.

Solutions to roadblocks

Edenworks' original intent to build rooftop greenhouses raised issues with roof availability and energy. Jason Green stated the proper way to secure rooftop space is first to convince owners and developers of the project's "cool factor" and second by the produce quality. For now the majority of owners and developers do not generally care about the decrease in energy costs provided by rooftop greenhouse, but rather want the cool high-tech farm and to have high quality produce. For BIA, it is still a possibility but the real estate industry still needs more proof points. Moreover, there will need to be proper business models developed as rooftop / BIA facilities, which have by nature smaller growing areas than plant factories, and cannot offer the same economies of scale.

As a new industry, private companies in many ways have to work and create administrative processes to bridge their development. In New York City, despite legislation that was adopted in 2012 for rooftop greenhouse development (Zone Green), Edenworks in 2015 had to deal with the fact that forms and processes still had to be adequately created for Zone Green projects. These issues are moving in the right direction.

The asset-intensive nature of vertical farming has been an aspect of the industry and their business that Edenworks sees as both a hurdle and an opportunity. On the one hand, raising financing to construct new CEA assets is a challenge at an early stage, when technology and operational risks still exist. Over time, as Edenworks' business and the industry overall mature, the stable cash flows at high margins create a uniquely attractive real asset investment opportunity. The change from "greenhouse" to "warehouse", which is allowed by technology (lighting) helps lower the capital-intensive nature of vertical farming and improve productivity. Jason Green sees many parallels with the renewable energy industry, where companies like Sun Edison, Sungevity, and Solar City have attained massive scale by creating structured products to finance real assets that generate stable cash flows.

Spread Co Ltd

Interviewee: J.J. Price, Global Marketing Manager, Spread Co Ltd
Interviewers: Howard Brin, Association for Vertical Farming
David Murayama, Association for Vertical Farming
Vincent Fesquet, New'rban View

Integrating the fresh produce value chain with the Kameoka Plant

Spread Co Ltd ("Spread"), a subsidiary of Trade Group[1], is one of the leading Japanese vertical farm companies with the objective to become a turnkey vertical farm provider. Trade Group is important to the success of Spread, which is a group of five companies with businesses specialized in the fresh produce value chain covering trade, distribution, logistics, marketing and design. Spread was conceptualized by Trade Group when it was finding a way to further integrate the value chain and produce fresh vegetables based on data gathered since 2001 on Japan's fresh vegetable markets. The decision resulted in the establishment of Spread in 2006, and shortly after in 2007, the Kameoka Plant became operational. J.J. Price noted Spread designed and built the Kameoka Plant solely with their own model and design, since there were no other models to innovate from.

The Kameoka Plant is a 2,870 sqm (30,892 sqft) building with a growing surface area of 25,000 sqm (269,097 sqft), and approximately 16m in height. To date, the Kameoka Plant produces 21,000 heads of lettuce per day and about 7.7mil per annum. The type of crops produced are varieties of Frilly, Pleated, Romaine and Red Coral lettuce. J.J. Price mentioned 95% of sales are made to approximately 2,100 supermarkets within the Kanto and Kansai regions, and 5% to restaurants and private companies (e.g. in-flight services). As for distribution, it is under cold storage delivery and is serviced by other Trade Group businesses, and its workforce employs about 130 people (80% are part-time workers).

The Vegetable Factory™

Based on experience with the Kameoka Plant, Spread designed and is building a second generation vertical farm, the Vegetable Factory™. The new vertical farm will produce approximately 30,000 lettuce heads per day with enhanced cultivation techniques and automation within a 3,500 sqm (37,700 sqft) building. In addition to producing fresh produce for the Japanese market, the Vegetable Factory™ is also to be viewed as a showcase for overseas expansion and is scheduled to be opened in 2017.

The Vegetable Factory™ planned streamlined operational costs will allow to lower prices and be comparable to conventional produce price points. The 10-year experience from the Kameoka Plant has helped to dramatically enhance future plant cultivation techniques and develop a more compact design for the Vegetable Factory™. The workflow process has been reviewed and optimized within the Kameoka Plant and will help maximize cultivation spaces. There will better control systems implemented, including LED lighting, will shorten cultivation period. At the Kameoka Plant the production time is approximately 40 days, but according to J.J. Price, the Vegetable Factory™ from seed to harvest will about a week shorter. NFT techniques will be used at the Vegetable Factory™ instead of current culture techniques at the Kameoka Plant, in order to enhance water savings that will recycle up to a 98% level. As a comparison to the Kameoka Plant, the new vertical farm should decrease payroll costs by 50% and energy costs by 30%.

Although the Kameoka Plant operations have been profitable since 2012, Spread recognizes the Vegetable Factory™ is a long-term payback investment. J.J. Price noted investments have been financed through debt thanks to the Trade Group operating history and success.

Spread plans to have 20 vertical farms constructed and operating in the next five years in Japan and targets a 10% market share of the Japanese lettuce market. Future projects also include partnering and / or licensing Spread vertical farms expertise in the Asian region as well as in the US and potentially Europe. Partners will be chosen in order to provide access to logistics and sales channels in the contemplated geographies.

Vertical Farming developments in Japan

According to J.J. Price, no specific issues are blocking the development of vertical farming in Japan. However, for the Japanese market the cost of land, access to water and building costs related to earthquake resistant technology are factors that increase project costs. As a leader in the industry, Spread will look to help with regulations and standardization in Japan, in order to prevent possible risk of harmful practices or food safety and water issues.

[1] According to J.J. Price, as of 2016 Trade Group has approximately ¥28bn (≈USD 254,302,720) in revenue.

Grownex

Interviewee: Mark Kaijima, Plant Factory Division / Translator, Grownex
Interviewer: Howard Brin, Association for Vertical Farming

State of vertical farming in Japan

In Japan, the relationship among vertical farming with government and the general public has been generally accepted. The acceleration of the industry began in 2009 when the Japanese government (Ministry of Economy, Trade and Industry) provided substantial support for vertical farm enterprises throughout the country. In that year, approximately JPY 50bn (approximately USD 491mil) was provided through subsidies, grants and financial support for vertical farming and greenhouses. As a result, a large number of vertical farming start-ups were established giving the industry great momentum as there was plenty of support, demand and need for agricultural innovation in Japan. In 2013, there were reported 125 medium-size vertical farms with the majority utilizing hydroponic technologies and growing leafy greens, basil, arugula, tomatoes.

Today, the situation has changed despite this significant past commitment by government bodies. Since 2009, there has been limited government funding and the growth of vertical farms has plateaued. Several companies that were operating a few years ago are not in business anymore. For now, government support has shifted to local government entities, supporting projects that can stimulate the local economy, where vertical farm ventures rely on to be built today.

Agriculture is very important for Japan's culture and government sustainability goals. For this reason, Japan is harnessing one of its biggest strengths, R&D and tech innovation. The Japanese government is facilitating university-manufacturer collaborations in order to promote and aid technology innovation in the LED lighting systems space. Several top science universities are pursuing critical research projects where they focus in studying electric currents and electricity to collaborate and contribute for the next generation of LED lighting technology systems.

Challenges to moving forward

Japanese vertical farming companies are facing existential issues due to high operational and equipment costs. Capex are so high that vertical farms are greatly struggling to be financially sustainable. Equipment, including LED lights and racks systems tend to be very capital intensive and hard to contrast against other products and technologies in the market, as there is no standardization prices since there is a lack of competition in the space.

Mark Kaijima said Grownex has changed its strategy, and is now focusing on developing cheaper and more accessible technologies to reduce operational costs. The company concentrates on electricity aimed to develop high efficiency solutions, which are key for vertical farm growers to become more sustainable businesses. Grownex has extensive collaborations with reputable universities in the region and with their operational knowledge, they are providing consulting services to aspiring vertical farm growers. There is still great demand and interest in vertical farming from both government and consumers.

Vertical farming startups and Japanese perception

With limited funding opportunities, aspiring entrepreneurs usually obtain funds from family and friends, former businesses and bank loans. Only recently the trend for early stage VC firms has started in Japan, but in the near future they could become key enablers for the vertical farming industry.

Although there is a lack of funding sources in combination with high operational costs and expensive Japanese real estate, vertical farming is in high demand from the consumer side. An alarming situation Japan had to endure in 2011 was the Fukushima disaster, and the aftermath of soil and food contamination made Japanese consumers extremely concerned with food safety. Since then consumers in Japan have welcomed vertical farming vegetables, which is crucial for vertical farmed produce to gain commercial traction. The overall acceptance and interest for vertical farming seems to be high and very positive, but because of struggles with financial sustainability, it is a barrier that needs to be overcome.

FarmedHere

Interviewee: Jolanta Hardej and Paul Hardej, FarmedHere co-founders and former CEO and CTO
Interviewers: Howard Brin, Association for Vertical Farming
Vincent Fesquet, New'rban view

To be or not to be, an aquaponics indoor farm

Farmedhere is an indoor hydroponics and aquaponics farm located in a 8,360 sqm (90,000 sqft) warehouse in Chicago, USA. The farms produce mainly basil, arugula, kale, microgreens and process a basil vinaigrette dressing, which are sold to approximately 200 supermarkets in the Chicagoland area.

FarmedHere began in 2009 in a modest 46 sqm (500 sqft) indoor farm to first test systems and trial how to scale. Paul Hardej said a greenhouse was first tested prior to the R&D indoor farm, but in the end it was concluded a greenhouse in Chicago's climate inconsistent natural light is more difficult to manage, prone to risks and disease. An indoor vertical farm was determined economically more viable.

The mission was always to be organic. This affected the decision to use an aquaponics system: to obtain an USDA Organic label. Paul Hardej said fish are a by-product of the operation, volume is limited and there is a granular need to spend time and money marketing and selling fish. The focus is to find where revenue is generated, and this is through growing and selling organic high quality produce.

First take care of labor, next step trial LED lighting and then go to market!

Master growers are a difficult and rare asset to find, and an important step to positive productivity is an investment in training labor: growing, cutting, packaging and overall workflow. To solve these issues FarmedHere designed and implemented a job training program, and partnered with educational institutions and non-profits that train urban and organic farmers. As labor productivity improved overtime, and sales grew and were recurring, FarmedHere turned to upgrade its artificial lighting operations.

FarmedHere originally used fluorescent lighting in 2009 and 2010 since LED lighting was still inefficient and very expensive. A turning point to test LED lighting was to increase energy savings and biomass production. With stable sales and servicing over 100 supermarkets, FarmedHere revisited the feasibility to invest in LED lighting. The team set up side-by-side trials using different LED lighting products, and the outcome over 12 - 18 months of tests led to applying Illumitex lighting technology.

FarmedHere was aggressive to bring their product to supermarkets. The first strategy was to introduce and educate consumers about vertical farming products through demonstrations inside supermarkets. Jolanta Hardej pointed out this was essential to receive immediate feedback and adapt; and to control freshness and quality every day, direct delivery was made to every store. Jolanta Hardej said pricing is extremely important, and with the USDA Organic label, FarmedHere prices aligned with other organic products.

Most common mistakes performed under farm set up

Paul Hardej's said he finds common mistakes made in two areas: technology and operations. The technology for cooling systems, electrical requirements, loads and lighting equipment are often undersized. There needs to be more attention to designing for exchange rate, pressure and air management since it is often too weak. As for operations, space is congested and not providing enough room for workers to be safe and productive. High stacking operations questions practicality, in relation to airflow, lighting and crop maintenance; and workflow should be more scrutinized as it drives productivity, while people tend to focus only on technology to squeeze more yields.

As an architect, Paul Hardej posits that in order to solve design issues, architects and engineers should be involved but only after having understood indoor vertical farming by collaborating with growers.

Financing is uneasy but customers are helpful

For such an innovative project it was difficult to raise money. Financing was a combination of their own money, equity and angel investors and a latter partnership with Whole Foods. Capital was also raised through a special line with agricultural lender 1st Farm Credit, to aid in the operating credit to scale up. Although details of FarmedHere financials cannot be disclosed, the founders stated in order to successfully fund a vertical farm at scale, the requirement for capital ranges from USD 5 to 10mil. Over time the cost of essential technology such as LED lighting and hydroponics will decrease as the industry matures and new players come into the market space.

WHAT DOES A VERTICAL FARM NEED?

Better articulation of a technology and regulatory roadmap, to help entrepreneurs and regulators focus on meaningful unmet needs.

Sandor S.

TOP PHOTO: Plantform BOTTOM PHOTO: Fraunhofer IME (Photo Credit: Dirk Mahler)

4

BIOPHARMING & MEDICAL PLANTS IN CEA

Authors: Evan Bromfield, Howard Brin

Medical Applications of vertical farming

The oldest evidence of plant-based[1] medicines was found by archaeologists on a 5000-year old Sumerian clay tablet. The tablet mentions over 250 plants and instructs for making 12 drug preparations.[2] Ancient holy texts like the Indian Vedas, the Bible, the Talmud and more mention using different herbs and spices as medicines. The Iliad and The Odyssey name 63 plant species from the Minoan, Mycenaean, and Egyptian Assyrian pharmacotherapy.[3] Cloves, aloe, ginseng, poppy, and garlic; humans have had a long relationship with the healing powers of plants.

Since early human history, science has vastly expanded our knowledge of medicinal applications across different domains. The germ theory of disease for one allowed doctors to treat pathogens instead of bad spirits. Then came antibiotics, knowledge of hygiene and vaccines. Blood transfusions, trauma treatment, nanotechnologies, and hundreds of other medical advances are changing modern medicine in ways unimaginable to the Sumerian authors of the above mentioned tablet.

Plants still have many potent and undiscovered medicinal applications that we have yet to unlock.

Not only are plants used directly in various herbal therapies, but also some of the most successful drugs are derived from plants. There is also an increasing recognition for their value in solving the complex problems that have stumped even the most cutting edge of modern medical advancements.

With the advancements in modern medicine came a reliance on new chemical entities (NCEs) that target single symptoms or maladies. However, this treatment paradigm has failed to make strides against more complex diseases like cancers and autoimmune illnesses and researchers are starting to use more complex proteins derived from plants to solve these challenges.[4]

An illustration of this trend can be seen with aspirin. While a single molecule of aspirin consists of 21 atoms, a biopharmaceutical molecule might contain anything from 2,000 to 25,000 atoms.[5] Aspirin, while an important drug, is nowhere near as sophisticated as drugs like Provenge, which is used to treat cancer, or other biopharmaceuticals. Industry growth reflects those trends: in 2005 there was an 8% growth in the small-molecule drug market, a number almost doubled by the 15% growth for more complex therapeutic proteins.[6]

This chapter demonstrates that growth in medicinal plants and biopharming operations will happen for the vertical farming industry, because it is uniquely suited to overcome the most common challenges associated with those industries. Those challenges include; providing sufficient supply when wild habitats are endangered and biodiversity loss is a key threat, focusing growth on specific plant parts, mitigating contamination risk of genetically engineered organisms in the natural environment, and increasing yields of specific chemical compounds dependent upon specific environmental conditions. In addition to those challenges, we will look at the state of the medical plant and biopharming industries and examples of vertical farms in the space.

While each of these concepts will be reviewed in greater detail, a distinction should be made between medicinal plants and biopharmed plants. First, medicinal plants refer to plants grown for use a remedy such as with herbal teas, extracts, fluids, powder, pills, or capsules. Medicinal plants can also be subject to further extraction and purification procedures to isolate specific compounds, which can then be used as a drug such as quinine, digoxin, and ergotamin.[7]

[1] In this report we do not cover medicinal marijuana due to the complex political nature, and the difference in laws from country-to-country (and state-to-state for the USA).
[2] Kelly K. "History of Medicine." New York: Facts on file. (2009): pp. 29–50.
[3] Petrovska, Biljana. "Historical review of medicinal plants' usage." Pharmacogn Rev.; 6(11): (2012): 1–5.
[4] Raskin et al. "Plants and human health in the twenty-first century." Trends Biotechnology. 20 (2002): 522-531.
[5] Otto, Ralf, Santagostino, A, and Schrader, U. "Rapid growth in biopharma: challenges and opportunities." McKinsey & Company. December 2014. Web. 18 Feb. 2016. <Rapid growth in biopharma: challenges and opportunities>
[6] IMS Health. IMS world review. (2003). Available at :http://www.ims-global.com/insight/insight.htm
[7] Quinine: a malaria drug from the bark of the cinchona tree; digoxin: used to treat heart conditions and derived from the foxglove plant; ergotamin: from the ergot fungus and used to treat acute migraines

On the other hand, biopharming constitutes using crops as drug-producing bioreactors[8] and is separate from using plant crops to produce other substances such as biofuels or genetically engineered crops for traits like herbicide resistance. The bioreactors are essentially genetically modified living cells that produce target molecules in a particular media.[9]

However, both medicinal plants and biocrops (in the context of this paper) are used to treat human illnesses and face unique challenges that controlled environment agriculture can overcome.

Medicinal Plants in CEA

Approximately 80% of the developing world relies on traditional plants and herbs for their medical needs.[10] Knowledge about traditional medicine grows out of traditional practices and serves to inform our modern medical practices- 30% of drugs sold worldwide contain compounds from plant-based sources (FAO, 2004).[11] While some argue that these types of medicines are inferior to synthetic or more technologically dependent medical practices, botanical drugs are widely prescribed and used in China, Japan, India, other Asian and African countries.[12]

There is a significant global market for traditional plant based medicines. The World Health Organization estimates that the demand will continue to increase further:

"The diversity of regulations and regulatory categories for T&CM[13] products makes it difficult to assess the size of the market for T&CM products across Member States with any degree of accuracy. However, available data suggests that the market is substantial. The output of Chinese materia medica was estimated to amount to US$83.1 billion in 2012, an increase of more than 20% from the previous year (National Development and Reform Commission of China, 2013). In the Republic of Korea, annual expenditures on TM were US$4.4 billion in 2004, rising to US$7.4 billion in 2009 (WHO, 2012). Out-of-pocket spending for natural products in the United States was US$14.8 billion in 2008 (Nahin, 2009)."[14]

Challenges

In the United States alone, industry analysts estimate a yearly USD 200mil – 300mil market for domestically grown medicinal plants, and in Germany, each year around 45,000 tons of medicinal plants are used.[15] [16] However, there are real obstacles to the growth of this industry.

First, there are issues with scarcity caused by losses in biodiversity. While many medicinal crops are grown commercially, in some areas, the most common way to obtain crops is wild harvesting. For example, in KwaZulu-Natal, South Africa, 54% of Zulu herbal medicine contains tree bark, yet ring-barking, a traditional way of harvesting, is known to kill trees and deplete natural populations, even leading to extinction.[17] Root harvesting is equally disastrous for the region as it removes the underground parts of plants.

This scarcity creates price premiums in the developing world markets that rely on these plants the most. While there are systems in place that indicate a particular product is not doing ecological harm, the costs associated with establishing and maintaining rigorous sustainable resource management plans, and independent inspections and certifications to ensure the sustainable origins of the products from both an environmental and producer community perspective are consequential.[18]

The second major challenge is that crops with medicinal applications are often more difficult to grow than conventional

[8] Elbehri, Aziz.i "Biopharming and the Food System: Examining the Potential Benefits and Risks". United States Department of Agriculture Economic Research Service. 2005.
[9] Otto, 2014.
[10] World Health Organization. "Traditional Medicine." Fact Sheet. 2003. Web. 2 March 2016. <http://www.who.int/mediacentre/factsheets/2003/fs134/en/>
[11] Trade in Medical Plants. Rome: Food and Agriculture Organization of the United Nations. 2004. Web. 1 March 2016. <ftp://ftp.fao.org/docrep/fao/008/af285e/af285e00.pdf>
[12] Raskin et al, 2002.
[13] Traditional and Complementary Medicine
[14] World Health Organization. "WHO Traditional Medicine Strategy 2014-2023." WHO Report 2013. Web. 26 Feb. 2016. <http://apps.who.int/iris/bitstream/10665/92455/1/9789241506090_eng.pdf.>
[15] Esch, Mary. "Chinese medicinal herbs provide niche market for US farmers." Associated Press. December 2015. Web. 20 Feb. 2016. <http://bigstory.ap.org/article/9808ca6d89274f739476830f79e33214/chinese-medicinal-herbs-provide-niche-market-us-farmers.>
[16] Heller, Lydia. "Medicinal Plants are Big Business in Germany." Deutsche Welle. 2008. Web. 26 Feb. 2016. <http://www.dw.com/en/medicinal-plants-are-big-business-in-germany/a-3106747.>
[17] Zschocke et al. "Plant Part Substitution – a Way to Conserve Endangered Medical Plants?". Journal of Ethnopharmacology. 71 (2000): 281 – 292.
[18] Market News Service. "Medicinal Plants and Extracts." Bulletin 2009.

food crops. For example, there is often a long maturation period for medicinal crops, upwards of several years.[19] Different parts of the crops are useful in different instances, meaning there is no one farming system that will work for all medicinal plants. For example, the top 20 herbs in the herbal dietary supplement market represent 17 different botanical families and five different plant parts.[20]

Greenhouse studies in the United States compared biomass data from NFT systems, aeroponic A-frame systems, and soil grown burdock root, stinging nettle, and yerba mansa, ginger, and skullcap across different plant parts including rhizomes, roots, and leaves.[21] The study found that; phytochemical concentrations were generally similar, though slightly higher in soil production; root mass production was significantly lower with both NFT and deep water culture hydroponics; and A-frame aeroponic systems are superior for producing true root crops due to increased space efficiency and production, but are not ideal for rhizome production.

Opportunity

Where CEA and vertical farming are poised to shine is in the stratification required for seed germination.[22] Research is being conducted on medicinal plant crops in order to determine the most efficient means for growing them including: increasing light levels to increase hypercin (an important phytochemical from St. John's wort), increasing biomass with various growth regulators in Thyme, and pinpointing peak harvest times for phytochemical composition.[23] [24] [25]

These minute changes in growth conditions are facilitated by the increased levels of control available to producers working in CEA systems. This is especially important for medical plants because of how plants produce phytochemicals. Phytochemicals targeted for medicinal purposes are often secondary metabolites in plants, and frequently serve as adaptations to abiotic stresses like antioxidant production for changing temperature or flavanoid production for infection.[26] For example, cool-grown Papaver somniferum (poppy) contains more morphine than the same plant grown in warmer conditions.[27] By using controls inherent in CEA, growers can tweak environmental stresses to increase phytochemical concentration.

Additionally, as the world struggles with both scarcity of medicinal plants and even their extinction, CEA provides an alternative to natural harvesting that threatens at-risk populations. By relying on indoor vertical farms as a production source, natural populations will be free to recover from excess harvesting and a sustainable supply chain can be established, reducing investment into high-cost certifications.[28]

Research has shown hydroponic and aeroponic production systems producing increased foliar biomass compared to soil-based production systems and aeroponic methods have allowed for increased root growth.[29] Depending on the plant parts being cultivated, this could be an additional advantage for vertical farming in medicinal agriculture since, as we have seen, hydroponic and aeroponic systems see increased productivity in vertical farming operations.

Finally, with increased global urbanization and ethnic migration, bringing these culturally important medicinal crops to cities will allow people to continue to use the same medicinal plants that they have relied on for generations.

Medicinal Plant Companies

Currently, there are very few companies developing vertical farms strictly for herbal or medicinal plant production. Exceptions include The Plant (Chicago, USA) where there are experiments underway to cultivate Aloe Vera in a stacked aquaponics system with plans to expand cultivation to Common Valerian, Epazote, Common Chamomile, and Rue in a stacked media bed using ebb and flow techniques.

[19] This web page shows a 30-year harvest period for sandalwood. Odisha Forest Development Corporation. "List of Important Medicinal Plants and Their Uses." 2016. Available at https://www.odishafdc.com/products_medicinal_plants.php.
[20] Blumenthal M, Goldberg A, Brinckmann J. "Herbal Medicine: Expanded Commission E Monographs." Integrative Medicine Communications, Boston. (2000).
[21] Hayden, Anita. "Aeroponic and Hydroponic Systems for Medicinal Herb, Rhizome, and Root Crops." Horticultural Science Vol. 41(3) (2006).
[22] Canter, Peter, Howard Thomas, and Edzard Ernst. "Bringing medicinal plants into cultivation: opportunities and challenges for biotechnology." Trends in Biotechnology Vol.No. 4 April 2005.
[23] Affonso, Vanessa, Humberto Ribiero Bizzo, Celso Luiz Salgueiro Lage, and Alice Sato. Influence of Growth Regulators in Biomass Production and Volatile Profile of in Vitro Plantlets of Thymus vulgaris L. Journal of Agriculture and Food Chemistry 57 (2009) 6392-9395.
[24] Briskin, Donald, and Margaret C. Gawienowski. "Differential effects of light and nitrogen on production of hypericins and leaf glands in Hypericum perforatum." Plant Physiol. Biochem. 39 (2001): 1075-1081.
[25] Hudaib, Mohammad, Ester Speroni, Anna Maria Di Pietra, and Vanni Cavrini. "GC/MS evaluation of thyme (Thymus vulgaris) oil composition and variations during the vegetative cycle." Journal of Pharmaceutical and Biomedical Analysis 29 (2002): 691-700.
[26] Canter, 2005.
[27] McChesney, J.D. "Quality of botanical preparations: environmental issues and methodology for detecting environmental contaminants" In "Botanical Medicine; Efficacy, quality assurance and regulation" (Eskinazi, D., ed), (1999): pp 127-131.
[28] International Trade Centre. "Medicinal Plants and Extracts." Market News Service Bulletin. December 2009.
[29] Hayden, 2006.

Common Products

Botanical Family/Classification	Common Name	Plant Part Used
Actaea racemosa	black cohosh	rhizomes and roots
Aloe vera	aloe vera	leaves
Anemopsis claifornica	yerba mansa	rhizomes and roots
Angelica archangelica	angelica	roots and leaves
Arctium lappa	burdock	tap root
Astragalus membranaceu	astragalus	tap root
Dioscorea quarternata	wild yam	rhizomes and tubers
Echinacea angustifolium	echinacea	roots
Glycyrrhiza glabra	licorice	rhizomes
Hydrastis canadensis	goldenseal	rhizomes
Hypericum perforatum	St. John's wort	flowers, leaves
Lomatium dissectum	lomatium	roots
Matricaris retutica	chamomile	flowers
Melaleuca alternifolia	narrow-leaved tea tree	leaves
Panax ginseng	ginseng	roots
Piper methysticum	kava	rhizomes and roots
Podophyllum pelatum	mayapple	rhizomes and roots
Rosmarinus officinalis	rosemary	flowers, leaves
Sanguinaria canadensis	blood root	root
Syzygium aromaticum	clove	flowers
Thymus vulgaris	thyme	leaves
Trillium erectum	trillium	rhizome and roots
Urtica dioica	stinging nettles	rhizomes, roots, leaves
Zingeiber officinale	ginger	rhizomes

Table: Plant species with roots or rhizomes commonly used in the medicinal and phytopharmaceutical industries

Beyond Plants: Biopharming Vertically

While plants have been valued for their medicinal properties for thousands of years, it has only been recently that we have been able to use them as "biopharms." Remember, a biopharm refers to using the metabolic processes of a plant's cells to produce target molecules. Another way to think about this type of cultivation is that the end goal is "plant-made pharmaceuticals" (PMPs), which are produced by genetically engineering plants to produce specific compounds that are extracted and purified after harvest, and are distinct from naturally occurring plant products or enhanced foods.[30]

When scientists first began to understand this potential, there was a large focus on recombinant proteins, though plants have also been used to produce peptides and different secondary metabolites. Recombinant proteins, however, are things like antibodies and, of particular interest to the nascent biopharming industry, vaccines. Initial efforts even focused on producing the vaccines in edible plants like potatoes, but these projects have largely been abandoned due to poor initial results.

Tobacco was the first plant to express a recombinant antibody in 1988 and is still widely used in biopharming operations today.[31] Compared to other methods for producing recombinant proteins, there are many benefits to using plants that are summarized in the table below. The principle benefit is the increase in production speed from four to nine months compared to mammalian cell culture.[32]

Additionally, there is a general perception that PMPs are safer than recombinant proteins from microorganisms or cells, and like with medicinal plants of the above section, there are real diminishing returns with using single NCE to drug discovery and disease treatment that can be overcome by using more complex molecules derived from plants.[33]

[30] Kamenarova, Kunka, Nabil Abumhadi, Kostadin Gecheff, and Atanas Atanassov. "Molecular farming in plants: An approach of agricultural biotechnology." Journal of Cell and Molecular Biology. 4 (2005): 77-86.
[31] Raskin, 2002 citing During, 1988.
[32] Kamenarova, 2005.
[33] Elbehri, 2005.

System	Overall Cost	Production timescale	Scale up capacity	Product quality	Glycosylation	Contamination Risk	Storage Cost
Bacteria	Low	Short	High	Low	None	Low risk	Moderate
Yeast	Medium	Medium	High	Medium	Incorrect	Low risk	Moderate
Trangenic animals	High	Very long	Low	Very high	Viruses, correct	Oncogenic NA	Expensive
Plant cell cultures	Medium	Medium	Medium	High	Minor differences	Low risk	Moderate
Transgenic plants	Very low	Long	Very high	High	Minor differences	Low risk	Inexpensive

Table: Comparison of production systems for recombinant proteins

Challenges

The primary challenges for biopharming medicine stem from the use of genetically engineered organisms. There are real risks and many past examples of contamination to the food supply by supposedly controlled genetically engineered crops that are in clear violation of the zero-tolerance contamination requirements present in regulations around the world.[35,36] Contamination is not only a costly mistake for the integrity of the world's food supply, but also for the companies that have to pay the costs for cleanup. The more notable contamination instances were in 2002 and 2004 when volunteer maize plants expressing a therapeutic capsid protein were harvested and mixed in with soy and corn harvests.[37]

In addition to volunteer plants, a number of causes could contribute to this contamination including cross pollination by insects, often following vectors through roadside plants, wind pollination, or supply chain mismanagement.[38]

Another consistent challenge is that transgenic crops often produce low yields.[39] This is especially important for different intake forms. For example, the Landmark 2005 potato-produced HBsAg shows that orally ingested vaccines require higher levels of protein than parenteral administered vaccines for the same immune response.[40]

A final obstacle, specifically related to vaccines, but applicable to any form of production where precise concentrations of target molecules need to be obtained from a given quantity of plant cells, is quality control in food plants. If these medicines were to be administered orally, by directly consuming the plant, it would be impossible to guarantee correct dosage levels without assaying every single portion of an engineered food.[41]

So that these difficulties are not underestimated, It is worth pointing out that there are almost no PMPs on the market despite the fact that companies have been successfully granted licenses from regulators since 2006.[42] However, instead of an obstacle, this lack of competition could actually be one more opportunity along with those discussed below.

Opportunity

Biotechnology, of course, is a rapidly growing market with the number of applications for biotech patents growing at 25% annually since 1995.[43] Additionally, as the pharmaceutical industry continues struggling to replace old products with new alternatives, best exemplified by a 40% increase in R&D spending from 1996-2001 that yielded few results, the unique means of production offered by biopharming offer a promising alternative.[44]

CEA and vertical farming could potentially change this market in key ways. First, because of the impossibility to comprehensively monitor each biological variable in an open environment, researchers have concluded that it is unlikely field-grown plants will meet quality standards for use with prescribed pharmaceuticals.[45]

[34] Ma JK-C, PMW Drake, and P. Christou. "The production of recombindant pharmaceutical proteins in plants." Genetics. 4 (2003): 794 - 805.
[35] Elbehri, 2005.
[36] Greene, Stephanie, Sandya Kesoju, Ruth Martin, Matthew Kramer. "Occurrence of Transgenic Feral Alfalfa (Medicago sativa subsp. sativa L.) in Alfalfa Seed Production Areas in the United States." PLoS ONE 10(12). (2015).
[37] APHIS. "Noncompliance history." USDA APHIS. June 2008. Web. 17 Feb. 2016. <www.aphis.usda.gov/publications/biotechnology/content/printable_version/BRS_FS_Corn_compreg6-08.pdf>
[38] Greene, 2015.
[39] Rybicki, Edward. "Plant-made vaccines for humans and animals." Plant Biotechnology Journal 8 (2010): pp. 620-637.
[40] Rybicki, 2010 citing Thanavala et al., 2005.
[41] Rybicki, 2010.
[42] Sparrow PAC, Irwin JA, Dale PJ, Twyman RM, Ma JKC. "Pharma-Planta: Road testing the developing regulatory guidelines for plant-made pharmaceuticals." Transgenic Res. (2007) 16:147–161.
[43] Otta, Ralf, Alberto Santagostino, and Ulf Schrader Rapid growth in biopharma: challenges and opportunities. (2014)
[44] Raskin et al, 2002.
[45] Raskin et al, 2002.

In much the same way, vertical farms can also facilitate contamination control. Compliance with regulations is one of the major costs of biopharming, and a single contamination event can cost a company over USD 3mil, in addition to opportunity costs associated with missing revenue. The closed systems that vertical farms operate with can minimize those expenses by preventing pollen or seed dispersal.[46] Since vertical farms already have sterile systems in place to prevent outside contamination, they can easily adapt to preventing gene outflow. Containing these transgenic crops in a sterile environment also opens unique possibilities for moving from plant cultivation to chloroplast / plastid expression within the same sterile facility, reducing complexity in supply chain planning.

Companies working in this space include: Medicago, PlantForm, SemBioSys Genetics, iBio (formerly Caliber Biotherapeutics), Kentucky Bioprocessing, and Fraunhofer. Processes include up to 10 level of NFT of shallow water culture trays and even forays into system automation.[47]

Conclusion

Vertical farming and CEA offer advantages over soil and field-based farming for medicinal crops and biopharmed crops. Creating more efficient stratification processes, enhancing targeted phytochemical production, supplying new urban markets, increasing yields, and decreasing contamination risks are all unique advantages vertical farming can bring to each of these industries. With few companies competing in these spaces, even compared to the relatively small number of all vertical farms globally, there is a large opportunity to create and test new markets.

[46] Elbehri, 2005.

[47] Fraunhofner. "Automated Tobacco Farm Produces Vaccines." Online video clip. YouTube. YouTube, 10 June 2015. Web. 3 March 2016 <https://www.youtube.com/watch?v=7usRz7d4w0k>

Fraunhofer IME

Interviewee: Markus Sack, Research Scientist, Fraunhofer IME
Interviewers: Howard Brin, Association for Vertical Farming
Evan Bromfield, Urban Vertical Project

Vertical farming: a production and containment solution

Fraunhofer IME ("Fraunhofer") is a German research institute specializing in the applied life sciences. Markus Sack has worked for more than 15 years in the field of plant molecular farming, which aims to produce pharmaceutical proteins in plants. He explained that in many countries, particularly European Union (EU) member states, the political climate is antagonistic towards genetically modified (GM) organisms. There is a particular concern with open field trials, so field trials of GM crops are virtually impossible throughout most of the EU.

However, given recent breakthroughs in LED lighting, Markus Sack predicts that vertical farming will offer a promising alternative to open field trials of GM pharmaceutical plants. These are enclosed facilities where plants can be grown on vertically-stacked platforms. Vertical farms have another advantage in an organization like Fraunhofer where research space is at a premium: all the laboratories are fully occupied by other researchers, so vertical farms can save space by locating indoor operations adjacent to the main research facilities.

Vertical farms increase crop productivity and reduce expensive labor costs through automation, because each farmer is also a scientist. This makes otherwise costly research and development more affordable and efficient. The vertical farm unit where Markus Sack works currently has three small experimental layers, but the final unit will have 10-15 layers with adjustable conditions to suit different plants.

The vertical farm will be operated by a research scientist and two engineers to maintain consistent production conditions and monitor the results. During the entire process, the plants will move automatically through different layers with the least amount of human contact to prevent contamination. Markus Sack sees this as an economical and more controlled alternative to greenhouse-based molecular farming. The worst case scenario is infestation by plant pests, but the likelihood of such events is strongly reduced by indoor vertical farming with LEDs.

Regulatory challenges and opportunities

Even compared to the United States, Markus Sack considers the German regulations for GM crops highly restrictive. He believes this has created an environment where only a few selected players will be able to enter the markets as stringent regulations lead to much longer development cycles, driving up the cost of new products. Although vertical farming and LED technology will have a huge positive impact, the capital costs are high, thus favoring larger companies in industrialized countries. Vertical farming and plant-made pharmaceuticals have a bright future, let us see that globally everyone can benefit from this equally.

PlantForm

Interviewee: Don Stewart, President & CEO, PlantForm
Interviewers: Howard Brin, Association for Vertical Farming
Evan Bromfield, Urban Vertical Project

Why not a greenhouse?

Don Stewart is the President and CEO working to bring PlantForm to life, using a tobacco-plant-based production system developed by plant scientist Dr. Chris Hall to lower the cost of biologic drugs for cancer and other diseases. Don Stewart brings deep experience in the pharmaceutical industry to the vertical farming company, PlantForm, which launched in 2008. Don Stewart outlines three main advantages of using tobacco plants to produce drugs: tobacco has a high biomass for its small footprint; the biogenetics are already well known after research by the tobacco industry; and tobacco is not part of the food chain, a strength when it comes to regulatory issues.

Using their vertical system, PlantForm hopes to produce biopharmaceuticals at 1/10th of the cost of competing products that are made using fermentation systems. The system they are using is a multilayer system of up to 10 layers with two feet between each grow rack when it is fully built out, that has a mechanical lift system to move the plants but relies on gravity-powered irrigation in order to minimize the number of failure points for an operator.

So, why wouldn't they use a greenhouse for this kind of work? With a greenhouse, it can be difficult to control all growth variables, specifically heat and light, which may affect the amount of drug a plant produces. When plants are exposed to variable amounts of light, potential issues with product consistency and regulatory challenges may arise – companies would have to validate their process during different seasons, depending on light.

Regulation Issues

Despite that fact the companies like PlantForm are working with genetically engineered plants, Don Stewart says the timeline to bring an innovative drug to market would be around the same, 12-15 years. While each country has its own regulatory challenges, PlantForm is focusing on a range of countries, including Canada, Brazil, India and China. However, their main focus in in Canada where Don Stewart talks about the regulations in terms of the United States and there is already a history of transgenic acceptance from products like GE canola.

PlantForm only uses fully-contained environments to make it easier to control all of the production elements, which helps with regulation, and is using vertical farming technologies to reduce the amount of space required.

Products

Currently, PlantForm's system takes about five weeks for production. Their drugs fall into two categories. The first is cancer and arthritis drugs, where there is a marketing infrastructure in place to develop sales. The second is measures against bioterrorism. Don Stewart believes that vertical farming can contribute here because of the fast growth times and ability to produce a well-controlled product.

Intravision Group AS

Interviewee: Per Aage Lysaa, Managing Director and Owner, Intravision Group
Interviewer: Howard Brin, Association for Vertical Farming

There is no perfect lighting solution, but it helps to know your light spectrum

Intravision Group AS ("Intravision") headquartered in Oslo, Norway (supported with subsidiaries in Canada and Mainland China) is a bio-light and systems integration company developing technologies for food production and plant made pharmaceuticals (PMPs). In 2010 a partnership between Intravision and the Controlled Environment Systems Research Facility (CESRF) at the University of Guelph was established to develop advanced LED lighting systems for the facilities space research infrastructure. Since 2012 Intravision has been designing, building and manufacturing LED light systems for CESRF's hypobaric and controlled environment chambers. The cooperation has led to the development of new biological understandings of plant optimization.

In addition to its relationship with CESRF, Intravision is collaborating on various projects globally. For example, a food security project with the Kuwait Institute of Scientifice Research (KISR), where Intravision in partnership with CESRF designed a multilayer growth system called Modular Agriculture Production Systems (MAPS). Per Aage Lysaa explained research has focused on secondary metabolites and tests have included Catharanthus roseus (Madagascar periwinkle), strawberries, cherry tomatoes, as well as leafy greens, with the aim to scale and ultimately grow under the desert floor. Intravision is also working with PlantForm, a leading biotech company developing a wide range of plant-made pharmaceuticals through its patented production technique. Products include monoclonal antibodies, therapeutic proteins and vaccines for the treatment of cancer, HIV/AIDS, Ebola virus and other life-threatening illnesses. Intravision has developed a proprietary manufacturing platform integrating LED lighting to apply specified and optimized light spectrum variations and photoperiods for Genetically Engineered (GE) tobacco production in an automated vertical farming system called GravityFlow.

Per Aage Lysaa stressed there is no single perfect lighting solution for operators. Intravision is not coming to market advertising to have all the answers, but instead the most advanced tools supported by a leading advanced life support agriculture institute to help the industry figure it out. Intravision can take a few well educated guesses where growers need to be in terms of lighting recipes with environmental control in order to be successful, and can promise to support their system through continuous R&D. In other words, Per Aage Lysaa said Intravision is not selling a perfect solution, instead they are selling a lighting spectrum - if you know which spectrum you need, Intravision is capable of tuning it to your specification.

Decreasing our freshwater use

Freshwater conservative use is of great importance to our planet. For instance, to grow a soil-based tomato on average we use 200 liters of freshwater. If we grow the same tomato in a greenhouse we use 20 liters. However, if we grow that very same tomato in a vertical farm we use two liters, according to Per Aage Lysaa.

Today, traditional agriculture uses 80% of all freshwater resources. The Earth is 70% covered in water, but freshwater, the type we use for agriculture and livestock production is about 2.5% of that amount. To put more stress on the situation, only 1% of our freshwater is easily accessible, and the remaining 99% is in glaciers and snowfields. That leaves our planet's freshwater situation to 0.007%. Freshwater availability should not be ignored, and in addition to this growing issue, there are other problems that will possibly affect our global food system and supply, and not in a positive way.

There is unprecedented population growth, decrease in arable land and food shortages worldwide, and with continuous unstable oil prices and growing water shortages, disruptions in the global food supply are bound to increase. So, where are nations and companies looking next to continue supplying the demand for agricultural products? Companies from the Netherlands, Saudi Arabia and Mainland China are purchasing land around the African equator belt, which are intended for agricultural and food production for export to wealthier nations. Paradoxically, local governments in those regions fail to adequately feed their own people.

This highly complex social, cultural, political, environmental and potentially fatal web of issues will change interactions between nations and the trade of food between borders. Freshwater and food are mutually exclusive and vertical farming provides a solution to decreasing the over-use of freshwater resources. Intravision's expertise in systems integration and environmental controls, and the industry in general, can help address these growing problems.

WHAT DOES A VERTICAL FARM NEED?

> *The industry needs to develop modular and easy to use products (usable for non-farmers and non-tech experts), and more success stories of profitable projects, information sharing, standardization-certification and products labelled as organic.*
>
> **Timo B.**

TOP PHOTO: CRAFT BOTTOM PHOTO: FarmedHere

5

REGIONAL DEVELOPMENTS

GREATER CHINA

Mainland China, Taiwan and Hong Kong

Author: Howard Brin

Understanding and attitude on vertical farming

Vertical farming is undoubtedly an imported concept to the Greater China region.[1] It is widely perceived as a modernized, intelligent and efficient way of growing plants faster compared to traditional soil-based cultivation methods. However, nuances in local reception and practices do exist.

In mainland China, vertical farming has conceptually been assimilated to hydroponics, and aeroponics more recently. Almost all the so-called operational "plant factories" are in hydroponics. Aquaponics combined with artificial lighting are also developing quickly, but they appear to have been considered a modernization of the traditional aquaponics techniques that stem from Asia and have been practiced in south China since ancient times. Generally, by contrast, Taiwan and Hong Kong's understandings of vertical farming are in line with the concepts prevalent in the leading countries in this industry.

In Greater China academic and public sources, the term "plant factory" is generally used to describe vertical farms. In the interest of keeping language standardized, we will use vertical farming as the standard term of reference.

Food safety is a priority

Taiwan, despite its relative richness in arable land, has only 40% of its foodstuff self-produced.[2] Taiwan has also suffered from scandals in food safety in recent years, although not to the same extent as in Mainland China. This has increased the need for clean and safe food. The leading position in the world of Taiwanese enterprises in LED lighting and electronics have prompted these enterprises to seek for new business opportunities in vertical farming in a persistently stagnant world economy. Given the limited size of the local market and the sufficiency of arable land (hence reduced needs for vertical farms), however, these players have to turn their eyes elsewhere and in particular mainland China.

Hong Kong is a completely different landscape. With only 2% of its vegetables being supplied by local farms, Hong Kong imports the majority of its vegetables from mainland China. As people in Hong Kong are more and more worried about food safety in mainland China, the need for safe food has grown rapidly. In the meantime, the Hong Kong government has also encouraged the development of farming projects in hydroponics[3], but are currently dealing with how to categorize non-traditional cultivation practices such as hydroponics and aeroponics.[4] Nowadays, according to the Hong Kong government, there are more than twenty hydroponics farms operating in vacant industrial buildings.[5] However, the amount operating on a commercial level are limited.

In the eyes of the general public in the region, the idea of vertical farming is completely new. People who can afford to purchase vertical farming products are willing to pay only because of the higher quality and safety associated with these products. Consumers of vertical farming products in mainland China are essentially located in tier-one[6] cities

[1] Greater China is a term used to refer to mainland China, Taiwan, Hong Kong and Macau. In this report we will exclude Macau.
[2] "Big Names in Taiwan's Optoelectronic Industry Take Over Plant Factory, How LED Lighting Enterprises Seize Opportunities?" Guangdong LED. January 2016. Web. 7 May 2016. <http://www.lightingchina.com/news/46127.html>
[3] People's Republic of China of the Legislative Council of the HKSAR. "Hydroponic Cultivation." Legislative Council Secretariat Information Services. 2015. Web. 15 May 2016. <http://www.legco.gov.hk/research-publications/chinese/essentials-1516ise02-hydroponic-farming.htm>
[4] Lo, Vincent. Telephone interview. 16 February 2016. Environmental Company of Hong Kong Limited. See interview on pg. 66.
[5] "Legislative Council Question 11: Hydroponics." 3 June 2015. Web. 4 March 2016. <http://www.info.gov.hk/gia/general/201506/03/P201506030612.htm>
[6] In Mainland China, classification of Chinese cities is represented by a tier system: one, two, three, four and five. The factors considered are population size, development of services, infrastructure and economic growth. The system effectively allows to categorize cities based on consumer behavior, income level and local trends to create

such as Beijing, Shanghai and Guangzhou. The fact is that most of these consumers are not really clear about what method has been used to grow products normally labeled as "organic", since growing methods are not communicated. This is very different from Taiwan where products from hydroponics or aquaponics farms are more often sold at sales points or stores directly associated with the farms.[7] People are often attracted by the fame of the farms to purchase their products. On the other hand, we can observe a much more critical population in respect of environmental protection and food safety issues. The situation in Hong Kong is more or less similar to Taiwan, but sales channels for vertical farming products in Hong Kong are less developed.

In the section below we highlight how mainland China is positioned for rapid growth, as long as the central government, industry associations and private sector can eventually agree on industry standards and definitions. This issue appears to be one of the major roadblocks for the development of vertical farming in Greater China and particularly mainland China.

Government support and associations

While governments in the region generally hold positive views on vertical farming, their support has thus far focused on R&D, with limited funding and projects for commercial applications. In Greater China, there has not been a standardization or certification achieved at any level for the industry or the products generated by vertical farming. The application of existing related agriculture standards and certification requirements (e.g. greenhouse and conventional agriculture) might hinder the healthy development of the emerging industry.

The Chinese central government in 2013 set the policy of "industry regurgitation-feeding agriculture"[8], to increase investment in agriculture, and the Ministry of Science and Technology added vertical farming into the national "863 Program". As mentioned in the Education chapter, the 863 Program is a central government-level policy research initiative to close technology gaps between mainland China and foreign countries.[9] The focus of this policy is the adoption and advancement of technologies in various sectors to assure mainland China's financial independence from other countries foreign technologies. With this policy, selected universities and institutions have received funds to research and optimize vertical farming-related technologies (e.g. application of semiconductor lighting on plant tissue culture).

The central government has begun to bring together stakeholders in the vertical farming industry by forming in mid-2016 the Plant Factory R&D and Industrial Innovation Strategic Alliance Association (PFIISAA), which has begun its registration process in Beijing.[10] The association is set up as a bridge between government and private-sector interests, which is a combination of vertical farming operators, LED lighting companies, semiconductor companies, research institutions and universities that organize workshops, events and promotions for the developing of vertical farming in mainland China. PFIISAA is chaired by Professor Yang Qichang, the director of the Institute for Environment and Sustainable Development of Agriculture (IEDA), a division of the Chinese Academy of Agricultural Sciences.[11] PFIISAA plans to develop an industry definition and standards to start a baseline for collecting actual and representative data.

To accelerate the cooperation between LED and agricultural companies and facilitate R&D on LED lighting equipment for agricultural applications, the Strategic Alliance for Agricultural Lighting Innovation and Application (CAAL) was established in 2015 in Guangzhou, China. The formation of CAAL is supported by IEDA, the Institute of Semiconductors of Chinese Academy of Sciences (CAS), Semiconductor Lighting Industry Association of Guangdong and Guangdong Solid State Lighting Industry Innovation Center (GSC). CAAL is also chaired by Professor Yang Qichang.

Funds are beginning to be available for vertical farming enterprises. As mentioned in the Finance and Business model chapter, the Investment Association of China (IAC), administered by the National Development and Reform Commission (NDRC), has recently launched a RMB 20bn[12] "Modern Agriculture Industry Fund"[13] that is focused on high-tech agriculture. Funds are awarded on a case-by-case basis and generally allocated to government-related entities. There is an approval of RMB 6mil[14] for upgrading and promoting a vertical farm built by Beijing Nongzhong

regional clusters and enable companies and organization develop a clear market entry strategy.

[7] Taiwan Plant Factory Industrial Development Association. Phone Interview. 12 May 2016.

[8] "Status and Trends of Domestic and Foreign Plant Factories". China Technology Transfer Network. 2015. Web. 5 March 2016. <http://www.ciccas.ac.cn/a/wutucaipei/guonawaizhiwugongchangxianzhuangyuqus/2015/0728/5266.html>

[9] Tan, Xiaomei. "Technology R&D and innovation in emerging countries - Experience from China." Energy Policy: The Roles of Trust in Managing Uncertainties in the Transition to a Sustainable Energy Economy. 38.6 (2010) 2916 - 2926. Print.

[10] Original Chinese 植物工厂研发与产业创新战略联盟. The registration of its official status is in progress and targeted for Sept. 2016.

[11] "Preparatory Meeting Established in Beijing for the Plant Factory R&D and Industrial Innovation Strategic Alliance Association". Agrilighting. May 2016. Web. 20 May 2016. <http://www.agrilighting.cn/msg.php?id=269>

[12] ≈ USD 2.993bn

[13] Direct translation from original Chinese: 现代农业产业基金

[14] ≈ USD 8.977mil

Industry Co Ltd ("Beijing Nongzhong").[15,16] In a section below Beijing Nongzhong will be further described.

Across the Taiwan Strait, the Taiwanese government is paying attention to the growing industry, but there is no legislation for vertical farming operations to follow. This lack of legislation makes it impossible for vertical farming companies to obtain government grants.

On the contrary, associations have taken the lead to support industry growth in recent years. The Taiwan Plant Factory Industrial Development Association (TPFIDA) and Chung-hwa Plant Factory Association (CPFA), respectively founded in 2011 and 2012, were created to build up platforms for enterprises and R&D organizations to assist with vertical farming projects. The two associations are also active in organizing vertical farming exhibitions in Taiwan. Additionally, TPFIDA has been lobbying the Taiwanese government to provide the appropriate legislation. The timeline is unknown.[17]

Similar to mainland China, associations in the semiconductor, LED, and agricultural technology are active in the vertical farming industry. With the support of the Council of Agriculture (COA), the Photonics Industry & Technology Development Association (PIDA) and the Agriculture Multi-Discipline Management of Technology (AMOT) organize workshops, seminars and social gatherings for the purpose of promoting developments in vertical farming. The Industrial Technology Research Institute (ITRI) has also set up the Industry Promotion Alliance for LED Appliance in Agriculture, Forestry and Animal in 2012 to help LED companies expand into vertical farming.

In Taiwan there are two industry associations in support of growing systems: the Taiwan Aquaponics Association was set up in 2011 to promote private aquaponics projects, and the Taiwan Aquaponics Promotion Association (TAPA), currently has eight members.[18] In Taiwan, only products from aquaponics farms using natural media can obtain the Organic Taiwan / Traceability Agricultural Product (OTAP) certification for organic agricultural products.[19] However, the OTAP certification requirements basically rule out plants obtained from soilless methods.

In Hong Kong, the Vegetable Marketing Organization (VMO) under the Agriculture, Fisheries and Conservation Department (AFCD) established a Controlled Environment Hydroponic Research and Development Centre ("Centre") in 2013. The Centre has started the trial production of five varieties of hydroponic baby leafs, including five leafy greens under the brand "iVeggie". The Centre is used to introduce and demonstrate hydroponic technologies and equipment.

In December 2014, the Hong Kong government issued a consultation paper on new policies for sustainable development of agriculture.[20] The received opinions called for the expansion on the usage of industrial land given that vertical farming in vacant industrial buildings fall foul of existing laws and regulations on industrial land use. It was reported that the government would research that possibility.[21] It is still unclear if any significant developments have been made and additional research and consultation with the Hong Kong government is needed.

Vertical farming market in Greater China

Rooftop greenhouses

Rooftop farming is popular in the region, especially in Hong Kong, in terms of number of farms. However, most if not all of the rooftop farms are open-air farms using traditional cultivation methods and are generally small in size. Rooftop farming has generally been adopted in the region as a way of making use of limited vacant spaces to create additional greenery in urban areas rather than a means to obtain vegetables with modern methods. There are zero known commercial CEA rooftop greenhouses in Greater China.

[15] Original company name is Beijng Nongzhong Wulian Technology Co Ltd

[16] "Members of Leaders Group of Modern Agriculture Fund Conducted Survey at Nongzhong's Plant Factory." Sept. 2015. Web. 7 May 2016. <http://www.nzwl.com.cn/article/view/id/799.html>

[17] Taiwan Plant Factory Industrial Development Association. Phone Interview. 12 May 2016.

[18] See the full list of the association's members on its official website at http://www.tapa.org.tw/?page_id=67

[19] "Three Agricultural Certification Logos Safeguard Your Health." Council of Agriculture. Dec. 2007. Web. 16 May 2016. <http://eng.coa.gov.tw/suggest.php?issue=13436&id=13438>

[20] "Consultation Document – New Agriculture Policy: Sustainable Development of Agriculture in Hong Kong." Food and Health Bureau & Agriculture, Fisheries and Conservation Department. Dec. 2014. Web. 1 May 2016. <http://www.afcd.gov.hk/sc_chi/whatsnew/what_agr/files/consultation_on_agricultural_policy_tc.pdf>

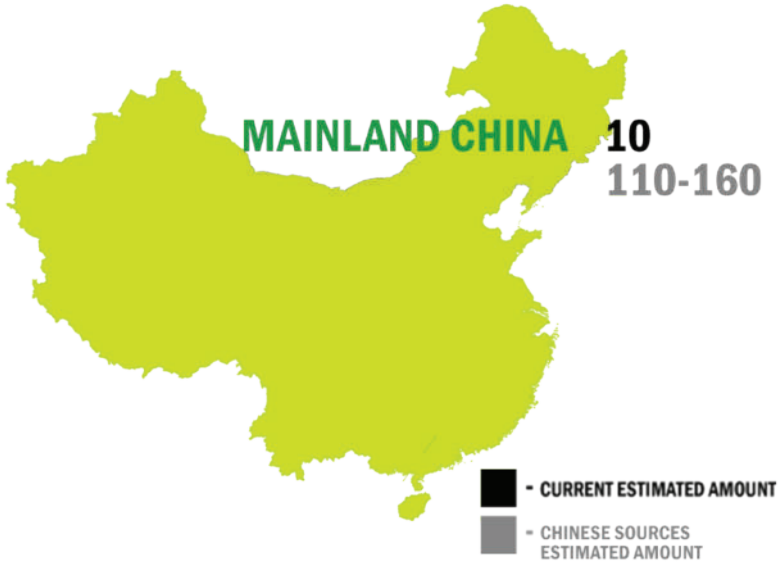
[21] "Oasis Besieged by High-rises: How Hong Kong develops Urban Agriculture." Orange News. 18 Sept. 2015. Web. 7 May 2016. <http://www.orangenews.hk/finance/system/2015/09/18/010020935.shtml>

Indoor vertical farms

Mainland China

The market size of vertical farms in mainland China has been reported at around 110 as of January 2016.[22] There are also claims the amount of vertical farms in 2015 has reached 160 (80 using artificial light), which was presented in mid-2016 at a PFIISSA conference. The market size given by PFIISSA represents vertical farms that use either artificial or natural light. However, the true market size is hard to determine based on the numbers reported in Chinese public sources and the PFIISSA conference.

To assess the true market size in mainland China, a standard definition of vertical farming as it is understood by the central government and industry players in mainland China would be welcomed to understand how the country evaluates vertical farming types and market size. Based on Chinese public sources and interviews, we assess the mainland China commercial indoor vertical farming size (excluding R&D operations) to be no more than 10 commercial scale vertical farm facilities in the private sector. However, additional analysis is needed to support this claim.



Nonetheless, mainland China is one of the leading countries developing technologies for vertical farming despite the majority of these being under the umbrella of R&D projects at government institutions and universities. The following are examples of vertical farms consisting of both government- and private-led projects.

In southern China a joint venture between Fujian San'an Group Co Ltd and the Institute of Botany, The Chinese Academy of Sciences formed Fujian Province Zhongke Biology Co Ltd. The joint venture is schedule to invest RMB 7bn[23] within four years to build a new vertical farming project in Anxi, Fujian Province. The project will include a R&D institute and a commercial vertical farm that produces fruits, flowers and medicinal herbs. The estimated output is forecasted at around RMB 8bn[24] per annum and the first vertical farm is reported to be put in production at the end of May 2016.[25] We are unable to find if the project is operational despite claims in public sources.

In northern China the company Shaanxi Xutian Optoelectronic Agricultural Technology Co Ltd is a relatively a new player in the vertical farming business, and has launched its patented "i-farmer" series of small-sized container farms for commercial spaces. There are reports claiming a production line with a capacity of 50,000 containers per annum that has been built.[26] As of 2015 the company had 30 patents in relation to container farms and has cooperated with high-end restaurants in Xi'an (northern China) to sell vegetables from its vertical farms.[27]

[22] "Plant Factory Brings in Option of Scientific Agriculture to Our Country." Xinhua News Agency. Jan. 2016. Web. 13 May 2016. <http://news.xinhuanet.com/fortune/2016-01/21/c_1117842814.htm>
[23] ≈ USD 1.046bn
[24] ≈ USD 1.195bn
[25] "'Plant Factory' Lift Veil of Intelligence, Zhongke Biology's Industrialization Base Put in Production End of This Month." Quanzhou Evening News. May 2016. Web. 28 May 2016. <http://www.hxnews.com/news/fj/mn/qz/201605/10/866383.shtml>
[26] "Notice on Record of Construction Project of Production Line of Energy-saving LED Lighting Plant Growing Containers of Shaanxi Xutian Optoelectronic Agricultural Technology Co Ltd." Yang Guan Fa Gai Fa (2013) No. 144. Dec. 2013. Web. 7 May 2016. <http://fzggj.yangling.gov.cn/info/1003/1379.htm>
[27] "Shaanxi Xutian Optoelectronic Agricultural Technology Co Ltd Has Grown Organic Vegetables with 'Plant Factory' of Independent Intellectual Property Rights." Yangling Newsletter. 24 April 2015. Web. 8 May 2016. <http://zsh.yangling.gov.cn/info/1076/61193.htm>

Beijing IEDA Protected Horticulture Co Ltd, the commercial arm of IEDA, is a pioneer in providing urban agriculture and turnkey farm solutions varying from large-size vertical farms to small tests and family formats (e-Garden series). The company also operates a National Agricultural Science & Technology Demonstration Park that includes a vertical farm covering 1,673 sqm (18,008 sqft) growing edible fungi and sweet peppers. The company has built around 30 turnkey greenhouses and vertical farms across mainland China in the past few years.

The company is also involved in the construction of the COFCO Eco-valley project in Fangshan District, Beijing. The COFCO Intelligent Farm is the core of the project and comprised of an intelligent agriculture center. The center is actually an agricultural complex comprised of a highly integrated vertical farm using artificial lighting, consisting of an edible fungi factory and a multi-layer leafy green factory featuring multiple new technologies.[28] The facility is not seen as a commercial entity attempting to be a food systems solution.

An important State-owned enterprise active both in domestic and international markets is Beijing Jingpeng Huanqiu Technology Co Ltd ("Jingpeng"), an affiliate to Beijing Agricultural Machinery Institute (BAMI). Jingpeng is a leading supplier of agricultural machinery, greenhouse and turnkey farm solutions. The company was an early player in the vertical farming industry and was responsible for building mainland China's first large-scale vertical farm that was put in operation in August 2010. The farm can produce 120,000 tissue culture seedlings and 15mil mechanized sowing seedlings per annum.[29] The company also set up the Research Center for Beijing Plant Factory Engineering in 2012 and was listed on the Shenzhen Stock Exchange in 2008.

As mentioned above, a major player in mainland China's vertical farming industry is Beijing Nongzhong. The company in January 2015 built mainland China's first and largest self-developed vertical farm consisting of 26,000 sqm (3,000,000 sqm in construction area).[30] It is reported the facility has core proprietary technology with up to 100 enterprise standards[31] for the vertical farming industry drafted by Beijing Nongzhong, the first of their kind in mainland China, which have been filed and recorded with the Beijing Bureau of Quality Supervision. These standards may become the blueprint for mainland China's first set of industry standards.

As for private aquaponics enterprises, Verdant Organic Farm in Suzhou, China is 23,333 sqm (251,154 sqft) indoor aquaponics farm combining LED lighting and IT network technology.[32] The farm is invested by Suzhou Verdant Agriculture Co Ltd. Zhang Qian, the founder of the company is a former IT engineer at HP in the USA. The company expects to develop its farm as a model company and expand the experience to the Yangtze River Delta region.[33] Additionally, in northern China, Shandong A-One Agricultural Technology Co Ltd claims to operate a 13,333 sqm (143,515 sqft) farm[34] that integrates aquaponics and aeroponics systems. The farm is also researching to grow medicinal plants such as Echinacea and burdock to generate income.[35]

Green Sense Farms, one of the largest vertical farming companies from the USA is partnering with Star Global Holdings to build, own and operate vertical farms throughout mainland China. The partnerships plans to establish more than 20 vertical farms, which will start in late 2016 with its first facility in Shenzhen, a southern Chinese city that borders Hong Kong.[36] The facility is reported to be approximately 1,858 sqm (20,000 sqft) and projected to produce about 1.5mil leafy greens and 750,000 to 1mil heads of lettuce per year.[37]

In Beijing, startup company Alesca Life Technologies specializes in providing smart urban container farms to businesses including restaurants and hotels.[38] Its EDN series turnkey solutions also enable remote control via a smartphone app.

In addition to the above examples, there are numerous companies that can supply both equipment and turnkey farm

[28] "Facility Agriculture Branch Arranges for Members to Visit COFCO 'Intelligent Farm'". Facility Agriculture Branch. November 2015. Web. 10 May 2016. <http://www.camafa.net/cn/fhdt_fhhd/11d4a1b6f7e642e897cfc604867c5519.html>

[29] "China's First Plant Factory Put in Operation, Grow Vegetables Without Sunlight." Beijing Daily. Aug. 2010. Web. 10 May 2016. <http://discover.news.163.com/10/0823/10/6EP0Q1P3000125LI.html>

[30] Vertical farm covering 279,861 sqft (32,291,731sqft in construction area)

[31] "Report on Comrade Li Yalin's Visits To Modern Agriculture Projects In Beijing." Li Yalin, Linxi County Executive. March 2015. Web. 12 May 2016. <http://www.xingtai.gov.cn/gkgl/jrxt/xtgk/lxx/201503/t20150330_152953.html>

[32] "Zhang Qian: Developing an 'Aquaponics' System at a Higher Level". Xiangcheng Today. July 2014. Web. 15 May 2016. <http://www.szxc.gov.cn/szxc/infodetail/?infoid=73bf7b40-b303-4109-8978-2a93376bfb69&categoryNum=002001>

[33] "Overseas Returned Tech Geek's Exploitation in Aquaponics." Yogeev.com. 8 July 2014. Web. 14 May 2016. <http://www.yogeev.com/article/50539.html>

[34] See A One Farm's forum at http://www.aonefarm.com/forum.php

[35] "A One Farm – To build Nationwide Aquaponics 'Farm Chain'." Yogeev.com. 24 June 2014. Web. 3 May 2016. <http://www.yogeev.com/article/50137.html>

[36] "Green Sense Farms to Build Farms in China". UrbanAg News. June 2015. Web. 8 May 2016. <http://urbanagnews.com/emag-articles/green-sense-farms-to-build-farms-in-china/>

[37] Wright, Lincoln. "Green Sense Farms' growth spreads to China, coming to South Bend". India Economic Digest. July 2016. Web. 10 July 2016. <http://indianaeconomicdigest.com/Main.asp?SectionID=31&SubSectionID=68&ArticleID=84509>

[38] "Meet The Urban Chinese Startup That Can Grow Your Lunch On Demand." Technode. November 2015. Web. 10 May 2016. <http://technode.com/2015/11/03/alesca-life-introduces-farming-service-model-indoor-farming/>

solutions; and some of the more established companies include Shanghai Soyono Machinery Technology Co Ltd, Hunan Green Rice Technology Co Ltd and Xiamen Sonneteck Optoelectronic Technology Co Ltd.[39] These companies are partnering with local governments and institutions on projects both for domestic and international markets. In an interview with George Xu (CTO) of Sonneteck reported below, he provides insight on mainland China's goal to reach standardization and certification to accelerate the growth of the industry.

Taiwan

The main development of Taiwan's vertical farming industry started with R&D and construction of facilities in 2010. As of December 2015, it is reported there are 112 enterprises that have invested in vertical farms with a total production capacity of 2,000 tons (4mil pounds) with the majority of production focused on lettuce and other leafy greens.[40] It is unclear the size and scale of the 112 vertical farms that have been invested in and whether they are all still operational. At the current stage of industry development in Taiwan, we are unable to make an accurate assessment of the market size and future projections. However, the majority of vertical farming players are located in the Hsinchu Science and Technology Park. In this part of the country, electronic companies have existing infrastructure to re-adapt warehouses as vertical farms and test their LED lighting products. This presumably explains the relative high number and relatively low vegetable production capacity in Taiwan compared to other regions. It appears Taiwan is positioning itself as a leader in LED lighting and turnkey farm solutions.

Public sources report three main Taiwan-based suppliers of turnkey farm solutions[41] are Nano Bio Light Co Ltd ("Nano Bio"), Chunghwa Picture Tubes Ltd (CPT) and Vegetables Plant Agriculture Technology Co (VPA).[42] In 2013, VPA built a 10,800 sqm (116,250 sqft) vertical farm, reported as the world's largest organic vegetable farm in Yangmei City, Taiwan. The aim is to bring down the price of vegetables by hydroponics means. It now operates dozens of membership stores to sell affordable healthy vegetables that have passed SGS[43] tests.

CPT is a leading monitor manufacturer in Taiwan, and expanded in 2011 into vertical farming initially relying on its advanced technology in monitoring systems. It quickly developed technologies and solutions for other control systems involved in vertical farms.

In Taiwan, Ruiyang Aquaponics Agricultural Technology Co Ltd operates a 198 sqm (2,131 sqft) aquaponics demonstration farm.[44] A company located not to far away is Pacific FreshONE Co Ltd, which runs the largest organic food supermarket in Taiwan, and has the largest LED lighting aquaponics demonstration wall in its store.[45] Season Farm under the management of Lishizhen Yangshengtang Co Ltd appears to be operating a successful business supplying small-sized aquaponics, hydroponics and aeroponics farms as well as limited quantities of leafy vegetables produced in its demonstration plant factory called "101 Factory" in Kaosiung in southern Taiwan.

Hong Kong

As for Hong Kong, the size of the vertical farming industry is relatively small with only two known companies: SCATIL and Farm66.

[39] See Sonneteck interview on page 67.
[40] "Plant Factory Social Gathering to Be Held 22 January." China Times. Jan. 2016. Web. 10 May 2016. <http://www.chinatimes.com/cn/newspapers/20160114000288-260210>
[41] The article mentions an additional company called San'ai Agriculture Technologies Co Ltd ("San'ai"). In an interview with TPFIDA the representative mentioned projects reported claimed to be built by San'ai have not yet materialized despite a recent report stating the company is engaged in vertical farming related projects.
[42] "LED Planting Do Not Bring Full Nutrition? See How Taiwan's Four Largest Plant Lighting Factories Fish Out 'Green Gold'". Guangdong LED. 16 Dec. 2015. <http://www.china-led.net/news/201512/16/31688.html>
[43] Leading inspection, testing and certification company headquartered in Geneva, Switzerland.
[44] "New Occupation in 2030: Build Terrace Farm at Home." X Workplace. 27 Oct. 2014. Web. 21 May 2016. <http://www.xzhichang.com/Leader/zArticle_106293.html>
[45] "Plant Factory Supermarket – FreshOne Supermarket." Jan. 2014. Web. 20 May 2016.

SCATIL is an indoor hydroponic farm using Japanese technology producing lettuce and leafy greens for local consumers. As for aquaponics farms, Farm66 is one of the two known commercial companies. Farm66 has been growing lettuce since 2012 in a vacant industrial building unit of 278 sqm (3,000 sqft) and involved in educating and promoting sustainable growing practices in local schools by setting up small demonstration aquaponics projects.[46] In an interview with the Environmental Company of Hong Kong Limited, a ground-based aquaponics company, the founder Vincent Lo provides insight on market strategy entering the Hong Kong space.

Conclusion

While the development of vertical farming in Taiwan has been receiving harmonized support between the government and private sector, its development in mainland China thus far has rather followed the top-down approach in many aspects. By far the largest market in the region, it is expected that vertical farming will expand dramatically if the government decides to give more attention and shift more resources to its development. This appears to be the case, with the official registration of PFIISAA scheduled for September 2016.

Innovation in technology, especially in helping reduce costs and increase output, is perhaps the most important factor to help the industry to gain momentum, and will in turn push the government to play a more important role in the standardization and regulation needed by a more developed market.

In the absence of high government subsidies that are available elsewhere, the region in general also has the potential to develop cheaper and viable vertical farm technologies and become the world's largest exporter of vertical farm solutions. The lack of government subsidies forces companies to innovate and create affordable technologies for the market. As the industry grows in both mainland China and Taiwan, these type of projects will be prevalent and lead private entities onto a path to becoming leaders in supplying vertical farming technologies. In this regard, Taiwan has been in an advanced position. Mainland China may well come from behind with innovation and intensified cooperation and exchanges with Taiwan and other regions.

[46] "Aquaponics Technology Look Forward To Markets At Multiple Countries." Mingpao Daily. 26 June 2015. Web. 30 May 2016. <http://chi.farm66.com/news_details.php?id=56>

EnCo Hong Kong

Interviewee: Vincent Lo, Founder and Financial Controller, Environmental Company of Hong Kong Limited
Interviewer: Howard Brin, Association for Vertical Farming

Aquaponics becomes as a business opportunity

Environmental Company of Hong Kong ("EnCo") is an aquaponics farm that opened in March 2014, located in Hong Kong near the wetlands. The management team consists of three main members, external advisors and outsourced employees. Vincent Lo, who formerly held a career in finance with a brief stint at Merrill Lynch, said his interest in aquaponics began when he was researching aquaculture funds. He eventually partnered with a local aquaculture expert from Hong Kong to start EnCo's aquaponics farm.

The EnCo aquaponics farm uses 12x7m diameter aquaponic pools, and each hold approximately 33 tons of water and is able to farm a maximum of 5,000kg worth of fish. EnCo processes part of the fish batches into canned soup, as an instant food product that has higher value and is easier for consumption. The EnCo farm produces a variety of fish such as: Jade Perch, Australian Long Finned Eel (near extinction in Mainland China) and Tinca Tinca (Doctors Fish). Vincent Lo made the choice of these rare fish types since higher market prices can be demanded.

The aquaponics farm is certified by the Hong Kong Agricultural, Fisheries and Conservation Department as an Accredited Fish Farm, which means the farm passes one of the higher standards of food health and safety, as well as water quality. Independent third party research has also been conducted on the farm with the conclusion EnCo's fish contain 60% less bacterial counts than fish that are readily available in supermarkets. In Hong Kong, the certificates and reports help attract customers.

Revenue generating opportunities

EnCo also runs a food waste recycling plant that turns food waste into fish food. The waste management revenue stream is only breaking even, but EnCo uses the recycling plant to lower operational costs. The company has found a niche profit opportunity since the Hong Kong government does not require separating the waste. At the moment EnCo targets schools, restaurants and hotels to obtain waste. Vincent Lo added the main the aquaponics farm cost is in feeding (60%), and by using food waste it cuts down approximately 50% of the total cost of goods.

In terms of revenue, EnCo's main source is currently in education for schools, tourist groups and corporations. The company provides school classes at the farm to promote education about the topic among the youth. Teaching addresses the value of food waste and sustainability through waste management.

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Vincent Lo believes there is a promising future for vertical farming and aquaponics in the next ten years, but warns that most businesses' ROI may not be attractive between two to five years. The opportunity is in the demand for not just food but a "safe and healthy" food source. To stay operational, EnCo received investment from angel investors in Hong Kong.

Government and Hong Kong landscape

In Hong Kong, the government is not currently supporting aquaponics and hydroponic farms due to a lack of understanding. At the moment, the Hong Kong government does not know how to categorize non-traditional operations such as hydroponics, aquaponics and vertical farms. Nonetheless, Vincent Lo claims that indoor agriculture is welcomed in Hong Kong and advises that a good approach is to target individual corporations that have available funds, land and old factory buildings.

As spaces are available, Vincent Lo has been pitching to property owners the idea to use vacant factories and turn them into alternative uses that can produce a profit. Vincent Lo noted it is important to warn about having patience in negotiating with these companies, as it is crucial in order for the farmer to obtain a desirable agreement.

Sonneteck

Interviewee: George (Hong) Xu, CTO, Sonneteck
Interviewer: Howard Brin, Association for Vertical Farming

Space programs and off-grid island container farms

Sonneteck headquartered in Xiamen, China is a LED lighting company with a focus on horticulture and agriculture lighting products. In Mainland China, Sonneteck collaborates with research institutions and universities to innovate LED lighting and modular growing units for the Chinese space program, and also container farms used for remote islands (South China Sea and off-grid areas). In the international market, Sonneteck provides services (consulting, light recipe, IoT system) and LED lighting systems for container and warehouse modular farms. In early 2016, Sonneteck and start-up PureHarvests Foods agreed on a partnership for the first vertical farm located in Phoenix, USA. Sonneteck is responsible for the design, build and shipment of the container farms that will be used by PureHarvests Foods's parent company, GrwoGreen Urban Farm.

Vertical farming in Mainland China

The perception of vertical farming in mainland China differs from Japan, Taiwan and the West, whereas: warehouses (and factories using) artificial lighting are included, and also CEA greenhouses with stacked layers using both natural and artificial lighting, according to George Xu. As for rooftop CEA greenhouses, the private sector has not initiated any commercial projects. In mainland China it is believed the total amount is 160 vertical farms (using artificial and natural light), which includes small-scale projects and commercial enterprises operated by either universities, research institutions, state-owned enterprise and private companies. George Xu noted in the private sector vertical farms are generally 500 sqm (5,381 sq ft) or less, since the Ministry of Science & Technology provides R&D funds at this scale.

Over the past couple years, entrepreneurs, investors and non-traditional farmers (factory owners, young urbanites) driven by food safety and environmental issues are attempting to diversify their business interests and launch vertical farming projects. Despite their efforts to create positive changes, the private sector will have difficulties to scale since there are not enough qualified growers in the market. The development of the industry heavily relies on the expertise of master growers.

As for market selection, only tier-one cities (Beijing, Shanghai and Guangzhou) are ready to accept vertical farm products; consumers are typically more sophisticated and willing to accept non-traditionally grown produce. If marketing is localized for Chinese consumers, the development of the industry can be possibly accepted and accelerated by consumer demand for fresh, local and safe produce.

Central government looking to standardize and certify vertical farms

To date, there has been limited success to access government funds for private companies. This is mainly due to the lack of product and system standardization for the Chinese market. In mainland China since vertical farms do not fall under any specific certification government body, and standardization for products and systems have only been recently studied, scaling to a private commercial level has proven difficult.

George Xu stated certifications for vertical farms are currently being discussed at the Standardization Administration of the People's Republic of China, and the proposed standardizations are being led by the Chinese Semiconductor Industry Association and China Association of the Lighting Industry, and in close cooperation with the China Agricultural Sustainable Association. The process is straightforward: approval of proposal, review, tested and qualified, and then vertical farms can receive government funding, particularly for artificial lighting. The central government supports the possibility of vertical farms, but there needs to be evidence on the proof of concept, in other words, a positive ROI.

There is no timetable to know when the standardization will be accepted and evolve into certification. There is a great need for data and at its current state there is not enough sufficient data to prove the efficiency and ROI for commercial growers.

INDIA

Authors: Parthu Kalva, Howard Brin

Understanding and attitude on vertical farming

In India, small-scale agriculture has been in a slow decline. According to the 2011 Indian agriculture census, the number of cultivators has declined from 50% of the total workforce in India in 1950 to 24% of India's workforce in 2011. In the 1950s, the output from Agriculture and Allied services was 51% of the country's GDP. Now, the number has decreased to 13%.[1] Although India's economy has diversified immensely since the 1990s, innovative and sustainable infrastructure surrounding agriculture continues to be in need.

Currently, 70% of India's population lives in rural areas[2], but this number is decreasing and strong patterns of urbanization are apparent from census data, as small farmers and artisans from rural India are increasingly moving into India's cities. As a result, India's agriculture sector is rapidly changing, specifically in the reduction of landowners and an increase in agricultural laborers, a paradigm being seen in countries all over the world.

In this context, vertical farming models have been increasingly establishing relevance as a solution, and there has been surging interest in hydroponics and vertical farming by farmers, entrepreneurs, and investors. In India, vertical farming is largely referred to as soilless farming or cultivation, including growing on rooftop greenhouses as well as in controlled indoor environments. To maintain consistency, vertical farming will be used synonymously with soilless farming in this section. For now, in India the distinction between ground-based and indoor vertical farming is not fully defined.

The market in India is ripe for the spread of vertical farming for a variety of reasons. For example, growing plants in controlled environments nullifies the climate variable, increasing expected yields and making agricultural businesses much more attractive for investors. In addition, the use of pesticides is reduced drastically when one is using hydroponics, since most pests reside in the soil. In South Asia, the usage of pesticides has driven farmers into greater debt as well as negatively impacting the environment.[3] The lack of dependency on pesticides will thus serve to help promote the livelihoods of Indian farmers and even incentivize policy efforts. The ability to re-sow seeds immediately, instead of waiting a year, increases the long-term profit margin of agriculture businesses and makes them more lucrative for investors.

Although Indian vertical farming has great potential, there are a variety of obstacles that need to be surmounted. For example, a notable obstacle is the lack of awareness and under-informed public perception of soilless farming in India. As noted later in interviews, much of the public continues to perceive different forms of soilless cultivation as a hobby or limit it to the scale of a private garden.

Vertical farming has not received mainstream attention, especially as a commercially viable source of food. Nevertheless, rising health concerns among the Indian public may incentivize it to turn to soilless farmed products for the increased accessibility to a diversified range of produce that they offer. In addition, as Indian cities continue to grow, there is a high chance that the urban agriculture sector will grow as well, attracting growers skilled in traditional forms of agriculture.

Another obstacle is the current lack of a reliable, cost-effective energy source, much of which is used to control the temperature and humidity of vertical farms and hydroponic greenhouses. In much of the developing world, issues with transparency and a lack of updated infrastructure causes public energy grids to be highly unreliable sources of power, driving up the potential cost of implementing vertical farming enterprises. Almost 50% of power transmitted in India stems from infrastructure owned and operated by the Power Grid Corporation of India, a government-owned entity.[4] Renewable energy infrastructure in India is a growing industry as well, and the growth of the solar and vertical farming industries may complement one another. The government, however, controls nuclear and petroleum energy

[1] Agricultural Census 2010-2011." Department of Agriculture and Cooperation. 2014. Web. 17 May 2016.
[2] "Rural Urban Distribution of Population." Censusindia.gov.in. Census of India 2011. n.d. Web. 18 May 2016.
[3] Shiva, Vandana. "The Green Revolution in the Punjab." Living Heritage. n.p., n.d. Web. 17 May 2016. <http://livingheritage.org/green-revolution.htm.>
[4] Overview of the Indian Power Sector." Indian Power Sector. Indian Power Sector. 2012. Web. 17 May 2016. <http://indianpowersector.com/home/about/>

infrastructure, so accessibility to these forms of energy may be limited.

Another significant obstacle is the logistics / costs surrounding the maintenance of both urban agriculture and CEA facilities. Due to a lack of pre-existing infrastructure surrounding urban agriculture and / or CEA, significant capital must be invested in training personnel and staff to maintain the facility. Although the location and activity of these farming operations may create many new jobs for city locals, the unique skillset needed to maintain a vertical farm, including technology, business development, and horticulture, will make finding qualified candidates challenging for now.

In order to address this, urban agriculture and CEA certification curriculums must be introduced at Indian agricultural science institutions, where currently no such degrees are awarded. Studies surrounding hydroponics, aquaponics and urban farming should also be made available at primary and secondary school levels in private schools, where funding is more available than for government schools.

Furthermore, an additional obstacle influencing the demand for vertical farming in India are the types of crops grown in indoor facilities thus far. Much of vertical farming's success globally stems from the growth of leafy greens such as lettuce, or crops that are not in high demand throughout India. Although crops like kale and spinach are becoming more popular, they are not central to Indian diets. Instead, crops not native to India but consumed in Indian diets, such as broccoli, tomato, etc., are key to increasing the growth and popularity of indoor farming. Moreover, the demand for these crops may vary within India as well, depending on the regional cuisine and diet.

Government involvement

Policy support for vertical farming is generally limited or sometimes even restrictive, although there is increasing support in the light of political or economic crisis. There are both advantages and disadvantages that vertical farming will face in maneuvering the policy landscape. An important advantage is that vertical farming and urban agriculture have several institutional linkages, since sectors affected by this industry include environment, health, microclimate and climate change, waste management, recreation, sanitation, land use, and employment, among others.

As a result, there is a wide range of interests that may leverage policy action involving vertical farming in India. This network must be channeled towards ensuring the legislative presence of Indian urban agriculture and building relationships with policymakers. In India, political lobbying is not actively pursued. However, policymakers may be influenced through consultancy partnerships with non-profit entities, along with universities and industrial leaders.

An excellent example of urban agriculture working through universities and grassroots programs to garner policy momentum takes place in the South Asian country of Sri Lanka, where the Minister of Agriculture reformed the National Agricultural Policy (NAP) to discuss urban agriculture in 2013.[5]

Wayamba University began an undergraduate module surrounding urban agriculture and actively engaged their master's students on projects linked to urban agriculture. In western Sri Lanka in particular, many urban poor grow their own food on small plots. However, the shortage of land and the limited access to fresh water means that the productivity of these urban plots are not usually high, and farmers are unable to profitably grow a surplus. As a result, International Water Management Institute, in partnership with the RUAF foundation and the NGO Practical Action, started a project to strengthen the skills and marketing capabilities of farmers.

In this project, a farming company was set up to manage microloans through a revolving fund. Urban producer field schools helped build capacity and trust, while Practical Action created training on skills such as the packaging and marketing of produce to make it more attractive to supermarket retailers. This resulted in over 1,500 households and 75 entrepreneurs as direct beneficiaries. Due to this program, the Minister of Agriculture amended the national agriculture policy to include a list of recommendations for urban agriculture. This may be used as an example for how momentum surrounding urban agriculture policy may be built in India and as a support for the future development of vertical farming.

In India's most recent NAP, there was no distinguishing between urban and rural agriculture, along with no mention of urban agriculture. The extent to which CEA was mentioned in the 2007 NAP was limited to a brief overview and recommendations surrounding greenhouse farming, omitting key information such as steps towards promoting the development of technologies such as LED lighting and hydroponics.[6]

[5] "Urban Agriculture Gets Policy-level Support in Sri Lanka's Western Province." International Water Management Institute. 2013. Web. 16 May 2016. <http://www.iwmi.cgiar.org/Publications/Success_Stories/PDF/2013/Issue_16-Urban_agriculture_gets_policy-level_support_in_Sri_Lankas_Western_Province.pdf>
[6] "National Agricultural Policy 2009-2015." Ministry of Agriculture, Land, Forestries, and Fisheries. n.d. Web. 15 May 2016. <http://faolex.fao.org/docs/pdf/stl146715.pdf>.

Since for Indian agricultural policy, formulation occurs at the central level and implementation occurs at the state level, a series of information sharing and networking efforts are needed to enhance coordination between the initiatives at the central and state levels. So far, efforts have focused on classifying urban agriculture under preexisting components of agricultural policy in India, including 'urban horticulture' and 'women in agriculture'. Ultimately, urban agriculture and CEA must comprise independent components of India's NAP, which may be achieved through strategic partnerships with influential research institutions in India.

Since official lobbying activities, as are protected by legislation in the United States, are sparse and unofficial in India, information sharing and networking must occur at a variety of individual and community outlets to reach a political level. Efforts are currently being taken by the Central Government of India to actively progress agricultural policy, particularly due to rising farmer suicides.[7] As a result, this is now a key time for urban agriculture professionals in India to seek policy inclusion. As mentioned earlier, a potential future initiative is to obtain the attention of key academic bodies, such as the Indian Council for Agriculture Research (ICAR). Involving ICAR in research and business initiatives will help shed greater light on the potential of CEA and help leverage policy promoting it.

Overall, the growth of Indian vertical farming is likely to be bottom-up. At the beginning, a grassroots program or business would pioneer large-scale urban agriculture or vertical farming initiatives. Afterwards, the initial success of the initiative would capture the eye of universities, which do one of two things. First, they provide funding or intellectual support to promote the further development of the initiative and second, they design growing systems, which they propose to government-sponsored research centers like ICAR for further development and study. If centers like ICAR take an interest, they may exercise their influence over government policy decisions and prioritize policy action to support vertical farming in India. This policy action may include measures such as subsidization, which would further support the growth of programs and businesses as mentioned in step one. This may occur either through the central government or state governments, depending on the research institution and non-profits involved.

Vertical farming and nutrition

In India, malnutrition has proved to be a persistent issue, particularly child malnutrition. According to the Global Hunger Report 2015, India has the highest number of undernourished people in the world at 194.6mil.[8] Although China had the highest number of malnourished people at 289mil in 1990, it has lowered this number by 53% over the past two decades. India, on the other hand, has lowered its malnutrition rate by 7% over the past two decades but increased it 2.6% over the past five years. Over the past few years, the proportion of undernourished Indians fell by only 0.4%.[9] The purchasing power of India's poor continues to be limited to sustenance from staple grains such as rice and wheat. Simultaneously, the obesity epidemic is also growing throughout India. This epidemic is heightened by the limited nutrient profile of popular diets as well as a lack of structural access to fresh and healthy produce.

In turn, since vertical farms in India have been postulated to be profitable in growing vegetables not native to India, these enterprises may increase access to a diversified range of fruits and vegetables to urban consumers, including tomatoes, broccoli, basil, etc. In the process, Indian urban agriculture and vertical farming will help increase the affordability of food while increasing micronutrient intake, ultimately helping combat both malnutrition and obesity.

Main players in India

Vertical farming and CEA in India show large potential in helping to diversify the Indian economy, whilst also empowering its agricultural sector. This emerging industry is proving to be as diverse as the paths that these businesses embark on, whether it be business strategy or technology. The Association for Vertical Farming has been in touch with around 30 companies supporting soilless farming in India, whether they be hydroponic greenhouses and consultancies. The current Indian vertical farming market has, reached up to seven commercial vertical farms. However, field research needs to be performed to validate the true vertical farming market size in India. Due to the lack of accurate detailed information we were unable to predict the growth of the Indian vertical farming industry.

Domes India, for example, is a construction company in India that has established a vertical farming hydroponics facility.[10] Its plants, technology, and machinery are sourced from the United States, paving the way for international cooperation in expanding vertical farming.

[7] "Panel to Revisit National Policy on Farmers." The Hindu. 18 Jan. 2016. Web.10 May 2016. <http://www.thehindu.com/news/national/panel-to-revisit-national-policy-on- farmers/article8117540.ece?utm_source=InternalRef&utm_medium=relatedNews&utm_campaign=RelatedNews#>

[8] "Last 5 Years, Number of Undernourished Indians Rises." India Spend. 2 June 2015. Web. 13 May 2016. <http://www.indiaspend.com/cover-story/last-5-years-number-of-undernourished-indians-rises-28391>.

[9] "The State of Food Insecurity in the World." Food and Agriculture Organization. n.d. Web. 13 May 2016. <http://www.fao.org/3/a4ef2d16-70a7-460a-a9ac-2a65a533269a/i4646e.pdf>

[10] "Hydroponics Indoor Vertical Farming." Domes India. n.d. Web. 12 May 2016. <http://www.domesindia.com/hydroponics_indoor_vertical_farming.html>

Green Chip sells garden trellises upon which vegetables and fruits may be grown in limited space.[11] The founders of the company ultimately want to decrease the dependency of Kerala, a state in India, on imported produce from other states.

The company Hamarikrishi is one of the first vertical farming consulting companies in India, implementing both commercial and home-based garden systems.[12] Precision Farmers is a company that focuses on developing the designs of precision agriculture solutions. Some of the technologies they offer include greenhouse automation that monitors moisture and humidity, nutrient measurement, soil health cards, solar power-enabled systems and developing bore well recharge.[13]

In addition, there are a handful of key players that have played an important role in guiding the development of India's budding vertical farming industry. One of these individuals is CV Prakash, founder and Farmer-in-Chief at Hydroponics Greenhouse Technologies India Pvt. Limited.[12] CV Prakash is credited with building India's first commercial, fully automated, climate-controlled hydroponics greenhouse in India in 2010. Among the multitude of projects that CV Prakash is working on is building a Center of Excellence for Hydroponics for the Gururaj Deshpande Foundation in Karnataka, India. In addition to his projects, he has trained over 7,000 students in simplified hydroponics.

An additional notable player is Sriram Gopal, an electronics and communications engineer and founder of Future Farms. Sriram Gopal is an entrepreneur in the sustainability and technology space with 10 years of experience in digital product development and hydroponics. As the founder and CEO of Future Farms, Sriram leads a team that designs and creates vertical farming modules towards growing food sustainably in urban environments. Technologies developed at Future Farms includes hydroponics, garden automation, and greenhouse facilities. Future Farms also sells a variety of hydroponics systems, nutrients, growth mediums, and instruments for growers to use.

Information on other influential figures in Indian vertical farming, such as Vijay Yelmalle of CRAFT and Bhaskar Rao, are provided in the interviews following this section.

Conclusion

The diverse dimensions of Indian vertical farming will heighten the adaptability and resourcefulness of the industry as a whole. Nevertheless, the industry must coordinate its efforts in order to maximize its long-term economic impact. For example, one of the biggest obstacles hindering private investment in vertical farming is that stakeholders have different visions backing their decisions and thus consensus building proves to be difficult. Building a framework to help centralize the vision of vertical farming in India and to provide measures on its progress will be integral to attracting investors by market-sizing, and in turn furthering the growth of the industry.

[11] "Green Chip Agricultural Systems, Private Limited." Facebook. n.d. Web. 24 April 2016. <https://www.facebook.com/Green-Chip-Agriculture-Systems-P-Ltd-208227122675184/>
[12] "Hamarikrishi Technology." Hamari Krishi. n.d. Web. 25 April 2016. <http://hamarikrishi.com/technology/>
[13] All India Seminar on Business Opportunities in Soilless Cultivation. Mumbai: CRAFT. n.d. PDF.

As mentioned above, over the next few pages, interviews with individuals from a variety of Indian vertical farming and urban agriculture companies are included. In addition to demonstrating the wide array of approaches towards building a successful vertical farming company in India, these interviews help shed light on the overarching vision driving vertical farming in India.

CRAFT

Interviewee: Vijay Yelmalle, Founder of CRAFT
Interviewers: Howard Brin, Association for Vertical Farming
Parthu Kalva, Analyst, Association for Vertical Farming

Plans to build a vertical farming hub in Mumbai, India

The Center for Research in Alternative Farming Technology ("CRAFT") located in Mumbai, India, is involved in the research and implementation of aquaponics, hydroponics, and organic farming technologies in both rural and urban spaces. CRAFT employs four staff that oversee client facilities totaling 500 sqm (5,381 sq ft) that grow produce such as spinach, lettuce, pak choi, basil and thyme. Vijay Yelmalle, a trained chemical engineer, has invested USD 20,000 into R&D and product development, and is working with investors to raise capital for 10-acre vertical farming plots.

Obstacles for vertical farming in India

Despite the increased interest in vertical farming within India, existing vertical farm concepts are currently small and need to improve their business models in order to grow into sustainable and viable businesses. The main obstacles preventing the expansion of vertical farming in India are high operating costs, market prices and a shortage of hydroponics and aquaponics experts.

To remain profitable in face of high operating costs, new or existing operators can compete on imported exotic vegetable price points. Vijay Yelmalle explained that imported exotic vegetables in India, or high-value crops, can be produced in India 50% of imported produce costs. There are many different type of crops but some that may be able to compete in today's market include Italian herbs, broccoli and arugula. Although demand for these crops is not relatively high, the feasibility of growing and selling these crops in vertical farms utilizing minimal space remains high. This is due to the hundreds of acres available on terrace tops, as well as the increased proximity to customers. Vijay Yelmalle added vertical farms can shed costs by utilizing water and energy infrastructure of the buildings.

A major issue in the India market lies in the lack of technical expertise. This inherently contributes to heightened losses stemming from inefficient technology or errors in the implementation and maintenance of hydroponic technology. CRAFT is looking for technical experts interested in furthering its mission to accelerate the development of Indian indoor vertical farming.

In the past CRAFT had partnered with the aromatic industry, which grow aromatic plants used in fragrance products. Many companies in this industry are interested in finding the most sustainable way to grow aromatic plants. CRAFT experimented with growing these plants in a hydroponic system, but were not successful, since the saplings could not adapt to the transplantation shock of the system

Education is a major key

There needs to be a support base to nurture a presence for vertical farm research in Indian universities. This essentially should start with educating growers: to understand growing techniques and business development. At the Institute of Technology Mumbai there are students working on aquaponics projects, and Vijay Yelmale and his team are presently working on a greenhouse management program in Ramnarain Ruia College under Mumbai University. With the program, he explains hydroponic technology and discusses innovative means of promoting vertical farming locally. As many individuals are coming up with agricultural models of interest, competition is increasing.

Al Ghalia Farms

Interviewee: Bhaskar Rao, Farm Operations Manager, Al Ghalia Farms
Interviewer: Parthu Kalva, Association for Vertical Farming

Imported exotic vegetables is a start for vertical farming in India

Bhaskar Rao has been working in indoor agriculture for almost 22 years, 70% of which were in the Gulf countries of the Middle East. Currently, he works as a farm operations manager at Al Ghalia Farms, a company based in Bahrain, while distantly supervising the development of vertical farms in India and Kuwait. Al Ghalia Farms is a group owned company with a total of 33 staff, and has an operational indoor vertical farm for fodder grass, pea shoots, bean sprouts and microgreen cultivation. The company uses a floating raft system (DWC) for growing lettuce and basil, and passive hydroponics techniques (coco peat substrate) for the cultivation of baby spinach, arugula, edible flowers and various other culinary herbs.

In the late 1990s and early 2000s in India, Bashkar Rao stated hydroponics and CEA were widely distrusted by the public; the landscape has changed, and there are approximately 1,600 hectares under polyhouse cultivation in India today. Indian vertical farming continues to show great growth potential, especially in the cultivation of exotic vegetables. For example, the Indian Council for Agriculture Research (ICAR), released information showing the market for exotic vegetables is growing in India at around 15-20% per annum and since 85% of exotic vegetables are imported for a much greater price abroad, growing these vegetables vertically is an attractive business model.

Perception in India: need for consumer education

In India, the vertical farming industry needs to address public misconceptions. These include vertical farming to be limited to rooftop gardening, rich man's hobby, and the belief the taste, texture, color, and consistency of produce is negatively affected if grown soil-less or indoors.

If farmers decide to be invest in and apply hi-tech farming, they need to shift to growing high-value crops and begin to cater to a high-end clientele. The most likely outcome is initial customers will consist of individuals with high purchasing power in urban areas. As growing technical expertise and infrastructure help decrease vertical farming costs, consumers in regions with lower purchasing power may be targeted as well.

An approach to commercializing vertical farming in India

In India there is great opportunity for growth, since CEA is more client-focused and organized specifically with the end-user in mind, which may appeal to health-conscious consumers since better traceability can be kept for all controlled variables that go into growing and tending the produce they purchase.

For individuals looking to start a commercial hydroponics farm in India, Bhaskar Rao recommends they grow on at least five acres of land. If an entrepreneur decision to only grow on 500-1,000 sqm (5,381 – 10,763 sq ft) unit, their business will not be feasible. Thus, it is important for future Indian growers to understand what the ROIs are projected to look like in the next five years, and to continue to think large scale and long-term.

Kerala Agricultural University

Interviewee: Dr Giggin T., Assistant Professor, Kerala Agricultural University
Interviewer: Parthu Kalva, Association for Vertical Farming

Local exotic vegetable production can compete with native products

Dr. Giggin T., Assistant Professor at Kerala Agricultural University with a background in animal husbandry, develops experimental vertical farming demo units in a non-commercial way. Dr. Giggin T. believes the main challenges that Indian indoor vertical farming faces are associated with technology, maintenance and structural issues. As technologies and demand hopefully develop, solving these issues require growing high-value products for consumers with high purchasing power (exotic vegetables or produce that is non-native to India: lettuce, broccoli and celery). Most customers with high purchasing power are situated in metropolitan areas, such as Delhi or Mumbai. In these areas, microgreens are very popular, and health-conscious customers will prioritize the quality of the produce. Dr. Giggin T explained since the cost of establishing and maintaining a vertical farm in India is so high, high value crops should be grown in these mediums in order for the businesses to have a positive profit margin, for now.

Support by the Indian government is needed but should not be overbearing

Government subsidies are a crucial step towards successful transition to high-tech agriculture. The government budget prioritizes the wide category of organic farming over vertical farming, since public advocacy has allowed the solutions offered by organic farming to become more mainstream than those offered by vertical farming. When looking ahead, it is important to note that the government prioritizes subsidizing technology and programs gauging how much employment and infrastructure is generated, services offered, and the number of people that are affected. In Kerala, the government provides 75% subsidy for outdoor polyhouses, some of which are trying soil-less vertical cultivation. The National Bank for Agriculture and Rural Development (NABARD) provides funding in full for innovative designs. NABARD fully funded a frontline demo unit of an integrated vertical farm designed by Dr. Giggin T.

Although the government should provide industry backing, the support should not dictate the progress of Indian vertical farming in its totality, according to Dr. Giggin T. The Indian Council for Agricultural Research (ICAR) decides research problems across India in universities. If vertical farming is to progress in India, getting ICAR involved is very important. Once ICAR shows interest in vertical farming, they may support a variety of indoor agriculture models throughout India and increase vertical farming's subsidy eligibility. With ICAR's participation and involvement, the vertical farming movement across India and its different agricultural institutions can also be better coordinated.

Overall, Dr. Giggin T is optimistic about vertical farming's potential in India. As purchasing power of Indian consumers' increase, they will be slowly shifting towards consuming high-value, organic produce. Since chronic diseases such as diabetes has been on the rise, health and nutrition are being increasingly prioritized, and CEA produce will be the perfect means to meet that demand.

In Dr. Giggin T.'s opinion, the ideal place for commercial-scale vertical farms is in the outskirts of cities (peri-urban areas), where the land cost will not be as high as in urban areas, and the energy and water infrastructure will be pre-existing. Growers will be able to find more affordable labor in peri-urban areas than in urban areas. By meeting the demands of urban consumers and growing in small to medium units located in peri-urban areas, growers will be able to minimize initial costs while supplying consumers with high purchasing power in urban areas.

Terra Firm Project P. Ltd

Interviewee: Kukku Joseph Jose, Architect, Terra Firm Project P. Ltd
Interviewer: Parthu Kalva, Association for Vertical Farming

An architect's dedication to promote Indian Vertical Farming

Kukku Joseph Jose is an architect at Terra Firm Projects P. Ltd ("Terra Firm") based in Kochi, Kerala, India, and author of the thesis, "Vertical Farming in India' from the School of Architecture at Lovely Professional University. He leads classes for 'Architectural Design', where the concept of vertical farming is reflected through the closed loop approach, at the Asian School of Architecture and Design Innovation. Terra Firm is an architectural design firm that promotes and designs innovative, sustainable technologies to support Indian agriculture, including the ongoing project of designing an closed-loop farming system. In Kukku Joseph Jose's opinion, the need for vertical farming stems from the need for Indian smart cities, especially in light of India's increasing urbanization.

Roadblocks ahead and moving beyond food production

India has no shortage of skilled engineers and supporting facilities to develop vertical farming. Despite this there are implementation limitations in technology, expertise and public awareness, and a formidable challenge is supplying energy to run vertical farming facilities. Kukku Joseph Jose states that nuclear energy supplied through closed-loop infrastructure shows the greatest potential to support vertical farming and efficient artificial lighting sources such as LED lighting to carbon nano-lighting systems should be adopted.

Vertical farming should not be limited to only food production, but also to cultivate medicinal plants and raw chemicals for medical and other chemical industries. There also needs to be a place for leveraging vertical farming infrastructure to design sustainable means of rearing chickens, goats, pigs and fish, which may help promote the success of vertical farms by providing an additional line of revenue.

Vertical farms are a key component in building smart cities

The central Indian government has ambitious goals to execute 100 smart cities in the next five years - two of the projects will be in the state of Kerala. Indian architects are tasked to design smart cities to accommodate a growing population and diversifying economy. The need for designing sustainable infrastructure surrounding urban energy, land and water resources will continue to climb in the near future. Kukku Joseph Jose envisions vertical farming as a part of smart city designs in India.

Kukku Joseph Jose discourages over-pursuing government support to promote vertical farming. The government works within a limited focused budget and functions bureaucratically. In the long-term, it would be more productive for vertical farms to partner with private non-governmental organizations (NGOs) to build off pre-existing agricultural programs and obtain additional funding.

Whether in urban or rural areas, the need for vertical farming is equal in all locations. Initially, the most promising medium for vertical farming operations is urban. Once established in cities, the growth of vertical farms to rural areas will be more targeted and cost-effective. Thus, the progress in vertical farming in urban and rural areas of India may progress hand in hand.

EUROPE

Author: Vincent Fesquet

Vertical farming landscape in Europe

From a grower standpoint, since vertical farming is not dealt with at the European Union ("EU") level, nor on a state-by-state or even on a city-by-city basis, the evaluation of this new industry has to be done on a case-by-case basis. Only a few projects are emerging led by new comers, especially in aquaponics and artificial lighting, and some commercial projects will and should be operational in 2016. Based on the number of operational projects, vertical farming within the EU seems today less advanced than North America and Japan from an operational standpoint, while in respect to equipment and technical developments, the EU houses leading worldwide companies associated with CEA such as Certhon and Kubo[1] (greenhouses), Priva (climate management), and Philips Lighting City Farming and Heliospectra (artificial lighting).

Supermarkets and wholesale retailers

Wholesale retailers are experimenting with vertical farming as a part of their supermarket shopping experience and as distribution models. Metro Group has invested into the vision of net-zero distribution[2] by implementing a small-scale modular building block vertical farm developed by InFarm inside of a Metro Cash & Carry Supermarket in Berlin, Germany. Metro Group is showcasing and educating professional customers how indoor vertical farms can be a part of the consumer experience. In a different format, Migros, Switzerland's largest retail company and supermarket chain, collaborated with UrbanFarmers and tested a display of branded products within a Migros supermarket in Basel, Switzerland.[3]

Aquaponics developments

While in North America large incumbent players begin to rollout rooftop hydroponics concepts, EU players are focusing on smaller rooftop aquaponics projects. There exist very few commercial aquaponics operations in Europe, only three to four. The two main rooftop aquaponics and first to market players are UrbanFarmers[4] and ECF.[5] UrbanFarmers currently has two aquaponic rooftop greenhouse sites located in Basel, Switzerland (test format) and the Hague, Netherlands (first commercial format of size). ECF has a dedicated ground site in Berlin, Germany and designed and built a commercial rooftop aquaponics farm in Bad Ragaz, Switzerland for Ecco Jaeger. The two companies although both developing rooftop aquaponics greenhouses have different approaches to reach the market.[6] On the one hand, UrbanFarmer's focus is producing fish and vegetables for B2B direct sales, and on the other, ECF provides Engineering, Procurement and Construction service (EPC) services to sell aquaponics farm systems. The two companies have plans to expand in the EU and abroad, particularly with UrbanFarmers planning to operate in NYC.

Overall in the EU, the relatively slow developments may be due to a combination of a limited amount of proof of concepts, available arable land, food mile distance and an organized vegetable production system. However, with the increase in public awareness and development of techniques and technologies, the end of 2016 and 2017 should see further operational projects through both expansions of existing players and new players entering the market.

Test platforms and R&D sites from private to academia

Similar to UrbanFarmers and ECF, in the EU there are aquaponics companies testing business models to scale commercially. The R&D platforms include small formats of less than 200 sqm (2,153 sqft), which are designed to optimize technology and gain operational confidence prior to pitching to investors and establishing a first commercial format in an urban context. These types of R&D sites are often made on the ground or in containers.

[1] Kubo and Lufa Farms developed a partnership to design rooftop greenhouses and maximize energy savings and in financing.
"Le financement des prochaines serres innovantes sur toits des Fermes Lufa est assuré" CNW Telbec. Oct. 2012. Web. 7 Feb.2016. <http://www.newswire.ca/fr/news-releases/le-financement-des-prochaines-serres-innovantes-sur-toits-des-fermes-lufa-est-assure-510892251.html>

[2] Net-zero distribution is energy conservation by displacing energy intensive transportation, to reduce carbon footprint and produce for local consumption to provide hyper-local fresh produce.

[3] "UrbanFarmers wins Migros Basel to launch its "Fresh Revolution" in retail store MParc Dreispitz". UrbanFarmers AG. Aug. 2013. Web. 1 Feb. 2016. <https://urbanfarmers.com/wp-content/uploads/2013/08/UF_UF-MIGROS-Press-Release_FINAL1.pdf>

[4] Graber, Andreas. Video conference interview. 22 Jan. 2016. UrbanFarmers AG. See interview on pg. 83.

[5] Leschke, Nicholas. Video conference interview. 25 Jan. 2016. ECF Farmsystems GmbH. See interview on pg. 42.

[6] Note that ECF's own flagship farm based in Berlin is ground based.

For instance, the London based GrowUp Urban Farms ("GrowUp"), with a start-up team of nine employees, are testing an aquaponics concept using a greenhouse on top of a container equipped with a fish tank. GrowUp is now dedicated to opening a 560 sqm (6,028 sqft) aquaponics unit in an old warehouse and use LED lighting. Production is expected to reach 20 tons of sustainable-produced salads and herbs, and 4 tons of fish (tilapia) per annum to be sold through supermarkets.[7]

In Blainville sur Orne, France, a company called Aquaprimeur developed a test at the "Maison de l'Air" in Paris and is now looking for expansion on the ground close to the port of Caen in the Normandy region of France. The company is looking to expand on a space of 1,500 sqm (16,146 sqft) to produce fish, aromatics and leafy greens. Interestingly, the decision to expand on the ground was made for investment cost arbitrage and to avoid further project complexity on top of administrative issues in order to focus on production.[8]

Other projects mentioned in public sources include a 4,000 sqm (43,055 sqft) rooftop farm[9] on top of the Anderlecht, Belgium (former Brussels slaughterhouses), which have been transformed into a food market. It will include an 1,800 sqm (19,375 sqft) aquaponics greenhouse and 1,800 sqm (19,375 sqft) of productive gardens.

In order to aid with production techniques and technology applications, the majority of commercial aquaponics players have developed relationships with universities. UrbanFarmers worked with ZHAW Life Sciences and Facility Management in Zurich, and ECF with Leibnitz Institute in Berlin. In France, the I.N.R.A. Institute (Paris region) is testing aquaponics through its APIVA project[10]. On a country-by-country basis, many universities and institutes involved in fostering technique development liaise with projects and companies. These initiatives focus on aquaponics techniques regardless of site location and seem to indicate a demand for local, fresh and food safety although any market size definition is out of reach for now.

To further develop aquaponics, the EU Aquaponics Hub[11] is a four-year Cooperation in Science and Technology ("COST") networking action to facilitate cooperation and education and develop aquaponics within the EU, help harmonize legislation and give a proper status to entrepreneurs. COST Action FA 1305 has a budget of EUR 48mil[12] to develop primarily three areas: urban agriculture aquaponics, country industry frame and industrial scale aquaponics. It organizes free training and student exchange programs and has gathered more than 60 researchers from all EU countries.

In the EU aquaponics activities are not yet clearly defined, since their status lies in between aquaculture and plant cultivation. In a recent paper, the EU Aquaponics Hub highlights three main issues to overcome to develop commercial aquaponics. Firstly, the daunting issue of administration; as aquaponics is often regulated by different governmental bodies (fisheries / aquaculture vs. agricultural), there are therefore multiple permits and authorizations requested. Within the EU, only the UK has a written framework to operate aquaponics (see CEFAS[13] for further information). Secondly, environment and water: there is often a lack of regulation and different statuses applicable to potential water discharge. Lastly, product safety: there are food safety departments that still have doubts about the ability to distribute aquaponics products, while others have defined strict protocols to follow and allow food distribution. At the moment, Germany and Switzerland are on the forefront to aid these activities.

The fact that these issues are still present may explain the reason for the EU's slow start in commercial activities while research is improving.

Growers and artificial lighting technique developments

In the EU, artificial lighting techniques have improved thanks to industrial players' resources. In July 2015, Philips City Farming opened the GrowWise City Farming Center in Philips High-Tech Campus in Eindhoven, Netherlands. The facility has eight different climate-controlled rooms to test a variety of crops under different lighting and climate conditions to assay the best lighting recipes. It is based on an "open innovation" model to test technologies and improve systems. In Waregem, Belgium, Urban Crops opened a 90 sqm (969 sqft) PFAL test format that has been in operations since February 2015.

At the moment the Japanese concept of newly built infrastructure for indoor vertical farming using artificial lighting has not yet reached Europe. In general, entrepreneurs enter into very different projects dedicated to maximize space and / or take advantage of unused existing space.

[7] "GrowUp Urban Farms: Sustainable Food for a Local Market." GrowUp Urban Farms. n.d. Web. 20 March 2016. <http://growup.org.uk/>
[8] Joly, Agnès. Personal interview. 30 Dec. 2015. Aquaprimeur. (Agnès Joly is a member of the EU Aquaponics Hub)
[9] "La ferme en aquaponie des abattoirs s'etalera sur 4000m2 de toit." Lavenir.net. 7 Dec. 2015. Web. 4 March 2016. <http://www.lavenir.net/cnt/dmf20151207_00747135>. Note that the rooftop farm is developed by BIG and ECF Farmsystems
[10] APIVA (Aquaponie, Innovation Végétale et Aquaculture) is the first R&D program on aquaponics in France. For further details, see https://projetapiva.wordpress.com/
[11] See EU Aquaponics Hub website at http://euaquaponicshub.com
[12] ≈USD 54.4mil
[13] Centre for Environment Fisheries and Aquaculture Science

The London based start-up Growing Underground subterranean[14] farm at 33m (108 ft) below ground floor, uses 550 sqm (5,920 sqft) within the Clapham North tunnel using hydroponic systems and LED lighting technology to grow micro greens on racks. The produce is sold to restaurants and groceries, and the company was expecting to have 1,200 sqm (12,917 sqft) under management by the end of 2015.

Also in the UK, Intelligent Growth Solutions based in St Andrews, Scotland, has a "photon factory"[15] project under design and test format with the help of the James Hutton Institute, Dundee, Scotland, which aims at cultivating an equivalent 50ha regular baby leaf production within 250 sqm (2,691 sqft). It uses 12m (39.3 ft) to 15m (49.2 ft) high towers made of 100 to 150 racks. This fully automated farm is to use LED lighting and the Tornado storage solutions[16] (vertical storage system) developed primarily for IKEA.

In Lyon, France, the Ferme Urbaine Lyonnaise (FUL)[17] project is reported to be on its way to test a prototype with full LED lighting leafy greens production on a 50 sqm (538 sqft) ground-floor area and three-storey high hydroponic farm. The project benefits from various French industrial expertise in climate management, agro production, etc. In addition, in Paris, France, Agricool[18] is also testing strawberries production in freight containers.

In today's market, artificial lighting developments primarily benefit the greenhouse vegetable industry, and also two additional segments in the vertical farming industry: B2B[19] small building blocks combined with IoT technologies, and B2C home farm concepts developed and integrated by start-ups as home appliances. The vertical farming small building blocks concept is conceptualized and developed by InFarm (Berlin, Germany) as an "in a capsule, plant out" model. As mentioned above, one of the first known projects using this concept is being tested by Metro Group at a Metro Cash & Carry supermarket in Berlin. The home farm appliance model is in development by Agrilution with its PlantCube™ device. The company is located in Munich, Germany.

It is important to point out that in the case of artificial lighting being used as a supplement to sunlight, some urban growers have made the choice to implement experimental artificial lighting solutions and postpone the use of LED lighting. This is to wait for next generations and more proven solutions, in order to arbitrage investment cost and lighting efficiency.

Rooftops soil-less open-air and CEA farms

While some cities promote rooftops as potential vegetable growing areas (e.g. Paris), these are often dedicated to open air cultivation techniques managed by local non-profits. Each situation varies depending upon local climate.

Rooftop greenhouses are confronted to rooftop size vs commercial activity constraints. Thus, the number of commercial rooftop hydroponics projects are limited. In the EU, contrary to aquaponics, there is no European network or COST-like initiatives that exist for hydroponics. Exchanges between academic research and projects are handled on a case-by-case basis, which may further explain the lack of commercial projects on rooftops.

In Europe, research and commercial projects under open-air and CEA conditions that aim at developing vertical farming concepts are few. In Paris for instance two start-up projects have developed to test their production and business models.

Sous Les Fraises, a start-up developing an open-air rooftop model, has equipped the rooftop on the Printemps flagship department in Paris with fully removable vertical hydroponic growing systems covering 1,000 sqm (10,764 sqft) using 2m (6.5 ft) high panels (500 sqm of floor area). The company grows strawberries, tomatoes, edible flowers and aromatics, which is sold to high-end groceries and restaurants. The test format has been in operations since April 2015 and will continue through October 2016.

In the field of rooftop CEA greenhouses, the startup Toit Tout Vert recently announced the future construction of a rooftop farm unit in 2016, which is intended to be operable in 2017. The unit will use mainly hydroponics and aeroponic systems on an industrial building covering approximately 1,500 sqm (16,145 sqft), including technical areas for an

[14] Carrington, Damian. "Growing underground: the fresh herbs sprouting beneath Londoners' feet". The Guardian. April 2016. Web. 29 April 2016. <https://www.theguardian.com/environment/2016/apr/26/growing-underground-the-fresh-herbs-sprouting-beneath-londoners-feet>

[15] See video of Demonstrator at https://www.intelligentgrowthsolutions.com/demonstrator/

[16] See Tornado Storage Solutions website at https://tornadostorage.com/fr/

[17] Le Goff, par Aimée. "Agriculture: une ferme urbaine à la Doua pour l'été". Lyon Capitale: Les Esprits Libres. Feb. 2016. Web. March 2016. <http://www.lyoncapitale.fr/Journal/Lyon/Actualite/Environnement/Agriculture-une-ferme-urbaine-a-la-Doua-pour-l-ete-2016>. See the FUL project website for further details at http://www.projetful.fr/

[18] "Agricool, installation hydroponique en container dans le Parc de Bercy". Observatoire de L'Agriculture Urbaine et de la Biodiversit. Oct. 2015. Web. 7 Jan.2016. <http://agricultureurbaine-idf.fr/nouvelles/agricool-installation-hydroponique-en-container-dans-le-parc-bercy>. See the Agricool website at http//agricool.com.

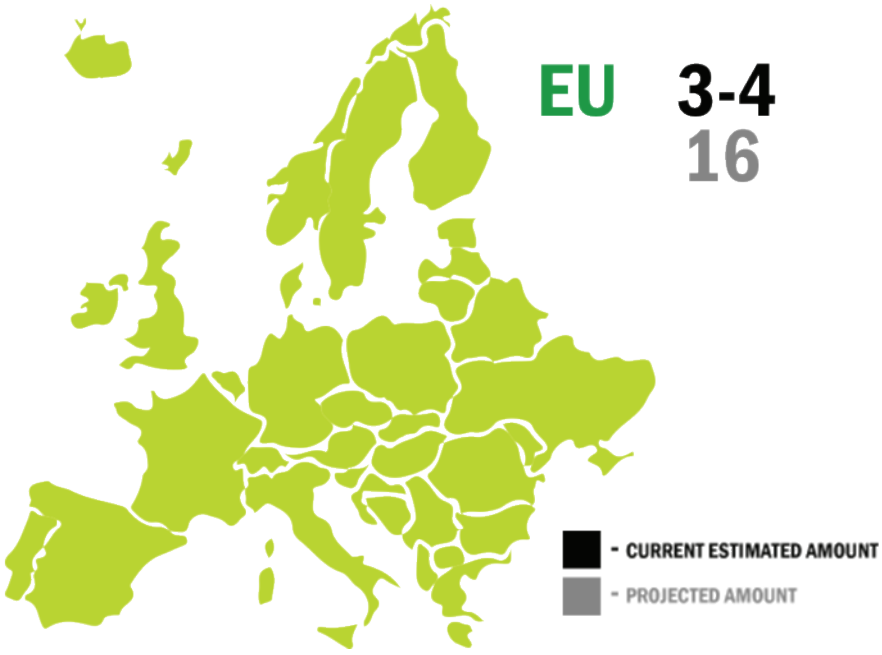
[19] Golanska, Erez. Video conference interview. 9 March 2016. InFarm. The company's B2B model is focused on supplying their product for restaurants, hotels, supermarkets and entrepreneurs. InFarm has already raised EUR 500k through "European pioneers" funding, angel investors and friends and family. The company is preparing for further expansion and plans to employ twenty people by the end of 2016.

announced approximate investment of EUR 2mil.[20,21,22] The location is within a social housing property, Paris Habitat, in the 12th arrondissement of Paris. Production of items such as salads and tomatoes will be supplemented by selected vegetables varieties produced by organic farmers close to the city, to provide approximately 500 baskets per week at competitive price points. This will potentially be the first commercial hydroponic rooftop greenhouse unit in Europe.

Furthermore, other projects mentioned in public sources include REO, which manages the Roeselare vegetable and fruits wholesale auction place, which will be a 10,000 sqm (107,639 sqft) rooftop greenhouse on the wholesale auction site in Belgium, with a EUR 4 – 6mil investment.[23],[24] Additionally, a vertical farming "greenhouse building" project in Romainville is planned to occupy approximately 1,500 sqm (16,146 sqft) within two greenhouses reaching 16m (four storeys) and 24m (seven storeys). The financing of the EUR 4.6mil[25] project would be completed through a foundation under creation.

Conclusion

In Europe projects are very diverse and test the entire range of business models: from growers selling vegetables and / or fish to turnkey farm solutions of different scale (from home farm appliance and indoor farming modular units to commercial rooftop greenhouse). The technology applied for open air, greenhouse and warehouse vertical farming facilities use highly technological approaches supported by European agriculture suppliers and Dutch greenhouse companies.



The commercial vertical farming market size is estimated at 3 – 4, but is expected to triple over the 2016 – 2017 period. It relates to both incumbent aquaponics players and R&D formats establishing new operational facilities, and new rooftop greenhouse hydroponics projects to open. Indoor vertical farming is also being tested although for now at a small scale.

Alongside entrepreneurs, some players within the distribution chain have started to become involved such as wholesalers (e.g. Ecco Jaeger) that have distribution access through their own logistics network, or companies / organizations that manage buildings already dedicated to market place (Abbatoire, REO). Conglomerate distribution players are also testing concepts through both vertical farming products distributed within supermarkets (e.g. Migros) and in-store supermarket production (e.g. Metro Group).

[20] Le Borgne, P. Personal interview. 11 May 2016. Toit Tout Vert.
[21] Van Eeckhout, Laetitia. "Une premiere serre urbaine commerciale verra bientôt le jour en plein cœur de Paris". LeMonde. April 2016. Web. 9 May 2016. <http://www.lemonde.fr/planete/article/2016/04/21/une-premiere-serre-urbaine-commerciale-verra-bientôt-le-jour-en-plein-c-ur-de-paris_4906440_3224.html>
[22] ≈ USD 2.26mil
[23] Reussir F&LN°357 – Janvier 2016, p28
[24] ≈ USD 4.5 to 6.8mil
[25] Romainville. L'agriculture urbaine à Romainville. Romainville Village, n.d. Web. 8 Feb. 2016 <http://rtes.fr/IMG/pdf/Dossier_Presse_tour_maraichere.pdf>

Metro Group

Interviewee: Fabio Ziemssen, Head of Food Tech and Food Innovation, Metro Group
Interviewer: Howard Brin, Association for Vertical Farming

METRO Cash & Carry: a net-zero supply chain test and in-store customer experience

METRO GROUP, an important international retail company with its sales brands METRO Cash & Carry, Media Market, Saturn and Real, is always looking for innovative solutions to address the needs for the consumer of tomorrow: freshness, quality, authentic regional products and transparent / traceable growth and distribution processes for professional customers (horti-customers). For Fabio Ziemssen, the in-store farm is a proof-of-concept to further test customers' interaction and response. The concept has experienced a huge impact in the area of fresh leafy greens and herbs, and with proper training management capabilities are able to deliver fresh and pesticide free produce. The solution is not only economical and sustainable, but also educational and marketable. As for education, it is to learn how to handle the topic of indoor vertical farming, particularly for overseas market expansion, and how they can leverage their stores to the next step of consumer experience.

Conceptual in-store farms have the purpose to become a whole store agriculture ecosystem in order to reduce the supply chain to net-zero distribution. Fabio Ziemssen sees this point as the most convincing statement when pitching indoor vertical farms. METRO Cash & Carry in Berlin-Friedrichshain is the first to test InFarm's compact building block design within a self-service wholesale store. The six sqm (64.5 sq ft) and three meters (19.6 ft) high in-store farm by InFarm located in the vegetable section benefits from the cold air to calibrate the ideal controlled temperature and all inputs are filtered from the in-store farm. For regulation issues (HACCP), end customers are prohibited to enter into the pressurized growing space.

The InFarm modular farm allows METRO employee farm operators to monitor each stage of plant cultivation, and according to Fabio Ziemssen, all products are sold at the same price points as other fresh products. The visible glass structure has created immense customer curiosity, prompting produce sales. For the time being METRO GROUP has received highly useful feedback, and METRO GROUP is working to further optimize the model to obtain better output and operations with the pilot project.

METRO GROUP indoor vertical farming future plans

METRO GROUP will continue working on several projects by looking at other opportunities in Berlin. To date, it is difficult to predict the direction these technologies will integrate with retail stores. As emphasized by Fabio Ziemssen, METRO GROUP is currently looking into further developments of in-store integrated systems and continue to work with local farms and regional operators, and seek the right technologies as a commitment and effort to solve supply chain issues in mega-cities and other rapid growing cities.

Currently, there is a knowledge gap in the value chain form ready-to-harvest to ready-to-sell – METRO GROUP is focusing on this area to pioneer the new retail concept. Fabio Ziemssen stressed the implementation of the right standards is imperative for organizations, in order to build trust and high quality produce. Today, different companies in the vertical farming industry are claiming that their technology solutions are the best; however, by being secretive or "black boxes" it is very difficult to compare or prove the solution to one another.

Philips City Farming

Interviewee: Gus van der Feltz, Global Director City Farming, Philips Horticulture
Interviewers: Howard Brin, Association for Vertical Farming
Vincent Fesquet, New'rban View

Philips City Farming is not only focused on LED lighting

Philips City Farming ("City Farming") was established to not only to develop optimal LED lighting for growers, but also solutions relevant to business issues, control irrigation and other farm parameters. To find these solutions, City Farming built and operates its own research center, partners with academic institutions, companies, a provincial government, and has a team of approximately 75 employees (15 focused on City Farming) led by Global Director, Gus van der Feltz.

GrowWise City Farming Center

The GrowWise City Farming Center ("GrowWise") is a 234 sqm (2,518 sq ft) research facility located in Philips's High-Tech Campus in Eindhoven, Netherlands, where application research is conducted on system challenges. GrowWise operates based on an open-innovation platform: partners (companies and universities) collaborate to test technologies and improve system designs on irrigation, nutrition, workflow processes, production economics, etc. Research is carried out in eight different climate-controlled rooms: four light recipe rooms / climate chambers, two production chambers and two R&D chambers, where varieties of lettuce, leafy greens, baby greens, basil, strawberries and types of herbs are grown. Gus van der Feltz mentioned production module tests on strawberries have very good results, but are not yet market ready. These positive results show the next steps are to optimize soft fruit growth, develop attractive economic positions for soft fruit products and work on nutritional value-added products.

At GrowWise production economics and workflow processes are performed concentrating on spacing strategies and automation and mechanization organization. In this area, City Farming is not looking to fundamentally change plants, but instead work with plant breeders to have varieties that will be advantageous with automation and spacing strategies.

GrowWise application research ultimately is looking to create the best environment for vertical farming and, according to Gus van der Feltz, City Farming is not concerned with competition, but rather the end goal is to use their research findings to develop the best economically sound business models for the industry.

Partnerships with HAS University (BrightBox) and Osaka Prefecture University

The BrightBox Research Centre ("BrightBox") in Venlo, Netherlands is a JV among HAS University, Philips Horticulture, Limburg Province and Botany. The JV partners financed the 220 sqm (2,150 sq ft) facility to train and develop the next generation of growers, and HAS University uses BrightBox for experiments and classes. Philips supports HAS University courses, particularly "Growing Without Daylight", which is offered both as a regular and online course, and HAS University maintains full control and responsibility of the courses. BrightBox also rents out space to companies interested in managing their own R&D, which are able to take advantage of its resources to improve growing methods and business models.

The combination of companies, students and researchers has created an internal open-source environment. It functions as a model for open cooperation and HAS University has access to the R&D. Gus van der Feltz pointed out at BrightBox people are hungry for information and many are looking at growing optimal plants, and innovation is being carried out, but eventually the fact that genetics will not change immensely, there will be common knowledge on how to grow plants. In the end, everyone is looking for the same growing answers, but the key lies in other farm parameters.

The GNG City Farm in Osaka Prefecture University located in Japan opened in late 2014 is to promote City Farming. Gus van der Feltz's said this collaboration allows Philips to provide their LED lighting expertise and at the same time better understand Japanese requirements for vertical farming and local market needs.

Financing is still a major roadblock and training is key

The sustainability of City Farming projects depend highly on local food prices and availability of production. In Gus van der Feltz's opinion, limited local availability and desire for high quality products are key to the development of a sustainable city farming business case; and as a very new industry, financing is still an issue and it is extremely important for people to get familiar with the new technologies. Training and workflow processes are a major key to apply the new technologies. Gus van der Feltz stated over the next three- to five-years future developments will need to include the progress of more efficient systems and advancement of growing recipes to further variety of crops.

UrbanFarmers

Interviewee: Andreas Graber, Director of R&D and Co-founder, UrbanFarmers
Interviewers: Howard Brin, Association for Vertical farming
Vincent Fesquet, New'rban view

Changing a business model to stay ahead

UrbanFarmers AG ("UF") is a rooftop aquaponics farm company that produces fish and vegetables. Originally, the company set out to sell farms but now has moved onto selling fish and tomatoes to be more flexible and be able to pitch landlords as partners, not as customers. The company has been testing a 255 sqm (2,750 sq ft) operation in Basel, Switzerland since 2013, and opened in May 2016 its first commercial unit, a 1,500 sqm (16,150 sq ft) aquaponics farm on top of a six-storey building in The Haque, Netherlands. Andreas Graber said the total investment of the commercial unit is EUR 2.7mil and production is expected to reach 19 tons of fish and 50 tons of vegetables per annum. The greenhouse will use supplemental artificial lighting (HPS) in order to ensure proper production levels and a new dedicated heating system (gas burners) as there was no waste heat sources to be used. Distribution channels is B2B and includes supermarkets, restaurants and canteens. Fish are processed at the farm and sold to market as gutted fish or fillets. UF plans to launch two farms in Zurich, Switzerland, and has 24 projects in pre-development. As a part of their overseas strategy, in August 2015 UF established a subsidiary in Manhattan, New York City, to pursue development on the US east coast.

The choice of aquaponics by UF was simple, combining fish and plant production in a symbiotic loop is a key technology to achieve maximum resource efficiency in farming. Contrary to the food industry which searches to produce food as cheap as possible, UF seeks to grow the best food as possible and sell it as premium quality. As for the choice to go vertical on a rooftop, Andreas Graber explained it is the willingness to eat food where it is produced, and within a dense city, potential farm sites have to be searched on the city rooftops rather than on the ground.

Expansion to strategic regions, roadblocks ahead and technical improvements

UF's expansion reflects a need of being present where knowledge and main developments are. Andreas Graber said Dutch expertise involved in the development of the The Hague farm will strengthen the market position of their UF rooftop farm product. Since in the US there is a lack of rooftop aquaponic farms, UF will be in a position to demonstrate technical ability to establish a farm portfolio and address a new market that will readily embrace the new UF brand "Fresh.Revolution".

The time needed to host rooftop farms is highly dependent on real estate players recognizing the added value. So far, renting empty rooftop space was not an issue considered, and landlords are surprised now by the abilities UF can unlock for them by offering a solid business case for BIA. However, one of the main issues is finding adequate rooftop availability, since actually building a farm does not represent a technical issue. The point loads of greenhouse and fish tanks (900 kg/sqm) are placed on existing pillars and the remaining approximate 80% of the farm area are plant cultures, which are low area loads. Andreas Graber is confident that a lot of rooftops would be suitable.

As with any rising industry, there are numerous administrative issues to overcome. Andreas Graber stated regulations are there for a good reason, and mostly farm design is constrained by regulations such as fire safety, working safety, architectural aesthetics and load allowance. As for now, zoning has not been seen as an obstacle; however, this is dependent on each country and city. As far as growing activities are concerned, UF is compliant to Global GAP certification. The focus on rooftops prevents from enlarging site locations, however, every vertical setup that results in higher productivity and ultimately profit per square meter will allow UF to build and operate farms of smaller scale.

Farming is farming, not gold mining

UF farms can deliver to investors an approximate 8 to 12 years ROI, depending on size and preparation work required. The financing of the farm is distinguished from the financing of the company. The Hague project was financed through private and local institutional investors. For projects in Switzerland, UF is receiving bank financing as the model was already proven in the Swiss context. At the company level, CHF EUR 2.1mil Series A have been raised in 2015.

Vydrofarm by Hydrogarden

Interviewee: Stephen Fry, Commercial Sales Manager, HydroGarden
Interviewers: Howard Brin, Association for Vertical Farming

The VydroFarm system

HydroGarden based in Binley Coventry, UK, has been a supplier of hydroponics equipment for 20 years. HydroGarden from their own funds has invested more than USD 288,000 (GBP 200,000) developing its own vertical farm system, the VydroFarm. Stephen Fry, Commercial Sales Manager at HydroGarden, described VydroFarm as a complete CEA indoor farm system designed and sold as a turnkey solution, that provides growers with every component and service needed including templates, nutrients, growing media (specific to each crop) and pre-selected seeds. The goal is to provide their clients with the ability to buy a growing package on a service level agreement for maintenance and crop monitoring. Their ideal targets range from small-scale hobbyists to serious entrepreneurs and large-scale commercial growers.

Producing higher nutrition and oil value

The VydroFarm has been designed and developed by a team of professional engineers, crop consultants and electricians, and collaborations with a number of universities. The design is a mobile rack modular structure fitted with NFT gully enabling adaptable space allocation; since space is a premium and to maximize space, the patented hardware can compress racks together for one universal walkway without the need to disconnect electrics and irrigation. The lighting system and NFT channels are adjustable to accommodate plant height. The system also has a novel way of delivering the environment, which pre-mixes air to a prescribed quality before it is delivered down the entire length, thus giving optimum growing conditions and air flow per crop. Stephen Fry emphasized the system focuses on the plant – if the plant does not benefit from a variable – it is not incorporated into VydroFarm.

As for crops, it grows leafy greens and a variety of fruits and vegetables. According to Stephen Fry, the current system can produce Alega lettuce in 28 days, and reach up to 13 crops per annum. The most optimal crop type is lettuce but swiss chard, bok choy, pak choy, spinach and basil all grow with high output. A key ongoing focus is manipulating the LED light spectrum and growing recipes to enhance nutritional and oil value.

UK outlook and trends

In the UK there is a demand to grow and supply local farmer markets and supermarkets; however, the latter is comparatively restrictive to supply - there are a number of requirements related to hygiene, packaging and handling. In urban areas there are a fair amount of industrial warehouses on short-term leases that can be utilized for urban indoor intensive growing that can target the demand.
Stephen Fry explained HydroGarden is currently collaborating with a local real estate developer on urban agriculture projects. The idea is to combine VydroFarm technology with professional architectural know-how to improve office working environments. The vision is to produce turnkey technologies that can be used in combination with architectural projects, and on a higher level, the application in eco-friendly city projects.

NORTH AMERICA

Authors: Howard Brin, David Murayama

Vertical farming landscape

The USA being the biggest economy and one of the most competitive countries in the world, some of the leading vertical farming players are determined to become the "biggest" and "largest" vertical farms and not only expand domestically but also internationally. In the USA the competitive nature of the private sector combined with a strong consumer demand for organically certified and locally sourced produce are the vertical farming industry's leading drive. The local food industry projections in the USA have drastically increased in the past decade, with sales totaling approximately USD 12bn in 2014, up from USD 5bn in 2008, and experts anticipate that value to hit USD 20bn by 2019.[1]

While the industry is still considered to be in its infancy, vertical farming has been acknowledged by the White House's President's Council of Advisors on Science and Technology ("Council"), where it recognizes the positive impact soil-less systems can bring to cities, economy and consumers. The three clear benefits from vertical farming, according to the Council, are fresher produce, cleaner delivery and more efficient water use.[2]

However, similar to Europe, vertical farming although mentioned by the Council, it is not dealt with at the federal government level, nor at the state level and should be viewed on a case-by-case basis. Only recently have cities begun to adapt urban regulations and begun dialogues to support vertical farming.

In Canada, the vertical farming sector is also gaining traction, although on a smaller scale compared to the USA. The market is currently driven by start-ups that include rooftop greenhouses, indoor vertical farms, turnkey solution providers and technology developers. Several regions in Canada have employed large-scale greenhouses using soil-less technologies. The provincial government of British Columbia is looking to boost the agri-food sector to USD 14bn by 2017 (25% growth)[3]. This could represent a major positive impact in vertical farming across the country as greenhouse operators can turn their eyes into more efficient and reliable processes and technologies that only CEA environments can provide as cities and urbanized regions expand.

Test formats and partnerships

In the USA and Canada companies are in a constant state of adaptation and readjustment in order to overcome early-stage phase challenges. Vertical farms may be built to conduct research, educational and commercial purposes or a mix of these as core business models. It is not uncommon for both growers and technology developers to provide consulting services (e.g. building, engineering, process implementation, logistics and growth cycle), and / or build proprietary cloud-based databases that can later be monetized by incorporating it into their own practices, consulting services and R&D developments.

Cross-discipline partnerships and alliances among players in the sector are common across the USA. Vertical farms have been founded through university research spinoffs into startups, where they maintain R&D relationships with universities as they mature. Other companies engaged in collaborations with large or established electronic (LED lighting systems) and ICT technology companies (cloud-based technologies and sensors) have been established to further accelerate their product development and operational efficiencies and become high-potential businesses. For example, iUNU, a Seattle, USA based company, is helping with Microsoft's experimental vertical farm cafeteria.[4] The collaboration applies to iUNU's future plans aiming to automate their plasma lighting systems (full-spectrum lights) to increase efficiency in a tailored manner and manage the entire growing cycle. As for Microsoft, it is finding solutions to feed its employees with produce within its own campus.

Trends and developments

There are notable trends across the emerging industry in the USA. The prevailing technologies across industry players

[1] United States Department of Agriculture. USDA Results: Local and Regional Food Systems. Washington: USDA. May 2016. Web. 25 May 2016. <http://www.usda.gov/wps/portal/usda/usdahome?contentid=usda-results-local.html>

[2] Executive Office of the President's Council of Advisors on Science and Technology. Report to the President: Technology and the Future of Cities. Feb. 2016. Web. 15 May 2016.<https://www.whitehouse.gov/sites/whitehouse.gov/files/images/Blog/PCAST%20Cities%20Report%20_%20FINAL.pdf>

[3] Hein, Treena. "State of the Industry". Greenhouse Canada. December 2014. Web. 1 May 2016. <http://www.greenhousecanada.com/business/trends/state-of-the-industry-30080>

[4] Henretig, Josh. "See Microsoft's in-office urban farming experiment". GreenBiz. Dec. 2014. Web. 7 May 2016. <https://www.greenbiz.com/article/see-microsofts-office-urban-farming-pilot>

are hydroponics systems in combination with LED lighting applied in CEA facilities. Another emerging technology worth mentioning is aeroponics[5], which has gained traction with big players such as AeroFarms leading in this category as one of the largest and innovative companies using aeroponics technology. The company's headquarters will be located in an industrial building redevelopment project that occupies 6,410 sqm (69,000 square foot) in Newark, USA. It claims that its systems can produce up to 2 million pounds of leafy greens per annum.[6]

Green Collar Foods ("GCF") based in Detroit, USA also utilizes indoor aeroponics combined with cloud-based technology, Microsoft Azure and Shaping Cloud. GCF plans to construct 557 sqm (6,000 sqft) facilities that will cost under USD 500k, which will acquire revenue through licensing and IP and forward-purchase contracts utilizing their cloud-based data.[7] On the other hand, many vertical farms are developing proprietary analytic systems to manage data from a plant's temperature to pH levels, which rely on data scientists and engineers instead of agronomists. The data enables vertical farmers to optimize color, texture and taste.

In the current stage of technology development, the concentration of vegetable production is focused on microgreens, leafy greens and lettuce in the USA and Canada. Depending on yield output and location, the client segments can be retailers and / or restaurants, and in some cases, direct to consumers. Vertical farming companies that are able to produce on a commercial-scale level have entered into partnerships with retail supermarkets including Whole Foods. In 2014, Whole Foods selected FarmedHere as a recipient of the "Whole Foods Market's Local Producer" loan program for USD 100k.[8] One deciding factor to choose FarmedHere was because its leafy greens and herbs are USDA organic-certified.

In recent years there have been an increasing amount of vertical farms receiving certifications and / or verifications - an important factor for B2C consumers to accept higher prices in supermarkets. Companies such as Urban Produce (Irvine, USA) and Sky Harvest (Vancouver, Canada) have obtained certifications, and a handful of companies including Metropolis Farms (Philadelphia, USA), Green Spirit Farms (New Buffalo, USA) and Gotham Greens have received Non-GMO and / or additional types of certifications / verifications to label their vertical farming produce.[9] In an interview with FarmedHere, the co-founders Paul and Jolanta Hardej both mentioned it was important to receive USDA certification in order to compete with similar products in Chicago supermarkets.

Commercial indoor vertical farms and rooftop greenhouses

In the past five years commercial scale growers have clustered in or near cold-weather cities such as Chicago and NYC. This can be explained by the increase in consumer demand for all-year-round locally sourced produce colder regions, which has created business opportunities for vertical farming facilities. The city of Chicago has experienced an increase in vertical farms and operational facilities less than 321km (200 miles) away that supply local consumers. The increase in vertical farms in Chicao is also from favorable government policy that provides a flexible and supportive environment.

The main players in Chicago are FarmedHere, Urban Till, Gotham Greens and The Plant. FarmedHere is looking to scale and develop vertical farms in 18 cities across the nation. The company plans to expand out of Chicago to the West Louisville FoodPort (location for food-related businesses). There is preliminary approval of state tax incentives for FarmedHere to build, own and operate a 5,575 sq m (60,000 sqft) indoor vertical farm project in Louisville, USA.[10]

Urban Till expects to grow from 20 employees to 75 within the next year. The focus of the company is to increase efficiencies in the supply chain operations and logistics. The company was founded in 2011 and uses hydroponics to grow and supply mainly to restaurants in Chicago. In 2016, Urban Till will expand nationally and internationally (possibly to the UAE) with its proprietary hydroponics technology. The company is reported to be building a 10,962 sqm (118,000 sqft) facility in Las Vegas, USA.[11]

Gotham Greens is the only known commercial scale rooftop greenhouse based in Chicago, which recently opened its

[6] Aeroponics applies periodic misting of plant roots saves, which saves approximately 98% of water and about 60% of nutrients compared to traditional soil-based agriculture.

[7] Garfield, Leanna. "The world's largest vertical farm will produce 2 million pounds of lettuce every year". TechInsider. April 2016. Web. 10 April 2016. <http://www.techinsider.io/photos-of-aerofarms-the-worlds-largest-vertical-farm-in-newark-2016-2>

[8] "How Green Collar Food is Scaling Low-Cost Indoor Ag in Inner Cities". Agfunder News. May 2016. Web. 6 May 2016. <https://agfundernews.com/how-green-collar-foods-is-scaling-low-cost-indoor-ag-in-inner-cities5802.html>

[9] "FarmedHere Takes Vertical Urban Farming to New Heights". Whole Foods Market: Newsroom. July 2014. Web. 9 April 2016. <http://media.wholefoodsmarket.com/news/farmedhere-takes-vertical-urban-farming-to-new-heights>

[9] Vegan certification is awarded by the American Vegetarian Association. For additional information see: https://amerveg.org/Certification

[10] Peters, Adele. "Farmedhere Wants To Bring A Vertical Farm To Your City". Fast Coexist. Nov. 2015. Web. 1 April 2016. <http://www.fastcoexist.com/3053217/farmedhere-wants-to-bring-a-vertical-farm-to-your-city>

[11] Braff, Danielle. "Urban Till registers with restaurants who want local, fresh produce". Chicago Tribune. Dec. 2015. Web. 1 April 2016. <http://www.chicagotribune.com/bluesky/originals/ct-urban-till-indoor-farming-1228-bsi-story.html>

largest operational facility occupying 6,967 sqm (75,000 sqft). The expected annual production is 1mil pounds of lettuce, leafy greens and varying types of vegetables that will be sold to retailers, community groups, restaurants and farmers markets in Chicago.

Nearby Chicago Green Spirit Farms and Green Sense Farms are operating in separate states but also supply Chicago. Green Spirit Farms located in New Buffalo, USA was founded in 2011 and uses rotary vertical growing stations (omega garden units) where the plants rotate around a central full spectrum induction lamp within a cylinder, with a modified hydroponics technology. The company grows lettuce, kale, radishes, spinach and basil, and has plans to construct a new 4,645 sqm (50,000 sqft) vertical farm in Medina, USA.[12]

Green Sense Farms located in Portage, USA is 64km (39.8 miles) from Chicago and supplies the Chicagoland area. Green Sense Farms has also engaged in a partnership with Philips to develop a unique spectrum of blue and red lights to make produce growth and photosynthesis more efficient.[13] Green Sense Farms is partnering with the Dutch company Rijk Zwaan, a world leader in the market of vegetable seeds, in order to find the best possible seeds for indoor agriculture.[14]

In NYC and the surrounding region, there has been a steady increase in both commercial scale rooftop greenhouses and indoor vertical farms. Some of the main players have aggressive expansion plans to position themsleves as leaders in the northeast region and USA.

In NYC Gotham Greens and Sky Vegetables are the only commercial scale rooftop greenhouses producing hyperlocally for consumers. Gotham Greens has become the front runner since getting off ground in 2011. In NYC alone it owns and operates three rooftop greenhouses facilities (plus one facility in Chicago, see above), which have scaled in total surface area over the past five years. The first CEA rooftop greenhouse opened in 2011 occupying a modest surface area of 1,393 sqm (15,000 sqft). Two years later Gotham Greens opened its second rooftop greenhouse and increased its facility to 1,858 sqm (20,000 sqft). Its largest operational facility in NYC was then opened in 2015 tripling in size covering 5,574 (60,000 sqft) in total surface area. This facility is reported to produce over 5mil heads of leafy greens per annum and employs over 50 full-time employees. The same facility is equipped with supplemental LED lighting, uses fully automated environmental controls, and energy curtains to manage the harsh NYC winters. The company appears to be actively continuing its expansion phase with interests to open new facilities across the USA.[15]

Sky Vegetables began producing leafy greens and herbs for local consumers in 2013 with its 740 sqm (8,000 sqft) rooftop CEA greenhouse. Sky Vegetables sits atop of an affordable housing complex that is platinum LEED certified[16].

Indoor vertical farming in NYC still has not reached the commercial level. This is about to change when Edenworks, an aquaponics indoor vertical farming company expands to a new warehouse location in late 2016 to raise tilapia and grow a variety of greens for NYC.[17] Since 2013 the company has been testing its aquaponics growing systems and business model to supply the local NYC demand with high-quality, safe and flavorful produce. In an interview with Jason Green, CEO of Edenworks, he sheds light on the decision from starting out as a rooftop greenhouse and pivoting the company's business model to a warehouse indoor vertical farming facility.[18]

Also supplying the NYC market is Aerofarms. The company does not have any operational facilities in NYC but instead is operating in the nearby city of Newark, USA (less than 26km (approximately 16 miles) from NYC).

In Canada and other regions in the USA, there are a few large commercial-scale growers also with the goal to supply all-year-round fresh produce locally. Vertical Harvest (Jackson Hole, USA) in occupies 1,254 sqm (13,500 sqft) of growing area in a three-storey façade greenhouse using a conveyor belt hydroponics system with supplemental LED lighting. The façade greenhouse farms leafy greens, herbs and tomatoes that is estimated to produce in total up to 50 tons (100,000 pounds) annually and also serves as an educational facility.[19]

[12] Bromfield, Evan. "Just a Generally Good Vertical Farming Article". The Urban Vertical Project. Dec. 2015. Web. 27 March 2016. <https://urbanverticalproject.wordpress.com/2015/10/16/just-a-generally-good-vertical-farming-article/>

[13] Gray, Kevin. "How We'll Grow Food in the Future: Traditional Agriculture Has Bought the Farm". Popular Science. Sept. 2015. Web. 29 March 2016. <http://www.popsci.com/farms-grow-up-thanks-to-technology>

[14] "Marco van Leeuwen Joins Green Sense Farms Advisory Board". UrbanAg News. Nov. 2015. Web. 29 March 2016. <http://urbanagnews.com/blog/stories/marco-van-leeuwen-joins-green-sense-farms-advisory-board/>

[15] Coneybeare, Matt. "Gotham Greens Opens 60,000 Square Foot Rooftop Farm in Hollis, Queens". Viewing NYC. Feb. 2016. Web. 29 March 2016. <https://viewing.nyc/gotham-greens-opens-60-000-square-foot-rooftop-farm-in-queens/

[16] See interview with Sky Vegetables on page 31.

[17] Garfield, Leanna. "This startup uses fish poop to grow fresh leafy greens inside a Brooklyn warehouse". TechInsider. March 2016. Web. 28 March 2016. <www.techinsider.io/edenworks-brooklyn-vertical-farm-2016-5>

[18] See interview with Edenworks on page 44.

[19] Martin, Claire. "A Ski Town Greenhouse Takes Local Production to Another Level". The New York Times. March 2016. Web. 28 March 2016. <http://www.nytimes.com/2016/03/27/business/a-ski-town-greenhouse-takes-local-produce-to-another-level.html?_r=0>

The Canadian landscape has also been experiencing an increase in indoor vertical farms and rooftop greenhouses across the country. In the eastern city of Montreal, Lufa Farms has developed two rooftop greenhouses[20] that use hydroponics methods to grow a variety of vegetables and leafy greens. According to Lufa Farmss website, together the two rooftop greenhouses produce up to 190 tons[21] annually. As part of its business, Lufa Farms sells directly to consumers through a click-and-choose model[22], which also supplies an assortment of locally produced products that reaches approximately 2% of Montreal's residents. The products are through a dedicated distribution point of drop location.[23] The company has plans to expand operational facilities in Vancouver, Toronto and Boston.

Near Toronto, Aqua Greens is an indoor vertical aquaponics systems farm founded in 2013. The aquaponics farm produces tilapia, arugula, basil and lettuce for restaurants and resorts in the local area.[24]

In Saskatoon, Canada, Ecobain Gardens has been operating since 2012, growing a variety of leafy greens and herbs, which are reported to be both organic and non-organic products. The farm has partnered with Philips to outfit its shallow water culture system stacked seven layers high in a climate-controlled warehouse.[25]

Technology developers and turnkey solution providers

Technology developers and turnkey solution providers have a particular focus in pursuing technological improvements and breakthroughs in fully integrated fixtures, artificial lighting, HVAC systems, etc. These companies devote their resources in developing a new line of products with higher efficiency and cheaper costs in order to support entrepreneurs and sophisticated vertical farmers with a demand for efficient and reliable products.

Local Roots Farms based in Los Angeles, USA, provides hydroponic integrated farming solutions to enable farmers to produce consistent produce 365 days a year. The company is utilizing containers to create their insulated modular farms as ready to use. The company was founded in 2013 and is working directly with local restaurants and has launched pilot programs with major food retailers.[26]

The southern part of the USA and more specifically the state of Texas has a relatively high concentration of technology developers.

Texas-based companies Illumitex and Indoor Harvest have developed a partnership to engage in R&D and coordinate business development activities to integrate a "truly complete hardware solution for the indoor farming industry".[27] In the same state, Fluence Bioengineering develops LED technologies to bring new products to the market that improve "efficiency, performance and economic limitations of lighting".[28] The company based in Austin, USA shares R&D collaborations with several research institution that include Princeton University, USDA, University of Florida and Bayer CropScience.

In Canada, TrueLeaf in Nova Scotia is focusing on precision agriculture with their Smart Plant Systems® leveraging multi-level farming technology to create highly efficient CEA systems, and increase nutrients levels and antioxidants in plants. The company provides R&D, training and consulting services.[29] Motorleaf has developed a hardware device that can be viewed as the 'Nest' for agriculture. The company builds hardware devices and software analytics for growers to use the capture data and make better decisions for plant growth. The hardware developed by Motorleaf can be used in warehouse-type vertical farms and greenhouses.[30]

[20] Laval location is 3,994 sqm (43,000 sqft) and Ahunstic is 2,972 sqm (32,000 sqft)
[21] 190 metric tons is equivalent to 209 US tons
[22] See Lufa Farms click and choose model here: https://montreal.lufa.com/en/superMarket/families
[23] "Canada: Flexible ordering helps Lufa Farms flourish". HortiDaily. Jan. 2016. Web. 15 March 2016. <http://www.hortidaily.com/article/23668/Canada-Flexible-ordering-helps-Lufa-Farms-flourish>
[24] Hein, Treena. "There's no place like home for urban farming". Greenhouse Canada. March 2016. Web. 15 March 2016. <http://www.greenhousecanada.com/business/trends/theres-no-place-like-home-for-urban-farming-30974>
[25] "Canada: Indoor, vertical farm grows greens in industrial Saskatoon". HortiDaily. June 2016. Web. 22 June 2016. <http://www.hortidaily.com/article/27097/Canada-Indoor,-vertical-farm-grows-greens-in-industrial-Saskatoon>
[26] Miller-Wakeham, Brady. "Local Roots Farms Uses Robotics for Vertical Indoor Farms". Startup50. Nov. 2015. Web. 17 March 2015. <http://startup50.com/local-roots-farms-uses-robotics-for-vertical-indoor-farms/>
[27] "Illumitex and Indoor Harvest Announce Worldwide Partnership For Indoor Growing Systems". IndoorHarvest News. Oct. 2015. Web. 10 March 2016. <http://indoorharvest.com/blogs/news/59382149-illumitex-and-indoor-harvest-announce-worldwide-partnership-for-indoor-growing-systems>
[28] "Fluence Bioengineering Demonstrates Next-Gen LED Horticulture Systems at Indoor Ag-Con". April 2016. Web. 10 March 2016. <http://finance.yahoo.com/news/fluence-bioengineering-demonstrates-next-gen-134700920.html>
[29] Burwood-Taylor, Louisa. "How Canadian Vertical Farming Company TruLeaf Aims to Prevent Disease Through Nutrition". AgFunder News. Sept. 2015. Web. 9 March 2016. <https://agfundernews.com/canadian-vertical-farming-company-truleaf-aims-prevent-disease-through-nutrition.html>
[30] "How Motorleaf is Helping Automate Indoor Farming". AgFunder News. July 2016. Web. 22 July 2016. <https://agfundernews.com/motorleaf-helping-automate-indoor-farming.html>

Government Support and associations

Support from government across the USA and Canada varies widely. There is a mix of support and flexibility depending on the city and / or state (province), which dictates policies and funding in the vertical farming space and related technologies. Areas with significant vertical farming activity have started from local-specific demand growth, and only recently have local governments began to acknowledge and embrace the industry through urban regulation adaptation and financial support.

There are funding sources not specific to vertical farming, but companies in the space qualify by meeting specific requirements. Some programs include the USDA Specialty Crop Grant Program; vertical farms that partner with a research organization may apply for funding that focuses on specialty crop research. The USDA Value-Added Producer Grant Program is available to vertical farms that can add value to raw products, and the USDA Rural Energy for America Program (REAP) for vertical farms in rural areas may be eligible for energy-efficiency funding by switching to LED lights. There are also local utility programs and rebates for energy-efficiency improvements for companies that choose to use energy-efficient LED lights instead of fluorescent lights in vertical farms.

The USDA 'Urban Agriculture Toolkit' for urban farmers and agri-business entrepreneurs is designed to help with financial and technical resources in the space. The aim is to promote, support and encourage the next generation of innovative urban farmers and small-business owners. Information includes cost estimates to starting outdoor or indoor farm operations, as well as best practices to guide start-ups and early-stage companies.[31]

As for associations, the Aquaponics Association led by Meg Stout focuses on the promotion of aquaponics through education across the USA. Its vision is to educate the general public about aquaponics benefits and safety, while dispelling rumors and myths about the method. The organization holds events in major city areas in the USA to reach out to the aquaponics community.[32]

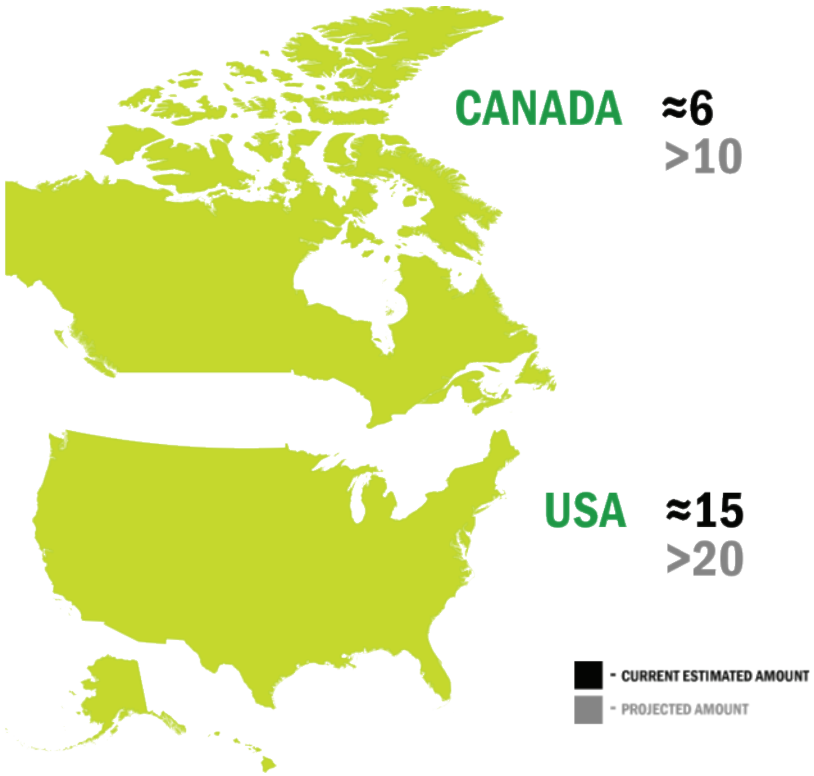
Conclusion

Overall, the movement in the industry has gained substantial momentum across North America over the past few years. Support for urban agriculture has been growing rapidly, which is providing a degree of public awareness for vertical farming to continue its fast-paced growth. Although vertical farming in North America is still a novelty, several regions have shown great advancement in both technological developments and entrepreneurship.

The entire North American region is rapidly improving their technologies and innovating in their business models. The USA is the leader in North America with a much greater number of vertical farms and technology developers than Canada. In the USA there are diverse business models ranging from large-scale warehouse indoor vertical farms to rooftop greenhouses and shipping container farms to home appliance units. With the support of leading technology developers, the industry is bound for accelerated growth. There are approximately 15 commercial vertical farms (indoor vertical farms and rooftop greenhouses) in the USA and it is possible the market size acn increase to more than 20 in the next 12 months. In Canada there is an estimated six commercia-scalel vertical farms and over the next 12 months the market size is expected to double. Notably, there are many players in both the USA and Canada at the R&D stage and we will wait to see if they are capable of expanding to a financially sustainable first operational unit.

[31] United States Department of Agriculture. USDA Unveils New 'Urban Agriculture Toolkit' for Urban Farmers and Agri-business Entrepreneurs. USDA Office of Communications, 2016. Web. 1 May 2016.
<http://www.usda.gov/wps/portal/usda/usdamediafb?contentid=2016/04/0099.xml&printable=true&contentidonly=true>

[32] See Aquaponics Association website at http://aquaponicsassociation.org/



Where consumer demand and community adoption for organic and locally sourced are present, there should be a considerable increase in vertical farms across the continent. Governments are now starting to readjust policies and provide wider funding alternatives. However, for accelerated industry growth more beneficial changes to regulations are needed and the creation of Urban Agriculture Directors.

Indoor Harvest

Interviewee: Chad Sykes, CEO and Founder, Indoor Harvest
Interviewer: Howard Brin, Association for Vertical Farming

Indoor Harvest based in Houston, USA, is a full service EPC firm for the vertical farming industry. The company designs, manufactures and supplies production platforms and custom-designed build-outs tailored for a specific vertical farm, project and crop. Indoor Harvest fixtures and HVAC systems are designed to efficiently grow produce from microgreens to medicinal plants for bio-manufacturing, which can include advanced plumbing for aeroponics, and layered rack and LED lighting systems that aim for high efficiency and easy assembly for multi-tier installations.

The soup and deli vertical farm that led to Indoor Harvest

The opportunity to establish Indoor Harvest developed from an original idea to create a soup and salad deli combined with a vertical farm. In early 2012, Chad Sykes realized this was impossible since there was no equipment designed for the idea. As a licensed plumber and mechanical systems contractor, he designed and built an aeroponics demo as a solution. This demo gained the interest from MIT CityFarm and eventually led to Chad Sykes and Caleb Harper, Principal Investigator and Director of the Open Agriculture Initiative at MIT Media Lab, design and build prototypes for MIT CityFarm in late 2013. The MIT CityFarm success made it possible for Indoor Harvest to attract attention from investors and raise expansion capital.

The second major company milestone was a research partnership with Canopy Growth / Tweed, a Canadian medicinal marijuana company, running a technology pilot with Indoor Harvest's patent pending commercial platform for cannabis plant expression and biomass. The result of the project led Indoor Harvest to John Choo, who became President and Co-founder of Indoor Harvest and is now leading the company with key activities to scale.

Addressing market needs

The market and users face barriers to understand complex systems and equipment that hamper their ability to effectively organize their business. One fundamental principle is not understanding equipment pricing or technology, which results in obstacles to build a successful business. To address this, Indoor Harvest designs its products with a fixture-based approach that are pre-designed production platforms and full-spectrum custom-designed build-outs for users to plug the products to systems to enable easier plant growth and scalability. Their network of partners and vendors allow a wide arsenal as a design builder to accommodate various production methods wrapped into their commercial engineering.

Indoor Harvest is underway to add additional product solutions for indoor farms: higher efficient HVAC systems and an open-source data platform. Chad Sykes mentioned vertical farms with stacked layered systems 6-9m (20-30ft) high can not maintain adequate airflow and be efficient. If a vertical farm is built with very high stacked layers, the upper layers capture heat mass load that have to be pushed off the racks, and therefore, highly efficient integrated airflow has to be available.
Indoor Harvest is committed to support the whole industry movement by making their data accessible to the public through open-data and help others build their business.

CLARA

The open-data platform will be developed and at Community Located Agriculture Research Area ("CLARA) in Pasadena, Texas. The indoor agriculture facility will help solve two major problems: the lack of open-source data and qualified indoor farmers.

Illumitex

Interviewee: Paul Hardej, VP Hortitecture™ Lighting Solutions, Illumitex
Interviewer: Howard Brin, Association for Vertical Farming
Vincent Fesquet, New'rban View

More than just horticultural LED lights

Illumitex, headquartered in Austin, USA, is a horticultural LED lighting company that not only innovates and sells LED grow lights but also provides solutions for indoor farming clients using artificial lighting. Since 2015 Illumitex delivers full installation services by their own qualified contractors and project management team – known as Hortitecture™ Lighting Turnkey Solutions". The company has found many growers appreciate this service, as they prefer to stay focused on growing crops than managing installation projects. Paul Hardej mentioned the company has delivered several seamless installations at prominent vertical farms and greenhouse operations since the program was launched.

At Illumitex approximately 20 out of its almost 100 employees (70 based in Austin) are experienced in horticulture, which ranges from ex-growers to plant biologist and lighting engineers to electrical engineers. Paul Hardej uses his experience as the former co-founder and CTO of FarmedHere, to provide whole and / or focused solutions for vertical farms. One of the most common issues he finds is related to growing recipes - vertical farms have systems and operations poorly designed compared to modern greenhouses - many vertical farms have growing recipes, but fail to successfully transfer to operational use at larger commercial scale. Under this scope, Illumitex works with companies to solve these issues.

Developing customized lighting spectrums

As a vertically integrated company, Illumitex owns the entire value chain by controlling production, assembly, and pre- and post-sales of its products and services. Paul Hardej noted this competitive advantage is what gives Illumitex the resources to provide 10 different lighting spectrums (and the possibility of customized wavelengths) to its clients. In 2016 Illumitex and its strategic partners plan on bringing improved light recipe products and solutions to the market.

For example, Illumitex's product Quantum Research LED Grow Light is a dynamic fixture that allows a user to change the light intensity and spectrum, which has been used until now in research and development. The product is widely used by universities, research institutions and PlantLab, which has assisted in developing lighting recipes. Paul Hardej commented that Illumitex sees a tremendous increase in productivity from LED lights. Its driven not only by improvement in the efficiency of the luminaires itself but also as an outcome of better understanding of the benefits coming from focused lighting spectrum by more experienced growers. According to Paul Hardej, Illumitex is moving forward to provide a wide variety of luminaires and lighting spectrums, and in partnership with companies like PlantLab, there are plans to provide a more complete turn-key solution. Ultimately, the goal of Illumitex is not to design an entire operation for a vertical farm but to provide expertise and the best solutions possible for crop growth and operational efficiency.