White paper on Vertical Horticulture
International overview of Vertical Horticultural Projects

White paper in the MeetingMoreMinds Series on Feeding MegaCities

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Smart Cities and Vertical Farming:
a Rational Combination based on Needs to Feed Citizens in Megacities
with Healthy Food and Fresh Produce

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Introduction: Re-thinking the dominant production paradigm in greenhouse horticulture

If the Dutch want to stay world-class they have to re-think the current way of producing vegetables, plants and fresh produce in greenhouses. Notwithstanding the fact that the Dutch are the world most advanced producers and traders in horticulture, floriculture and highly innovative in green technology installations that support this clusters, the world is changing. But are the Dutch? And are they in time?

In this research paper on Smart Cities and Vertical Farming we challenge the dominant paradigm in horticulture and in the slipstream the ornamental plants and floriculture cluster. From thinking in endless hectares of horizontal greenhouses we would like to open the conversation on re-thinking the mainstream way of production towards vertical farming in the perspective of the steep rise of megacities in the world. The future world consumption of fresh produce and plants is increasing. Most of the world population will live in cities. Feeding the world means more and more securing access to fresh food in megacities where 5 billion people will live in 2030. The governing bodies of these cities will look for other solutions to feed their citizens than the traditional Dutch solution of building horizontal greenhouses at a large distance from cities where land is cheap. From a sustainability perspective the loss of often 30% or more of the harvested production due to inefficient transportation and inadequate infrastructure is untenable, unsustainable and not defendable in the light of Sustainable Development Goals (SDG’s) as proclaimed by the United Nations in 2015.

While the dominant production paradigm in horticulture of horizontal greenhouses still leads to well filled international order books for greenhouse builders and green tech installers and while the Dutch growers in horticulture and floriculture are exporting to all parts of the world at all times records high, now is the time to re-think the mainstream with a future perspective. If the Dutch want to keep their world-class position in the decades to come it is necessary to take a closer look to what is happening internationally in the field of urban farming, vertical and indoor farming.
The outsider view challenges the mainstream

As a professor for Strategy and Transformation Management at Nyenrode Business University, Annemieke Roobeek lectures about innovation, ecosystems and clusters like the Dutch horticulture and floriculture clusters. These two clusters in the Netherlands are great examples of clusters with the typical characteristics of geographical proximity, mutual cooperation and dependence, of innovation and competitiveness, of efficiency and international excellence. When teaching a renowned Harvard flower case for the MBA students, she discovered that it sketched a terribly outdated picture of the cluster and the suppliers. She found that it lacked dynamics and important changes over time. Although horticulture and floriculture clusters in the Netherlands are almost totally export-oriented with world class enterprises operating internationally, there is also a kind of stubbornness in keeping a short-term view and getting stuck in the traditional way of doing business while ignoring what innovators, start-ups and potential competitors from outside the industry are doing.

Together with her team at MeetingMoreMinds she decided to do research into the driving forces behind the changes in the horticulture and floriculture clusters. While doing interviews, numerous working visits, technology reviews, and analytical data research Annemieke Roobeek came up with an new international growth perspective for the Dutch export based on creating the collaborative advantage in ecosystems. Having many specializing companies is great, but creating collaboration between these super specialists in an emerging paradigm is even better.

The need for inter-industrial collaboration to get to the next level

In this international overview of Smart Cities and Vertical Farming is becomes clear and visible that the traditional way of building greenhouses for horticulture is not the way forward in cities with millions of inhabitants. The overview shows that in dozens of cities in the world all kind of experimental initiatives are taken to explore new ways of producing fresh produce within cities. These initiatives in urban farming, rooftop farming, indoor farming and vertical farming can be seen as an innovative search for new ways to a healthy style of living in cities. Fresh produce forms a crucial part of the complex puzzle to sustain and create an increasing population in cities with millions of inhabitants. Access to fresh food is as necessary as access to electricity, internet, water, education and work. Smart Cities are often identified by technology and in particularly in putting digitalization strategies into action. A closer look at the more advanced forms of vertical and indoor farming makes clear the blending of Smart Cities with Vertical Farming. It takes a lot of high tech to create a successful indoor or vertical farm. Many green technologies, such as climate systems, LED-lighting systems, water systems and growth protocols are all based on data and digitalization.

What will the integrated concept of advanced urban farming look like?

It is a data-driven, at distance monitored growth system where recipes for fresh produce secure stable production through the year in climate controlled production settings. Selling an integrated concept including advanced knowledge, combined information, construction and installation processes and data surrounding horticulture is different from growing tomatoes and exporting the products. The focus on systems does not mean giving knowledge away, but selling tailor made knowledge for a specific location in the world together with sustainable production recipes for high quality products. This results in a competitive advantage of the Dutch horticulture with higher
margins for all parties involved. In fact, in the concept we developed we combine clusters and networks into larger ecosystems where collaboration is key. The Dutch world class position in floriculture, horticulture and its specialized suppliers around the green house sector gives the entire ecosystem an enormous competitive advantage. The focus for the new growth strategies is on the world’s megacities. Growing fresh produce in the first place and later also flowers and plants in advanced, climate-controlled greenhouses close to a city, wherever in the world this may be. Because of the unique knowledge position of The Netherlands, knowledge can be aggregated and put into data systems and the Dutch can fulfil a directing role in sustainable growth processes. You can even see it as an advanced form of horticulture tailored to the demand of specific locations in the world. It will result in creating trade on high tech production systems with a higher value and more impact than just growing and transporting tomatoes or cucumbers all over.

Thinking big: high tech growth systems

Thinking big is difficult for many entrepreneurs. Most companies only look at their own part of chain. There certainly are traditional growers and greenhouse builders who think this is a bridge too far. Creating an international and sustainable ecosystem indeed is an enormous challenge that all stakeholders in the horticulture sector need to commit to. However, not committing to this challenge of taking urban farming as a serious gamechanger is a missed opportunity in the medium and long term. With such an ecosystem around high tech growth systems in development, a real contribution towards the World Goals (SDG’s) can be made.

A new generation is combining knowledge and technology

At any rate, the new generation looks differently at growing flowers and plants than the old generation. It is not by chance that many sons and daughters of horticulturists now study informatics and big data. They already see the potential of an international sustainable ecosystem and are ready to anticipate on it. Amongst other things, they can do so with the experiential knowledge and know-how of their parents and grandparents, which they can translate in bits and bytes into advanced growing programmes. This inter-generational knowledge and know-how is key in the transformation process and it will be applied with artificial intelligence and machine-learning. It will be used in another way together with the dynamic innovations in installation technologies, robotics and drones. Not so much the production of fresh produce, flowers and plants will be the head of the game, as the knowledge for the systems to produce in stable, high tech climate controlled environments.

About this overview of vertical farms

The overview we show you in this White Paper is a snapshot of what can be found in public sources until. We selected those vertical farms with a stable production track record. However, since this industry is in flux, and many new vertical farms are set up, as are many going bankrupt as well, the list does not pretend to be complete. It is much more a visual impression of how many serious vertical farming projects set up in the past few years, particularly in smart cities with conscious consumers and high tech savvy entrepreneurs at hand.
The Netherlands: Overview of vertical farming activities

<table>
<thead>
<tr>
<th>Cities</th>
<th>Name</th>
<th>Description</th>
<th>Image</th>
<th>Type / Size</th>
<th>Status</th>
<th>Production capacity</th>
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<tbody>
<tr>
<td>Dronten</td>
<td>Fresh Care Convenience, Staay Food Group</td>
<td>The first real vertical farm in Europe, which produces for retail.</td>
<td></td>
<td>Vertical farm</td>
<td>Opening in 2018</td>
<td>300 tonnes vegetables per year (2017)</td>
</tr>
<tr>
<td>Amsterdam</td>
<td>GrowX</td>
<td>Small-scale vertical farm in Amsterdam, where vegetables are produced for restaurants. The company has a focus on sustainable logistics.</td>
<td></td>
<td>Vertical farm</td>
<td>Active since 2016</td>
<td>180 tonnes of salads and herbs per year (2016)</td>
</tr>
<tr>
<td>Den Haag</td>
<td>The New Farm</td>
<td>The New Farm is the international hub for food production within the city. It is a place for start ups to experiment with new ideas. There already exist a vertical farm and a research field lab.</td>
<td></td>
<td>Vertical farm, research</td>
<td>Active since 2017</td>
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<tr>
<td>Zwaagdijk</td>
<td>Proeftuin Zwaagdijk</td>
<td>Proeftuin Zwaagdijk is a research institution to optimize the impact of LED light on the growing process. Furthermore it teaches trainees the different facets of growing vegetables. At this moment they work with a 3-level grow system.</td>
<td></td>
<td>Vertical farm, research</td>
<td>Active since 2012</td>
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<tr>
<td>Venlo</td>
<td>Brightbox</td>
<td>Brightbox is an expert centre on growing vegetables without daylight. Different parties such as, Botany, Philips, de HAS and the province of Limburg work together to innovate the process.</td>
<td></td>
<td>Vertical farming, 192 square meters</td>
<td>Active since 2015</td>
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<tr>
<td>Location</td>
<td>Company</td>
<td>Description</td>
<td>Industry</td>
<td>Date Active</td>
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<tr>
<td>Innoveins</td>
<td>Innoveins</td>
<td>Innoveins combines plants and technique to develop innovative ecosystems for the market.</td>
<td>Indoor farming</td>
<td>Active since 2017</td>
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<tr>
<td>Eindhoven</td>
<td>Philips Grow Wise Center</td>
<td>The research lab of Philips test the impact of LED lights on greens and other vegetables. They have designed a special room where they test precisely, which light works for which vegetable.</td>
<td>Vertical farming, 234 square meters</td>
<td>Active since 2015</td>
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<td>Beesel</td>
<td>Deliscious</td>
<td>Deliscious uses a 8 meter tall climate room, where it tests together with Philips, which different plants they can grow.</td>
<td>Vertical farming</td>
<td>Active since 2016</td>
<td></td>
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<tr>
<td>Poeldijk</td>
<td>Certhon Innovation Center</td>
<td>Certhon designs and implements innovative and reliable technologies that enable the cultivation of horticultural products worldwide. Certhon wants to improve its own daylight-free cultivation techniques in Poeldijk in 8 different growth cells of a total of 240 square meters.</td>
<td>Indoor farming, service, 240 square meters</td>
<td>Under construction</td>
<td></td>
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<tr>
<td>Den Bosch</td>
<td>PlantLab</td>
<td>The head office of PlantLab is located in the heart of Den Bosch. The company focuses on the various possibilities of indoor farming. More than 5.000m2 includes high-tech breeding rooms in which cultivation recipes are developed, under the brand name Plant Paradise.</td>
<td>Indoor, vertical farming 5,000 m2</td>
<td>Active since 2008</td>
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<tr>
<td>Location</td>
<td>Company/Concept</td>
<td>Description</td>
<td>Type</td>
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<tr>
<td>Utrecht</td>
<td>Wonderwoods</td>
<td>The Wonderwoods plan includes two towers of 90 and 70 meters high with room for living, working, relaxation and entertainment. The highest tower looks like a vertical forest, where the planting is designed along the balconies and on the façade.</td>
<td>Vertical gardens</td>
<td>Concept, construction starts 2019</td>
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<tr>
<td>Vlaardingen</td>
<td>Hoogendoorn Growth Management</td>
<td>Hoogendoorn, together with worldwide partners, provides sustainable automation solutions that seamlessly harmonize all processes and systems in your horticulture organization. The modular software ensures that the available raw materials such as natural gas, fertilizers and water are used as efficiently as possible.</td>
<td>Indoor farming, service</td>
<td>Active since 1974</td>
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<tr>
<td>Burgh-Haamstede</td>
<td>Vitro Plus</td>
<td>Vitro Plus has extensively industrialized the cultivation process of greens with specially designed growth chambers. Currently, VitroPlus focusses on plants, but it is investigating possibilities for greens such as lettuce.</td>
<td>Vertical Farming</td>
<td>Commercial, Active since 1990</td>
<td>Over 3 million ferns a year (2018)</td>
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# International overview of smart cities with urban & vertical farming activities

<table>
<thead>
<tr>
<th>North America</th>
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<tbody>
<tr>
<td><strong>Cities</strong></td>
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<tr>
<td><strong>United States of America</strong></td>
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<tr>
<td>New York</td>
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<tr>
<td>Bowery Manhattan</td>
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<td>Bowery New Jersey, Kearny</td>
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<td>Location</td>
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<td>New York</td>
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<tr>
<td>Boston</td>
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<tr>
<td>Location</td>
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<tr>
<td>Higher Ground Farm</td>
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<tr>
<td>Chicago</td>
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<tr>
<td>Metropolitan Farms</td>
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<tr>
<td>Chicago Area</td>
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<tr>
<td>Philadelphia</td>
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<tr>
<td>Location</td>
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<td>Los Angeles</td>
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<td>Seattle</td>
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<td>San Francisco</td>
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<td>Canada</td>
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<td>Vancouver</td>
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## Mexico

| Mexico City | **Greening Rooftops across Mexico City** | The City promotes rooftop hydroponic gardens and installed beds of succulents on public buildings to tackle air pollution | Open-air RTF, Edible walls & balconies, ca. 12,300 sq m in the city | Ecological City, Private |

## Europe

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### France

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<th>Status</th>
<th>Production capacity</th>
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- **Paris**
  - **Vertical Farm Romainville**
    - French architecture firm Ilimelgo have designed a vertical farming complex in the Parisian suburb of Romainville. The project integrates production of produce into the city through a greenhouse that maximizes sunlight and natural ventilation.
    - Vertical Farm / Greenhouse 1000 square meters
    - Funds are being raised, concept

### United Kingdom

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- **London**
  - **Grow Up Urban farms**
    - The farm combines two well-established farming practices – aquaculture (farming fish) and hydroponics in a recirculating system.
    - Indoor / Vertical Farm, 6000 square feet
    - Commercial, active since 2013
    - Projected annual production of 20 tonnes of greens and 4 tonnes of tilapia (2016)

  - **Growing Underground**
    - The WWII shelter in Clapham consists of two large tunnels that were set to link the London Underground. Instead, Steven Dring and Richard Ballard grow an array of vegetables using hydroponic growing methods
    - Indoor Farming / Vertical
    - Commercial active since 2012
    - Currently the subterranean farm can produce up to 60kg of herbs a day (2016)
North Lincolnshire  | **Jones Food Company & GE** | Current, powered by GE (NYSE: GE) and Jones Food Company Ltd. (JFC), today announced that construction is underway toward building one of the world’s largest indoor farms. | **Vertical Farming** | Production starts autumn 2018 | Producing up to 420 tonnes of leafy greens per year across a growing area of 5120m², arranged in racks rising to the height of 11m. *(2018)*

**Germany**

| **Berlin** | **InFarm** | A company that tries to eliminate the distance between farm and fork. Has a vision to build an indoor farm in every grocery store. | Indoor, vertical farming (in every grocery store) | commercial active since 2012 |

**Sweden**

| **Stockholm** | **Plantagon** | Plantagon develops, implements and operates innovative Agritechture solutions, creating green spaces in urban environments while adding value to surrounding real estate. | Indoor, research farming | Research, Concept |

**Oceania**

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<th>Cities</th>
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**Australia**

| Sydney | **Green Camel Farms** | An integrated aquaculture-horticulture system that produces both fish and vegetables in a symbiotic manner with zero pesticides. Green Camel uses computer controlled planting and one staff to lay young herb seedlings on conveyor belts. This is intensive food production, whereas on the storey above conveyor belts of herbs move slowly but grow fast, in the regulated warmth and sunlight. | Indoor farming, 5,000 square meters | commercial, active since 2015 | Capacity to produce over 130,000 Kg of herbs per year and 15,000 Kg Barramundi per year *(2015)* |
Melbourne  FarmWall  Farmwall is a start-up that designs and installs farmwalls in cafes and restaurants to grow fresh herbs and greens  Vertical Farm  commercial (start-up), active since 2017

### Asia

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<td><strong>China</strong></td>
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<td>Beijing</td>
<td>IEDA Protected Horticulture</td>
<td>A vertical plant factory on top of the Chinese Academy of Agricultural Sciences in Beijing.</td>
<td></td>
<td>Vertical farming 800 square meters</td>
<td>Commercial, active since 2002</td>
<td>With rows 10 feet high, the indoor patches yield between 40 and 100 times more produce than a typical open field of the same size. (2017)</td>
</tr>
<tr>
<td>Shanghai</td>
<td>Sunqiao Urban Agricultural District</td>
<td>The city is planning a 250-acre agricultural district with vertical farming, which will function as a space to work, live, shop, and farm food. It will include 753,000-square-feet of vertical farms.</td>
<td></td>
<td>Vertical Farming / Smart City 753,000 square feet of vertical farms</td>
<td>Smart city, vertical farming Concept</td>
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<tr>
<td>Nanjing</td>
<td>Vertical Forest Tower</td>
<td>The tower has a plant covered facade that is thought of to help chinese cities to tackle pollution and to absorb up to 25 tons CO2 in a year.</td>
<td></td>
<td>Vertical gardens</td>
<td>vertical garden Concept</td>
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<tr>
<td>Hong Kong</td>
<td>Rooftop Republic</td>
<td>Rooftop Republic’s team has been pioneering the urban farming movement over the last five years. They run several urban (rooftop) farms in Hong Kong</td>
<td></td>
<td>Roof top farming</td>
<td>Community building, active since 2012</td>
<td>Runs 34 farms (2018)</td>
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<tr>
<td>Country</td>
<td>Company</td>
<td>Description</td>
<td>Year</td>
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<tr>
<td>SCATIL</td>
<td>With the passion in agricultural development, our founders introduced Japanese hydroponic technology and an indoor hydroponic farming in 2014 as the stepping stone.</td>
<td>Indoor Vertical Farm</td>
<td>Commercial, Active since 2014</td>
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<tr>
<td>Shenzhen</td>
<td><strong>Green Sense Farms Shenzen</strong></td>
<td>This is the second vertical farm from Green Sense Farms. Their partners are, among others, Philips, Hortimax and Rijkzwaan</td>
<td>Indoor Vertical Farm</td>
<td>Commercial, Active since 2016</td>
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<td></td>
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<td></td>
<td>750,000 to 1 million heads of lettuce and about 1.5 million leafy greens (2016)</td>
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<tr>
<td>Taiwan</td>
<td><strong>Ting-Mao Corp.</strong></td>
<td>TingMao Agricultural Biotechnology was an early pioneer, starting its plant factory in 2007, and today is the leading producer of LED-grown vegetables in Taiwan</td>
<td>Indoor farming, Vertical farm, 3300 square meters</td>
<td>Commercial, active since 2007</td>
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<tr>
<td>Taipei</td>
<td><strong>Agora tower</strong></td>
<td>A twisting, smog-eating tower with vertical gardens is nearly finished in Taipei, Taiwan. The skyscraper’s facade, roof, and balconies will contain 23,000 trees and shrubs – nearly the same amount found in New York’s Central Park. Inside, it will hold 40 luxury condos. The plants are projected to absorb 130 tons of carbon dioxide per year</td>
<td>Vertical Gardens</td>
<td>vertical gardens, in progress</td>
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<tr>
<td><strong>Japan</strong></td>
<td><strong>Tokyo</strong></td>
<td><strong>Pasona Headquarters</strong></td>
<td>The Headquarters of the Pasona Group blooms a garden in the sky that provides Tokyo with a striking display of foliage.</td>
<td>Vertical gardens</td>
<td>vertical gardens, active since 2010</td>
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<td><strong>Kashiwa</strong></td>
<td><strong>GE &amp; Mirai</strong></td>
<td>Claims to be the world’s largest indoor farm. The high-tech indoor farm is illuminated by 17,500 LEDs and is nearly half the size of a football field</td>
<td>Indoor farm 25,000 square feet</td>
<td>commercial, active since 2012</td>
<td>10,000 crops of lettuce a day (2014)</td>
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<tr>
<td><strong>Aizu Wakamatsu (100km from Fukushima)</strong></td>
<td><strong>Fujitsu</strong></td>
<td>A vertical farm, about 60 miles from the site of the deadly 2011 nuclear disaster in Fukushima prefecture, inside a former silicon chip manufacturing facility owned by the Japanese computer company Fujitsu</td>
<td>Indoor vertical farm, 1850 square meters</td>
<td>commercial, active since 2015</td>
<td>12,000 crops of lettuce a day (2016)</td>
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<tr>
<td><strong>Kyoto</strong></td>
<td><strong>Spread Factory</strong></td>
<td>Spread is Japan's largest vertical farm, a blend of agriculture and industry. Spread grows and ships out four varieties of lettuce.</td>
<td>Vertical / Sky Farming, 4.780 sqm</td>
<td>commercial, active since 2006</td>
<td>More than 20,000 crops of lettuce a day (2017)</td>
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### South Korea

**Seoul**  
**Urban Skyfarm**  
The Urban Skyfarm is a vertical farm design proposal for a site located in downtown Seoul, right adjacent to the Cheonggyecheon stream which is a heavily populated dense urban area.  
Vertical gardens  
Vertical garden, Concept

### Indonesia

**Jakarta**  
**2017 green aisle program in 75 areas**  
Jakarta administration plans to introduce a program to grow vegetables medicinal plants and pot fruit plants aiming to ensure food security. The administration has allocated Rp 5 billion (US$ 375,855) for the program.  
Food production, urban farming  
In progress

### Singapore

**Singapore**  
**Sky Greens**  
Sky Greens is a private-public project that endeavours to become the world leading provider for integrated agriculture technology.  
Vertical / Sky farming  
commercial, active since 2012  
1000 kg vegetables a day (2016)

**Packet Greens**  
Through a multi layered shelf design they are able to produce up to 30kg vegetables daily to meet Singapores self sufficient food target.  
Vertical / Sky farming, 1,500 square feet  
commercial, active since 2014  
30 kg daily yield of vegetables (2016)

### India

**Mumbai**  
**Terra Farms**  
Terra Farms is the first ‘Urban Vertical Farm’ in Mumbai based at Malad. We aspire to bring the farm as close to the city as possible  
Micro Farming / Sky Farming,  
Commercial, Research, active since 2012
### Khagaria

**Mega food park**  
The 70-acre food park will create immense opportunities for entrepreneurship and employment in the state bestowed with huge agriculture production potential. It will benefit farmers, growers, food processors and consumers in the state of Bihar.

### 100 cities across India

**Smart cities mission**  
Smart Cities Mission is an urban renewal program by the Government of India with the mission to develop 100 cities across the country making them citizen friendly and sustainable. It is a 5 year program, starting 2017, funded by the government. One criteria is to preserve and develop open spaces in order to create more livable areas.

### United Arab Emirates (UAE)

**Badia Farms**  
Badia Farms is starting the GCC’s first indoor vertical farm. We have a growing reputation for supplying the finest micro-greens and herbs to Dubai’s top restaurants, caterers, and chefs.

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**Mega farm**  
Commercial, in progress  
On completion, the park will have facilities of 40,000 tonnes dry warehouse, 10,000 tonnes grain silos, 5,000 tonnes multi-products cold storage, 10 tonnes per hour packing house, two tonnes per hour IQF, 1,500 tonne deep fridge, besides having modern testing labs and reefer vans (2018).

**Smart city**  
In progress  
15 billion dollars has been made available for the project (2015).

**Vertical Farming**  
Commercial, active since December 2017  
Since December 2017, Badia has been producing 1,000 heads of lettuce and has over 30 clients across the UAE. (2018).
Crop One Holdings and Emirates Flight Catering (EKFC), one of the world’s largest airline catering operators, have announced a $40 million joint venture (J.V.) agreement to build the world’s largest vertical farming facility in Dubai, United Arab Emirates. Construction starts in November, 2018. The 130,000 square foot controlled environment facility will produce three US tons (6,000 pounds or 2,700 kg) of leafy greens. (2018)

| Crop One Holding | Crop One Holdings and Emirates Flight Catering (EKFC), one of the world’s largest airline catering operators, have announced a $40 million joint venture (J.V.) agreement to build the world’s largest vertical farming facility in Dubai, United Arab Emirates. | Vertical Farming | Construction starts in November, 2018 | The 130,000 square foot controlled environment facility will produce three US tons (6,000 pounds or 2,700 kg) of leafy greens. (2018) |

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Please note that MeetingMoreMinds does not guarantee the accuracy, relevance, timeliness, or completeness of any information on these external websites.
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