New'rban view

Vertical Farming, from utopia to a business model
Recent developments

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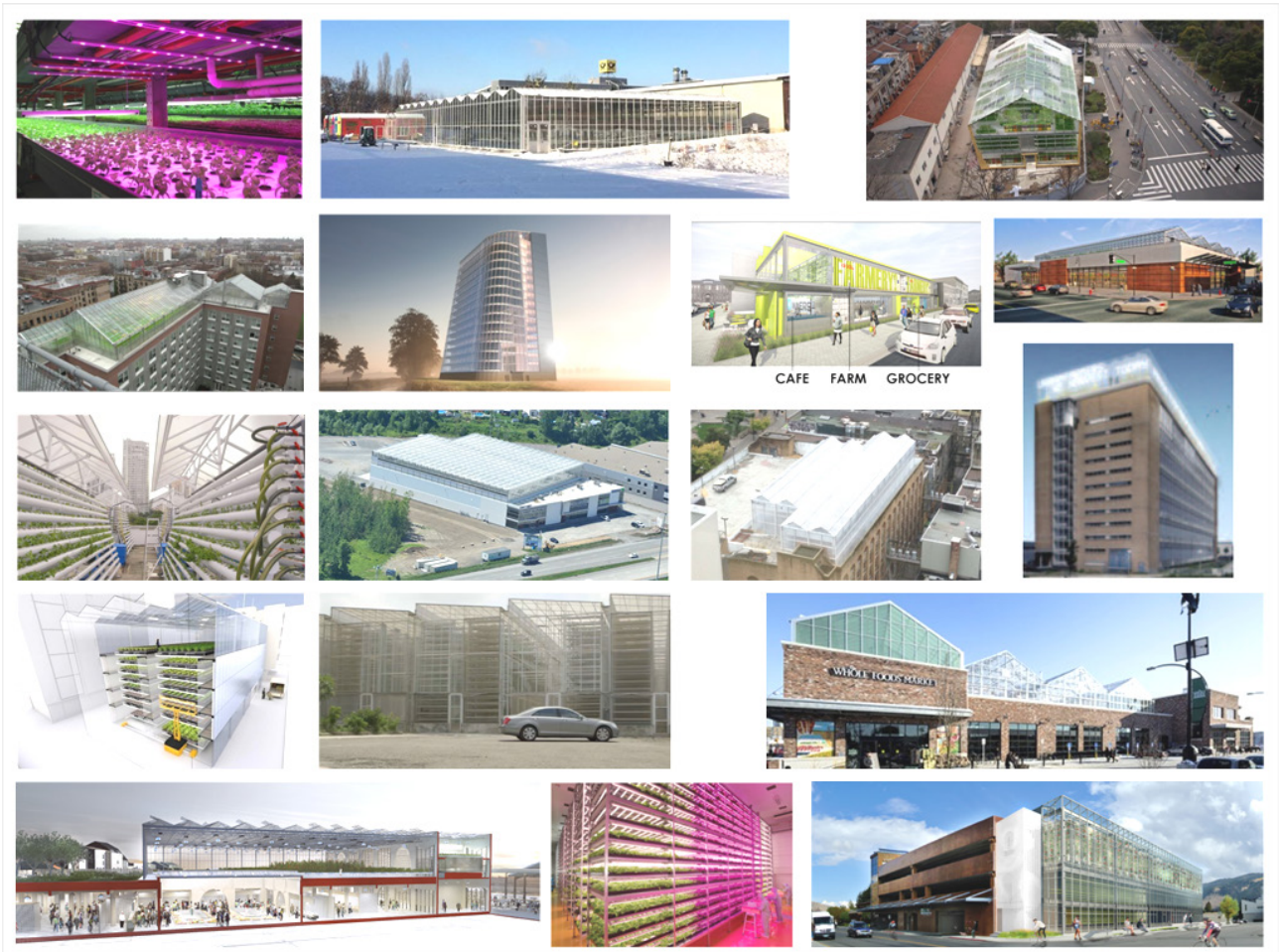

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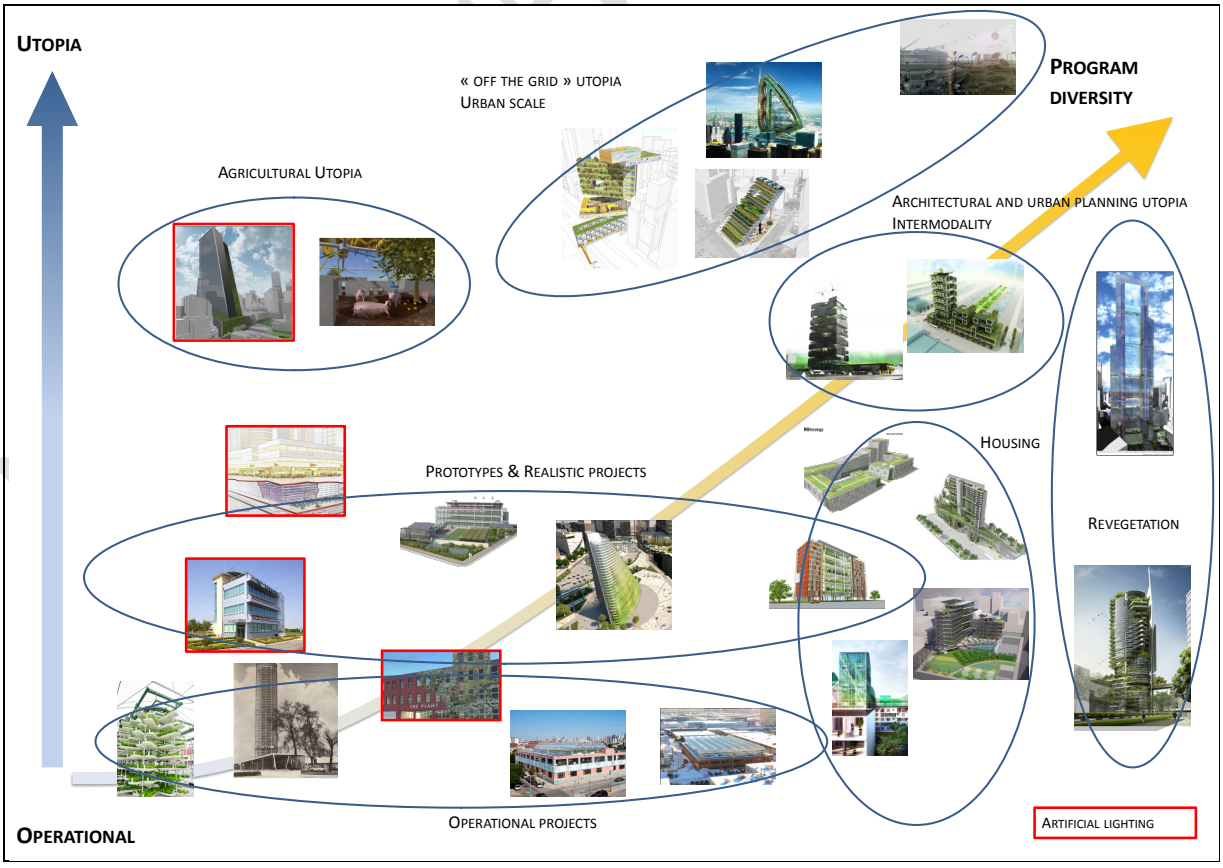
Examples of Studied Projects

Pictures' source: internet

Two years ago, as part of a research project[1] , I analyzed and compared and tried to classify about 30 vertical farming projects. Such projects were usually showing up in press and internet researches related to Urban Agriculture ("UA") and vertical farming. The main conclusions of this analysis were the followings:

- Vertical farming projects translating into multiple stacked production floors in a building is still an utopia,
- Projects become more realistic prototypes as they are of lower height. They often include a research and educational program that tends to legitimate them, although more often than not, they are not yet economically viable. None of these projects are built yet nor financed. Projects are mainly thought to be operated through natural lighting vs artificial lighting as the high level of energy required is still an issue,
- Operational projects consist mainly of rooftop hydroponics (greenhouse soilless cultivation techniques which optimize water consumption and allow to get rid of pesticides and herbicides[2]), installed on top of 2/3-floor buildings,
- It is difficult to assess whether such urban agriculture projects can become real business models. Nevertheless, these projects demonstrate a strong willingness to optimize food production to feed cities with less natural resources consumption and mutualize resources within the city. There is a prospective attempt to rethink cities across many "savoir-faire" and to come to a more systemic approach,
- Vertical farming projects demonstrate and foster the introduction of a thought process around food within urban planning policies.

The graph mapping the reviewed projects using a utopia / reality scale which also aimed at distinguishing the level of diversity of the building program is the following:



2013 study

Looking at the current developments of operational projects, it is fair to say that pragmatism, willingness to test formats, first business model rollouts and to some extent financial constraints are themes surrounding the evolution of vertical farming projects. We are no more at the stage of pure out of scale or theoretical "paper" projects. A study published for the 3rd Indoor Agriculture Conference held in Dallas – March 2015, reported that the number of commercial players in North America should triple in 2015[3], from 15 to 45 operational commercial projects (both vertical and rooftop farming). Hence, vertical farming is today and for now, more focused on rooftops than on high rises dedicated to urban agriculture and also on the conversion of former industrial buildings in "brown field" or so called declining / shrinking cities areas. Rooftops on one side and former industrial buildings on the other side, stress two very different approaches related to the natural or the artificial lighting of the production as well as a cost per sqm factor.

In order to review the main evolutions, we will first and mainly focus upon rooftops and then comment upon former industrial buildings or warehouses conversion before coming to other new developments.

1. Rooftops

There are many ways to integrate vegetables' production to rooftops. The solution ultimately retained is a function of weight of the equipment, investment levels and production yields[4]. For the purpose of this analysis, we will mainly focus on controlled rooftop production within greenhouses such as hydroponics and its "derivatives" i.e. aquaponics. Being inside a greenhouse, production is also potentially less subject to air / rain pollution issues. Rooftops will have to allow for this weight and be accessible. When built upon existing premises, roof waterproofing membranes need most of the time to be reshuffled.

Within the greenhouse rooftop category, some trends are worth mentioning:

i) Expansion/ Rollout of category first movers
ii) Urban rooftop greenhouses are gaining momentum across Europe
iii) The business model is being refined
iv) Raising interest from the industrial and financial communities
v) Enlargement of premises on which vertical farming is taking place and beginning of new building design incorporating greenhouses,
vi) Emergence within the city of food production / distribution dedicated buildings of low height,
vii) Increasing researches on aquaponics and tests.

Going through these items, and although we are mainly talking about rooftop developments, we will also mention "ground based" hydroponics and aquaponics evolutions as they do participate to the urban agriculture trends.

Expansion / Rollout of category first movers

Hydroponic operators such as Lufa Farms, Gotham Greens and Sky vegetables, which have been pioneering ventures in rooftop farming, and BrightFarms on the ground, are now all expanding to different locations, shooting mainly for bigger formats through new capital increases, in New York with 1,900 sqm in Gowanus, Brooklyn and 5,600 sqm in Queens and in Chicago with a 7,000 sqm project for Gotham Greens; in Laval, Canada with 4,000 sqm for Lufa Farms. All contemplate potentially new ventures in other cities and new agreements. Interestingly, Lufa is not only expanding but is also improving its partnering program with other local growers to enlarge its baskets' offer.

Urban rooftop greenhouses are gaining momentum across Europe

Projects are now developing in Switzerland (proof of concept format – Urban Farmers; and commercial format in the verge of being operational – Ecco-Jäger), the UK (proof of concept format), Belgium (operational projects seeking finance – Urban Farmers), and France (FUL research stage). Although most of them are still tests or proof of concept on a low scale basis, cash is being raised across Europe to implement an operational format, and construction permits are being delivered as we speak.

Many hydroponics and aquaponics projects are also designed on the ground close or within cities (e.g. in Berlin, Germany - newly built 1,600 sqm and on the verge of being operational Efficient City Farming Systems). In certain cases, some projects do propose to use the heat generated by the activity within other buildings which would be lost otherwise.

The Business model is being refined

First comers are refining their business model to boost profitability and enlarge the greenhouse format they implement to get economies of scale, Sky vegetables being somewhat contrarian with a new 500 sqm hydroponic greenhouse on top of Arbour House in New York. They also tend or try to:

- Avoid greenhouse investment and focus on operating it,
- Improve selection of vegetables being grown to focus on high value / easy to crop species. In that respect, veggies are distributed to local restaurants and grocery stores / supermarkets. Ultimately, the closer from the distributor, (next or on its rooftop), the better. When baskets are directly offered to customers, some operational farms complete their baskets with "regular" production from local producers to enlarge their product range and benefit from their existing logistic / dropping points delivery scheme[5]. As a consequence, the farm's site becomes a gathering and dispatching point. Professional urban agriculture is therefore dealing both with veggies growing techniques and logistics. Ultimately, greenhouses are more or less dedicated to few vegetables as leaf veggies, flowers ones and fruits ones require different nutritive solutions and climate controls, especially when the farm runs several greenhouses in the same area. At the end, the assortment is as for "regular production" a function of yield, shelf life and taste/flavor.
  In a different way but also potentially using an existing logistic truck fleet, the fruit & vegetable Swiss wholesaler Ecco Jäger Früchte und Gemüse AG[6] develops rooftop aquaponics on its Bad Ragaz's site, which may benefit from the existing fleet and customer base.
- Increased vegetable production density through "going vertical hydroponic techniques" especially in Asia ("A" shape racks[7] and rotating conveyor belt)[8].

New emerging projects are more in the 1,000 – 2,000 sqm range, as 1,000 sqm is said to be the threshold under which economics are probably made difficult to work. In some new examples, coupling vegies production with fish production can help the business case when operating a smaller vegetables' production format. These smaller projects are also probably the result of the difficulty to find proper larger rooftops and of a willingness to arbitrage investment cost vs risks on first projects to be implemented.

Raising interest from the industrial and financial communities

Cash is being raised to finance such projects (USD 10 million[9] raised in 2014 / beg 2015 for Gotham Greens, USD 4,5 million additional having been raised by Lufa in oct 2012 and BrightFarms said to have raised USD 7,3 million[10] in 2014 for various projects). A global USD 32 million would have been raised in 2014 in the US by Venture capital funds to fund indoor agriculture projects[11]. Industrial players (greenhouse and greenhouse equipment manufacturers are getting closer to projects through partnerships and sometimes investment performed (Kubo in Gotham Greens for instance). Some food producers (Bonduelle Fresh

Europe in FUL[12] project) are getting involved while schools and universities research programs are reinforcing their interests. As projects are more numerous, the question of the professional training of this new type of farmers, operating within the city, will emerge and will have to be addressed within universities and schools.

Projects now raise cash not only through friends and family, public grants and subsidies but also through family offices and seed capital (e.g. Emil Partners and NGEN Partners in BrightFarms, Cycle Capital management in Lufa Farms), or through participating internet platforms which tend to demonstrate the growing interest of people in UA.

Enlargement of premises on which vertical farming is taking place and beginning of new building design incorporating productive greenhouses

Trends are threefold:

- Test formats which have been historically built are made on existing premises but many operational hydroponic greenhouse formats are now designed and built on new premises, which have also for purpose, to take into account the fact that exchanges occur between the greenhouse and the underlying premises, although this is still to be formally demonstrated. Nevertheless, it is true that designing the rooftop greenhouse at the same time as the underlying building, helps to dimension roof structure, forecast accesses and rationalize the location of rooftop emerging items and technical equipment (e.g. shelters, staircase, lift, equipment…) in order to maximize the roof usability and avoid greenhouse operational issues. Moreover, heating can be mutualized. Implementation costs are lower on new buildings than on existing premises,
- Increasing greenhouse formats on industrial premises and development of greenhouses on top of grocery stores as a perfect food distribution short cycle (minimize logistics and transportation),
- Enlargement of a variety of premises on top of which a greenhouse is set up, to include even housing. In that respect, Arbor House, (NY – USA) is the first hydroponic greenhouse being operated on top of apartments. As housing rooftops are thinner than the ones on which UA usually expands, one could question the future profitability of these hydroponic greenhouse formats. Following this project will therefore be interesting as it could open new horizons for vertical farming. Parking are also used (rooftop – see Alterrus Systems Inc [13]/ Local Garden Vancouver Inc, Vancouver, Canada, or as an "additional façade" – see Vertical Harvest[14] project in Jackson Hole, WY, USA).

Emergence of food dedicated buildings of low height

Several projects, (some of which are already operational, or seeking finance), do gather both vegetable production on rooftop and direct distribution in the basement (market place – e.g. abattoire project in Anderlecht , Belgium; grocery stores - e.g. Gotham Greens in Jamaica NY; corner shop in China[15] or the farmery project in Raleigh[16]). Some projects also explore food transformation. Project size is very diverse from local food store to big formats seeking to supplement their offer with "ultra-fresh" products. Mass distributors are therefore contemplating aquaponics or hydroponics, like Migros with Urban Farmers in Basel[17], Switzerland. Short food circuits are developing.

In parallel, others, such as NY based Brightfarms supply supermarkets with hydroponic grown vegetables produced close to them. As long as there is enough space on the ground and cost of land is low, the concept is less expensive to develop on the ground than on rooftops.

Increasing research on aquaponics

Coupling fish with vegetables (i.e. aquaponics) is an increasing trend. In a nutshell, fish water, once ammonia is transformed into nitrogen thanks to bacteria, is used to feed plants, regenerated and used potentially back into the fish tank. It benefits to both fishes and veggies. Nevertheless, fish species grown and vegetables produced have to be somewhat "compatible". Water consumption to produce 1kg of fish in aquaculture is reduced from 100 cubic meters (open water breeding) to 7 cubic meters[18] in aquaponic systems. The fish species called Tilapia is for now the main one produced as it is a fast growing, presents an interesting feed conversion to weight and is a robust fish. Nevertheless, in some region (and although Tilapia is a worldwide market), this fish is not that much consummated (e.g.France). This may slow the aquaponics move from research to operations. Aquaponists are working on the expansion of the model to new species, such as rainbow trout (e.g. Bioaqua farm in the UK), but they need lower water temperature and are more fragile than Tilapia. Most urban hydroponic greenhouse projects in Europe are actually aquaponics' ones.

Aquaponists do tend to be implemented by scientists or entrepreneurs coming from the aquaculture world who may value water as a "by-product" to grow vegetables and recycle it. It might be a reason why vegetables' production metrics and performance in these aquaponic projects seem still below pure hydroponics ones. Nevertheless, we can probably assume that going forward the performance gap will be bridged through cross fertilization and techniques being replicated.

This category triggers specific building issues as the fish production side of the business is very structure heavy, (about 800kg / sqm for fish tanks), and requires structural reinforcements, should fish production be implemented on rooftops, while pure hydroponics greenhouse are closer to 40 - 100kg / sqm. This is probably one of the reason why aquaponics also develops into former industrial buildings where the robustness of the structure does not trigger weight issues. In these projects, they have to use artificial lighting techniques to grow vegetables (see thereafter).

"Pure vertical farming" developments and "on the ground" developments

As artificial lighting is still not really used, mainly because of cost, or only to supplement sunlight, "pure vertical farming" has not developed so far apart from specific researches in Asia and façade developments to maximize sunlight exposure. Vertical Harvest in Jackson Hole, WY, USA and Plantagon in Linköping, Sweden are examples of very different scale projects that develop conveyor systems to use façades as growing surfaces and sunlight exposure.

It is worth mentioning in that respect that a 60m-high building has been announced by Plantagon in Linköping (Sweden) with a construction phase to start end of 2015[19] after a 2/3 year break[20]. Communication shows a greenhouse façade coupled with an office building program.

So far, entrepreneurs, in order to boost vegetables production's density have used height through racks of about 6m high (Comcrop for instance), or rotating conveyor belts where plants are alternatively exposed to sunlight at the top and fed with water and nutrients at the bottom ("A-Go-Gro" patented system of Sky Greens in Singapore for example).

Business model format

It is still quite difficult to get a sense for the rooftops business real profitability. Some studies mention an investment ratio up to 1,000 usd / sqm to build rooftop hydroponic greenhouses, which according to a Quebec study may represent about 3,6x the cost of a greenhouse of similar size based on the ground[21]. As a matter of fact, as the greenhouse expands on a roof, it becomes "part of the building" and therefore has to meet stronger specifications than on the ground. Aquaponics projects of equivalent size require even more capital due to fish production, but offer interesting operational synergies. It is still difficult for now to offer a compelling price to rent the roof. The amount of the rent is a well kept secret. The farmers need therefore to grow high value and fast rotating vegetables.

Remaining questions to fix the business model

- Although numbers may change from one media to the other, aquaponics vegetable production metrics and performance seem still below hydroponics. This is probably due to the fact that aquaponics start ups' managers come from the aquaculture's world. Nevertheless, we can probably assume that going forward the performance gap will be bridged through cross fertilization,

- As the rooftop hydroponic greenhouses are seeking profitability, the product range concentrates on high value/productivity vegetables, which tends to shrink the assortment diversity. In the case of the direct distribution model, the ability to gather other vegetables from other local sources will become increasingly important, and therefore site location (close transportation connections) might become discriminating, as the catchment / delivery area is,

- So far, growing techniques need to improve in order to break the 1,000 sqm hydroponic somewhat minimal growing surface, and rooftop hydro or aquaponic greenhouses are still much more expensive than on the ground. Undoubtedly, implementing a farm on a new building is more efficient than on an existing one. Energy needs and resources mutualisation is a work in process and should bring potential gains.

- Who is to invest into the greenhouse facilities? Projects demonstrate that 3 routes can be considered,
    i. the investment is performed by the owner of the underlying asset and the greenhouse facility is then rented to the farmer;

    ii. the investment is performed by a third party willing to find a financial yield in a "project financing" type of scheme with a potential tax benefit, the roof lease needs to be long enough, and the greenhouse needs probably to be removable at maturity. This scheme seems already used for "on the ground" greenhouses, where investing in and then renting a greenhouse serves a 4 to 5% rate of return, which can come across as attractive in the current low interest rate environment[22];

    iii. the greenhouse's investment is performed by the farmer.

  One way to approach it is probably to keep in mind that a greenhouse may be used for other purposes than growing vegetables, such as an additional meeting space. Therefore, the investment could meet overtime different objectives.

- Although we are talking about roofs, the ability to benefit from corners and surfaces at ground levels is important (logistics, transformation, distribution). Therefore, this is both the roof and the basement of the building that the model can address. Hence, vertical farming becomes all the more so attractive to architects and urban planners who may use it to liven up ground floors in connection with public spaces.

- Players are thinking about the right positioning going forward: Farm Manager or EPC companies (Engineer, Procure and Construct), or both. While some have already chosen, all will need to demonstrate through proper sizeable tests and prove the business model relevance prior to seeking expansion and raising further capital. The industry is beginning to rollout the concept, and although web sites do mention the willingness to develop and license, the actual leaders do operate so far the rooftop farms they have designed and implemented themselves.

2. Developments in former industrial buildings or warehouses

Interestingly, some entrepreneurs develop urban agriculture in brownfield or former factories / warehouses where activities participate to revitalize the neighborhood while cost of premises is low. The low cost of premises may balance the energy cost while being within the city. Some do develop in this respect, specific strategies.

The Plant in Chicago[23] hosts now more than 10 companies related to UA- aquaponics, hydroponics, mushrooms, brewery etc… - in a 8,700 sqm building and develops a "zero waste, net zero energy" vertical farm in a circular economy concept which is under way and which will be completed by an anaerobic digester to turn up to 30 tons of daily food waste into energy.

As examples of this trend, Urban Organics develops[24] aquaponics in former breweries in St Paul, Minesota. FarmedHere develops aquaponics in Chicago using LEDs on a 9,000 vegetable production surface in a former warehouse in the Chicago suburbs. Garden Fresh Farms develops fishes, herbs and lettuce in a former warehouse in Mapplewood, Minesota[25], and just launched through MnPharm[26] a concept to use hydroponics to grow tobacco plants for the medicine industry which could offer new developments to urban agriculture. The last one on the screen is Aerofarms, who develops a 6,400 sqm vertical farm and headquarter in a former steel factory in Newark[27], New Jersey, to open in 2015.

These 100% artificial lighting spaces mainly produce green leaf vegetables.

3. Other developments

LED lighting and CEA developments

To reduce energy costs and improve yields, the traditional greenhouse vegetable producers are testing LEDs, especially in the Netherlands[28] (growing chambers and production greenhouse). LEDs also allow lamps to be closer to vegetables and therefore to have a better impact on vegetables' growth. Some are also moving towards the Controlled Environment Agriculture concept ("CEA") in which all growing parameters are controlled and production is made in warehouses without sunlight. As a matter of fact, lighting industrials are developing LED lighting, (grow chambers, green houses) which are now used in production. Philips Lighting has partnered with Green Sense Farm to create an indoor 30,000sqm farm to grow lettuce in Portage (Indiana, USA). GE and Miyagi Fukko Park in Japan are exploring CEA. LED energy consumption is said to be reduced down to 15% of traditional lighting energy consumption[29] and LED use

optimizes lighting design schemes. These techniques will benefit to vertical farming, although talking about CEA, production seems for now mainly related to salads.

Minimal energy requirements and product diversity approach

On the other side of the spectrum, some hydroponics or aquaponics farmers take a very different view and tend to implement "bio" approach on the ground. In this category, greenhouses tend to be smaller. Each time, they tend to differentiate themselves from local competition:

- "Les sourciers" (hydroponics) in France[30] are still testing numerous products, including exotic ones that could not be produced by "regular" local growers. Heating is only used to keep the greenhouse "out of freeze" during the winter season.
- Bio aqua farm (aquaponics) in the UK[31], do not heat nor use artificial lightings. They grow rainbow trouts and vegetables. They transform fishes into smoked filet, to avoid local competition.
- In a different approach, the Home Grown Hydro Farm seems to demonstrate that a 3,300 sq feet hydroponic greenhouse can supply for a family leaving[32] through specific assortment and plantation density.

These examples also highlight the importance of testing and fine tuning which the model overtime.

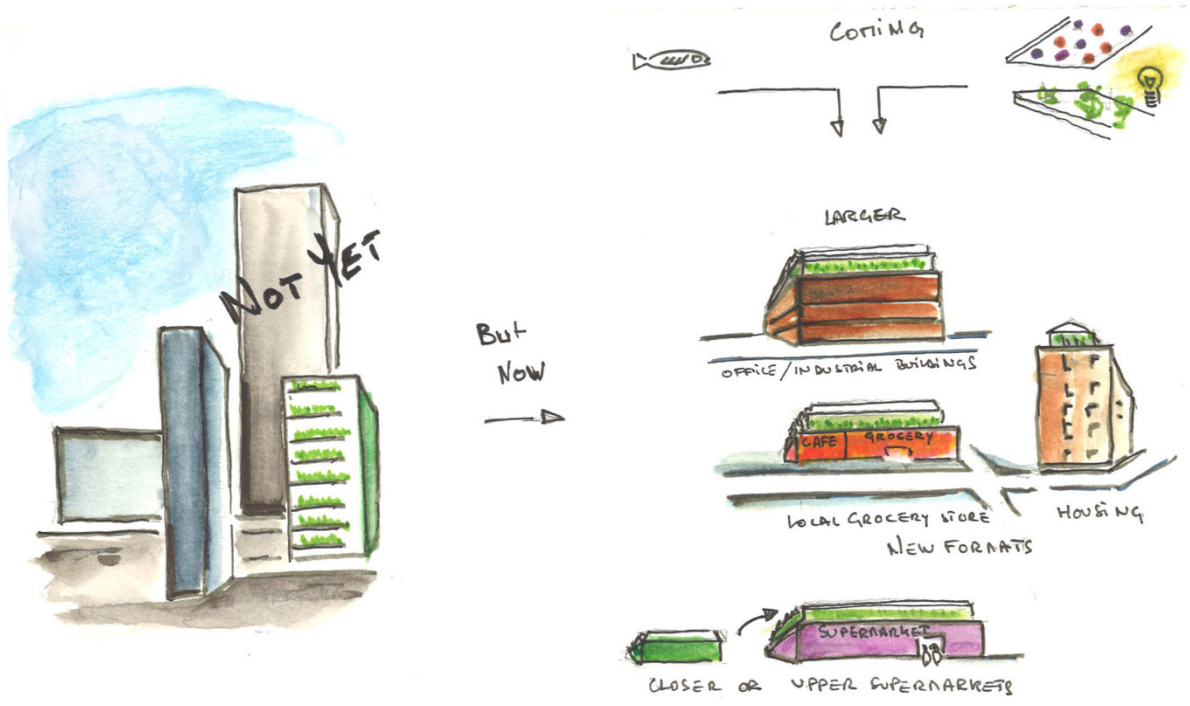
Conclusion

The last 2 years have seen strong developments in both the concept of providing ultra-fresh products to customers with limited "food miles" either directly or through distributors, and of rooftop hydroponic greenhouses. Techniques and expertise are improving and when there is no space close to consumers, growing food on rooftops is a solution despite being significantly more expensive than on the ground greenhouses. Alternatively, some begin to use former industrial buildings and where the rental cost of sqm is more affordable.

Nevertheless, one point is still poising: all these new projects are developed by newcomers and not by "regular on the ground – out of the city" greenhouse vegetable producers while they enjoy years of growing expertise and are testing / improving growing recipes (LED lighting etc...). On this segment people go larger and larger outside the city. Why? Is it because they are too heavily invested into their business model to consider getting into cities or because they do not believe in the UA business model? Some are rumored to come closer and get used to this new format but have not yet bridged the gap.

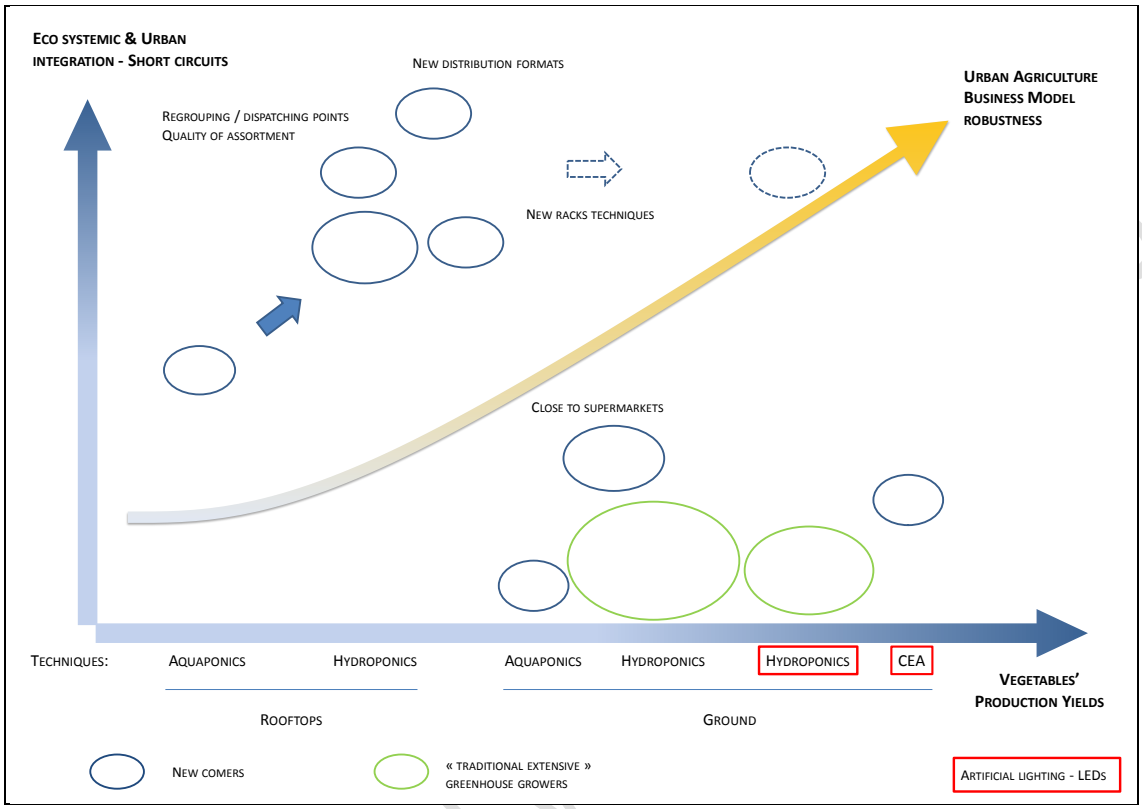
Undoubtedly, as soon as aquaponics fans will come closer to hydroponic experts, and rooftop start-ups will come along regular greenhouse vegetable producers on techniques, the business model will become more robust. In the meantime, industrial players such as Philips Lighting, GE Lighting[33], Illumitex or Toshiba expand into LED lighting agriculture. Then, in all likelihood, a key factor of success will be to find the right farmer to operate the farm. For now, operators are still limited to few passionate people, but professional training is under way.

From utopia to a business model

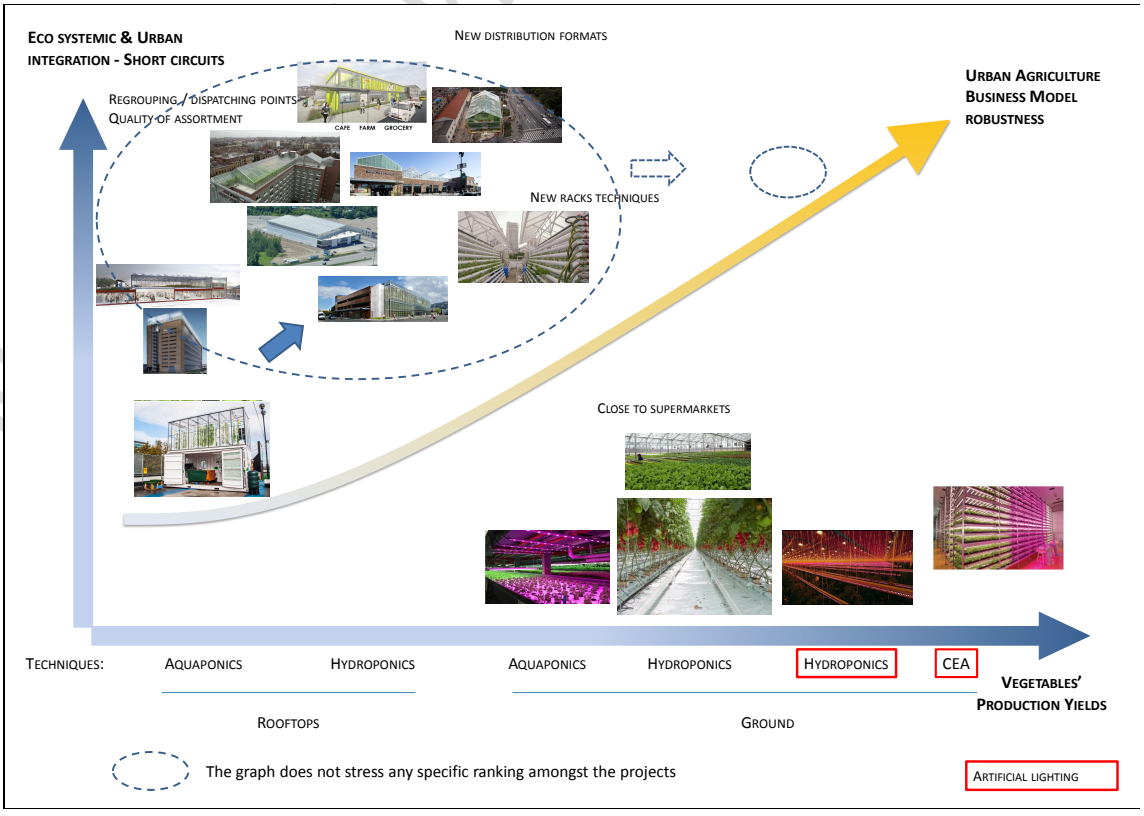


Annex:

The following graph represents the various formats evolution as a function of veggies production yields. It compares various techniques both in terms of vegetables production yields and urban integration or ability to benefit from food short distribution circuits.



The tentative mapping of the projects being reviewed under the same criteria is the following:



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About New'rban view and Vincent Fesquet:
New'rban view was set up by Vincent Fesquet in 2014 to reflect upon the impact of circular economy and functional economy, and of urban agriculture on architecture and urban planning. Vincent spent 17 years in consulting and private equity prior to becoming architect.

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Notes and references

[1] *Les fermes verticales, utopie ou réalité ? Tentative de typologie*, Vincent Fesquet, ENSA Paris La Villette, 2013, 143p. Research project led to graduate as an architect. An executive summary can be found at http://www.newrbanview.com/medias/20131023_vincent_fesquet_vertical_farming.pdf
[2] In France, as these techniques are soilless, they cannot get the "bio" label
[3] IndoorCropProduction2015WebFinal.pdf available at indoor.ag
[4] On this topic, see Sustainable rooftop agriculture, a strategic guide for city implementation, Quesnel, Foss, Danielsson, 2011
[5] See for instance Lufa Farms product offer on this topic. http://lufa.com/fr/
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[8] For design see future.arte.tv/fr/les-villes-du-futur – les fermes verticales http://tinyurl.com/lsxyerb
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[11] IndoorCropProduction2015WebFinal.pdf p3 and p36, available at indoor.ag
[12] FUL stands for Ferme Urbaine Lyonnaise in France
[13] Alterrus Systems Inc and its subsidiary Local Garden Vancouver Inc went unfortunately bankrupt in jan 2014 due to growing issues. See http://www.vancourier.com/news/alterrus-bankruptcy-soils-garden-vision-1.803650
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[24] www.urbanorganics.org
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[28] For further information see Jami Farm or Deliscious Farm in the Netherlands
[29] http://www.lighting.philips.com/b-dam/b2b-li/en_AA/products/Horticulture/about-the-market/201409-forbes-Will-There-Be-LEDs-In-Your-Lettuce.pdf
[30] www.lessourciers.com
[31] www.bioaquafarm.co.uk
[32] www.hortidaily.com/article/15296/How-to-Make-a-living-from-a-3300-sf-green. Consultation Jan 2015.
[33] One of the biggest indoor farm was opened mid 2014 in Miyagi prefecture in Japan, filled with 17,500 LEDS http://www.gereports.com/post/91250246340/lettuce-see-the-future-japanese-farmer-builds