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Architecture for urban agriculture
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Spaces and architectures for commercial indoor "zero-acreage farms"

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Turin, April 29, 2019

Summary

From the early 2000s, the focus on global issues, such as global growth, climate change, and food security, have shaken the various scientific disciplines. Among the most pressing problems is the need to provide for agricultural production systems that can respond to the urban population growth. Architecture has also tried to make its own contribution to the global debate with the creation of the concept of a new type of urban farms: The Z-farm. A Zero Acreage farm make it possible to cultivate inside or atop the buildings, in a different way from the on-soil technique. These utopian projects had to face technical, economic and environmental feasibility challenges. However, architects and designers have been experimenting new solutions for years to transform it into a viable production.

This integration of agriculture in architecture turns out to be entirely new, and very few researches have been conducted on the architectural features of commercial indoor farms (Caputo, 2012). This is because, before technological innovation such as LED and no-soil growing techniques, scholars had investigated the link between architecture and agriculture as a historical relationship between production and place of consumption, farmland and built environment, or agricultural activities and structures supporting them, mostly with a planning and architectural landscape approach.

In contrast with these, this thesis attempts to analysing, by first, the evolution of the agricultural spaces that have become urban, built and indoor, to then define its new forms through a survey of case studies, and finally to figure out a "toolkit" built by using best practices derived from the cases that have been investigated in the research.

The structure of the thesis is composed of three parts. The first part gives an overview on the evolution of urban agriculture spaces, how these practices have been linked to different needs over the centuries, and which roles they had in the urban environment (eg. "Victory Gardens"). This part defines also the research framework and provides the base and the assumption for developing the topic of the research. The integration "city-agriculture" has been investigated starting from the evocation of some topical projects more relate to urban design and planning, such as "Broadacre City" (1934–35) by F.L.Wright and "New Regional Pattern" (1945–49) by L.Hilberseimer. Then, the studies conducted on the continuous productive urban landscape (2012) by A.Viljoen et al. and the first example and studies on the buildings integrated agriculture investigated by M. Gorgolewski, J. Komisar, J. Nasr in the publication *"Carrot City"* (2011) have consolidated this

research background, approaching to the pivotal point: the architecture for urban agriculture.
Hence, the second section contains the definition of the research topic: the indoor commercial Z-farms and its in-depth analysis (typologies, characteristics, and elements of weakness) through the case studies. The method used is the case studies analysis. Since the lack of official sources and solid scientific literature, this method has been chosen as a tool to analyze the architecture and the relationships that Z-farms establish with the city. This part answers the research questions on the identification of the spaces for urban Z-farming and it defines the issues encountered by this new production. the methodology followed this path: the first step has been the definition of what is meant by case study, then the subsequent identification of cases and, finally, the analysis of the components of the object from the architectural-formal and relational-urban point of view. The book "Case study research and application"(2017) by Robert K. Yin has been used as guidelines for the analysis. I collected data from field surveys where it was possible. I have also gathered information from protagonists of the sector, by conducting semi-structured interviews with stakeholders, such as urban farmers, consultants, agronomist, professors, architects, developers, experts in the cities of Montréal, Toronto, New York, Boston, Chicago, Detroit.
The previous analysis has been preparatory and useful in understanding the strengths and weaknesses of the urban indoor Z-farms. This has allowed identifying the elements considered more virtuous and, therefore, more reproducible to create a "practical design toolkit" that could be helpful for architects, urban planners, and municipalities, that represent the third and conclusive part of the research.

Acknowledgment

I would like to acknowledge my tutors Matteo Robiglio and Roberta Ingaramo for guiding and supporting me during my research paths, advising me which setting to give to the thesis and which objectives to achieve. Hence, thank you for believing in my research. A special thanks to F*UL*L for supporting part of my on-field survey in North America.

I would like also to thank all those people – professors, architects, farmers, people involved in urban agriculture- I met on my research path during meeting and interviews, that have contributed to enrich my knowledge.

Ai miei Nonni Rinaldo e Ludovica
e Prozii Pietro e Aurelia

Per avermi trasmesso l'amore per la natura, per il cibo e la conoscenza della "vita agreste", sicuramente influente nel mio percorso di ricerca.

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Introduction

Research topic and objectives

In the last decade, the advent of new technologies (such as LEDs and hydroponic systems), as well as new global challenges[1] have encouraged experimenting what was once utopia: cultivating in and on buildings inside the city. The phenomenon of urban agriculture integrated with buildings has also attracted the attention of many investors, who wanted to transform this activity into a commercial and profit-making business. As a result, this once rural activity has led to new forms of hybrid architecture, born to adapt and accommodate the new built substrate.

The need to study this phenomenon, which generates architectural forms and effects on the city both at a spatial and an economic-social level, arises from the observation of a gap in theoretical research, probably also caused by the contemporary nature of the topic. Since it is still a relatively new study field, just a few types of research have focused on the architectural features of commercial indoor farms (Caputo, 2012), known also as commercial indoor Zero-Acreage Farms (Z-farms)[2]. This term has been used to describe all forms of urban agriculture defined by the non-use of traditional on ground technique[3] both in open vacant spaces a/o connected to buildings (either in or on). For this reason, the aim of this research is to bridge this absence by analyzing, critically, this new phenomenon (the commercial indoor Z-farming) from birth to evolution and envisioning future scenarios from an architectural point of view.

Hence, this thesis endeavors to address the topics posed above and provide answers to the following questions:

- How did the idea of urban agriculture integrated with buildings come about? How did it develop and why?

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[1] Among the global challenges, there is the need to provide sufficient food supply systems for urban growth forecasts, to develop new types of agriculture to respond to climate change, natural resources scarcity, in order to increase food security (Kulak, Graves, & Chatterton, 2013).

[2] This term has been created by Thomaier et al. (2014)

[3] The non- ground-based technologies are hydroponic, dryponic, aeroponic and aquaponic. These technologies do not use traditional soil but an inert material, or water or even air as a growth substrate.

- Which typology of spaces do the Z- farms occupy within the city and which architecture features do they have/ develop?
- What are the problems encountered in the process and may arise afterward?
- Best practice guideline and a toolkit for future urban farming design

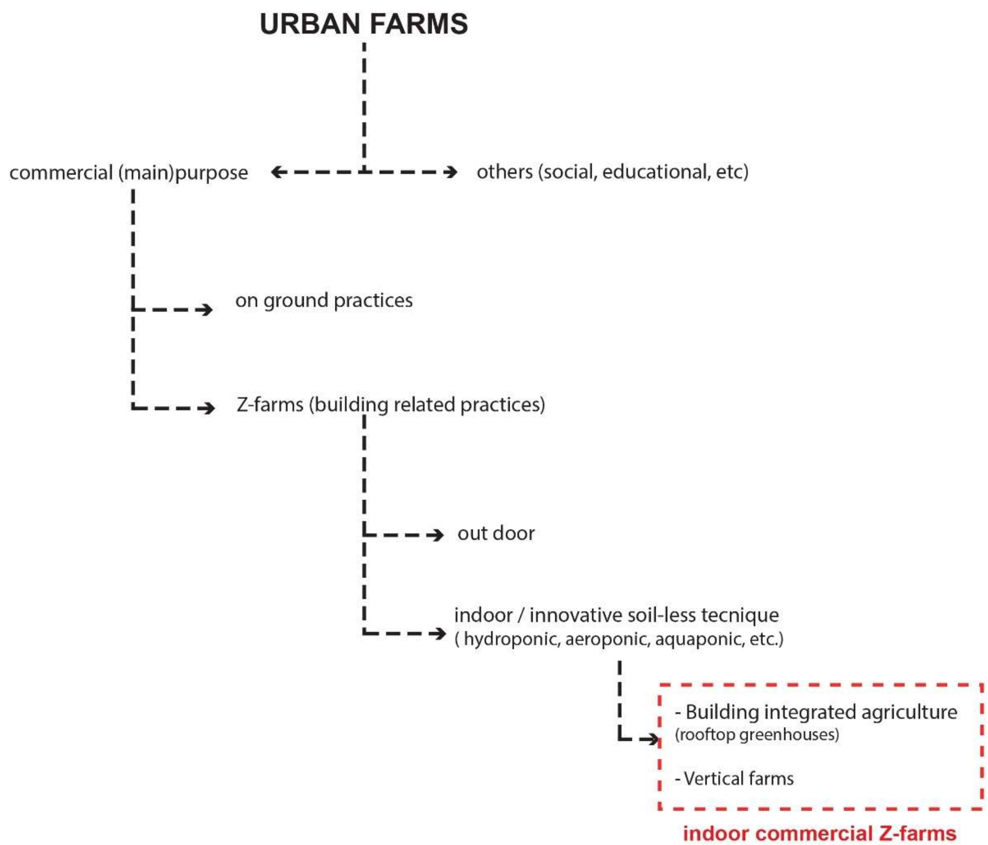

Table 1 Taxonomy of the research objects

Academic disciplinary field

This research highlights how this area of study has barely been studied as an architectural discipline. However, over the last two decade[4], growing interest in the design and the spatial effects of urban farming have decisively gained momentum in the Global North(André Viljoen & Bohn, 2014, pag. 8). As mentioned, the gap this research aims to fill that is due to the contemporaneity of the phenomenon. In the early 2000s, this new idea of urban farms has been expressed only through graphic representations of projects that have never been realized, due to technical - but above all- economic viability. Only in recent years, thanks to technological advances and substantial funding[5], some of these experimental projects have been executed, being able to materialize this new so-called "hybrid architectures.
Although it had already been researched by other disciplinary sectors (mostly related to environmental and agricultural sciences but also in planning and landscape design fields), there were very few or no survey on individual buildings (Marston, 2019). Scholars who previously had investigated agricultural production in the city mostly focused on green practices with social and educational purposes. These examples were usually located in urban green residual fringes - mostly with no use or not committed for agricultural use - or in the suburbs. Nowadays, this production has moved inside the cities, in and above buildings, and has become profitable and year-long, thanks to controlled indoor environments.

Therefore, the architectural characteristics can be considered fundamental objects to investigate and understand how the new activities merge with the urban fabric, from a spatial to a relational approach, in order to evaluate its iterations.
The architectural factor is hence key to comprehending this "new-born industry- Moreover, Architecture comprises competences from other sectors, such as agriculture or building technology, thermal science, to provide adequate design responses to agricultural activity. A high level of interdisciplinarity in which architects and designer can and must play an active role when it comes to management and design. However, as said, there are no texts that critically analyze and detail the architecture of the Z-farms, what they produce and how they interact with the city and agricultural production. The scope of this research is to provide a design toolkit to overcome the current disciplinary "black hole" that hold back these new typologies.

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[4] In the early 2000, some scholars, as Viljoen, Bohn et all., started to work on the idea of interrelation between built environment and agriculture, creating the concept of "Continuous Productive Urban Landscapes (CPUL)"

[5] Investments in indoor agriculture increased 653 percent between 2016 and 2017. This data can be found here: https://i3connect.com/tag/vertical-farming. They collected data related to the investment of 40 different companies into indoor urban farms' business from 2013 till now (2018)

Research structure and method

This thesis is developed in three macro parts. The first part (chapters 1 and 2) defines the research framework and the main focus of the thesis. This section is characterized by a study of sources and literature composed of books, scientific articles, and historical photographic records.
The first chapter provides a historical overview of urban agricultural production as well as an overview of the examples of holistic and spatially integrated city food production. The excursus focuses on how urban agriculture is a practice linked also to periods of crisis and how today, in the area analyzed, it has mostly become an activity with social/educational connotation, except for some urban and peri-urban commercial realities. The chapter concludes with how the urban agriculture sector is moving towards commercial practices that, thanks to innovative technologies, create the new idea of indoor Z-farming.
The second chapter traces the evolution of the idea of urban agricultural production supported by technology and by the desire to transform this activity into a "light manufacture" with production and commercial purposes. In this chapter, the origin of Z-farming is illustrated, from the achievements in the 60s up to the most utopian projects, concluding in today's reality.

The second section (chapters 3, 4, 5) is the definition of the targeted urban farm typologies (indoor commercial Z-farms) and in-depth analysis (types, characteristics, weakness) through case studies. This method was chosen as a tool to analyze the architecture and the relationships with the city, especially in the absence of other sources. The methodology is based on the definition of what was the design scope in each case study and analysis from the architectural-formal, relational-urban point of view. The book "Case study research and application. Design and methods"(2017) by Robert K. Yin has been used as guidelines for this analysis. In order to gather first hand data, semi-structure Interviews have been carried out to professionals of the sector such as urban farmers, consultants, agronomist, professors, architects, developers, experts in the cities of Montréal, Toronto, New York, Boston, Chicago, Detroit.
The third chapter focuses on the collection of case studies. This part defines what a case study is and selects a geographical area (North America and Europe) to circumscribe the search field. Subsequently, a survey model is established, based on a grid that defines the typologies of farms. Then, for each case, a data sheet is created, including data such as (year of construction, size of the farm, production, jobs), photographs, information on the location, the business models, urban network.
Chapter four collects the analyzed data and define the "anatomy" of the Z-farms components. Which factors that affect the location, type of buildings and

architectural elements, in addition to models of interaction with the city through the urban market/economy are investigated in this chapter.
The fifth chapter represents a milestone of this research, as it turns out to be the most critical part. This section covers the failures of some case studies found during the research period. Originally, this thesis was born with an analytical spirit. However, after experiencing first-hand the issues present in Z-farms projects, it was indispensable to introduce this part with a new approach, by turning the problem into an opportunity to improve future projects and expand the thesis scope. This section critically investigates the problems that the z-farms have encountered in their process of adaptation to the urban context. Only after understanding the failures, it was possible to understand the limits of these practices and, subsequently, define guidelines for future developments.

The third part (chapter 6) offers a “practical toolkit” for Z-farms design and ideas to be considered, extracted from the previous analysis.
The last chapter (sixth) gathers all the knowledge drawn from all the research in order to propose tools for the design of Z-farms Only from the analysis of the case studies (pros and cons) was it possible to extract the conclusions necessary to generate said design toolkit in a critical and proactive way,

Chapter 1

Overview of the evolution of urban spaces for agriculture

1.1. Urban agriculture and the industrialization: a brief introduction on how farming become just a rural activity

From the early records of urban life, the city and agricultural production[6](Vejre et al., 2016) have influenced each other by indissoluble bonds of subsistence with different intensities (Benis, Reinhart, & Ferrão, 2017a). Over the centuries, different variables – demographic, economic and spatial – have determined its growth or /and decline. This relation has been a determining factor in the development of cities that, first of all, had to ensure – almost – food self-sufficiency. The necessity of food supply meant that the proximity of the production areas was a decisive factor in the definition of the agricultural spaces close to the urbanized environment (depending on the type of production).

In fact, between the eighteenth and nineteenth centuries, the agricultural production spaces were rationalized according to the costs of the transport and the perishability of the goods, thus creating a relationship between urbanization and the countryside that could be defined as a city, as a complementary unit incorporated in the urban economy. The "urban" agriculture spatiality, studied by the German economist Johann Heinrich von Thünen (in his book *The Isolated State*, 1826), faded over time. Above all due to the industrial revolution and the invention of the railway and the steam engine, the international food system bloomed, making the market more globalized. Food supply chain became more independent of the space of "local production" and urban farms lost their advantages in producing close to the urban market. Economic and social development became more and more connected to the process of industrialization, relegating agriculture to the countryside and entrusting to it the task of providing food at low cost, which was only possible through the industrialization of the production process (Henke, 2015, pag. 156). From this point on, agriculture begins to lose its urban character - excluding some rare contexts-, creating an urban-rural dichotomy (Steel, 2008) or remains a marginal activity due to obvious spatial requirements with traditional systems. However, in some cases in the last two decades, farms have innovated their business models, not only based on the production of goods but also services[7] for the territory.

In times of need and crises, agriculture has nonetheless returned to the city occupying areas that were previously destined for other functions. In fact, during periods of war or depression, growing food in cities has always been indispensable to urban citizens (Deelstra & Girardet, 2000, pag. 46). All over Europe, like in other

[6] "The origins of agriculture are obscure, but what can be said with some degree of certainty is that before farming come along, there were no cities"(Steel, 2008, pag. 10). Meantime, Stewart Brand (2010, pag. 36) argued, contrary to Jane Jacobs(1969), that the origin of agriculture has led to the birth of cities and consequently to the creation of the city-agriculture bond.

[7] Educational farms, workshops, agritourism, etc.

parts of the world, city lands were transformed in edible garden, urban crop field for agriculture: *Schrebergaerten* in Germany, *Liberty Gardens (1917-20), then Victory garden* (between 1941-45), (also called *War gardens or food gardens for defense)* in the USA, UK, Canada, Australia, *Orti di Guerra* in Italy, *jardins ouvriers,* then *Jardins familiaux* (after the law of the 26 Juillet 1952) in France, Belgium, etc. Many nations and local governments created campaigns, such as "Dig for Victory" set up during WWII by the British Ministry of Agriculture, which brought much urban area into farming, including both backyard gardens and allotments on public areas (Lawson, 2005; Taylor & Lovell, 2014).

Figure 1 J. Montgomery, (1918), poster of World War I era US, lithograph, color; 56 x 36 cm

Anyhow, after the war periods, agriculture, once again, was confined to the countryside. The economic boom of the last forty years made it affordable for urban citizens to buy their food and have no longer to cultivate it themselves (Deelstra & Girardet, 2000). Agriculture would occasionally return to the city whenever the economy could not feed the hungry mouths of Western cities in critical situations. Therefore, it represented a salvation, a consolation, a possibility of livelihood. Some dramatic events and economic uncertainties, like the energetic crisis in 1969, or the 1973 oil embargo in Québec, caused inflation and unemployment, a sustained economic hardship that induced an attitude shift in considering the resources: it was an era of crisis and opportunity to "think outside the box." (Bhatt & Farah, 2016). It was within this broader context that in many North American cities such as Montréal, New York, Toronto, etc., numerous groups and organizations that advocate of urban agriculture were born for the creation of collective gardens and farming initiative (Bhatt & Farah, 2016) made the current urban agriculture renaissance possible. (Cohen & Reynolds, 2012). As a consequence of globalization and urbanization, a greater quantity of ideas, practices and environmental demands, coming from everywhere, began to circulate worldwide and societies became increasingly sensitive to environmental issues and urban agricultural activities (Brand, 2010, pag. 38). From this point on, agriculture begins to obtain a small part in urban spatiality and, becoming an activity more and more compatible with urban life, but lacking the conventional commercial characteristics typical of industrialized agriculture.

1.2. Urban agriculture as a social, educational and planning tool in western cities

Around the 90s, urban agriculture became like a real urban activity, with aspects, however, less temporary than in previous phases, although "planners by and large established restrictive zoning that inhibited those practices" (Brinkley & Vitiello, 2014; Horst, McClintock, & Hoey, 2017). Precisely in these years, some scholars began to give a definition to this new activity that was gaining momentum in the western developed cities.

What does urban agriculture mean?

Urban agriculture has been considered as "food and fuel grown within the daily rhythm of the city or town, produced directly for the market and frequently processed and marketed by the farmers or their close associates" (Smit & Nasr, 1992). Further on this definition has been retrieved by Luc J.A Mougeot, who considered "urban agriculture as industry located within (intra-urban) or on the fringe (peri-urban) of a town, an urban center, a city or metropolis, which grows or raises, processes and distributes a diversity of food and non-food products, (re)using mainly human and material resources, inputs and services found in and around that urban area, and in turn supplying human and material resources, outputs and services largely to that urban area"(Mougeot, 2000).

However, the prevalence of the "non-productive" characteristics of urban agriculture led to regarding these practices more like virtuous examples of a social nature rather than a real productive activity (and not commercial/viable), even though Mougeot (2000) has considered it as an "industry". A decade later, environmental interests began to enrich urban agriculture with planning meanings that could respond to the demands of sustainability and resilience. In fact, De Zeeuw, Veenhuizen, and Dubbeling (2011) have acknowledged urban agriculture as "a strategy for spatially and temporarily reconnecting food production, waste disposal, and consumption to strengthen future city resilience and self-reliance and to improve city capacity to adapt to climate change". At the same time, critical voices have also been raised, mostly in developing countries: on some occasions, urban agriculture has been perceived by governments mainly as a health and environmental risk, a source of problems.

Urban agriculture as a social and educational tool

Social and educational characteristics are among the first benefits offered by urban agriculture. Usually, these practices have risen in the poorest sectors of urban societies (Bourque, 2000; Hallett, Hoagland, & Toner, 2016, pag. 94) as a response to poverty or employment issues. At the same time, these places dedicated to urban agriculture (as leisure and work) are important as a social inclusion[8] tool, where community trust is built, community-development strategies can be developed (Teig et al., 2009) and other significant social ideals can be provided.

From a spatial point of view, this allotment or community gardens[9] occupy abandoned or leftovers urban spaces, parts of city parks, green public area (as the Battery Urban Farm[10] at Battery Park, in the heart of Manhattan or on the lakefront in Vevey[11], Switzerland), or backyard garden (see the Hellgate Farm[12] in Queens) with minimum plot area that can vary from 50–100 m2 to 200–400 m2 (Rubino, 2007). Usually, these practices are in-between gardening and food farming.

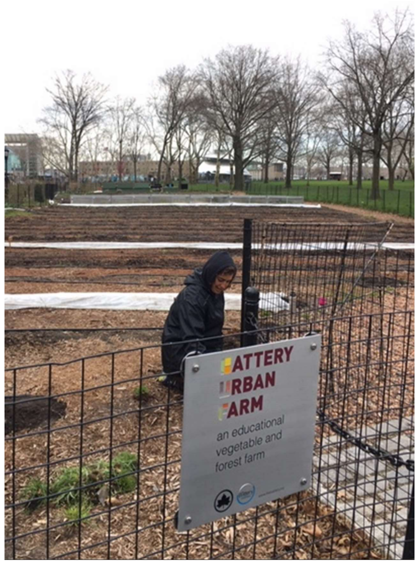

Figure 2 Battery Urban Farm, Manhattan (2018), Maicol Negrello

Figure 3 Urban Edible Gardens, Vevey (2017), Maicol Negrello

[8] It contributes to the integration of older people, child, retired or un-employed adults, socially deprived groups (Rubino, 2007), or with physical and mental problems and to the mitigation of racism (Teig et al., 2009) and to the social involvement in the development of community sense of belonging(Armstrong, 2000; Holland, 2004; Patel, 1991).

[9]Allotments are mostly private legally fixed forms of urban gardens (van den Berg, van Winsum-Westra, de Vries, & van Dillen, 2010), whereas community garden are usually organized as associations and are legally fixed in zoning plans (Opitz, Berges, Piorr, & Krikser, 2016)

[10] Visited on April 2018 during the author's research period in the USA, http://thebattery.org/destinations/urban-farm/

[11] This interesting project

[12] www.hellgatefarm.com/

Urban agriculture as designing and planning tool

The agricultural projects mentioned above were very often the result of bottom-up activities, with or without limited planning and urban designing. Nowadays urban agriculture is becoming more and more involved in the interests of the municipalities in organizing these practices, which can almost be considered an instrument, a function able to improve the city's project. However, *"Nihil sub sole novum[13]" (translation: "There is nothing new under the sun"),* the interest towards the planning aspects of urban agriculture found their roots already at the beginning of the XIX[14]- XX century. In the past urban agricultural spaces have already attracted the attention of architects, urban designers, and planners, although the results of these mixed agrarian cities projects have never been adopted. Among the well-knew architects, it is considered appropriate to mention Frank Lloyd Wright with his project "Broadacre City" (1934–35), Ludwig Hilberseimer with "New Regional Pattern" (1945–49), and Andrea Branzi with "Agronica" (1993–94).

Figure 4 Wright, F.L., (1950), Broadacre City. Source: www.urbannext.net

[13] («nihil sub sole novum - Wiktionary», s.d.)

[14] It worth mention as early-modern examples of agricultural integration in architecture the gardens of the Arts and Crafts houses, where part of the backyard gardens (mostly close to the kitchens) hosted vegetables and orchards.

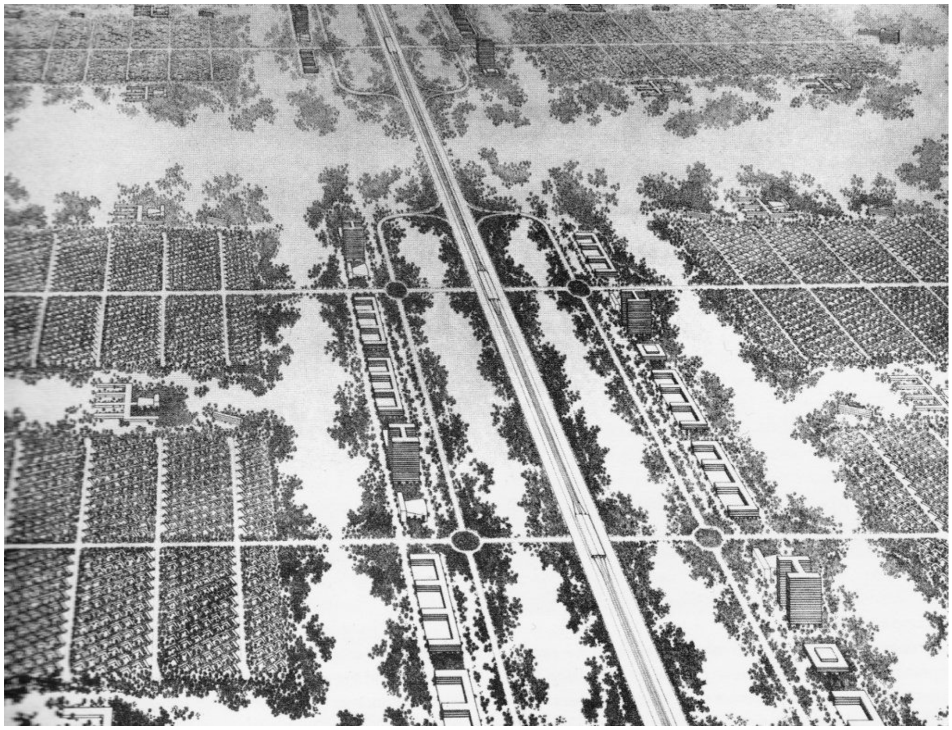

Figure 5 Hilberseimer, L., (1944), Bird's-eye view of commercial area and settlement unit. In The New City, Chicago: Paul Theobald

As also mentioned by Waldheim (2010), the idea behind these proposals was the will of making farming a decisive component of the urban structure, instead of being just an activity, "an adjunct", that accessory adapts to an already consolidated reality.
This view of city integrated with its green productive infrastructure, in addition to the contemporary interest in a more sustainable living[15], it has been partly carried out by scholarly research such as "*Continuous Productive Urban Landscapes"* (CPUL) by Andre Viljoen, Katrin Bohn and Joe Howe, from whom two books[16] have been published. These scholars have approached the topic with a more concrete vision, far from the utopian plans of their predecessors. Their vision deals

[15] This terms can summarize practices associated with local food production, reduced carbon footprint, better public health and the related benefits of pre-industrial farming techniques, including enhanced biodiversity and ecological sustainability, etc. (Waldheim, 2010)

[16] Viljoen, A., Bohn K., Howe, J. (2005). *Continuous productive urban landscapes*, Burlington, MA: Architectural Press

Viljoen, A., Bohn K. (2014). *Second Nature Urban Agriculture: Designing Productive Cities,* Routledge

with the contemporary urban environment, with the needs and problems typical of dense and consolidated cities, especially European ones. Their approach does not hide the current state by proposing a vision of a "new city" with a "*tabula rasa*" as Wright did with his project "Broadacre City", rather than being limited to represent utopian visions result of the designer's superego, it confronts the city reality and tries to solve problems with urban designing tools.
Over that period, Mark Gorgolewski, June Komisar, Joe Nasr (professors at the Faculty of Architectural Science, Ryerson University in Toronto) continue similar/complementary studies, investigating how architecture and urban planning can be tools for introducing urban agriculture in city dwellers lives. Urban agriculture, in fact, can be a truly effective strategy to transform city wastes into resources, convert vacant and under-utilized areas into productive use, and preserve natural resources outside towns while improving the environment for urban living (Smit & Nasr, 1992). From these researches, it was published "*Carrot City: Creating Places for Urban Agriculture*"(2011), a book that contains completed experiments and visions of productive architectures.

This academic reality related to the food system and urban agriculture at the beginning of the millennium was considered as "a stranger to the municipality planning field" (Pothukuchi & Kaufman, 2000), mostly because those topics affect superficially the cities agenda, even though informal movements were emerging. The city planner's role in urban agriculture has changed over time (Horst et al., 2017). Hence, in 2009, food planning and urban agriculture started to become a fundamental point for urban strategies, as happened in Canada with the Toronto Food Policy Council (Blay-Palmer, 2009). It was the first step for a paradigm shift that changed the perception of traditional food systems and what urban agriculture can do. After Toronto, other cities, as Bristol[17] (Morgan, 2013), started to promote the interest in urban agriculture and food planning.

These new visions have encouraged to develop critical thinking about the potential benefits of urban agriculture. An informal action of civic sensitivity, "very expressive and rich in design potential" (Torreggiani, Dall'Ara, & Tassinari, 2012), can acquire the structure of a planning tool, with a possible productive (and viable) future.

[17] Bristol has created the first Food Policy Council in the UK, and it is also the first British city to produce and urban food audit under the title of "Who feed Bristol?".(Carey, 2011)

1.3. Towards productive urban agriculture: the border between commercial production and social activities

As previously mentioned, urban agriculture has traditionally been repeatedly considered more for its social (educational, recreational, integrative, etc.) and environmental results rather than for its economic impact, as a temporary activity, awaiting for more redeeming developments (Bourque, 2000).
Some researchers, as Zasada (2011), have often seen urban agriculture as a hobby instead of a viable commercial activity, whereas peri-urban agriculture (usually placed at the border between suburban and rural) has retained its archetypically professional and entrepreneurial purpose,, even if it coexists with other functions, such as the residential one, craft activities, etc.
It is, therefore, required to explain briefly which urban and peri-urban spaces are intended for commercial agricultural production. And, above all, what are their characteristics, in order to understand the subsequent developments of urban agriculture, which will be discussed in the following chapter.

Three decades ago, Heimlich e Brooks (1989; Heimlich & Brooks, 1989) defined different typologies of urban-peri-urban spaces for agriculture. The first is the farm that passively is absorbed by urban sprawl and still maintains its rural character, an agricultural vocation that relates to its previous target market, despite the gradual incorporation into a metropolitan economy.
The second typology shrinks and adapts to urbanization and to the demands of a new urban market, specializing in typical quality products. Finally, the third type is the most reactive and "resilient" to external context changes. It is particularly attentive to market signals and requests, and to seize public funds, bestowed thanks to government rural development plans (Henke, Pedace, & Vanni, 2013). The last two typologies are more representative of the surrounding urban features, not depending only on their position, but also on their connections and relations with the urban socio-economic and ecological system (Mougeot, 2000). It is means that fresh products are produced (La Rosa, Barbarossa, Privitera, & Martinico, 2014) by urban employees(Dubbeling, Veenhuizen, & Zeeuw, 2010, pag. 9) and sold inside the metropolitan area to inhabitants, that are influenced by city conditions (H. De Zeeuw et al., 2011). Moreover, these farms contribute to generate a diversified and rich urban landscape and provide socio-educational functions(Ba & Moustier, 2010).

However, in the last decade, the situation has changed: agriculture becomes urban not by adaptation (as in the previous cases) but by choice, placing itself in the network of exchanges of the hub-city. This paradigm shift is due to technological innovations that made it possible to transform this usually rural activity into a new urban viable factory, or at least have tasted it. Furthermore, the concept of smart city is spreading, and this can facilitate innovation and the creation of new forms of economic activities and productions, that, even if of small dimensions, they enrich and diversify the proposals for a smarter and more social future city (Manzoni, Cattaneo, Delsante, Bertolino, & Sandolo, 2013).

Chapter 2

The genesis of indoor commercial z-farms

2.1. Urban indoor agriculture and Technologies: a new era for innovative commercial farms.

This paragraph illustrates how new ideas of urban agriculture have been influenced by green post-war modernism ideas, technological progress, and cities demands. The excursus traces the history of this new form of urban production. This innovative approach to urban agriculture distances itself both from the traditional farming methods and major goals.
Hence, in order to conform experimental farms able to adapt to the urban build environment with a commercial purpose, new technologies such as LED and high-tech cultivating soil-less systems (hydroponic, aquaponic, aeroponic, dryponic) have been invented and developed.
Furthermore, this fundamental section introduces the concept of urban agricultural architecture with the definitions of "zero acreage farms" (Z-farms), and other indoor sub-typologies as "building integrated architecture" (BIA) and vertical farm(VF).

In the last decade, the perception of urban agriculture has shifted from a typical recreational activity that could provide food and give social support, to proper agribusiness. Hence, "commercial farms have been emerging in major northern cities" (Benis & Ferrão, 2018). This transition has been motivated by the increasing interest of part of urban inhabitants in having a higher quality and organic food. As a consequence, stakeholders have started to investigate innovative technologies and commercial strategies in order to satisfy those urban dwellers' requests and create a business able to attract and generate capitals.

Nowadays, food represents an incredibly interesting and profitable market sector where urban agriculture can play an active role in the urban economy. Indeed, Pollan(2006, pag. 139) points out – raising a subtle criticism- that "the organic movement, as it was once called, has come a remarkably long way in the last thirty years, to the point where it now looks considerably less like a movement than a big business". This "agri-revolution", which led urban agriculture to be a possible viable business, has been more likely stimulated by today's most pressing global challenges, such as food security, cities' capability to adapting to the climate changes and to the urban growth population, as some scholars[18] have claimed. Revolutionizing the urban farming means also changing its traditional aspects and redefining -by updating- its definition. Hence, Mougeot (2000)considers urban farming as an industry[19]; this vision lays the foundation for thinking about agricultural production[20] from another point of view: as a "light manufacturing activity" able to integrate itself within the urban life, and this is what is actually happening in the reality of many northern cities[21].

If we consider urban agriculture as a light manufacturing activity that means its connotation is not only urban - and no more restricted to the rural world – but also it is profitable, it is linked to urban networks, it generates capital and it has its own spaces and rules. Mougeot (2000, pag. 1)underlines that what distinguishes urban agriculture from rural one is "its integration into the local urban economic and ecological system".

So far, most examples of urban cultivation practices are "the result of an ongoing adaptation of agriculture to the city's influence" (Lohrberg & Simon-Rojo, 2016),

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[18] Among the scholars, one could mention: Benis & Ferrão (2018), Caputo (2012, 259-270), Despommier (2010).

[19] The definition that Mougeot (2000) gives to urban agriculture "it is as industry located within (intra-urban) or on the fringe (peri-urban) of a town, an urban centre, a city or metropolis, which grows or raises, processes and distributes a diversity of food and non-food products, (re)using mainly human and material resources, inputs and services found in and around that urban area, and in turn supplying human and material resources, outputs and services largely to that urban area."

[20] It should be noted that the term agricultural production, includes also all the kind of production and not only food. For instance, in many cases, z-farms produce medicinal plants used for pharmaceutical companies.

[21] The cities to which I refer are located in North America and Northern Europe, among which we can mention New York, Montreal, Toronto, Berlin, London

to the spatial, socio-cultural, economic and -least but not last- to the environmental conditions. Urban farms, indeed, have been accommodated in interstitial spaces, vacant lots, parks, gardens or, in the last few years, on rooftops: none of the above-mentioned built spaces were defined purposely for this practice. In fact, it has usually been spoken of "practices" rather than "profitable activities". Up until now, the main characteristics of this activity is typically related to responding to social-recreational needs and educational purposes. Because of its "social nature", these activities use basic and very low-cost technologies. As a result, as prof. Scazzosi (2016, pag. 214) emphasized, many people usually connect the term "urban agriculture" with just leisure practices and food gardening, without considering its commercial potentialities and economic value, even if the latter is becoming more and more popular.

In the latest years, the attention towards urban agriculture as viable production derives also from the fact that in high-income economies there are interests in producing food in a local and more sustainable way, aiming to have smarter and greener cities (at least it what they think). Therefore farming has become part of this green revolution: food is not considered just food, it is not a question of satisfying basic need[22] but it represents an ideal; according to (Kaufman, 2012), today's urban agriculture should respond to the personal tastes, the food preferences of the millennials urban citizens that are requiring more local, high-quality products. To be local, production must be inside (or around) the city. Nevertheless, farming in the built environment needs to face various challenges: an "urban farm must respond to the presence of the city and adapt to the frame of conditions that the city dictates, but it can also take advantage of this location" (Zasada, 2011). Listing the predominant issues, it is possible to identify the high financial value of urban space, accordingly an economically viable venture would require exceptionally substantial productivity (Graamans, Baeza, van den Dobbelsteen, Tsafaras, & Stanghellini, 2018). Moreover, the low availability of space in densely built-up areas, the necessity of having a higher and year-round production, were among the main reasons - beyond the ones previously mentioned - that led to some experimentation of innovative urban farming solutions. Before the most recent solutions, in the literature, it is possible to identify some experimentations dating back to the 60s.

The idea of having a high-production farm in a limited surface area, integrated within the urban environment, was designed and shown for the first time at the Wien International Garden show (WIG1964) by the Viennese mechanical engineer Othmar Ruthner. He described his patent as "three-dimensional space for the cultivation of plants independently of seasons and climatic conditions" (Ruthner,

[22] Produce traditional food

1966). This can be considered a trailblazing idea of what is now called vertical farming[23], also according to Benis and Ferrão (2018).

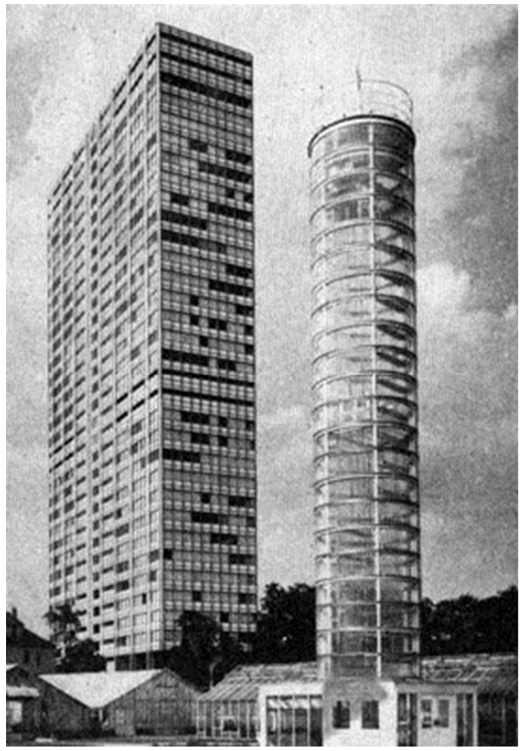

Figure 6 Ruthner, O., (1965), Turmgewächshaus. Source: https://www.swr.de/swr2/wissen/urbane-landwirtschaft/-/id=661224/did=11430370/nid=661224/qgagc6/index.html

Using a single area and replicating it on different layers to create new spaces was an innovative concept in farming, but not new to architecture. Already in the early Twentieth century, (more precisely 1909) a print of a utopian Manhattan skyscraper by A.B. Walker appeared on Life Magazine[24].

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[23] Further definitions will be illustrated in the following paragraph

[24] Published in Life magazine's "Real Estate Number" of March 1909, the full-page cartoon by A.B. Walker shows conventional houses stacked on an open skyscraper frame. Its caption reads, "'Buy a cosy cottage in our steel constructed choice lots, less than a mile above Broadway. Only ten minutes by elevator. All the comforts of the country with none of its disadvantages.' – Celestial Real Estate Company"

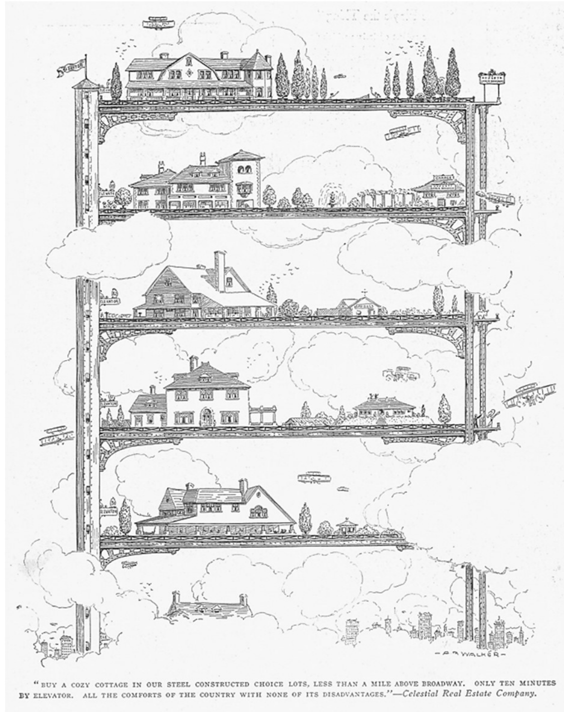

Figure 7 Walker, A.B.,(March 1909), Illustration of skyscraper frame. In Life Magazine, 3-09, New York

In the context of land-scarcity, like in New York City, it can be possible to create innumerable new lands from a single urban area. Hence, Koolhaas (1978, pag. 83) defined skyscraper "as a utopian device for the production of unlimited numbers of virgin sites on a single metropolitan location". In the architectural literature, other similar strategies were often re-proposed during the 80s' as in the theoretical project "High-rise of Homes" by James Wines[25]. Although James Wise's project is not directly related to productive agricultural aspects, it is interesting to note how the idea of verticalization - and therefore of the creation of new soils - is the starting point for the concept of zero acres farms, more precisely vertical and greenhouse rooftop farms.

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[25] James Wines, a founding member of the SITE (Sculpture In The Environment) architectural group, described the Highrise of Homes project as a "vertical community" to "accommodate people's conflicting desires to enjoy the cultural advantages of an urban center, without sacrificing the private home identity and garden space associated with suburbia." Publication excerpt from an essay by Bevin Cline, in McQuaid, M ed. (2002), *Envisioning Architecture: Drawings from The Museum of Modern Art*

Figure 8 Wines, J., (1981), Highrise of Home (Exterior project), Creative Common: https://journals.openedition.org/rga/3672

Most probably all the previously mentioned cases have acted as inspiration for the contemporary project of the urban farm. However, until 2000, there were no records of any existing forms of high-tech urban farming. Probably no one believed that agriculture could become an "urban manufacturing activity" able to fit into cities 'architectures.

In 1999, Professors Dickson Despommier[26] from Columbia University (New York City) started to work with his students on a utopian concept of urban agriculture with no soil, no sunlight and on different layers: a food-productive skyscraper. A year later, in 2000, the Netherlands-based architecture firms MVRDV proposed a utopian tower of 87m with 76foors in which pigs were bred for meat production. Inside this multi-layer building, pigs could rise around their "apartments with terrace", with trees and bushes, and subsequently slaughtered.

This was just a "hypothetical solution" to sensitize people to think about the unsustainability of meat production and the need to find a different solution to the growing consumption. De Vries (MVRDV) underlined the necessity to solve urban food issues and the soil occupation, and maybe combining sustainable agriculture with an high-intensity production could be a hypothetical solution(De Vries, 2010). However, the critic was clear: "either we change our consumption pattern and become instant vegetarians, or we change the production methods and demand

[26] Dickson Despommier is an emeritus professor of microbiology and Public Health at Columbia University

organic farming. But is there space?"[27].

This architectural project influenced the Despommier' s idea of urban agriculture, in fact, he wrote an article[28] about the main reason to invest and adopt this unusual typology of urban productive architecture. In 2010, his first book[29] was published. Also thanks to this publication, the year 2010 was considered, according to the media, the year of vertical farming (Cockrall-King, 2012, pag. 263). In this volume, the author described how, due to the lack of (agricultural) soil in dense cities, it could be possible to farm inside buildings by cultivating on different floors (to increase the crop surface and occupying just the same footprint) and by using crop-specific nutrition and lighting solutions. This farming practice was called vertical farming[30] - although it is not a neologism- whereas the building (skyscraper), that hosts the production, vertical farm. Although this idea was rather provocative, the interest of many disciplines started to experiment with the feasibility of this ambitious project. Architects, designers, engineers began to develop the first visions of building types suitable to accommodate this futuristic production. Other scholars from biology to chemistry, from food engineering to lighting technology in different universities around the globe (Wageningen University in the Netherlands, University of Nottingham (UK), Princeton University (USA), and others) are still analyzing further solutions from their own specific point of view.

The ferment that was on the theme of urban farming has led to experimenting with other solutions, apart from vertical farming.

For instance, during the same years - in the early 2000s - Prof. Arch. Andre Viljoen[31] and his team approached urban agriculture by design and urban planning[32], with an innovative vision of urban agriculture considered as an activity that required urban space, planning tools, as well as policies and rules that can help to be better integrated into the city. Although the team comes from an architecture school, it does not investigate in detail the relationship between the architectural

[27] https://www.mvrdv.nl/projects/181-pig-city.

[28] See. Despommier, D. (2009). The rise of vertical farms. Scientific American, 301(5), 80-87. (Despommier, 2009)

[29] See Despommier, D. (2010). The vertical farm: feeding the world in the 21st century. Macmillan.

[30] The term was already existing since 1915. It was invented by Gilbert Ellis Bailey for his book, but giving it, another meaning compared Despommier's one. In fact, Bailey referred it to the underground structure of plants, interpreted as vertical living systems.

[31] Andre Viljoen is professor in architecture and urban design at the University of Brighton (UK). He is a leading figure in the field of urban food production, its rationale, urban and architectural design implications.

[32] See the book "Continuous Productive Urban Landscapes: designing agriculture for sustainable cities" written by Andre Viljoen, Joe Howe and Katrin Bohn published in 2005

aspects (buildings) and the food production, however, it provides an interesting response on how urban agriculture could merge with at the landscape level.[33]

However, based on the data I found in my research, I agree with Cockrall-King (2012, pag. 263) and Shamshiri et al. (2018) that until 2010, "there was no report of evidence for VF construction[34] before it began emerging in USA, Canada Singapore, Japan, and Korea[35]", neither other kind of indoor urban farms for commercial aim (except for some example of green rooftop or rooftop open-air farms[36]). This is understandable because - until then - no "affordable" technologies could respond to the design aspects proposed by the visions of architects, were yet on the market. Hence, Cockrall-King (2012, pag. 263) emphasized that, during that period, "there were a number of architectural renderings of projects on paper, waiting for a visionary developer or a wealthy billionaire looking for a legacy project", but no one built. Subsequently, in order to make those project real, many funds have been invested in different sectors, foremost in the lighting industry. In fact, thanks to "the advent of spectrum-specific, higher efficiency light-emitting diode (LED) grow lights, together with computer-assisted control systems for monitoring and delivering precise amounts of nutrients, adjusting the pH, temperature, and oxygen content of the nutrient solution, and for assessing the growth and overall health of each crop, controlled environment agriculture has rapidly evolved into a commercially viable approach for the large-scale production of a wide variety of crops in close proximity to, or even within, urban centers"(Despommier, 2013). It is hypothesized (and it is hoped) that the cost of these technologies for indoor farming, can become increasingly cheaper in order to develop new visions of agriculture integrated into buildings.

Nowadays, the recent development of technology - achieved so far - has made it possible to transfer innovations from experimentation to the real field, applying

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[33]They just illustrated an example of integration between architecture with green wall (vertical fields) for landscape and agriculture at the pag.248

[34] it should be note that, nowadays, there are no buildings that can be considered as a vertical farm according to Despommier's definition (skyscrapers), however, - in 2018 - there are architectures (former warehouse, rooftop, underground spaces) that host within them a production that can be defined as vertical farming.

[35] These nations for first developed these technologies for similar "needs". The increasingly high demographic growth of the North American urban areas (eg New York) makes these cities increasingly dependent on imported food. The Z-Farms seemed an attempt to reduce the distances between production and consumer, offering more quality and freshness, offering new opportunity for urban areas. Asian cities, due to the dizzying population growth in the last decades or, in the case of Japan, the scarce availability of land, are beginning to experiment with these strategies to reduce external demands and functionally densify urban areas.

[36] In this research I selected only indoor cases, however in 2010, in the Brooklyn Navy Yard (NYC), it was realised the world's largest urban rooftop open-air farm called Brooklyn Grange. During the same year Lufa Farm (Montréal) began to operate as the world's largest indoor commercial urban farm. Lufa Farm, indeed, can be considered as the first example of commercial Z-Farm (see 3.4 Lufa Farm)

them in solutions for indoor urban agriculture. Many of those solutions integrated agriculture in the building (BIA) in different ways such as rooftop greenhouses, vertical greenhouses on facades, productive containers. In fact, all this typology ("no-space or low-space technologies") are able to fit in the urban architectures and could "offer tremendous opportunities for space-confined growing" (Dubbeling, 2011).

All those typologies aim to "combine food, architecture, production, and design to produce food on a larger scale in and on buildings" (Specht et al., 2014, pag. 34) and fit into urban fabrics without occupying new soil; this idea can be considered the genesis of the concept of "zero acres indoor farms", that it will be illustrated in the following paragraph.

2.2. Definitions: commercial indoor urban zero acreage farm

This section of the thesis is focused on giving an explanation and defining the boundaries of the object of the study. Therefore, it is important to give a precise classification of what a commercial indoor urban z-farm is and circumscribe the topic to distance commercial z-farm from all "non-commercial" or "traditional soil-based" examples.

The term "Urban Agriculture" is abundant in definitions ranging from the literature of urban planning to the social science' one, from agrarian to economy. Scholars have described the activity, its network, the aims, and its urban environment but without considering - in detail - the spaces and the architecture forms it occupies. Traditionally "urban farms" are linked to conventional horticulture, with a ground-based production and low technique. The term "commercial indoor urban zero acres farm" add something more and new to the mainstream idea of urban farms. Most probably, due to the - still relatively - recent developments of new farms and the number limited of cases, only a few scholars have analyzed it from an architectural perspective and given a definition of the spatiality.

What is a "zero-acreage farm"?

In the literature, the term "Zero-acreage Farm" (Z-Farming) was introduced in 2014 -for the first time- to describe "all types of urban agriculture characterized by the non-use of farmland or open space, thereby differentiating building-related forms of urban agriculture from those in parks, gardens, urban wastelands, and so on" (Specht et al., 2014, pag. 35). This type of agricultural production does not occupy new soil, but it is overlapped on urban footprints (buildings). This term is a great starting point from circumscribing the object of this research: it includes different forms of farming related to architecture (farming in or on buildings) and, at the same time, it "avoids conflicts with existing definitions".

Z-farming must be considered as a specific sub-category of general urban agriculture which - in turn - contains several farm subtypes. As Specht et al. (2014, pag. 35) underlined, ZF is "a complementary rather than a competing practice". In fact, those farm typologies can be hosted in places where - anyway - traditional farming could not be placed due to the lack of urban green space for soil-based farming practices. The main differences and innovations of Z-farms is the use of technologies and the resources "to combine the requirements of architecture with those of food production" (Specht et al., 2014); indeed, most of the existing examples (where farming is inside built spaces[37]) take advantages of the use of hydroponic, aeroponic[38] and the LED technologies, that can be controlled throughout a growing season to emit a programmed spectrum of light that is optimal for photosynthesis for different types of crops(Benke & Tomkins, 2017, pag. 17); without them, it would not be possible to grow in spaces with no natural light. Furthermore, in some cases, there is a strong relationship, synergies, between the hosting building and the productive additional part expressed through architecture devices (vertical internal connections: stairs, elevators) and reuse of resources[39] (wastewater, waste heat). For instance, according to Delor (2011), the synergy between a building and a rooftop greenhouse farm could save up to 41% of energy for heating.

The use of the technologies previously mentioned is an aspect that characterized Z-farms - unlike soil-based farming - for this reason, "Z-Farming is often investigated separately from other urban agriculture practices" (Specht et al., 2014)

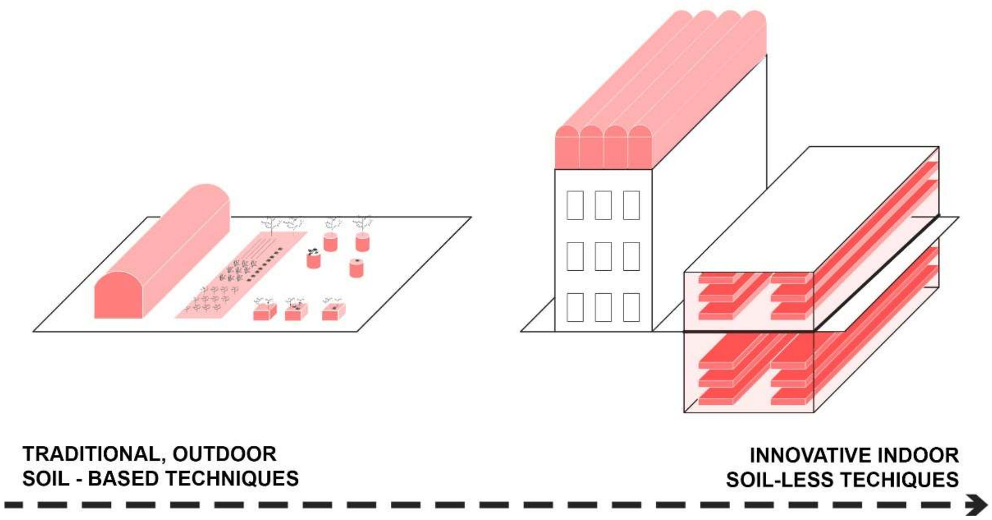

Figure 9 Urban agriculture techniques, illustration by Maicol Negrello

[37] The term "built spaces" includes building such as warehouses, former factories, or underground spaces like former parkings or abandoned metro tubes, or even containers converted in productive spaces.

[38] Those technology required less water than traditional growing system on soil. Hence, hydroponic uses 13 times less water in one crop cycle then traditional farming (Lages Barbosa et al., 2015), whereas aeroponic used 65% less water than hydroponics («Hydroponics», 2018).

[39] See Lufa Farm

Z-Farms: indoor and commercial typologies

Among the subtypes gathered under the term *z-farm*, I selected the indoor typologies. All the indoor z-farms presented are designed for commercial production, this means that the main[40] objective of this production is for the market and for generating income. in fact, only with a controlled indoor environment[41] can be possible to ensure a year-round production, also able to pay back -presumably- the great initial investment. In the literature analyzed I underlined and select some definitions – that in somehow can be considered misleading and ambiguous- of sub-typologies of Z-farms. The following definitions should clarify the main characteristics of those urban z-farms.

- *Building integrated agriculture* (BIA) is a new approach to production based on the idea of locating high-performance hydroponic greenhouse systems on and in mixed-use buildings, also to exploit the synergies between the building environment and agriculture-like energy and nutrient flows (Tom Caplow, 2009, pag. 48).

- *Vertical Farming* (VF) is defined as the concept of cultivating plants or animal life within skyscrapers or on vertically inclined surfaces (Despommier, 2010). However, this definition contains an inconsistency: the vertical farm is the structure, the architecture, the typology, that host the agricultural production; the iconography related to this is the skyscraper in which each floor is dedicated to a product. Whereas, vertical farming is more related to the production approach that can be host in any kind of infrastructure (warehouses, former factories, underground spaces, greenhouse rooftops, reused shipping containers).

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[40] In some cases, urban indoor farms have also additional secondary function, such as educational, events, green building certification, etc (Nasr, Komisar, & De Zeeuw, 2017, pag. 16) .

[41] Controlled indoor Environment Agriculture (CEA) is defined as a technology-based approach toward food production. The aim of CEA is to provide protection and maintain optimal growing conditions throughout the development of the crop. Production takes place within an enclosed growing structure such as a greenhouse or building. Plants are often grown using hydroponic methods in order to supply the proper amounts of water and nutrients to the root zone. CEA optimizes the use of resources such as water, energy, space, capital and labour («Controlled-environment agriculture», 2018).

2.3. From an architectural utopia to concrete realities

In this paragraph, the role played by the architecture at the beginning of the z-farming phenomenon will be examined. In the first stage of this "era", Architecture used its "power" to create visions, to impress, to push investors in getting involved in this "revolution", and also play a role of "placemaker". Subsequently, architects had to be more pragmatic and support the development of this activity by providing and adapting suitable spaces in the urban environment, in addition to managing with building and zoning code. At the end of the first phase, it is possible to notice how indoor urban agriculture has changed its spaces, in every step of its development and, in some cases, creating hybrid architectures.

During the early season of Z-farms the more creative area of the research, such as architecture and design, approached this new idea with strong utopian results. The first drawings that came up were attractive but, at the same time, unrealistic: no feasibility studies were conducted on real profitability.
The excitement for new urban farms started to spread across the world. Architects, designers, and engineers have developed interesting projects, analyzing technical aspects and experimenting with new technologies to create a new typology of urban building. Everyone has its own role in the process: urban planners have to face with city roles and zoning code, architects have to integrate this new typology of building in the city, by responding to requirements very different from the ones for residential use. Those professionals must collaborate in synergy with other technicians from all the other sectors involved[42] in the design of the z-farm. Z-farming and especially vertical Farming "is steadily becoming a subject discussed broadly in industrial and scientific communities"(Banerjee & Adenaeuer, 2014).

From the first Despommier's idea of indoor skyscraper farming, many studies took inspiration for their own urban farms: from France to China, from the USA to Japan. In less than ten years, from 2002 to 2011, several projects were designed but none was ever realized (except for some small experimentation). It is interesting how architects have expressed their vision by proposing models that are often independent and detached from any other previous building typology, present in urban contexts. Some indoor farm projects evoke futuristic lines, visions of "extraordinary" architectures, which seem to be inspired by Soleri or Sait'Elia' s projects, or by the science fiction landscapes sketched by cartoonists, such as François Shuiten. The collected results show that most of the design experiments

[42] Other technicians as environmental engineers, biologists and plant scientists, environmental technical physicists, structural engineers, investors.

are located in North America - where the was originated- some cases in Europe and Asia.

- Tour Vivante (FR) SOA Architects 2005
- Super Ferme (Paris, FR) SOA Architects 2006
- Vertical Farm (USA) Chris Jacobs+ D.Despommier 2007
- Sky Farm (USA) Gordon Graff 2007
- DRAGONFLY (NYC, USA) Vincent Callebaut Architectes 2009
- Harvest Green Project (Vancouver, CA) Romses Architects 2009
- Clepsydra (IT) Bruno Viganò + Florencia Costa 2011
- Plantscraper Vertical Farm (Linkoping, Sweden) Plantagon 2011

Figure 10 SOA Architects, (2005), La Tour Vivante (rendering), Rennes. Source: https://www.ateliersoa.fr/verticalfarm_fr/pages/images/press_urban_farm.pdf

Figure 11 SOA Architects, (2006), Super Ferm (rendering), Paris. Source: https://www.soa-architectes.fr/fr/agriculture/article/super-ferme

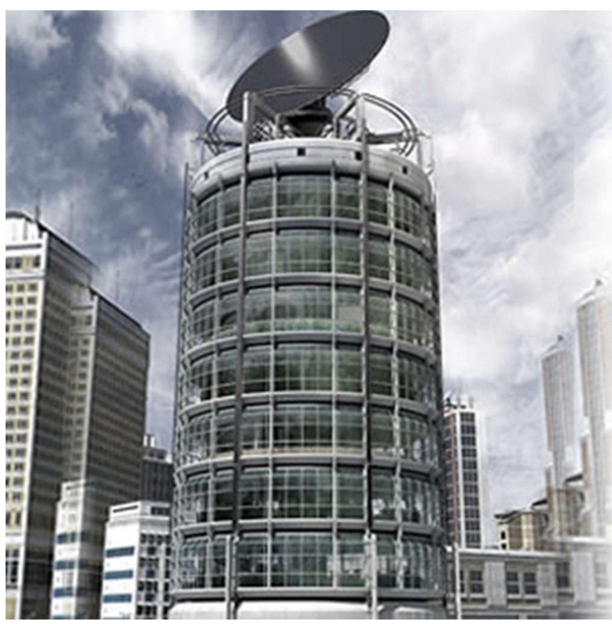

Figure 12 Jacobs, C., Despommier, D.,(2009) Vertical Farm (rendering), U.S.A. Source: https://www.greenandsave.com/green_news/green-building/towers-of-imagination-chris-jacobs-and-vertical-farming-theory

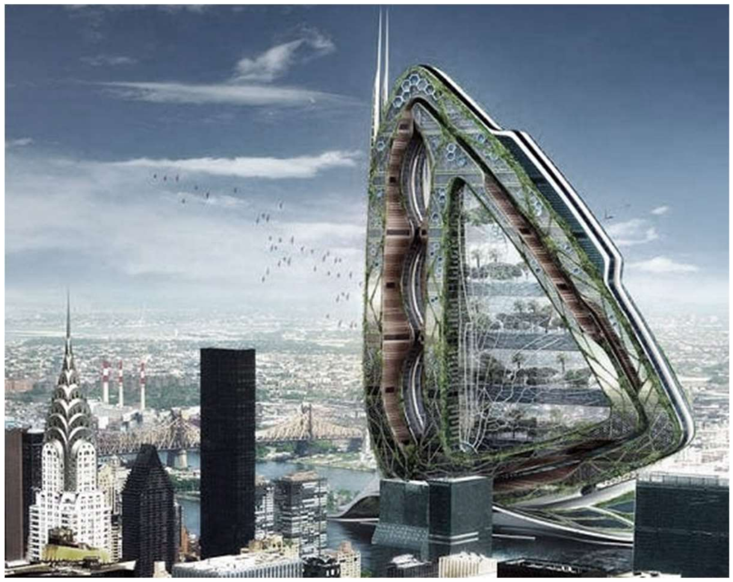

Figure 13 Vincen Callebaut Architects, (2009), Dragonfly (rendering), New York. Sources: https://inhabitat.com/dragonfly-urban-agriculture-concept-for-ny/dragonfly-building/

Figure 14 Romses Architects, (2009), harvest Green Project (rendering), Vancouver. Sources: https://www.designboom.com/architecture/romses-architects-harvest-green-project-vancouver/

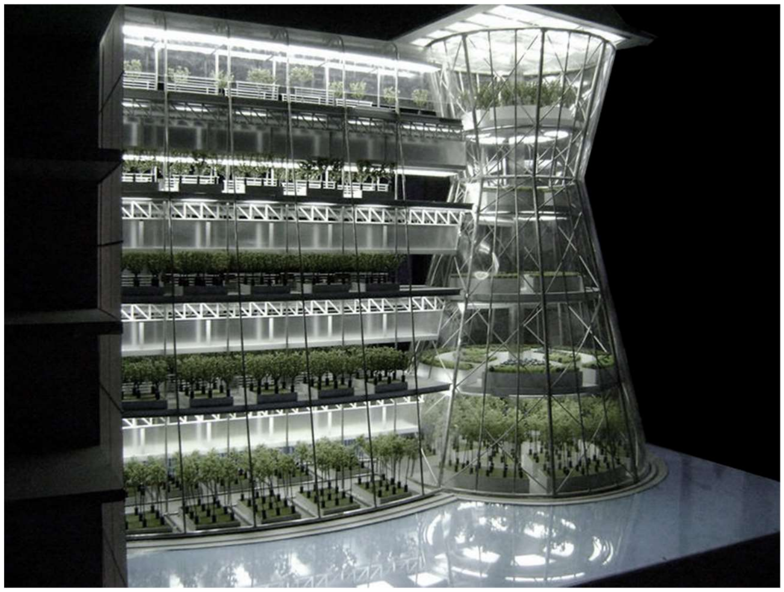

Figure 15 Viganò, B., Costa, F., (2011), Clepsydra (rendering), Italy. Source: http://www.florenciacosta.it/clepsydra-urban-farming-project/vaiefpa6q0pt5w9tx8qorf3344uoky

Figure 16 Plantagon, (2011), World Food Building, Sweden. Sources: http://www.plantagon.com/about/business-concept/the-linkoping-model/

According also with Naglieri (2014, pag. 248), there are two main trends in the approach to the project from a functional-typological point of view: in the first one, the urban farm is considered as a factory, characterized by productive spaces, destined for storage and research (2,3,4,7,8), whereas in the second approach, the productive agricultural sector is integrated in a synergic ecosystem, where different activities and functions[43] merge together (1,5,6). In these so-called vertical agriculture projects, the boundary between city and countryside seems to disappear (Torreggiani et al., 2012).

At the dawning of the new concept of urban agricultural production, it is possible to affirm that architecture has acted as a tool to offer visions in order to find possible solutions to current and future needs. The architect Michael Grove[44], during an interview[45] conducted at Sasaki, affirmed that architecture - in the first phase of z-farms - "can be the attraction, able to inspire and bring people to those innovative projects and to push more developers to invest in those researches"; he added that "architecture is the place making, it has to solve the problem of the city and the society (such as food safety, urban resiliency, climate changes issues, etc.)".

Figure 17 Sasaki Architects, (2017), Sunqiao Farm District, China. Courtesy of Michel Grove

[43] Residential, commercial and green spaces.

[44] Michael Grove is an architect, and the "Chair of Landscape Architecture, Civil Engineering, and Ecology" and he is also principal at Sasaki Associates, an international planning and design firm based in Watertown, Massachusetts. He leads Sasaki's Southeast Asia practice as director of the Shanghai office and provides unique insight into the rapid urbanization of the region.

[45] The interview was conducted by Maicol Negrello directly with Michael Grove at the Sasaki studio (Watertown, Boston) on the 12th April 2018, during a period of research in the USA.

Nevertheless, architecture must adapt to the real-world economy, hence, none of the projects previously mentioned have seen the light of day since the cost of a "utopian skyscraper farm" was not estimated (or it was an economically unsustainable/unprofitable business). Part of them were results of researches (both private and public institutions), architecture contests or professionals' experimentations (such as architects, designers, engineers). As a consequence, "low budget"[46], "minimum effort"[47] and more realistic projects have been developed collaterally to the previously mentioned unattainable proposals (in terms of costs, technology or policies). Low-cost architecture, such unused or abandoned spaces (former factories, warehouse, roofs, basements) acts as "platforms for emancipation"[48] since the cost for rent were cheaper and connection within the urban networks easier. Among the different cases[49] of the worldwide literature, The Plant[50] in Chicago could represent a perfect example of practices of the early phase. The Plant hosts a start-up, called Close Loop Farm, created by Adam Pollack. Adam took advantage of the cheap space, rented by the Bubbly Dynamics[51], and started

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[46] This term is referring to the approach to the architectural choices; the reuse approach, in fact, is based on investing in innovation and know-how, rather than in infrastructure and by using any flexible, wired-up space, compared to the "utopian trend", more focused on the design and the realization of urban skyscraper farms, which costs are extremely higher compare to the reuse approach.

[47] The first experiments of indoor urban agriculture tried to reduce the costs related to the infrastructure – by occupying industrial or under-exploited spaces - and invest most of the capital on the technologies. For a more in-depth study on the concept of reuse with limited costs (adaptive reuse) see the book "RE-USA: 20 American Stories of Adaptive Reuse, a Toolkit for Post-industrial Cities" written by Matteo Robiglio (2017, pag. 194) and "Rust Remix. Architecture: Pittsburgh Versus Detroit" by Roberta Ingaramo (2017)

[48] This expression derives from an extract of the article written with Caterina Montipò, presented at the 49th International Urban Affairs Conference "Shaping Justice and Sustainability Within and Beyond the City's" (held in Toronto, April 2018). In the article "Reuse for production. How new forms of production are reshaping North-American cities", the authors referred to the book "City as Loft. Adaptive Reuse as a Resource for Sustainable Urban Development" written by Martina Baum and Kees Christiaanse (2012).

[49] The Plant is one among different cases, however it is worth mentioning the example of Bowery, an indoor farming start up, started growing a small array of leafy greens out of what was once a shipbuilding yard in Kearny, New Jersey (Anzilotti, 2018). They decided to set in a post-industrial area because they needed a lot of space.

[50] The Plant is an 8,830 sqm former meatpacking facility belonged to Peer Foods built since 1925, located in the neighbourhood of Back of the Yards, South-Chicago. After being abandoned, in 2010 the building was bought for $525,000 by Bubbly Dynamics, a social enterprise that aims to create replicable models for ecologically responsible and sustainable urban industrial developments in derelict industrial areas (https://www.bubblydynamics.com/). Bubbly Dynamics decided to repurpose the four-floors building as a collaborative small business community dedicated to local food production, by maximizing the benefits of the existing infrastructure and food-grade surfaces.

[51] Bubbly Dynimics,LLC, established in 2002, is a social enterprise whose mission is to create replicable models for ecologically responsible and sustainable urban industrial development. The main aim is incubating small businesses in formerly vacant, industrial buildings located in disinvested communities. (https://www.bubblydynamics.com/about/)

to run his business. During an interview with Carolee Kokola[52] and Adam Pollak[53], they illustrated how a dynamic and affordable space can operate as an incubator, a fundamental starting point to test, as in a lab, a new activity such as the indoor farming. Adam underlined the importance to have a flexible space, especially when you "take the first steps"- almost like a pioneer- in business still unexplored. A flexible space allows a business to expand, thanks to (relatively) low-cost intervention, such as partition wall to create the workspace/lab that follows the production growth. In this case, industrial buildings, or warehouse, have a high degree of flexibility and offer a perfect environment to incubate a possible profitable business. Other case studies had similar backgrounds.
However, what happens with the architecture after a business wants to grow up? What kind of space does a z-farm need to be a commercial activity and distance itself from the concept of a start-up? Designers and architects have recently considered the promise of Z-Farming as a driver for developing new types of urban buildings (Specht et al., 2014). Hence, the following chapter will center on the hybrid architectures created to host indoor farming and the different typologies that so far have been observed in the urban environment.

[52] Carolee Kokola is a planner, urban designer and currently director of Enterprise Operations at Bubbly Dynamics, LLC / The Plant. The interview I conducted with her was held at The Plant (Chicago, IL) in March 2018.

[53] Adam Pollak is the founder and head farmer of Closed Loop Farms, the basement microgreens farm in The Plant building in South Chicago, Back of the Yards neighbourhood

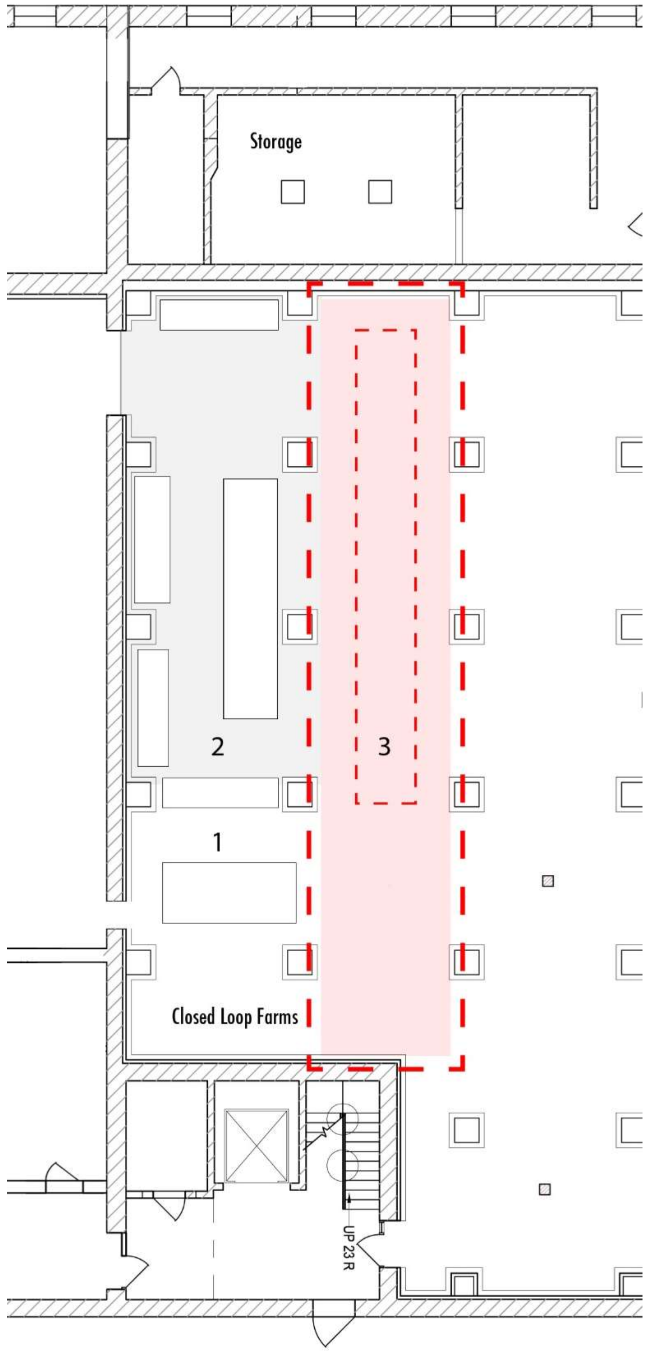

Figure 18 Expansion of Close Loop Farm, drawing by Maicol Negrello.
1. Start-up initial phase
2. First expansion
3. Future expansion

Chapter 3

The case studies of indoor commercial z-farms

3.1. Case studies analysis

What is a case study?

Before starting the research, I had to select some cases study in order to investigate which are the architectural features of those new building typologies, how they interact with buildings and within the city. First of all, it was important to understand what a case study is and how to choose it from different examples worldwide. In paragraph 3.2, it will be explained the reason why the area investigated is the Northern countries (North America and northern Europe). After this primary selection, I focused on the relatively small number of indoor z-farms and I selected the ones whose primary purpose was to dedicate to commercial farming. Since I started the research (in April 2017) I could notice an incremental number of z-farms, however, at the same time, some of them failed. For this reason, I decided to keep among the cases studies also the failed ones because it can be useful to better comprehend the causes of their unsuccess (criticism and unsuccess of indoor commercial z-farms will be explained in the chapter 5.)

The cases were chosen through a series of criteria, among which it is possible to identify:

- urban location is the first requirement to select the case studies. The cases have to be in a built urban environment
- indoor production through soilless technologies. To be selected, all the cases have to use hydroponic, aquaponic, dryponic technology and, if necessary (indoor vertical farming), use of LEDs
- the main purpose is commercial: basic precondition
- architectural integration solutions: all the case studies have to be integrated within building
- the precocity of the project: that means that all the “milestone”- for the “z-farms history”- and cutting-edge projects have been selected

3.2. Research geography

Why just northern countries?

The case studies selected for this research are placed in a geographical area that can be defined as the Global North. I decide to circumscribe this geographical perimeter for the reason that it seems that the genesis of this phenomenon is mostly North American (Thomaier et al., 2014, pag. 45). Moreover, urban horticulture has been gaining popularity particularly in this area over the last years (Benis & Ferrão, 2018). This can be observed by the creation of numerous projects related to urban agricultural production. In many of those projects, as previously mentioned, the main goals had social-educational backgrounds, however, as the result, they aroused the public interest and encourage the policy to work on environmental and food issues with greater commitment. Hence, Specht et al. (2014, pag. 43) stressed that, in the last decades, the Countries of the northern hemisphere are working to improve urban food production, though from a different perspective than in the south. Another important aspect to consider is that, normally, northern countries, that have long winters or climates that can be defined as extreme (even if only for some periods of the year), are more dependent on the import of food (such as vegetables, fruit). For this reason, in some cases, they can also be considered vulnerable from the point of view of food system resilience.

Nevertheless, the phenomenon of commercial z-farming is globally spreading, especially in some Asiatic metropolis like Singapore and in the Unite Arab Emirates due to the extreme environmental conditions (extreme climate and lack of arable lands) and the growing population. Despite these examples, the choice of circumscribing the area of research derives from the interest of investigating Western dynamics in a more detailed manner. In fact, Asian and Arab emirates cities have different dynamics, densities, dimensions and flows compared to Western world, such as North American and European ones. Moreover, as previously mentioned (see paragraph 2.2), this new urban production activity, to be firstly traced in North America, with prof. Despommier.

3.3. Methodological analysis approach

This section shows the process of analyzing the case studies, after the definition of the geographical region (see paragraph 3.2) and the selection of them (see the selection criteria in paragraph 3.1 Case studies analysis).

Each case study has been analyzed starting from the location within the urban network. The site provides information concerning the kind of business of the z-farm. As we will see in chapter 5, localization can be a determining factor for the success or failure of the urban farm. In fact, selecting the best placement is fundamental to set up a viable business.

Scaling down on the architectural dimension, it gives the information on the z-farm typology (among the three that will be illustrated in paragraph 3.3). Moreover, in this section dimension characteristics[54] are provided, such as the growing area (m^2 or sqm), the horizontal connections, the height of the z-farm, the element of vertical interaction/connection with the host building (such as stairs, elevator). Another crucial point is the production capability and the number of jobs that have been created. All those two aspects, in some cases, are depending on the season and market request.
Finally, the distribution strategy. It remarkably contributes, as the location, to the success or the failure of a company. How the food is delivery could seem a relative factor but it represents how the z-farms interact with the urban network. The tools used for retrieving information were primarily the written sources (books, articles, and the websites of the companies), but also the interviews conducted directly with the owners or employees. In many cases, I could not be able to obtain any material because of some apparently "important" privacy reasons. There is great mistrust in this "new" field[55], different companies did not want to give interviews or any kind of documentation. I used also the photography as a tool for analysis, most of the pictures are mine, in the cases where I could not be allowed to take any, I used the ones provided by the net or by the owners. It would have been valuable to have more detailed data on investment costs, incomes, on the path that Z-farms made to create this activity in areas where it was not allowed. In some cases, the data have been recovered, in others not, therefore they have been deduced based on comparisons between other cases. Surely, the use of these data would have given a clearer view of the economic impact (in numerical terms). In fact, very often the real economic impact of these activities is not understood, this precludes some aspects linked to the economic feasibility and

[54] It should be emphasized that in many cases this information (and many others) has not been released to me for reasons of privacy.

[55] Indoor urban farming. Since this business is relatively new, there is still no previsions about the future success or not for that kind of z-farms.

profitability of these companies. Certainly, the failure of some farms has been interpreted as a posteriori fact that demonstrates the scarce profitability, however with the same structures there can be successes and failures that depend also on the typology of adopted business.

3.4. Cases studies' typologies panorama

In this section are shown the main categories of the case studies, which architectural features will subsequently be analyzed in chapter 4.2. The architectural typologies panorama is characterized by three predominant strategies mostly used to integrate a viable agricultural production. Through the observation of these architectures (z-farms), I could identify similar characters between some of the cases and extrapolate them in order to categorize them. Then, I found two[56] architectural approaches and one "architectural device" and I defined them as: "addition", "insertion" and spot".

Addition (A)

This term is used to describe the type of intervention that involves the construction of a structure - the greenhouse - in addition to the existing building. The part designed to host the agricultural production is usually positioned above the roof of the building with which it often shares vertical connections (stairs, elevator/lift), as well as having synergic relationships (heat recovery, exhaust air recovery, water recycling, etc.). Among the most iconic examples, there are the rooftop greenhouses Lufa Farm, in Montréal (CA), Gotham Greens, in New York City and UrbanFarmers in The Hague (NL). Nevertheless, there is one aspect that deserves a particular mention that is the construction of the greenhouse on the façade of the buildings, for instance, the case of Vertical Harvest[57] in Jackson, Wyoming (USA).

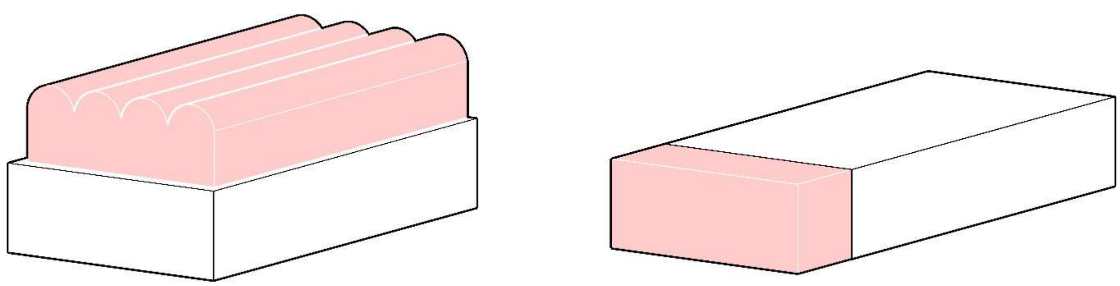

Figure 19 Addition, drawing by Maicol Negrello

[56] During this research, it has also been possible to find a sort of model "the hybrid". This is referring to a typology that can be defined "hybrid", since it is not a z-farm on a roof neither inside a building. Since, so far, it has been found just a case "the Greenhouse" in Utrecht, it is not possible to create a category. Hence, it represents an *unicum* and not a typology that has been replicated in other cases. in any case, I thought it appropriate to at least mention it.

[57] https://www.verticalharvestjackson.com/

Here some examples:

- **Lufa Farms, Montréal (CA)*** [58]
- GothamGreens, New York City (USA)
- Skyvegetable, New York City (USA)
- UrbanFarmers, The Hague (NL)
- Urban Farmers, Basel (CH)
- Ferme Abattoir, Bruxelles (B)

[58] * The following case has been used as a representative example of rooftop greenhouses Z-farms, for this reason there are more materials.

1. Lufa farms (Ferme de Ahuntsic-Cartierville)

Status: Active since 2011
Founder: Mohamed Hage, Kurt Lynn, Lauren Rathmell, Yahya Badran
Location: 400 Rue Antonio-Barbeau, H4N 1H5, Montréal, Quebéc (CA)
Urban land use: industrial area
Host building typology: industrial structure
Typology: Addition - Rooftop greenhouse farm
Architects: GKC Architects
Growing system: Hydroponic
Growing surface:
- 3000 sq.m, Ahuntsic-Cartierville (Montréal, Québec), 2011
- 4000 sq.m, Laval (Metropolitan area of Montréal,Québec), 2013
- 5850 sq.m, Anjoy (Montréal), 2017

Annual production: 110 tons per acre (circa 4000 sq.m)
Business: CSA
Employs: 140 people

Architectural features:

- *Vertical connections*
  It is provided by two different links between levels. The first one is the elevator to lift trolleys with vegetables between the greenhouse and the offices above, also connected by a stair. The second connection is between offices and packing area is equipped by a common elevator used by all the tenants. In order to avoid interferences among the users, the products are transported from the top to the packing area during closure hours (between 4a.m and 9a.m).

- *Horizontal distribution*
  The horizontal distribution takes place through a central corridor about 2/3 meters wide where the trolleys are moved. The layout of the rows, placed at about 80/100 cm from each other, allows the passage of the operators with the trolley to collect the vegetables.

- *Packaging area*
  The vegetable collected are then taken to the ground floor where they are placed in the customer baskets. In this area, products from the other partner farms, and the others two Lufa farms, are collected and redistributed. This area is connected to a corridor to the loading docks where they are distributed to costumers through electric cars.

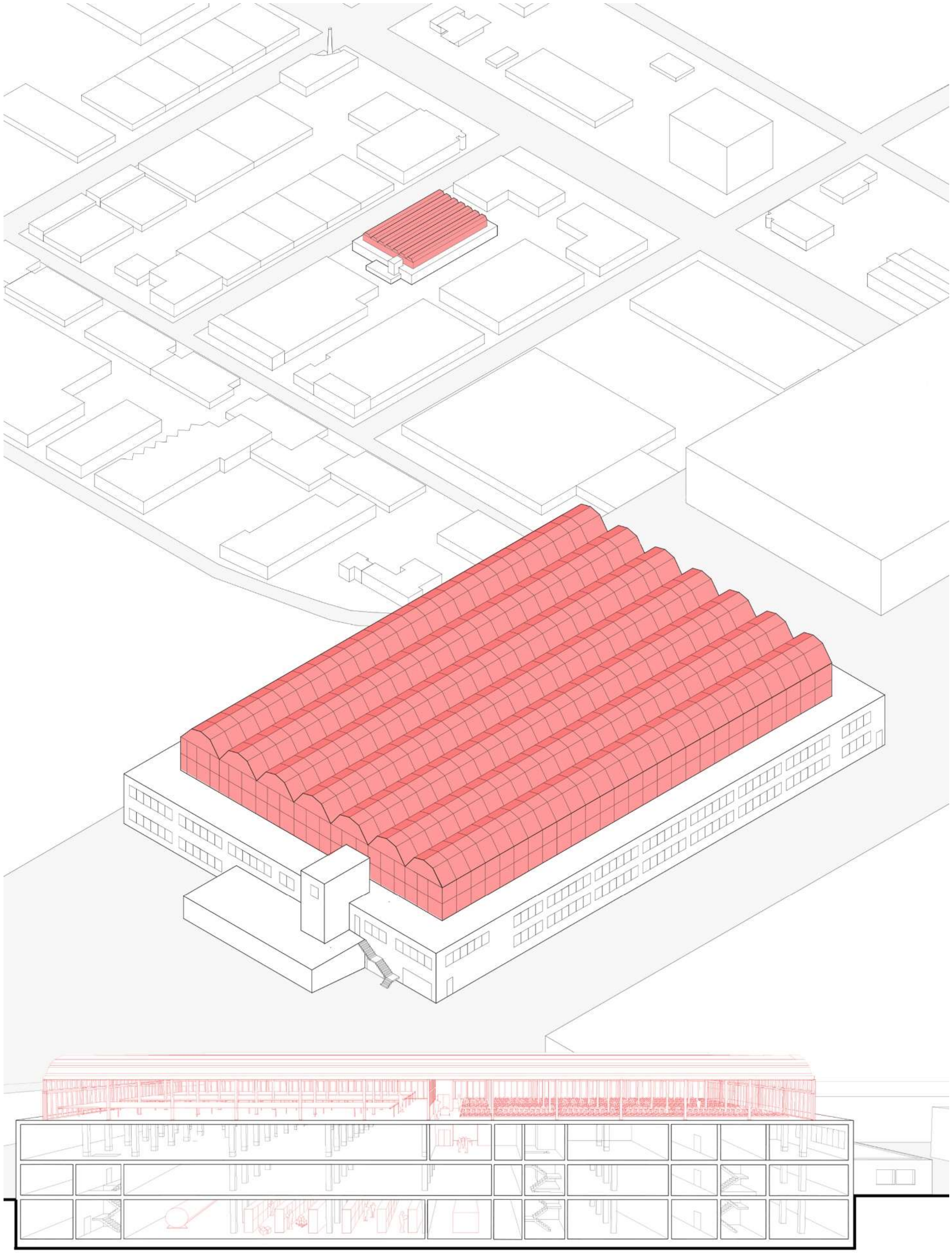

Figure 20 Urban location, axonometric view and section of Lufa Farms (new components in red)

Figure 21 Lufa farm exterior, Maicol Negrello

Figure 22 Lufa farms exterior, Maicol Negrello

Figure 24 Lufa farm boxing area, Maicol Negrello

Figure 23 vertical connection between greenhouse and offices, Maicol Negrello

2. Gotham Greens (Gowanus farm)

Status: Active since 2013
Founder: Viraj Puri, Eric Haley, Jennifer Nelkin Frymark
Location: 214 3rd St, Gowanus Brooklyn, New York City
Urban land use: mixed/ industrial area
Host building typology: commercial
Typology: Addition - Rooftop greenhouse farm
Architects: BL Companies
Growing system: Hydroponic
Growing surface: 1860 sq.m
Annual production: 90 tons per 1860 sq.m
Business: B2B (direct to market)
Employs: >100 full time

Architectural features:

- *Vertical connections*
  It is provided by a common elevator and stairs that connect the grocery to the upper floor where the greenhouse and a public bar/restaurant are placed. the common use of the lift for both goods and customers may sometimes represent a flow problem.

- *Horizontal distribution*
  The horizontal distribution takes place through central and perimeter corridors, and smaller ones between growing area.

- *Packaging area*
  The vegetable collected are packaged in a sterile area (small room), then boxes are taken to the grocery store.

Figure 25 Whole Food Grocery + Gotham Greens (street view), Brooklyn, Maicol Negrello

Figure 26 Whole Food Grocery + Gotham Greens, Brooklyn, Maicol Negrello

3. SkyVegetables

Status: Active since 2013
Founder: Joe Swartz (Director)
Location: 1071 Tinton Ave, The Bronx, New York City
Urban land use: residential area
Host building typology: residential
Typology: Addition - Rooftop greenhouse farm
Architects: Nexus
Growing system: Hydroponic
Growing surface: 750 sq.m
Annual production: 100 tons per 750 sq.m
Business: mixed B2B-B2C
Employs: 6 full time

Architectural features:

- *Vertical connections*
  It is provided by an exclusive-use elevator that connects the ground floor to the rooftop.

- *Horizontal distribution*
  The horizontal distribution takes place through corridors with different wide (between 80 and 170cm) depending on the usage of the area.

- *Packaging area*
  The vegetable collected are packaged in open envelopes (where the plants are still alive), then temporary placed in a refrigerated chamber before being delivered.

Figure 28 Aereal view of affordable housing and rooftop greenhouse. Source: https://www.housingfinance.com/management-operations/developer-raises-the-bar-in-the-bronx_o

Figure 27 Refrigerated chamber, Maicol Negrello

4. UrbanFarmer (De Schilde - The Hague)

Status: bankruptcy (activity period 2016-2018)
Founder: Roman Gaus
Location: Televisiestraat 2U, 2525 KD The Hague
Urban land use: mixed/ industrial area
Host building typology: former industrial (former 1959 Philips telephone and television factory, designed by D. Roosenburg)
Typology: Addition - Rooftop greenhouse farm
Architects: Space&Matter Architects
Growing system: Hydroponic + aquaculture
Growing surface: 1200 sq.m rooftop greenhouse / 900 sq.m fishfarm (last floor)
Annual production: 50 tons per 1200 sq.m / 20 tons fish
Business: mixed B2B-B2C
Employs: none

Architectural features:

- *Vertical connections*
  It is provided by an exclusive-use elevator that connects the ground floor to the rooftop. The connection between the greenhouse and the packaging and storage area is provide by an elevator.

- *Horizontal distribution*
  The horizontal distribution takes place through a wider corridor 3,5 m and smaller corridor between growing bed for leafy greens. The row for vegetable plants are placed at about 80/100 cm from each other, to allow the passage of the operators with the trolley to collect the vegetables.

- *Packaging area*
  The vegetable collected are packaged in the below floor, under the greenhouse.

Figure 29 UrbanFarmers, The Hague, exterior. Credit: Martijn Zegwaard. Source: http://www.spaceandmatter.nl

Figure 30 UrbanFarmers, The Hague, interior. Credit: Martijn Zegwaard. Source: http://www.spaceandmatter.nl

5. UrbanFarmer (Basel-Pilot)

Status: Bankruptcy (activity period 2013-2018)
Founder: Roman Gaus
Location: Frankfurt-Strasse 21, Basel
Urban land use: mixed/ industrial area
Host building typology: warehouse
Typology: Addition - Rooftop greenhouse farm
Architects: Conceptual Devices Studio
Growing system: Hydroponic + aquaculture
Growing surface: 300 sq.m rooftop greenhouse
Annual production: 3 tons per 300 sq.m / 1 tons fish
Business: mixed B2B-B2C
Employs: none

Architectural features:

- *Vertical connections*
  It is provided by an common elevator and a stairs that connect the ground floor to the rooftop where it possible to have access at the greenhouse and the office in the container.

- *Horizontal distribution*
  The horizontal distribution takes place through a central corridor.

- *Packaging area*
  The vegetable used to be collected packed in small room.

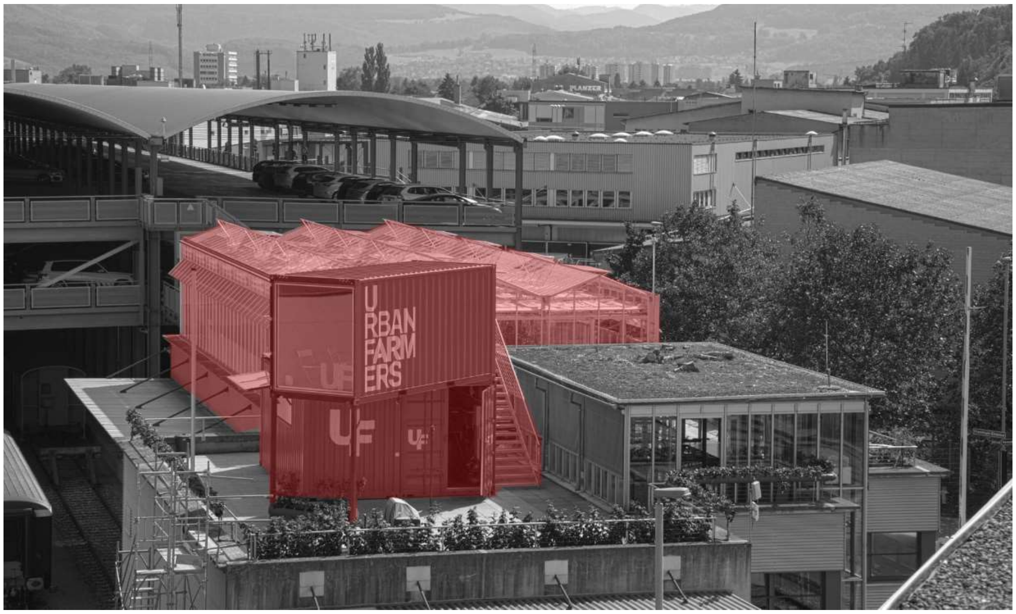

Figure 31 Urbanfarmers Basel, aereal view. Credit: Raphi See (Raphael Seebacher)/Urban Farmers

6. Ferme Abbatoir

Status: Active since 2018
Founder: Steven Beckers (BIGH FARM company)
Location: Rue Ropsy Chaudron, 1070 Anderlecht, Bruxelles,
Urban land use: mixed/ industrial area
Host building typology: commercial
Typology: Addition - Rooftop greenhouse farm (+ rooftop outdoor farm)
Architects: ORG Architects
Growing system: Hydroponic /aquaculture
Growing surface: 2000 sq.m rooftop greenhouse / 2000 sq.m outdoor rooftop farm
Annual production:
- Microgreens: 120,000 units
- Tomatoes: 15 tons
- Potted herbs: 140400 pots
- Fish: 35 tons

Business: mixed B2C -B2B
Employs: 5 full time

Architectural features:

- *Vertical connections*
  It is provided by elevator and stairs.

- *Horizontal distribution*
  Information unknown

- *Packaging area*
  Information unknown

Figure 33 Ferme Abatoir and market loading dock, exterior. Source: https://bigh.farm/

Figure 32 Ferme Abatoire rooftop greenhouse and outdoor edible garden, view from the top. Source:https://bigh.farm/

Insertion (I)

This term refers to all kind of interventions that involve in the construction of an urban farm in any built environment. Usually, former factories, warehouses, unused buildings are reuse for those agricultural activities. However, in the last years, underground spaces such as basement, underground parking, former metro tube, or disused tunnels[59] as the WW2 Air Raid Tunnels as it happened in London[60](UK), have been converted for producing vegetable and mushrooms. The layout of this type is very simple: the rows are spaced from each other by about 90/150 cm

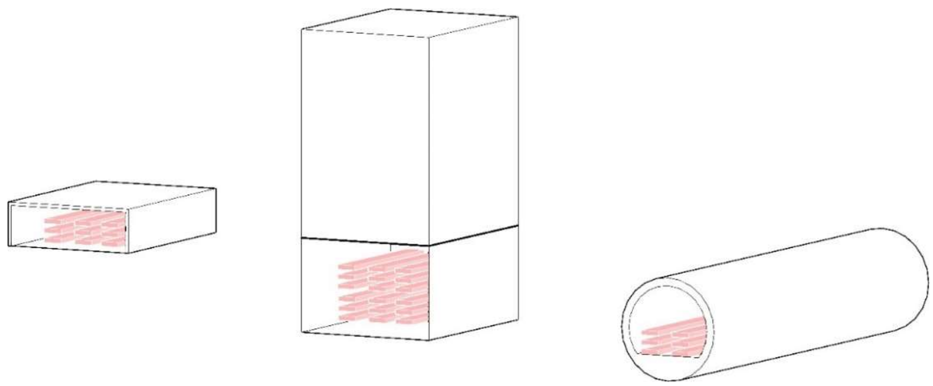

Figure 34 Typologies of insertion, drawing by Maicol Negrello

Here some examples:

- **Aerofarms (USA)*[61]**
- Aqua green (CA)
- Farmercut (DE)
- GrowUp farm (UK)[62]
- Infarm (DE)
- Growing underground (UK)
- Farm.One (USA)

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[59] Some example can be found in Okcheon (South Korea) where the farm NextOn based is business inside a tunnel, built in 1970 for one of South Korea's first major highways but subsequently abandoned. For further info see: («The South Korean highway tunnel turned into a vertical farm», 2018)

[60] See Growing Underground, http://growing-underground.com/

[61] The following case has been used as a representative example of indoor vertical Z-farms, for this reason there are more materials.

[62] This English bankruptcy company, based in London, used to have also a small container farm that presents a small greenhouse over the top of the module. The technology used is aquaponic (symbiosis between fish production and hydroponic cultivation for vegetable), hence inside the container fishes are reared while the vegetables grow in the greenhouse using natural sunlight.

7. Aerofarms

Status: active since 2016
Founder: David Rosenberg, Ed harwood, Marc Oshima
Location: 212 Rome St, Newark, New Jersey
Urban land use: industrial area
Host building typology: industrial /former steel mill
Typology: Insertion – vertical farm
Architects: KSS Architects
Growing system: Aeroponic
Growing surface: 6500 sq.m
Production: 1500 tons per 6500 sq.m
Business: B2B (direct to market)
Employs: >100 full time

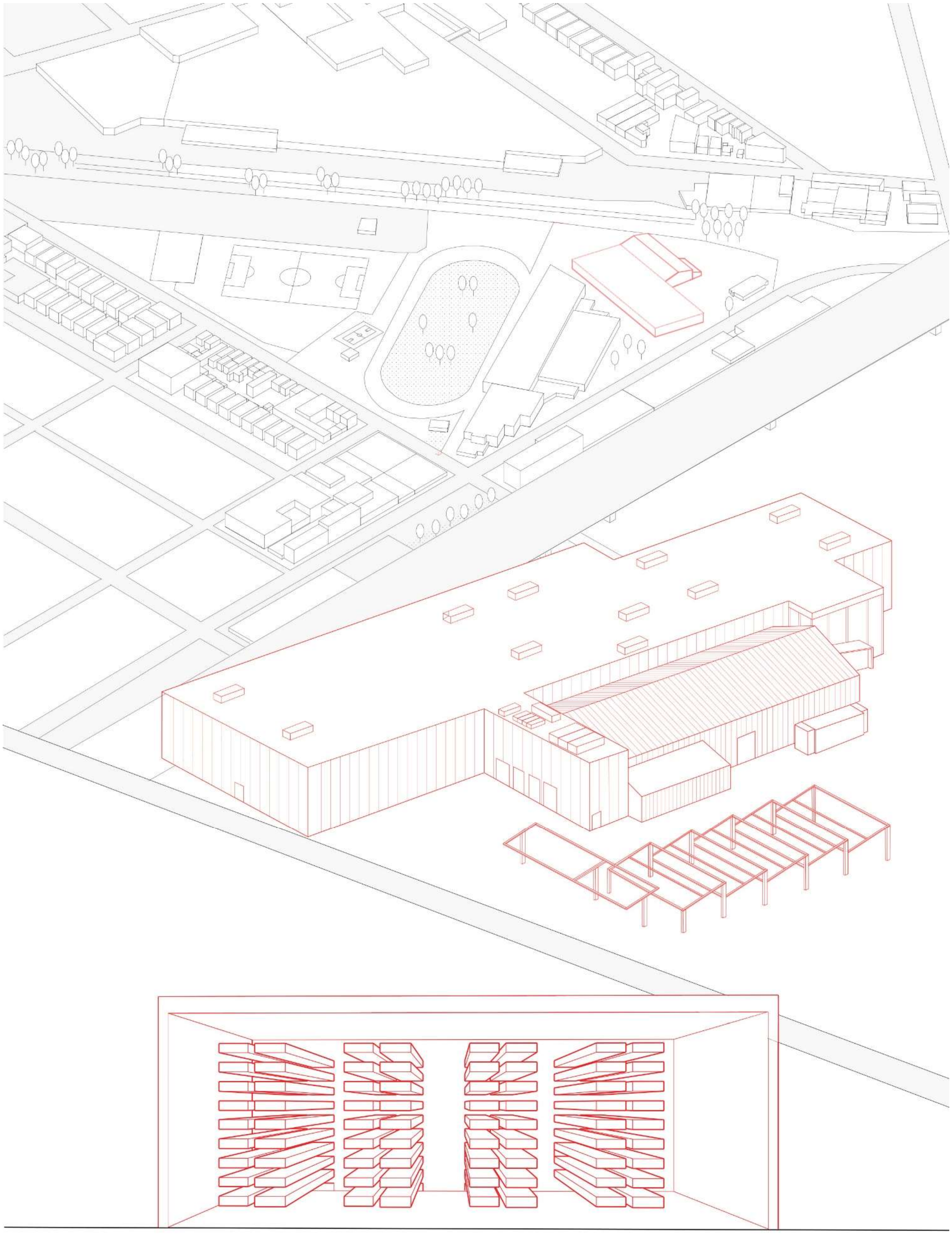

Figure 35 Urban location, axonometric view and section of Aerofarms (new components in red), illustration by Maicol Negrello

Figure 36 Aerofarms, growing structures and wide corridors (horizontal connection). Source: aerofarms.com

8. Aqua greens

Status: Active since 2013
Founder: Pablo Alvarez and Craig Petten
Location: industrial park, Missagua, Ontario
Urban land use: industrial area
Host building typology: industrial warehouse
Typology: Addition - Rooftop greenhouse farm
Architects: Unknown
Growing system: Hydroponic vertical farming + aquaculture
Growing surface: no data
Annual production: no data
Business: mixed, B2B+B2C
Employs: 5 < full time

Figure 37 Growing structure, interior of AquaGreens. Source:http://pllight.com/projects/aqua-greens/

9. Farmerscut

Status: Active since 2015
Founder: Mark Korzilius and Isabel von Molitor
Location Banksstrasse 28, Großmarktgelände Halle West II, Hamburg,
Urban land use: mixed/ industrial area
Host building typology: industrial warehouse
Typology: vertical farming
Architects: Unknown
Growing system: Drydroponic
Growing surface: 2000 sq.m
Annual production: 35 tons (eu) per 2000sq.m
Business: B2C (restaurants, cantinas, hotels), B2C
Employs: >10 full time

Figure 38 Farmerscut warehouse, exterior. Source: googlemaps

10. GrowUp Urban Farms

Status: Bankruptcy (Activity period 2015-2017)
Founder: Kate Hofman and Tom Webster
Location: 84, London Industrial Park, Roding Rd, London
Urban land use: industrial area
Host building typology: industrial warehouse
Typology: Vertical farming
Architects: Unknown
Growing system: Hydroponic + aquaculture
Growing surface: 2000 sq.m
Annual production: 20 tons per 2000 sq.m / 4 tons fish
Business: B2B (direct to market)
Employs: 2-10

Figure 39 Grow Up farm- Unit 84 (now closed), credit: Mandy Summit, Source: https://www.growup.org.uk/gallery/iqt6oxfde517ngqb9rexpe5wodm669

11. inFarm[63]

Status: Active since 2013
Founder: Osnat Michaeli, Erez and Guy Galonska
Location: based in Berlin, it has now expanded throughout Germany and other countries
Urban land use: mixed
Host building typology: mixed
Typology: Insertion
Architects: Unknown
Growing system: Hydroponic farm
Growing surface: various
Production: 14400 plants for a 1sq.m
Business: mixed
Employs: >10 full time

[63] This company distributes the infrastructure

Figure 41 Infarm growing moduls and trolley elevator. Source: https://infarm.com/grow/

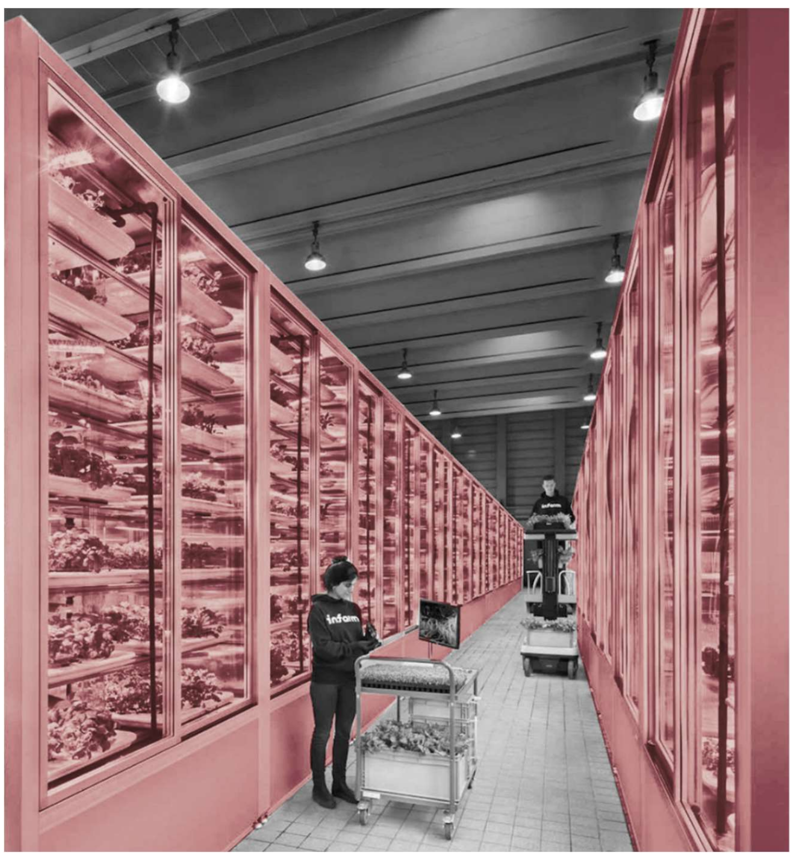

Figure 40 horizontal distribution betwween moduls. Source: https://infarm.com/grow/

12. Growing Underground

Status: Active since 2014
Founder: Richard Ballard, Steven Dring, Backed by 2-star Michelin chef Michel Roux Jr.
Location: 1a Carpenter's Pl, Clapham, London
Urban land use: mixed/residential area
Host building typology: underground tunnel
Typology: Addition - Rooftop greenhouse farm
Architects: Unknown
Growing system: Hydroponic – vertical farming
Growing surface: 6000 sq.m
Production: tons per 6000 sq.m
Business: mixed, B2B+B2C
Employs: >10 full time

Figure 42 Growing underground. Source: https://newatlas.com/growing-underground-subterranean-urban-farm-london/38297/

13. Farm.One

Status: Active since 2017
Founder: Rob Laing
Location: 77 Worth St Floor 1, Manhattan, New York City
Urban land use: commercial/residential
Host building typology: commercial
Typology: Insertion/
Architects: Unknown
Growing system: Hydroponic vertical farm
Growing surface: 111 sq.m
Production: no data
Business: B2C
Employs: 2-10 full time

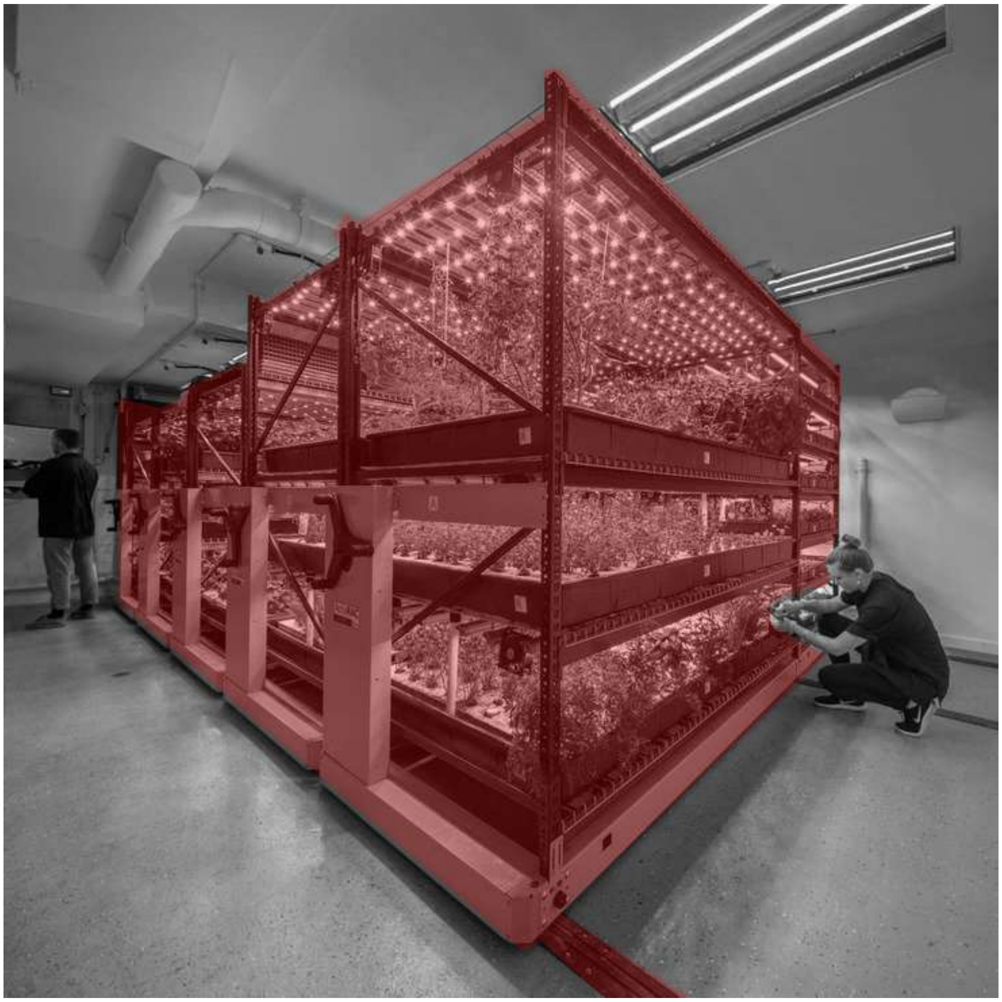

Figure 43 Growing structure, Farm.One. Source: https://farm.one/

Spot (S)

As aforementioned, this last "model" is quite misleading since it does not represent a real architectural typology, in the strictest sense of the word, but it occupies an urban space, or it can be placed inside or above buildings (as the former Boston-area taxi depot that now hosts Green Line Growers[64]). For this reason, I considered it appropriate not to take into account this model as a hypothetical replicable architectural element. However, it can be contemplated as a device - like an elevator- related to a building and designed to produce fresh lettuces, rocket salad and other species of leafy vegetables and fruit. Those modules, with a quite standard dimension (12,2x3x3m or 40x10x10ft), necessitate just an electrical connection and a small water supply. In short, no specific requirements need for the outside environment. Another aspect which should be highlighted is that this approach (modules able to fit in any place) have influenced architects and designers to create a module for home vegetable production. In many cases, even if it is not for commercial production, this creates a new product for home furnishings that is generating a trend in the newest market. Although the research does not investigate this subsector, many types of research in the design field are promoting this idea of a module that, probably in a few years, it could be common among the most traditional household appliances[65].
Below are some images of some case studies visited in the USA and Canada.

Corner stalk farms by FreightFarms[66] (USA)

This containers farm is composed of six containers in which are growing different kinds of leafy green. The farm is based in an urban void (a parking lot) in the Eagle Hill neighborhood of Boston. The products are sold to restaurants, bars but also at the Boston Public Market 100 Hanover Street, where locals farmers and artisans sell their products. Connie and Shawn Cooney rent a space where they sell also products from other farms in a CSA[67] logic. From the interviews with Connie and Shawn Cooney, owners of the farms, this business offers work to 5 part-time people, but the profits are only used to balance the costs, the profits are limited. This activity, although commercial, is almost a hobby for the owners. However,

[64] Green Line Growers is a Boston-based urban farm company that grows vegetables inside shipping containers (refrigerated modules for the agricultural production). Although this case could seem misleading, it is interesting to note how space is used merely as a protective box without any intervention of a structural or architectural nature to the existent building.

[65] Among the example it can be mentioned Natufia Labs, an Estonian based company that designed a kitchen indoor garden. For futher information see https://www.natufia.com/

[66] FreightFarms is a Boston-based company that provides the modules within which vegetables are grown in a totally controlled environment in terms of humidity, heat and light thanks to the use of sensors. Corner stalk, such as other clients, created its own business by using FreightFarms devices.

[67] Community supported agriculture

according to the owner, the production of other plant species (such as marijuana) could definitely increase the incomes.

Figure 46 Corner Stalk Farm, Containers farm, (April 2018), Boston, Maicol Negrello

Figure 44 Shawn Cooney-farm owner, Interior of container farm, (April 2018), Boston, Maicol Negrello

Figure 45 Farmers'Market Boston, (April 2018), Maicol Negrello

Ripple farms (CA)

It is a small agritech start-up founded in 2016 by Brandon Hebor and Steven Bourne in Toronto. The 15sq.m farm is located in Evergreen Brick Works (Toronto) a hub for sustainable companies, where a local farmer market is also held. This modular farm is composed by a container inside which there are tanks where the fishes are raised and on the top a greenhouse where leafy green are cultivated vertically. This small unit provides 365 plants for every plant circle (21 days) that are sold to the local market inside the Evergreen Building. Nowadays, the founders are selling other units, but their main aim is increasing productivity (reaching 600 plants) and scaling up.

Figure 47 Ripple Farm, (April 2018), Toronto, Maicol Negrello

Chapter 4

The anatomy of Z-Farms: spaces for agriculture in the urban context

This chapter represents the cornerstone of the research: it attempts to display a comprehensive and in-depth analysis of z-farm, ranging from the urban placement to the study of spaces - therefore architecture - and the relations with the city, expressed also through the distribution network. The object of the study is not explored only as static "entity" but rather as an urban activity, that occupies space, and by which interacts with the city. Therefore, it has been used the term "anatomy" because, although z-farm is not a living organism, the study will examine the morphology, the structure and all the part it is composed.

Farm	year	Country	Location	Designated area	Hosting building	Farm typology	Area (sqm)	Main distribution
Lufa Farm1st	2011	CA	Ahuntsic - Cartierville, Montréal	Industrial	Industrial /office	A. Rooftop greenhouse	3000	CSA + Online distribution
Lufa Farm 2nd	2013	CA	Laval, Greater Montréal	Industrial	Warehouse	A. Rooftop greenhouse	4000	CSA + Online distribution
Lufa Farm 3rd	2017	CA	Anjou, Montrèal	Industrial	Industrial	A. Rooftop greenhouse	5900	CSA + Online distribution
GothamGreens 2nd	2013	USA	Gowanus, Brooklyn, NYC	Mixed	Commercial	A. Rooftop greenhouse	1860	B2B (direct to market)
Skyvegetable	2013	USA	Bronx, NYC	Residential	Residential	A. Rooftop greenhouse	750	B2B
*UrbanFarmers UF001 LokDepot	2013 - 2018	CH	Dreispitz, Basel	Industrial, mixed	Warehouse	A, Rooftop greenhouse	300	B2B,B2C
*UrbanFarmers De Schilde	2016 - 2018	NL	Groente- en Fruitmarkt, The Hague	Mixed	Industrial	A + I. Rooftop greenhouse + inside building	1200 greenhouse 900 Indoor fish farm	B2C, B2B
Farme Abattoir	2018	B	Bruxelles	Mixed	Commercial	A. Rooftop greenhouse+ outdoor rooftop garden	2000 greenhouse 2000 outdoor garden	B2B (direct to retailers)
Aerofarm	2015	USA	Newark, New Jersey	Industrial	Industrial	I Vertical farm	6500	B2B (direct to retailers)
Aquagreen	2015	CA	Toronto	Industrial	Warehouse	I. Vertical farm	208	Mixed
Farmercut (pilot)	2017	DE	Hamburg	Industrial, residential	Warehouse	I. Vertical farm	1200	B2B
*GrowUp Urban farm Unit 84	2015 - 2017	UK	Beckton London	Industrial	Warehouse	I. Vertical farm	760	B2B (direct to retailers)
Infarm	2015	DE	Berlin	Mixed	Mixed	I. Vertical farm	variable	B2B (direct to retailers)
Growing underground	2015	UK	Clapham, London	Mixed	Urban infrastructure[68]	I. Underground vertical farm	6040	B2B (direct to retailers)
Farm.One	2016	USA	TriBeCa, Manhattan, New York	Mixed	Residential, commercial	I. Underground vertical farm	110	B2B (restaurants)
Corner stalk farms	2015	USA	Boston	Residential	None	S. Vertical farm	37 (each module) X 4	Mixed

Table 2 Case studies and data

[68] Growing underground is the first underground farms based inside a disused WW2 Air Raid Tunnels in Clapham, London, UK.

4.1. Defining the location: factors affecting placement

As previously illustrated in paragraph 3.2., the examination of the case studies focused, in the first step, on the farm's location in the urban environment. Among the reasons that affect the placement[69], there is a multitude of factors, such as:

- *the cost of the property*
- *the connection with urban infrastructures*
- *the typology (architecture model, scale) of the z-farm*[70]
- *the business models*
- *the species of plants produced*

The cost of the property

All those factors are determining for the placement, however, the most impacting one is - obviously - the cost of the property (either for rent or for sale) (Benis & Ferrão, 2018). In fact, most of the entrepreneurs chose to start setting up an urban agribusiness where the cost of premises is low. Hence, just with a low cost of the premises, it is may possible to balance the management cost (energy, labor, etc.) while being within the city (Fesquet, 2015). From the interview with the director of Enterprise Operations Carolee Kakola[71] at The Plant in Chicago, she underlined how the premise cost has a major impact on operations during the start-up phase of the business. She explained it was possible to transform the former meatpacking facility into a multi-tenant building dedicated to food production (The Plant), only thanks to the visionary Jonh Elder[72]that was able to buy the building for only 5,50 USD per square foot (Cockrall-King, 2012, pag. 271).
Another case study demonstrating the importance of low rent/building cost (or unused space, such as roofs or basements) is Lufa Farms, in Montréal (Québec). During the interview[73] with Laurence Hamelin, communication coordinator at Lufa

[69] A foreword is necessary to clarify this sentence: in some cases, the placement, or the desire to fit into a specific area, occurs before the choice of the farm type. This means that the positioning has influenced the decision of the architectural type, due to building and zoning codes related to the location that affect the architecture.

[70] This is referring to the three different typologies previously mentioned: addition, insertion and spot.

[71] Carolee Kokola is a planner, urban designer and currently director of Enterprise Operations at Bubbly Dynamics, LLC / The Plant. The interview I conducted with her was held at The Plant (Chicago, IL) in March 2018.

[72] Founder of the Bubbly Dynamic LLC in Chicago.

[73]The interview was conducted by the author to Laurence Hamelin, communication coordinator at Lufa Farms, and it took place on the 27th April at Lufa Farms Anjou Cartierville, 1400 rue Antonio-Barbeau, bureau 201, Montréal QC, H4N 1H5.

Farms, she illustrated the decisional process was strictly conditioned by the cost of leasing for the roof area. In fact, the founders managed to negotiate with the landlord of an industrial building in the Anjou-Cartierville (Montréal) a very cheap rent: only $1 per square foot per year. According to all the interviewees[74], low rent is at the base of a possible successful business. Another example to support this point is Bowery Farming[75], the co-founder and CEO Irving Fain decided to set the farm in New Jersey for cheaper rents(Zeldovich, 2018) whereas continue selling to New York markets but also targeting other urban locales close to the farm.

The connection with urban infrastructures

Another important point for a profitable ZF is the proximity and the connection with the urban infrastructure, logistics point or food distribution center. As it is shown in the table above, all the cases previously selected are located in metropolitan areas near to or inside the city center. Metropolitan areas are usually well connected with the urban infrastructure such as high way, train connections or easy city- accessible ways. Introducing the production inside the city positively affects the reduction of the food miles[76] (Specht et al., 2014), moreover, it guarantees to have a fresher and healthier food because it is harvested and delivered in less than 24h, so consumers can be sure to have a higher quality product.

Talking once more about Bowery, farming, its consumers' target is mostly based in New York City, despite the farm is in New Jersey, but thanks to the proximity of infrastructures food can be delivered to the city in less than a day.

The typology (architecture model, scale) of the Z-farm

Here, it is shown how placement can affect and also be affected by the Z-farm typologies. When the productive building (the Z-farm) is in the city, into a residential or mixed-residential zone, the relationship between location, goods/farmer and customer is different from the one in which the building is located in outlying or industrial areas.

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[74] During the period of research spent by the author abroad in U.S.A and Canada, he interviewed owners or workers in agrobusinesses such eas Lufa farms, Gotham Greens, Corner stalks farms, and others.

[75]Bowery farming is a vertical farm that produce leafy greens. Its headquarters is in Manhattan, while growing its produce in New Jersey.

[76] Compare to the traditional distribution in USA where vegetables and fruits mostly come from a refrigerate and long journey. In fact, food is transported long distances, generally between 1640 and 2500 km for delivery and 6760 km life-cycle supply chain on average(Schnell, 2013; Weber & Matthews, 2008; Worldwatch Institute, s.d.).

This relation is may be affected also by the farm, considering both the typological aspect (as the architecture of the farm: greenhouse, indoor building, shipping container, etc.) and the scale (dimension). Through the case of Gotham Greens Gowanus, it is possible to understand the relation location/farm/consumer expressed in the Viraj Puri[77]'s decision "to produce next to where the product is sold, close to consumers". This idea, firstly, has influenced the necessity to be in the city, that in turn conditioned the typological (so the dimension) choice of his farm; for those reasons, the Gowanus greenhouse was designed and realized over the Whole Foods grocery store. This case does represent the concept "produced-harvested-sold" of Puri's motto expressed during an interview: "We want to be near the market and have a mission of being urban farmers" (Kowitt, 2018).

Certainly, Gowanus it is the most representative case, however, the others Gotham Greens 'farms are located in the urban context, nearby where the product is sold (even if they are not a grocery store), by reusing or rebuilding on post-industrial site[78]. As stated previously, the choice to be placed in an urban reality[79]can affect the type of farm in a "cause-effect" relationship that can be reversed, hence is not univocal. In fact, building and zoning codes have an influence on the architecture of the farms. For instance, talking about the city regulations for a greenhouse, its realization is possible only if all the standards are respected: for structural safety, for fire prevention, for atmospheric events (snow, wind) and those deriving from urban decoration rules (use of materials such as glass and steel).

The Lufa Farms, for example, had to design its farms according to the very stringent regulations[80], that have influenced the shape and the materials of the

[77] Co-Founder and CEO of Gotham Greens

[78] Gotham Greens has four farms and one under construction, all of them on industrial buildings or former industrial site. Three greenhouses are placed in New York City, more precisely: the first one in Greenpoint, Brooklyn (on the Greenpoint wood exchange building), the second in Gowanus, Brooklyn (built together with the Whole food grocery store) and the last one in the Greater Jamaica neighbourhood of Hollis, Queens (built on the historic Ideal Toy Company factory complex first built in 1920). The 4th farm is in Pullman, Chicago (Illinois) is considered the world's largest and most productive rooftop farm in the world with its 7000 sqm of growing area. In 2018 Gotham Greens expanded also in Baltimore (Maryland) occupying an area of 9300sqm in the northern part of Tradepoint Atlantic and is scheduled to open in early 2019. The greenhouse area is on the former Bethlehem Steel plant in Dundalk that, after the redeveloped processes started three years ago, it has been able to attract also giant distribution centres such as FedEx Ground and Amazon.

[79] More precisely, it is not referring directly to the location itself, but to the rules or codes that stand on that area.

[80] All that information come from the interview with Lufa Farm Communication Office. Here an extract: "Existe-t-il des lois contre / pour la production d'aliments à effet de serre sur les toits? Aucune en particulier. Le zonage est le principal problème car nous ne sommes pas vraiment définis comme une ferme. Plutôt, nous suivons les mêmes exigences du code du bâtiment que le bâtiment sous nous (comme si nous construisions un autre étage, pas une serre / ferme). Par exemple, nous avons obtenu une dérogation pour ne pas avoir à construire de toilettes dans la serre! Dans certaines villes, comme Boston, des règlements de zonage ont été introduits pour aider les projets d'agriculture urbaine." Montréal, April 2018.

structure. These types of interventions modify an existing building to make them appropriate (both for structural/technical[81] needs and regulatory requirements) to growing plants inside or atop since all the structures are not designed for farming.

However, it is found that according to all the cases studies analyzed, the greater is the Z-farms proximity to the city center, the more numerous the laws and the building code restrictions must be adopted to create the agricultural business, especially for rooftop greenhouses. Nevertheless, the presence of these rules, in recent years many cities are changing their regulations in order to support the creation of urban farms. Anyway, in the latest years something is changed: North American cities such as Boston[82], New York City, Detroit, Seattle, Toronto, have undertaken the enormous task of rezoning the city and create a list of roles to allow and to ease urban farming within city limits, where previously it was not granted (City of Boston, 2013).

Back to the cases studies table, it is noted that z-farms mostly occupy industrial buildings[83] - in some instances abandoned- such as warehouses or with robust structures, designed with high carrying capacity, hence able to support a greenhouse structure. Typically, the industrial architecture offers frameworks with very large areas, high ceilings and a pillars layout with wide interaxle spacing, this kind of volume is the most suitable to host vertical cultivation. Moreover, industrial buildings have larger spaces for future expansions and are usually are in urban areas well-connected to the city center with the urban infrastructures. This is an important factor, especially for small business, because it ensures space flexibility for future expansions.

The business models

The business model is another aspect that influences the choice of positioning, which obviously also affects the farm products distribution model.

Usually, farms that have set as business strategy the creation of limited and selected products set in the urban core, in little spaces like basements in a residential area, rooftop, small warehouses, parking plot; among the example: as Farm.One (Manhattan, NYC), Close Loop Farm (Chicago), Farmercut (Hamburg, in

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[81] Load capacity of the floors (in the case of a roof greenhouse), accessibility to the cultivation areas, water / electrical demands, waste, etc.

[82] In 2013, the City of Boston—through the Boston Redevelopment Authority and the Mayor's Urban Agriculture Working Group—has undertaken the enormous task of rezoning the city to expressly allow for urban farming within city limits. Prior to this initiative, the zoning code—which dictates where certain uses within a city can occur—primarily did not mention agricultural uses; in Boston, if a use is not mentioned in the zoning code, that use is forbidden. The addition of Article 89— the new zoning article addressing urban agriculture—was the first step to facilitate urban agriculture in the city. (City of Boston, 2013)

[83] Among the selected cases, 10/16 are reusing industrial buildings.

Germany), Corner stalk's Farm (Boston). The product of those Z-farm model is direct to high-end environments such as restaurants, bars, or customers with high-quality demands and not conventional products (such as microgreens, edible flowers, uncommon herbs). This kind of business has direct contact with the consumers that receive with the home delivery the products; for this reason, city core locations are the most suitable because food can be delivered faster through different way (eco-delivery by bike or electric car, delivery app services, etc).

Whereas urban industrial locations by the cities have been mostly chosen when the business model is directed to large retailers and for a "mass-production". Almost all the cases that located inside former industrial building choose an intensive production (vertical farming) and dispose of great economic potential, due to private and non-private investments[84], such as company as Aerofarm[85] (Kearny, NJ), Plenty[86] (San Francisco), Bowery[87](Newark, NJ). From the case selected, it possible identify an average space for this business model with dimension around (or more) 2000 square. The flexibility of the industrial constructions represents a great occasion for new agri-urban businesses for two main points: the cost, usually low, and for the availability of space that can be occupied during different timing, according to the company growth. As previously said, the premise cost has to be low since the technological equipment and energy demands are economically high.

The species of plants produced

The species of vegetable affect the location, then the architecture of the farms.

To give a better explanation it is fundamental to know that vegetables and fruits as tomatoes, aubergines, cucumbers, zucchini, peppers, etc., require a high quantity of energy (more intensive light spectrum) to grow, whereas leafy greens and mushroom required less energy (both for lighting and heating). For this reason, if a company wants to produce leafy greens for retailers and large distribution, the more appropriated location would be both inside warehouses and on large rooftops, mostly in industrial area; indeed, leafy greens usually can be cultivated, thanks to LED technologies and hydroponic/dryponic systems, also vertically inside buildings. At the same time, if the goal is to growth economically-valuable products as cucumbers, aubergines, zucchini, etc, that require more energy to produce (light,

[84] Investments in indoor agriculture increased 653 percent between 2016 and 2017. This data can be found here: https://i3connect.com/tag/vertical-farming. They collected data related to the investment of 40 different companies into indoor urban farms' business from 2013 till now (2018)

[85] https://aerofarms.com/

[86] It is a 200 employees-Californian Ag-tech company that have two farms: one in South San Francisco (4650 sq.m) and one in in Laramie, WY. https://plenty.ag

[87] https://boweryfarming.com/

heat), greenhouses are the more suitable structures for those plants, since the greater part of energy supply come from the sun.

When the Z-farms have a small dimension under 1000sq m, usually the location is in the inner city and the products are microgreens, flower, rare and uncommon herbs. This type of business can adapt to tiny spaces like basements, containers, garages. Those are generally niche products.

4.2. Buildings and spaces suitable for Z-farming: an overview of the architectural typologies and the spatial dimensions.

This section analyzes the types of buildings that have developed over the past 10 years to describe the architectural features. From this survey has been possible to define the common peculiar characters for each category, that has been described according to the following criteria:

- *Host building*
- *Dimension*
- *Vertical connections*
- *Layout*

Rooftop Greenhouse Z-farm

Among existing forms of building-integrated agriculture, rooftop greenhouse represents the most common typology, since rooftop benefit from being large unutilized solar exposed urban areas (Benis & Ferrão , 2018).

0. *Host building*
According to the cases studies selected, the 62,5% of the host buildings are industrial structures or warehouses constituted by a very robust framed concrete structures with a medium interaxial space of 5m circa, able support the loads on the roof. The other cases the 25% are housed respectively on commercial buildings and the 12,5% on residential one. In some cases, it has been appropriate to reinforce (with pillars and/or beams) the structure for greater stability, because with the greenhouse the total load on the roof can critically increase. Great consideration must be given to the load of the wind[88] - therefore it is necessary that the junctions between the building and the superstructure (greenhouse) are very resistant- and also to the high load of the tanks for the recovery of water and nutrients if present. In cases of new construction, the structure has been designed to support the load for the greenhouse.

1. *Dimension*
The dimensions are usually proportional to the size of the building below. It is therefore obvious that the industrial buildings/warehouses have greater availability of roof surfaces, whereas residential buildings are characterized by

[88] The wind load depends also from the height of the building.

smaller roof areas (or, at least, useful floor area for agricultural purposes, without shading). Among the cases, studies of commercial/viable farms the 38% are over the 3000 sqm, 34 % between 1000-2000 sqm, and 25% less than 1000 sqm.

2. *Vertical Connection*
   The rooftop indoor Z-farms must be connected with the retail plan (in the case of a supermarket) or with the packaging area and then distributed. These connections usually take place through a lift dedicated exclusively to goods, as the case of Sky vegetable in Queens or Urban farmers in The Hague. However, in other cases (see Lufa Farms, Gotham Green Gowanus) the vertical elements (both stairs and elevators) are shared prior agreement with other users. According to Caputo et al. (2017, pagg. 42–43) not independent access can be "problematic in different ways, for instances privacy of occupants and closure after working hours". However, where it has been possible, external stairs have been built mostly for fire security requirements, maintenance, inspecting the roof or the air handling unit systems. In some cases, when the main connection to the roof was not present, a secondary connection has been realized to reach the greenhouse. Usually, the elevator shaft is located in a position to avoid shading the plants, but not always and this can create problems of correct illuminance.

3. *Layout*
   The greenhouse layout depends mostly on the plant species and therefore from the production technique. In fact, plants like tomatoes, aubergines, zucchini, cucumbers need a row layout with "corridors", wide between 80-110 cm so farmers can pick the products up and collect them in a trolley. The plants are cultivated with hydroponic drip system[89] inside long ducts where roots are moistened with nutrients. Whereas the system that has typically used for leafy greens (salad, basil, chou, etc.) is the Nutrient Film Technique (NFL)[90]. Since the ducts are very manoeuvrable, it is required only a corridor where operators can work. Usually, under those ducts systems, which are positioned at a height of about 1m from the ground, there are the water and nutrient tanks. In some

[89] "Water and nutrient solution are pumped up from the reservoir through tubing to the top of the growing media (where the plants roots are), from there it drips out of the tubing onto the growing media. The nutrient solution drains down soaking both the roots and growing media all the way to the bottom of the container. From there the nutrient solution flows through an opening/s, and gravity allows the nutrient solution to flow downhill through tubing all the way back to the reservoir." http://www.homehydrosystems.com/hydroponic-systems/drip_systems.html («Hydroponic Drip Systems», 2018)

[90] It a very common system where plants are placed in a duct and the roots are continually wet by a thin layer/film of water and nutrients

case studies, a small area has been used for germination: that is a limited space, humid and heated that favours the growth of the seeds.

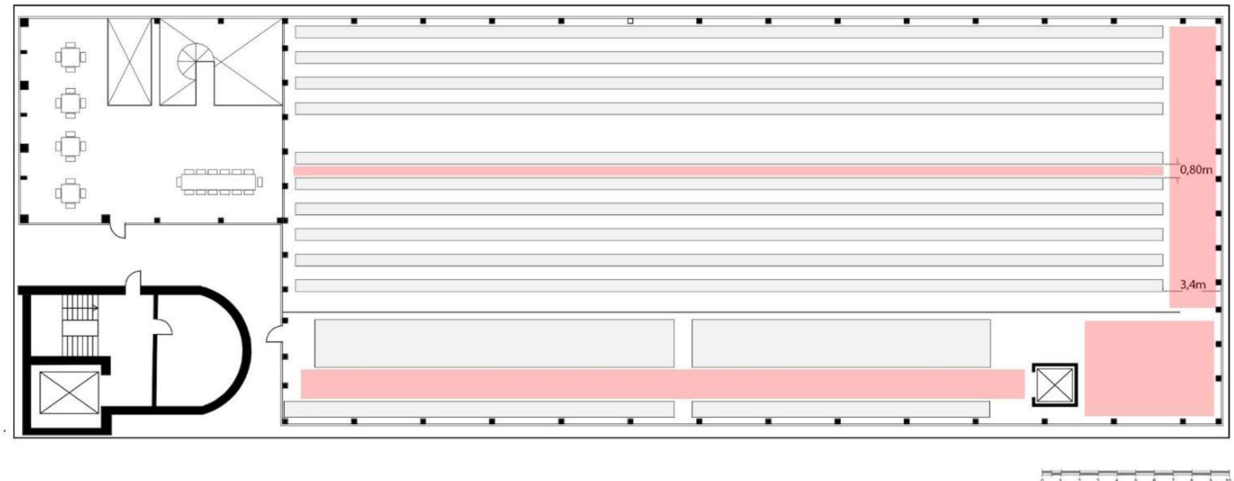

Figure 49 UrbanFarmers The Hague, rooftop greenhouse planimetry, horizontal connection in red, re-drawing by Maicol Negrello from the project of Matter and Space architecture studio.

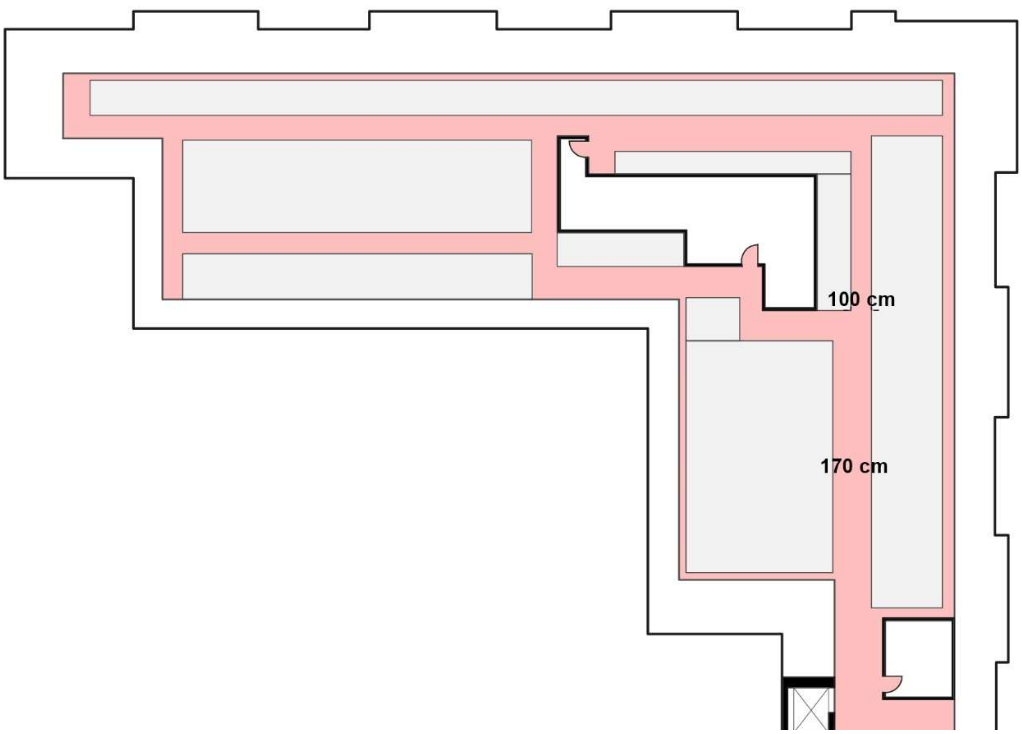

Figure 48 Skyvegetable, rooftop greenhouse planimetry, horizontal connection in red, drawing by Maicol Negrello

Vertical Z-farm

This research showed a wide range of case studies that vary in size. The vertical z-farms adapt to any type of space. as, as seen from the previous chapters, it does not need solar and soil intake but the energy and a fair amount of water.

1. *Host building*
   According to the cases studies selected, 90% of the host buildings is industrial structures or warehouses located in an industrial area close to the city. The 10% are housed respectively inside commercial or residential buildings, mostly in the downtown area. Most of the cases chose an industrial location for the flexibility of industrial places and cheap rent. Whereas, inner urban location is more for exclusive and niche products, that are home-delivered or distributed to high target restaurants.

2. *Dimension*
   Among the cases selected, 33% has an area greater than 6000sqm, most of them (50%) are under 1000sqm, 17% has a surface between 1000 and 6000sq.m.

3. *Vertical connection*
   Vertical connections are not an architectural feature, like elevators or stairs, but in this case, it can be considered the scissor lift used by employees to reach the growing shelves. The layers (shelves) have an average height of 40 cm circa, in order to suit leafy greens size(Kozai, Niu, & Takagaki, 2016; Molin & Martin, 2018, pag. 9)

4. *Layout*
   Vertical farms layout is very regular, with rows arranged at about 1-1.5 m from each other, in order to pass with lift. The height varies from the height of the ceilings. Each shelf is placed at a height of about 40-50 cm, enough to grow leafy vegetables and herbs.

4.3. Distribution strategies

This subsection illustrates the distribution strategies adopted by z-farms. As shown previously, the distributional strategy of a farm is directly related to the location, the products and the business target (niche, large distribution, etc.). The urban agricultural production partly is oriented its market towards local residents, rather than the supply chains of the food industry (Vejre et al., 2016, pag. 20). However, large size Z-farms (frequently vertical farms), due to the great number of products, can supply retailers, such as Whole Food in the U.S.A.

Traditionally, the distribution network of the urban agriculture, unlike the conventional food supply model, is based on a stronger sense of community that shares the same ideal: sustainability, supporting local producers, requiring a safer food. The urban agriculture model chooses direct sale in the local market, but it diversifies according to the products and the type of business plan (Proksch, 2016). Z-farming products have usually a different market range from traditional urban farming. The reason is that the price and quality of Z-farms goods are mostly incomparable with the ones from traditional on-ground urban and peri-urban agriculture. Since the production costs are higher, those products are meant mainly for private customers in preference to the market, that because an intermediary would increase more the final price.

Some commercial z-farms produce for local urban markets. Fresh or processed products are sold through on-site vending, farmers markets, community-supported agriculture or direct distribution to local restaurants and supermarkets. Other Z-Farms cooperate with regional farmers to increase product variety and use common marketing and distribution channels[91]. Commercial z-farmers compete on the basis of quality rather than price (Thomaier et al., 2014).

Finally, it is necessary to emphasize that the choice of a business model (distribution) does not preclude the possibility of adopting different models together (B2C + B2B + CSA).

Model B2C[92] (business to customers)

The model B2C “producer-customers[93]” represents a commercial exchange without intermediaries (considered the retailers, hence, it takes place normally in grocery stores). This relation, even if it is a transition of a good and, therefore, it can take place anywhere, from the study of the examples, it was possible to

[91] See Lufa Farms Montréal

[92] B2C means Business To Consumer and refers to all sales made directly to the final consumer

[93] The term “customers” means both private citizens and restaurants, bars and related services.

physically represent it. Usually, the sales area can be the "farmers' markets" (as Faneuil Hall Marketplace in Boston, the Eastern Market in Detroit, Artscape Wychwood Barns and Evergreen Brick Works in Toronto, etc.) or on-site production stands (as in The Plant in Chicago, or Corners stalk farm in Boston). However, thanks to new digital tools, food can be bought and daily delivered at home (at the workplace, at the restaurant if it is the buyer); in this way, food passes directly "from the front door and not via loading dock in the back lane" (Proksch, 2016, pag. 167).

In the urban agriculture distribution system, the direct sales to customers have traditionally been the privileged way for trade: since there are no intermediaries (as grocery stores), it became the most profitable option for farmers for increasing their income. In fact, according to the USDA[94], farmers' market sale bring twice the return of selling to conventional wholesalers. (Proksch, 2016, pag. 165). Small businesses or "at first start-up stage" Z-farms, opt for this solution because the price of their product would be less attractive if sold in a food store, where prices for the same items are lower. Moreover, people, local farmer markets, restaurant and bar in the neighborhood "like this at the forefront of development in local food culture and economics, and these small scale distribution networks stimulate pride[95] and economic development in the community" (De la Salle & Holland, 2010, pag. 78).

However, in other cases[96], it possible that this model is co-operating with others, as the B2B.

Model B2B[97] (business to business)

The model "business to business" is mostly adopted by large-size Z-farms, whose clients are wholesale groceries. In this case, the grocery store decides to adopt a "more local" products and support the urban "new industry" as Z-farming, to offer to its consumers more sustainable and higher quality products. The farms that prefer this model rely on the guarantee of having a regular customer, who can

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[94] Unite State Department of Agriculture

[95] Almost all the case studies found by the author proudly publish the urban origin of the product, such as GothamGreens "Grown in NYC", or GrowingUndergoound "Grown Locally in London", etc.

[96] Among the case studies, Growing Underground distributes its product selling directly to consumer (B2C) at the market, to wholesale (B2B), directly at the buyer's home (B2C+homedelivery), or food service distributors (such as restaurants, pubs, bar, catering companies).

[97] Abbreviation for business-to-business: describing or involving business arrangements or trade between different businesses, rather than between businesses and the general public (Cambridge Advanced Learner's Dictionary & Thesaurus, s.d.)

continuously absorb the production, hence ensuring the agro-company growth. For those farms, it is important to localize close to a fast connection with the city (if they delivered directly to the grocery store) or, if the buyers are more, to a wholesale food distributor, so to ensure fewer food miles. In other cases, the production is set right on the rooftop of the grocery, as in Gowanus Whole Foods market (Brooklyn, NYC). Whole Foods Market Brooklyn has partnered with Gotham Greens on the USA's first commercial-scale greenhouse farm integrated within a retail grocery space. This project aims to eliminate long-distance food transport and its associated emissions while ensuring product freshness, quality, and nutrition for thousands of customers in the area («Brooklyn Greenhouse», 2013). Usually, an agreement to finance the infrastructure and for the "long-term purchasing" regulates partnership between the farming company and the retail entity.

Community-Supported Agriculture (CSA)[98] *to customers*

The CSA model has been applied for a long time especially in rural or periurban areas, mostly in North America (Canada and USA). This model connects the farmers with the buyer within a service to subscribe[99]to receive weekly or bi-weekly at home, or at the pick-up points, the customized baskets with local product harvested from a group of farms. It is an alternative socio-economic model of agriculture and food distribution that allows the producer and consumer to share the risks of farming(Galt, 2013). In the latest year, this model improved and updated due to the internet and social media. By using the web site farm or an app it is possible to customize what buyers would like to receive in their basket before the delivery.
Lufa Farms represents a successful case of the CSA model. It gives the key to its achievement thank the choice to provide all year long a great variety of products, whereas traditionally the section of products was limited and depending on the seasons. Lufa, due to the large number of partnerships with local and seasonal organic producers in Montréal area (and also adding some "exotic" and seasonal fruit/vegetable from organic and sustainable farms), was able to create an innovative, dynamic, collateral and parallel type of market that challenges the traditional suppliers (grocery store).

The CSA model can be considered capable of enriching the territory from both an economic and a social point of view.

[98] Both classic CSA with up-front payment and the modern online version.

[99] Only on line or at the farm, traditionally paying in advance

Chapter 5

Critical issues for urban adaptation

In the last five years, there has been a lot of talk on those new high-yield commercial models of urban farming (Z-farms), especially for the potential of generating economic value from unutilized (or underused) urban space[100], by returning them productive and able to revitalize local economies (Benis & Ferrão, 2018; Mandel, 2013; Specht et al., 2014; Thomaier et al., 2014). Their innovative characters have fascinated the inventiveness of many - who have seen this as a future certainly possible- and at the same time attracted many criticisms, resulting from the failures of some experiments. Nevertheless, there are still many gaps and quite limited information on them. Neither the replicability of these start-ups nor their economic viability has been fully demonstrated yet, and this is mentioned in the literature as a major barrier to their large-scale implementation in urban contexts(Eigenbrod & Gruda, 2015).
The creation of this chapter was necessary, fundamental because during the research the failure of some case studies have occurred. This has led the author to review the premises and face the unforeseen problems that the Z-farms have encountered in their first phase of integration in the city environment. The analysis of failures has been conducted through interviews, conferences and informal documents, that have allowed the understanding of the main causes of the Z-farms' failures.

[100] Rooftops decommissioned industrial or commercial sites.

5.1. Why Z-Farms fail?

The first step for designing possible new solutions for future successful farms is understanding which parts have been neglected, which are the mistakes and the inaccurate choices made that caused the failures of different case studies.

It is possible to pinpoint among the main reasons for the failure's farms:

- Urban location and distribution model
- Competitive uses
- Market target
- Construction costs
- Maintenance and labor costs

Urban Location and distribution model

The position is fundamental for a successful farm: when it gets wrong the chances of failure are high.

Usually, large-size farms that sell its products to the wholesale distributor have to choose a location close to infrastructure and logistics center, to reduce the food mile and the cost for rent and energy.

For small and medium-size farms it is preferable to locate themselves in urban areas directly connected to retail and/or to adopt home delivery services.

The case of PodPonics can represent a negatively exemplary case. The first farm has developed in the city, where food is consumed but lately, when the business grew, they moved outside the downtown for a bigger location, although in an urban area where normally renting and energy cost are higher compare outsider areas. However, the wrong choice was, according to Matt Liotta[101] (CEO of PodPonics), the decision to stay still close to consumers, in an urban area. "It is important to be at the point of distribution[102], but not always at the consumption point[103]. When you become big enough inside the city, your products need to be distributed all around, here the problem. The goods need to be transported to logistic centers (usually far from the city) to be redistributed back in the city. So, transportation costs and food mile rise, food become no-more "sustainable", as it should be for the of urban agriculture fundamental aim.

[101] Matt Liota took part in the panel "An Examination of Shuttered Vertical Farming Facilities" during the Aglanta conference in 2017 held in Atalanta on the 2nd February 2017.

[102] Logistic centre, wholesale food centre, etc.

[103] This also depend on the dimension and model of the farms.

Moreover, one last thing should be carefully considered to avoid failure: the geographical location and the physical space for a Z-farm (Kalantari, Mohd Tahir, Mahmoudi Lahijani, & Kalantari, 2017).

Competitive uses

One of the first issues is to make sure the farm occupies a space that is able to host the business for a long time. There could be more competitive and profitable uses or changing over the years. It is advisable to rent a place (building, rooftop, parking lot) for enough time, in order to absorb investment spent for the construction and technology equipment (Cerón-Palma, Sanyé-Mengual, Oliver-Solà, Montero, & Rieradevall, 2012). In fact, rooftop greenhouse farms have to compete with other rooftop-integrated technologies such as solar photovoltaics or solar thermal, whereas indoor farming (as vertical farming) compete with other "more profitable" urban uses, such as residential or commercial functions. Such a high competition for urban plots and buildings turns real estate more and more expensive (Benis & Ferrão, 2018). In conclusion, economic evaluations need whenever to choose the suitable place and able to answer a very "provocative" and (still) open question like the one by Armando Carbonell[104]: "Would a tomato in lower Manhattan be able to outbid an investment banker for space in a high-rise?[105]" (Venkataraman, 2008).

Market target

Another problem that future farmers have to face in advance is the market target. In fact, the market target is a potential point for the success of a farm, moreover, it can also influence the dimension and the farm strategy. The bankruptcy of GrowUp, a Z-farm that grew vertically leafy greens in London, was mostly caused by the lack of a clear target strategy. Since it was one of the first farms in England and the business model was still rudimentary, a very common condition in the Z-farm start-up environment. Kate Holman, co-founder, and CEO of GrowUp said: "It's hard to run a business at the industrial scale, you cannot compete with the traditional supply food change. So, if you want to compete with large scale businesses, you have to get bigger in size farm"[106]. The lesson learned is that before starting a business it is important to set the goal, to understand who your client is,

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[104] Chairman of the department of planning and urban form at the Lincoln Institute of Land Policy in Cambridge in 2008

[105] This interview was released in 2008, currently the z-farms reality has evolved, as well as the spaces and architectures have adapted to accommodate agricultural production in the cities.

[106] This extract come from the presentation of Kate Hafman at the 2017 Unreasonable Impact World Forum, on the 2nd Oct 2017, CBS News. Here the link: https://www.youtube.com/watch?v=zhh44HQpeYs

to invest in quality and the customer experience and, finally, to choose the right place that could host the farm (and foresee spaces for possible expansion). Mark Korzilius, founder of Farmer's Cut in Hamburg, underlines[107] the importance of the right target and he suggests focusing on the customer experience and adding additional value to the products.

High construction costs

As often happens for innovative companies, it is no surprise that both the initial costs of new innovations and technologies and the risk of failure are high (Pinstrup-Andersen, 2018). In fact, in addition to the cost of the structure these spaces require the expensive technological system to create an optimal plant condition with humidity control and homogeneous temperature (avoiding thermal changes harmful to plants). Moreover, for rooftop greenhouses, the logistic difficulties related to the exiting in the building can contribute to increasing the expenses. In fact, issues such as reinforcing the structure, bringing the building materials on the roof, bringing the products down contribute to raising the cost.

Sanyé-Mengual, Oliver-Solà, Montero, & Rieradevall (2015) demonstrated that the construction cost of an RGH in the urban environment is one of the major expense to deal with. In fact, the economic costs of adapting greenhouse structures to the current building legislation were pointed out as a limitation of these systems in the literature. The author could personally verify this aspect through some interviews, for instance, the one conducted to Fabian Weinländer[108], former director of development for UrbanFarmers in Basel (CH). Weinländer underlined that one of the most problematic challenges is the construction cost. Indeed, the expensive outgoings for the building materials, such as heavy galvanized steel structure, aluminum, and double-glazed cover, and the cost for maintenance of them increase the risk of bankruptcy, if a careful capital-recovery program is not well planned and managed before the start. This is also supported by the interview conducted by Benis & Ferrão (2018) to the directors of rooftop greenhouse farm on the roof of De Schilde, a former Philips factory in The Hague. The 1200 sq.m expensive greenhouse has been commissioned by UrbanFarmer Basel to Space&Matter, a proactive architecture agency based in Amsterdam

Maintenance and labor costs

First, accurate maintenance costs are difficult to predict, because it depends on different internal and external factors: energy cost/weather, labor, materials for

[107] During the Vertical Farming Conference in Venlo, June 2018

[108] Interviewed by the author in Basel at UF001 LokDepot UrbanFarmers on the 7th July 2017

cultivation/nutrients/seeds. For example, greenhouses are subject to weather changes due to the external environment. This means that in case of heat waves the greenhouses must be air-conditioned to avoid the loss of the crop, as well as during the winter it is necessary to provide heating systems (preferably in synergy with the host building to save energy) to ensure an optimal temperature for the plants. Energy costs depend on the geographical area and on the access of the resource, Canada (6,42 €cent/kWh) and the U.S.A (7,13 €cent/kWh), Sweden (6,31€cent/kWh), Finland (6,43€cent/kWh) The Netherlands (8,10€cent/kWh) have cheaper prices compared to some Mediterranean country, like Italy (15,72 €cent/kWh) or Spain (10,78 €cent/kWh) [109], even if the Mediterranean climate has no harsh and long winters like North America, so the heating energy demands are decidedly lower. Moreover, the lighting requests (therefore electricity) depend also on the latitudes: The Northern Countries have a higher electric energy demand to illuminate during the winters. Whereas vertical farming cultivations inside building or container (or where there is little access to daylight) artificial light must be provided all years long (Specht et al., 2014), the same for cooling and heating. For indoor farms, the massive amounts of energy required to grow plants indoors are among the major disadvantages (Specht et al., 2014).

Secondly, long-term maintenance must be considered: environmental characteristics related to greenhouses (for example humidity) possibly will reduce the lifetime or other structures of a rooftop greenhouse, so increasing maintenance necessities and associated environmental effects and economic costs (Sanyé-Mengual et al., 2015).

The last point that concludes this section is focused on labor cost, which is directly related to architectural/design problems. In fact, many of the failed farms have ignored ergonomics and were not designed for efficient manual work. These issues probably derive from inexperience and from the fact that there are not yet manuals for design indoor urban farms. From the analysis of a multi-layered systems (vertical farming) with grow beds, going from the floor to the ceiling, it is clear that farmworkers have to move up and down from a scissor lift for any kind of operations (planting, inspections, maintenance, and harvesting); those operations required more time so more labor costs. Farmers should implement a growing system that reduces labor costs and does not require expensive automation technology to be economically viable (Michael, 2017).

In conclusion, who want to run a Z-farm business have to - necessarily - predict these costs in advance.

[109] Those data, referred to years 2013, have been found in the article of Il Sole 24Ore, and the source is Nus Consulting Group. For further info: https://www.ilsole24ore.com/pdf2010/SoleOnLine5/_Oggetti_Correlati/Documenti/Impresa%20e%20Territori/2013/07/costi-energia-elettrica-gas-naturale.pdf

5.2. Zoning and city regulations

It has been possible to ascertain[110] that, depending on indoor Z-Farming forms and types, one of the issue to face is generated by zoning and building codes and urban regulations; in most of the cases, there is a general absence of any regulations for urban agriculture, indeed it is often forbidden in city areas (Puri & Caplow, 2009; Thomaier et al., 2014). In fact, as identified by some scholars, urban regulations and city codes represent the "major barriers to the large-scale implementation of BIA" (Cerón-Palma et al., 2012), above all because there is a lack of appropriate policies contributing to integrate this emerging industry into the urban fabric(Benis & Ferrão, 2018). For instances, in the case of a rooftop greenhouse restrictive laws must be considered for safety requirements such as fire-resistance (no inflammable, pierceable by fire)(Montero, Baeza, Muñoz, Sanyé-Mengual, & Stanghellini, 2017), loading (snow), hail and wind power.
Thanks to the interview to Lufa Farms, in Montréal, it has been possible to understand which the main problems with laws and codes are. Here an extract of the interview:

- *Question A*
Author: *"Existe-t-il des lois contre / pour la production d'aliments à effet de serre sur les toits?"*

Lufa Farms *"Aucune en particulier. Le zonage est le principal problème car nous ne sommes pas vraiment définis comme une ferme. Plutôt, nous suivons les mêmes exigences du code du bâtiment que le bâtiment sous nous (comme si nous construisions un autre étage, pas une serre / ferme). Par exemple, nous avons obtenu une dérogation pour ne pas avoir à construire de toilettes dans la serre! Dans certaines villes, comme Boston, des règlements de zonage ont été introduits pour aider les projets d'agriculture urbaine."*

- *Question B*
Author: *"Devons-nous naviguer autour de certaines règles et règlements?"*

Lufa Farms:"*La construction de la serre ressemble beaucoup à la construction d'un autre étage ou d'un bâtiment régulier (ce qui rend le tout plus compliqué / coûteux que de construire sur un terrain dans une zone rurale plus typique)"*.

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[110] From the interviews conducted by the author with some representatives of the case studies such as Lufa Farm, The Plant, Corner Stalk, UrbanFarmers, and sector experts, including Melanie Collè (ArgoTech Paris, project "Parisculteur"), prof. Prof. Vikram Bhatt (Faculty of Architecture, McGill Universtity), Dr Mark Gorgolewski (Chair of the Department of Architectural Science, Ryerson University), June Komisar (Department of Architectural Science, Ryerson University), Joe Nasr (Department of Architectural Science, Ryerson University)

This last excerpt proves what Cerón-Palma (2012, pag. 15) said: the rooftop greenhouse farm "should be considered as another building installation (a new part over an existing building), in order to overcome the investment and long-term repayment of the project," in this way the agricultural use will not be considered "temporary", as the traditional on soil urban agriculture, but a more solid "industry".

By the way, it has become clear that, in many occasions, the licenses to build greenhouses or other indoor farms have occurred not in a traditionally regulated way, but through a debate with the municipality, which he granted with derogations the realization. Among the cases listed before, just a few of them have released information on how they avoided the issues of implementation and building regulations. This could mean that probably the licenses to build indoor Z-farms have been granted through *"ad personam"* exemptions.

5.3. Social acceptance: new technologies and food equity?

Among the critical aspect of the tackle in the process of adaptation to the urban environment for the Z-farms, social acceptance is an important requisite for success or failure especially during the early innovation phase (Specht, Siebert, & Thomaier, 2015). It was possible to identify, among a variety of factors, two main issues: the first one concerning those "new" technology for cultivation, the second one is related to the discrepancy between the desire to respond to the growing need for food for all and the creation of niche products.

New technologies vs traditional farming methods

Hydroponic, LED, vertical farming, etc., represent the farming innovations that optimize the productivity of the plants and human labor (Shamshiri et al., 2018). These technologies have partly revolutionized the traditional vision of the agriculture and now farming[111] is an activity that no longer takes place only "somewhere in the countryside" (Specht, Siebert, & Thomaier, 2015). This statement "astonishes" the public opinion[112], that is still well uninformed on the subject. Farmers, to be accepted, have to convince on the one hand consumers to choose Z-farm products and to guarantee them high quality, safety, and healthy food on the other municipality that this activity can become part of "urban social and spatial environment"(Specht, Siebert, & Thomaier, 2015).
According to some scholar, such as Specht, Siebert, Thomaie (2015), Swoboda, Weith (2016), that studied the perception and the social acceptance on the building integrated agriculture in the first phase of commercial launch of the urban vertical farms in Europe[113], they ascertained that people partly rejected the idea of cultivating in an "unnatural[114]" way, far from the bucolic and collective images of traditional agriculture in farmlands, systems that are more likely to be accepted, moreover some of the interviewed considered cities as polluted environments to growing food (Specht et al., 2016). It seems that new technologies scare because still "uncommon", while traditional soil-based urban agriculture (on green rooftops,

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[111] It is always referred to commercial farming.

[112] This want to include both consumer and stakeholders, who are not yet familiar with the topic of agricultural production, such as real- estate owners, urban planning departments, architects or a city's political leaders and public servants.

[113] The researches took place in Berlin and give a representation of the "European reality" (especially Mediterranean) based on the average knowledge that the population had on these issues during the commercial launch of these new high-tech urban farms during the period 2012-2016.

[114] It is referred to growing systems such as hydroponic, dryponic, aquaponic, and to technologies such as LED.

along with the urban fringe, on brownfields, and in backyards) shows a high level of acceptance. The reason is the socio-economic advantages (such as recreational, climate regulating, infiltration of rainwater as well as health benefits) of the traditional urban farming for the inhabitants are higher (van Leeuwen, Nijkamp, & Vaz, 2010) compare the ones of the indoor agricultural production (Molin & Martin, 2018)(intensive or high-tech agriculture, such as hydroponic, aquaponic and vertical farming), which are less evident, hence less appreciated and accepted (Specht et al., 2016). The problem is that many still do not know that traditional urban agriculture is more likely to be at risk due to pollutants, both in soil and in the air, whereas indoor Z-farms is a totally controlled environment, with no pollutants.

Another aspect is that European citizens, as in the case of Berlin[115] analyzed by Specht et al., generally question the need for urban Z-farms, although there is a growing demand for local food products, and urban agriculture could complement the existing food system. North America food situation is different from European ones, firstly because food miles are higher, part of the population have problems with food, cities are bigger, and the food desert are problematic.

Food equality: food for all or just a "niche market"?

When the first idea of a vertical farm (and in general Z-farms) has come out, it was proposed as the solution that allowed everyone to access a portion of fresh and healthy food. The first Despommier made a lot of propaganda on this point and, like him, all those who pushed on the creation of Z-farm (vertical), justified by the data[116] of exponential growth of the urban population worldwide by 2050. Later he had to face the reality: innovation costs, Z-farms products cannot be for everyone in the first phase of experimentation. In fact, he wrote:

"I am not naive enough to believe that the vertical farm will exist mainly for the benefit of the world's underserved communities, although I certainly wish that this could be so; on the contrary, there is the real possibility that the first couple of vertical farms might end up benefiting the few (commercial growers) and not the many... Unfortunately, I am afraid I will not be able to do much about this since the idea is already out in the public domain." (Despommier, 2010, pag. 221).

[115] Berlin, as many other European city, so far fortunately is not facing any food security problems, moreover it is surrounded by highly productive rural lands (Specht, Siebert, & Thomaier, 2015; Specht, Siebert, Thomaier, et al., 2015).

[116] The current world population of 7.3 billion is expected to reach 8.5 billion by 2030, 9.7 billion in 2050 and 11.2 billion in 2100, according to a new UN DESA report, "World Population Prospects: The 2015 Revision" (Unite Nations Department of Economic and Social Affairs, 2015)

The “fable” of vertical farming has struggled with the previous hypotheses of self-sufficiency, reaching the reality that Danielle Nierenberg, co-founder of the nonprofit Food Tank, has expressed by saying: "realistically, vertical farms will never grow enough food to feed cities”, “but it complements the way we produce and supply fresh food to cities” (Haßler, 2018a), “and may one day even create a new type of urban green space”(Wong, 2017). Still, producing some of the food is simply not enough (Januszkiewicz & Jarmusz, 2017), for even a partly food self-sufficiency.

Therefore, having ascertained that Z-farms cannot be the only solution to the hungry cities, the second aspect that must be clear is that, presently, the products cultivated inside or on buildings are overpriced and niche, destined mostly for a small group of wealthy people. Although there have been criticisms complain that Z-farmers “claim to deal with community food security issues, while the products are only accessible to those who can afford them” (Specht et al., 2014), this is understandable because, due to the high R&D costs for new technologies and solutions for urban farming, the idea (with the excellent ethical purpose of departure) to feed the entire urban population has dissolved. Others argue that for urban agriculture to move beyond serving a niche group of people and make a real impact on the global food system, it will have to engage a broader demographic and without include lower income groups, it will be problematic to shift towards a sustainable food system (Lovett, 2016); moreover, they Z-farms will enjoy higher levels of acceptance if they do not primarily target elitist customers (Specht, Siebert, & Thomaier, 2015). It is necessary to note that only in the last five years, the Z-farms are starting to be considered as productive realities and not (only) experimentation with educational or social characteristics. Indeed, technologies need time before becoming more accessible, in fact, companies are working and investing to reduce costs to make products within everyone's reach.

According to the scholars previously mentioned who investigated this topic, acceptance depends also on the relation that an urban farm creates with the neighborhoods where it is located. As expressed before, traditional soil-based urban agriculture is perceived as an element able to improve city quality, the integration with the neighborhood's population of different social ranks, as well as promoting sustainability education and creating open green spaces. For those reasons traditional farms are more accepted because have a more visual impact and more “public/common” on the neighborhood life, whereas Z-farms are as a “light manufacture”, a “plant factory” that produce for the locals but as private business even if they want to ensure greater community involvement as urban neighborhoods have greater voice and participation in producing their food locally”(Besthorn, 2013, pag. 195). Sometime

Concluding this paragraph with saying that social acceptation is above all fundamental to be economically supported, as Isabel Molitorb, founder of FarmerCut in Hamburg, said that "the biggest obstacle was being located in Europe, but particularly in Germany, when it came to funding. In the US, in NYC, everybody was willing to help. Here in Germany, people are more risk-averse; people are more critical. Here, people first tell you ten reasons why something couldn't work or doesn't make sense instead of saying what makes sense and supporting you" (Wagner, 2017).

5.4 Real environmental sustainability?

In the last decades, it has been much talk about the need to have access to a more local food production, able to reduce environment costs, such as greenhouse emissions in the air for cultivating and transport ("food miles[117]"), pollution from fertilizer in groundwater and "carbon sequestration" (Goldstein, Hauschild, Fernández, & Birkved, 2016). Firstly, Z-farms have appeared as the most suitable solution to encourage an "eco-friendlier" and high-quality agricultural production in the urban environment, however the real sustainability of these farms depends on various factors (Benis & Ferrão, 2018), that scholars have begun to actually quantify(Specht, Siebert, & Thomaier, 2015), such as:

- climate conditions
- urban location
- type of farms and synergy with the host building
- (fertilizers)

Climate conditions

Although there are several studies that attest to the environmental benefits of this type of production – such as reduced use of fossil fuels by avoiding transportation from rural zones to the urban customer base (Benke & Tomkins, 2017) - other scholars have demonstrated how this is partly incorrect and often dependent on the context in which farm is surrounded.
Benis & Ferrão (2018), Kalantari et al (2017) agree that local climate conditions (like long and harsh winters or hot summers like in the Arab countries) and the typology of the farm are among the factors that influence the "real sustainability" of Z-farming production; hence, depending on the climatic condition (and also on the season of the year), the energy consumption for Z-farming production can even accentuate the impacts on the environment.

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[117] It is advisable to make an annotation. The concept of "local" and "reduction of food miles" is very often considered as the correspondent of "more sustainable" and with a lower environmental impact in terms of reduction of carbon footprint. However, in many cases, the label "local" does not mean less "embodied energy" or minor "carbon foot print"; the concept of "food miles" is too simplistic an indicator for carbon emissions, it cannot be said whether local food as a whole is any worse or better than imported goods(Mok et al., 2014). Indeed, vertical farming products require large amounts of energy for growth and, therefore, more quantities of greenhouse gases emitted (especially if energy comes from fossil sources). This is not just an issue on where something is grown and how far it has to travel, but also it needs to be taken into account all the emission that occurred how it is grown, how it is stored, how it is prepared(McKie, 2008). The net carbon footprint depends therefore on emissions caused by energy use for farm operation versus avoided emissions related to the existing supply chain, including operational energy of the existing supplying farms, and energy used in transporting the produce (Benis & Ferrão, 2018).

Environmental impacts mean also a higher carbon footprint. Some researchers in Europe have demonstrated that the term "local" does not mean "eco-friendly", in fact Kulak et al. (2013) showed, for instance, that producing greenhouse strawberries in London had a higher carbon footprint than importing Spanish greenhouse strawberries; likewise, in Austria, Theurl et al. (2014) found that indoor locally produced tomatoes have a double carbon footprint compared to the ones imported from Spain and Italy. According to a similar study conducted by Goldstein et al. (2016) on six case studies in Boston, indoor Z-farms are ostensibly more financially tractable, however, are handicapped by energy demands of year-round production in a northern climate; furthermore, indoor Z-farms can potentially be ecologically deleterious[118], whereas the ones located in mild climates (like Mediterranean one) have a more sustainable footprint than traditional agriculture.

Urban location

Recently, some scholars have investigated from the environmental point of view how proximity to consumers can potentially contribute to decreasing emissions, not only in terms of shortened transport distances but also due to the reduced energy required for storage, packaging and cooling and the potential for exploiting the energetic synergies between agriculture and the building. (Specht, Siebert, & Thomaier, 2015). However, others[119] do not agree that reducing food miles does always mean a more efficient supply-chains or a reduced environmental impact, in fact, it depends on different factors, previously mentioned. Another aspect that influences the "eco" performance, therefore also the energy demands, is the urban morphology. In fact, according to Samuelson, Claussnitzer, Goyal, Chen, & Romo-Castillo(2016), in order to improve the performance in sustainability of a Z-farm, preliminary surveys are essentials to describe the behaviors of the surrounding urban environment, since the nearby building geometry can impact on the amount of solar heat gains and/or daylight[120], and therefore energy consumptions. In the case of vertical Z-farm, the architectural morphology of the context are does not affect the farm performances, as it adapts to any free space; being independent of external conditions (e.g. morphology, weather, etc.) is one among the "pro" of this farming technique. Talking about sustainability, it is also important to consider which are the food delivery modalities of Z-farm, in fact, in many cases, farmers try to reduce their

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[118] This conclusion, according to Goldstein et al., can be apply to other indoor z-farms located in northern cities with cold winters and fossil fuel energy sources.

[119] For instance: John Fernandez, Benjamin Goldstein, Michael Hauschild, Morten Birkved.

[120] This is related to rooftop greenhouse farms or side one.

impact by using smart mobility and electric cars, bikes, on foot, etc.

Type of farms and synergy with the host building

The Z-farms can have different typologies[121]and each one has its own technical characteristics and energy demands, hence “sustainability levels. The first result is that z-farms, due to the controlled indoor environment, directly consume energy (especially vertical farming) more than conventional way to grow vegetables and herbs, however, resources as water, nutrients, arable land, and pesticide use are noticeably reduced and CO2 saving (Cerón-Palma et al., 2012; Goldstein et al., 2016; Molin & Martin, 2018; Sanyé-Mengual, 2015; Sanyé-Mengual, Cerón-Palma, Oliver-Solà, Montero, & Rieradevall, 2013).
Among the Z-farms models, the one inside building needs higher energy input than greenhouses typologies due to the lack of daylight. Its efficiency depends on the resources required (Graamans et al., 2018). At the same time, since vertical Z-farms are “independent” from the outdoor environment and weather or natural disasters, they produce all year round. Moreover, from the land-use point of view, this typology is very efficient because it contributes to releasing pressure on arable land by multiplying the surface. Hydroponic avoids water thanks to closed systems, so it can be considered more sustainable and efficient than traditional farming. Although farming in urban contexts is not inherently more sustainable for the ecosystem due to the energy intensity of indoor Z-farms(Benis & Ferrão, 2018), the rooftop greenhouse represents the more efficient typology among them because part of its energy demands (lighting) comes freely from outdoor.
This energy conservation benefits[122] depend on local climatic conditions, the ambient temperatures, the intensity of solar radiation, and the relative humidity, the synergy with the interconnected buildings (Specht, Siebert, & Thomaier, 2015), and therefore the Mediterranean region suits better to capture those gains (Benis & Ferrão, 2018; T Caplow & Nelkin, 2007). Rooftop greenhouse farms can improve also the sustainability of buildings (especially in European urban environments) (Cerón-Palma et al., 2012) since it acts as a shell that can reduce the heat loss during winter (saving in heating) (Delor, 2011) and insulate in the summer. It is possible to improve its energy behavior by joining the sources flows of the Z-farm with the one of the host building (Cerón-Palma et al., 2012; Thomaier et al., 2014) and by optimizing the efficiency of the system through the implementation of passive conditioning methods, such as thermal insulation, natural ventilation, evaporative

[121] It is referred to: Addition (greenhouses), Insertion (vertical farming inside building/ underground) and Spot (vertical farming inside transportable container)

122 According to Delor (2011) a combined building/greenhouse structure could save up to 41 % in heating compared with standalone greenhouses and buildings.

cooling, and the use of highly energy-efficient technologies, such as LED lighting (Benis et al., 2017a).

However, potential energy savings through a symbiosis between a rooftop greenhouse Z- farm and its host building requires to be further investigated under other climates.

(Fertilizers)[123]

Organic,
adjective /ɔːˈgæn.ɪk/
(of food or farming methods) produced or involving production without the use of chemical fertilizers, pesticides, or other artificial chemicals.

(«organic | Definition of organic in English by Oxford Dictionaries», 2018)

Recently in developed countries, people start requiring more organic food. The previous definition clarifies exactly the meaning: *"food produced without the use of chemicals"*.

Z-farming producers consider their food "ultra-organic" because they do not use pesticide, however, fertilizers are required to grow food with nutrients. It is possible to say that they use less quantity of fertilizers than traditional agriculture, indeed due to the closed system the right nutrient solution is absorbed by plants without waste, but it is not possible to affirm that this is organic farming, since fertilizers are chemical. In fact, no promising concepts can be found in the literature that allows for the production of effective nutrient solutions for hydroponic systems from organic matter. Existing hydroponic projects mainly use industrial fertilizers[124] to optimize yields. (Specht et al., 2014)

In conclusion, according to the previously mentioned concept, the Z-farms energy requirements and the inefficient use of resources may overcome the advantages of decrease the food-miles. Therefore buying local has a negligible impact on reducing carbon emissions and, actually, might lead to an increase given the significant contribution of the production phase (Weber & Matthews, 2008).

In fact, in some circumstances, urban agriculture may lead to a net increase in greenhouse gas emissions through additional energy and fertilizer inputs for farming in hostile/not suitable environments[125](Mok et al., 2014).

When talking about sustainability, Goldstein et al. (2016) have admitted that

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[123] The author believes it is important to mention the topic, as hydroponics is often - mistakenly - considered totally organic / sustainable

[124] Produced through energy-intensive industrial processes / mining

[125] For instance, the tomatoes grown in Spain and transported to the UK versus tomatoes grown in heated greenhouses in the UK, mentioned by Mok et al. (2014) in their research.

comparing the different use that could be chosen for an urban area, the solar panels would confer greater benefits for the environment (such as mitigating climate change) than the urban agricultural production since it requires a high quantity of energy. For this reason, Z-farming could not be considered as the optimal application of space in northern cities to improve urban environmental performance, above all if steps are not taken to introduce recycling systems (Specht et al., 2014).

However, scholars have also demonstrated that rooftop greenhouse Z-farms could have a great potential for improving the urban production, mostly in temperate areas with Mediterranean climate (Benis & Ferrão, 2018; T Caplow & Nelkin, 2007; Cerón-Palma et al., 2012), and it efficiency can be improved through a design developments (e.g. of the thermal behaviours, synergy with the host building). Whereas for Z-farms with vertical production LED technologies are currently evolving to reduce costs and energy demands.

Chapter 6

Designing a possible future: the z-farm toolkit

Despite the failures of some cases, such as Urbanfarmers in The Hague and Basel, GrowUp Farm in London, FarmHere in Chicago, this research has also verified the successes of some of these new forms of production during the "pilot phase", laying the base - although still uncertain - for a possible urban future. The previous analysis has been preparatory and useful in understanding the strengths and weaknesses of the urban indoor Z-farms. This has allowed identifying the elements considered more virtuous and, therefore, more reproducible to create a design toolkit for architects, urban planners, and municipalities.

6.1. Best practices for Z-farms

This paragraph aims to show, among the cases studies, which forms have best performed in the urban environment. This evaluation will give us a list of characteristics that can be considered as best practices, or successful elements. These characteristics can also belong to different cases, both successful and unsuccessful. It must be clear that effective solutions are "site-specific" [126]*, so it mostly depends on the location (Al-Chalabi, 2015). This analysis has been conducted both for greenhouses typology and indoor vertical Z-farms.*

Each case study represents a complex system that can have different results depending on the disciplinary outcomes. For each farm[127], elements of weakness and positivity have been analyzed through a system of parameters, also tested by some scholar[128], such as Nigra and Dimitrijevic (2018). This analytic method is based on the approach that derives from the theory of innovation discussed by Henderson and Clark (1990), used to understand the impacts of a project. The impacts can be divided into economic, environmental and social, and have been evaluated through a rating scale that varies from irrelevant to radical change. Each impact section is subdivided into different parts, as it can be seen from the following table.

[126] "We cannot do a project without knowing where, why and what we are going to cultivate". With this statement Augustin Rosenstiehl, a Parisian architect at Atelier SOA that collaborated with Dr. Despommier, said that site specificity is the fundamental for any Z-farm project. Hence, any Z-farm proposal have to be designed to be adapted to precise place (Venkataraman, 2008).

[127] The "spot" type has been critically excluded as it represents an ephemeral architecture that has not a real strong relationship with the context, because it could be located everywhere.

[128] See: Nigra, M. (2017). Complexity theory as an epistemological approach to sustainability assessment methods definition. In *DS 87-5 Proceedings of the 21st International Conference on Engineering Design (ICED 17) Vol 5: Design for X, Design to X, Vancouver, Canada, 21-25.08. 2017* (pp. 159-168).

Nigra, M., & Dimitrijevic, B. (2018). Is radical innovation in architecture crucial to sustainability? Lessons from three Scottish contemporary buildings. *Architectural Engineering and Design Management*, *14*(4), 272-291.

Table 3 Criteria table

Environmental	Social	Economic
Reduction of food chain	Accessible/niche product	New urban economy
Building performance improvement	New spaces for the neighborhood	Jobs creation
Use of resources	Knowledge acquisition/ education	Market strategy
Reuse of building	Creation of new services	Construction cost
Reduction of heat island		Maintenance cost
Variety of products		Branding and communication
Resources generation		Success

For each point has been evaluated the performance on a scale of values from 0 (minimum) to 5 (maximum), 0 (for the unsuccess). In the end, it has been calculated the average impact for each class. The arithmetic mean has been used to calculate the average value of environmental and social impacts. Whereas, for the economic impacts has been used the weighted, by giving more importance, first to the economic success[129], and secondly to the number of jobs created. The data have been analyzed in the following paragraph and compared with the material collected during the research period.

Criteria analysis

As just mentioned, each criterion is evaluated on a scale from 0 to 5. the different criteria are used to analyze the various aspects of the farm and contribute to giving an evaluation that can bring out which of the farms has the best performance. Below are illustrated the meaning of each criterion used in evaluating farms.

[129] It was not possible to collect the precise economic data (annual turnover, costs, etc.) of the different farms since strictly confidential.

Environmental aspects: in this group are contained all those characteristics that have an impact in terms of sustainability understood as a reduction of carbon footprint, reduction of energy consumption, etc.

- *Reduction of food chain:* this value increases when steps from producer to consumer are reduced, by reducing this distance inevitably the foodmiles decrease, favoring fresher food (harvested during the day) and greater profits for the producer and not for the complex food chain (see also paragraph 4.3). The higher values refer to the greater step reduction, so when the product is directly sold by the producer to the consumer (eg farmer markets, retail greenhouses, value 5), there are other types of relationships (delivery at home via electric cars such as Lufa farm, value 5, or other means 4), up to the typical industrial distribution model through a very articulated chain that ends with the visit to grocery stores.

- *Building performance improvement*: this aspect refers to the improvement of the building's performance following the inclusion of the farm in the existing building. The thermal performance of the building is partly improved, for example, due to the creation of greenhouses on the roofs that have created greater insulation in the roof area and heat reduction (value 4). In other cases, the construction of an indoor farm has led to the entire redesign of the building body with very high thermal insulation performance (value 5). Performance does not increase visibly, or is relatively neutral in some cases (re-use of underground spaces, value 3)

- *Use of resources:* one of the most critical points of this type of production is precisely the use of resources. While in the open field the resources are mostly supplied by nature (light, rainwater, etc.), the Z-farms need energy in almost all the plant growth process. Energy requests vary from farm type (greenhouse or indoor building) and are higher for the vertical farms where the solar contribution is zero and therefore LEDs are used, unlike the greenhouses on the roofs that most of the lighting takes place in natural way.

- *Reuse of building:* one of the most critical points of this type of production is precisely the use of resources. While in the open field the resources are mostly supplied by nature (light, rainwater, etc.), the Z-farms need energy in almost all the plant growth process. Energy requests vary from farm type (greenhouse or indoor building) and are higher for the vertical farms where the solar contribution is zero and therefore LEDs are used (value 1-2), unlike the greenhouses on the roofs that most of the lighting takes place in natural way. However, depending on the geographic position, the greenhouses need energy supplies in terms of light and heat during the winter period (value 3), so the values can be variable (in some cases the required energy supply is produced by solar panels, so the values appear to be high, value 5). In some cases, vertical farms are located underground where there is an almost static climate all years long so, request for heating are low.

- *Reduction of heat island:* One of the benefits of urban agriculture is usually the reduction of the heat island as the soil and plants are able to absorb solar radiation and reduce the overheating of the surrounding urban environment. In the case of green roof or rooftop gardens the absorption values are very high (e.g. part of the Ferm Abatoire is a rooftop garden, value 5), the values decrease with the greenhouses (however they can absorb a lot of solar radiation and decrease the perception of heat, compared to a simple flat tarred roof), while they are null with indoor farms.

- *Variety of products:* depending on the type of farm, there are variable numbers of "biodiversity". The greenhouses allow you to grow many fruit-bearing vegetables (such as tomatoes, aubergines, courgettes, cucumbers) and this is made possible thanks to the use of solar radiation(for those reason valuer are high, 5), able to provide the correct contribution for the growth of the plant (in winter it they use lamps to make up for the lack of natural light), while indoor farms are more suitable for growing leafy vegetables, hence less variety of vegetables (value low 1). In some cases, even in the presence of greenhouses, there are mono-cultivations or cultivations with reduced variety.

- *Resources generation:* this aspect assesses the integration of energy production systems as solar panels (for electricity and/or heating, best value) and rainwater recovery (+ 1 points), intended as a fundamental resource. Among the resources it is also included the creation of compost (+1 point), in some cases reused in the farm or sold to third parties.

Social: in this group are contained all those characteristics that have an impact on the daily life of people, that improve the neighbour quality by creating new services and educate inhabitants.

- *Accessible/niche product:* this value is useful to understand how affordable the product is and which user base it can reach. This can be defined based on the cost of the products.

- *New spaces for the neighbourhood:* this value symbolically represents the spaces that these private activities offer to the community. These spaces can also be seen as recreational areas, for workshops and also for profit-making activities.

- *Knowledge acquisition/ education:* the introduction of these farms has in part led to greater food awareness in the neighbourhood where it is located. Furthermore, even in small cases, local staff are instructed, and educational activities are carried out for young people, visits and meetings with the local population.

- *Creation of new services:* this index is used to evaluate how these new farms have contributed to providing new services, such as customized bask delivery at home, new types of products, apps to improve the relationship between producer and grower, etc.

Economic: in this group are contained all those characteristics that have an economic impact and, since the case studies are private enterprises, the following elements are important to evaluate the real economic impact hence the success of these farms.

- *New urban economy:* this evaluate how globally have impacted this new enterprise. For instance, if there are collaboration between different stakeholders (partnered farms) that enrich the local economies

- *Jobs creation:* this represent the job offered by the enterprise (both inside the farm and for the distribution chain).

- *Market strategy*: this feature evaluates the efficiency of the choice to position itself in the market through b2b, b2c or mixed models. Very often "innovative" choices, such as mixed choices, have had better results (values 5). Other choices have been evaluated with lower values also based on the success / failure of their strategies.

- *Construction cost*: this assessment represents the construction costs and, therefore, the related loss risk. The highest values represent the lower costs, while low values represent high construction costs (and higher risks of recovering the initial investment).

- *Maintenance cost:* Higher value reflects minor maintenance costs. Costs are related, for instance, to the use of more durable materials, dimension (eg. small size farms required less resources).

- *Branding and communication*: the value of this aspect is linked to the company's ability to create a winning brand and excellent communication strategies (through social channels, internet pages, blog, etc.) in order to create a strong brand identity and a close to the users, trough social campaigns. The values vary according to the communication skills and identity of the farm: higher values are related to better communication and brand strategies.

- *Success:* the values represent the achievement of success (or bankruptcy-bankruptcy) of the farms. In cases of total failure(farm closure) the value is zero.

Greenhouse Z-farm projects	Reduction food chain	Building performance improvement	Use of resources	Reuse of building	Reduction of heat island	Variety of products	Resources generation	Average value	Accessible/niche product	New spaces for the neighborhood	Knowledge acquisition/ education	Creation of new services	Average value	New urban economy	Jobs creation	Market strategy	Construction cost (1 High)	Maintenance cost	Branding and communication	Success	Average value
	ENVIRONMENTAL								**SOCIAL**					**ECONOMIC**							
Lufa Farm	5	4	3	3	4	5	3	**3,9**	3	1	2	5	2,8	5	5	5	2	4	5	5	**4,7**
Urban Farmer The Hague	5	4	3	5	4	4	1	3,7	3	5	5	3	**4,0**	4	2	3	1	4	4	0	**1,7**
Gotham Greens Gowanus	5	4	5	1	4	2	5	3,7	4	1	2	1	**2,0**	5	4	5	2	4	5	5	4,5
Skyvegetable	4	4	3	1	4	2	1	**2,7**	4	1	2	2	2,3	4	1	2	2	4	2	2	2,2
Ferme abatoire	5	3	3	1	5	5	1	3,3	5	4	5	2	4,0	5	5	4	3	4	3	4	4,1

Table 4 Evaluation of Greenhouse Z-farm projects

	Indoor Vertical Z-farm projects	Aereofarm	Aquagreen	GrowUp	Growing underground	Farm.One
ENVIRONMENTAL	Reduction food chain	4	5	4	4	5
	Building performance improvement	5	4	4	3	3
	Use of resources	1	1	1	3	4
	Reuse of building	5	5	5	5	5
	Reduction of heat island	0	0	0	0	0
	Variety of products	2	3	2	2	4
	Resources generation	1	1	1	1	1
	Average value	2,6	2,7	**2,4**	2,6	**3,1**
SOCIAL	Accessible/niche product	3	4	4	5	1
	New spaces for the neighborhood	0	1	1	2	1
	Knowledge acquisition/ education	1	1	2	2	1
	Creation of new services	1	1	1	2	4
	Average value	**1,3**	1,8	2,0	**2,8**	1,8
ECONOMIC	New urban economy	5	4	4	4	5
	Jobs creation	5	3	2	4	2
	Market strategy	5	3	3	5	5
	Construction cost (1 High)	1	3	3	5	5
	Maintenance cost	3	3	3	4	4
	Branding and communication	5	3	2	5	5
	Success	5	4	0	5	4
	Average value	**4,5**	3,5	**1,6**	**4,7**	4,0

Table 5 Evaluation of indoor vertical Z-farms projects

The results: "ingredients" for a successful Z-farm?

It is not possible to give a unilateral answer to this question, as there are many variables in a complex system. However, starting from the failures and successes, it is possible to reach some conclusions, also using the results of the previous tables. In short, the results of the table consider Lufa Farm and Gotham Greens the best cases of the greenhouse on the roof. While the economic performances for Growing Underground and Aerofarm can be considered virtuous with regards to the indoor building typology. Shown below, an assessment is made in detail, starting from some considerations deriving from the research.

As previously mentioned, the position is one of the fundamental aspects. The location affects both the type of Z-farm and the products (leafy vegetables, herbs, edible flowers, tomatoes, courgettes, etc.). Likewise, the connexions created between these three variables are bilateral, if one changes, the others can also change. Beyond the material variables (location, architectural typology, cultivated products) there are also intangible ones, such as the business strategy.

Location – Architectural typology – Products

First, it is important to explain this trivalent bond. There is no term that has more priority than the other: everything depends on the initial choices of the future farmer. For example, if the position is chosen first, the architectural typology to adopt (greenhouse on the roof or cultivation inside the building) will be based on that choice and, consequently, also the products.
Analyzing the processes that led to the creation of some farms, it is possible to notice how the products choices, for example, have influenced the choice of the architectural type and location. In the case of Lufa farm, the entrepreneurs wanted to build a farm for cultivating different varieties of products (tomatoes, courgettes, aubergines, leafy vegetables, cucumbers, etc.)[130]. As a result, this was possible only with a greenhouse. Hence, they looked for a roof that could accommodate their farm. Among the criteria of the research, there were: the need for large sunny roofs, a very low rent, the proximity to the city and infrastructure networks. Other companies have shown how the desire, for instance, to replace the imported leafy vegetable market has led them to choose large disused factories or former warehouses in urban industrial area for indoor vertical farming. Farm.One shows, instead, how the business choice to offer a sought-after product (edible flowers and rare herbs) for a niche market (almost luxury), have led them to locate themselves in the city center (Manhattan), near restaurants and wealthy customers, settling their

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[130] The localization of Lufa farms is also fundamental because it allows them to collect products from other farms (both of Lufa and partnered ones) quickly, as they are in the city but close to major roads.

farm in underdeveloped places like cellars. Regarding this last case, Paul Hardei[131] has underlined how the study of the product is at the base of the technological choice of cultivation and of the suitable structure (greenhouse or indoor Z-farm building).
Therefore, the position of a Z-farm becomes perfect when meets the needs of the crop, the availability of resources and the selected target market. So, if the entrepreneur's desire is to build a farm that can offer a wide variety of products, then a greenhouse on an industrial roof, without shading and well connected to the city is the best solution, as in the case of Lufa Farm. If instead, the investors want to develop a monoculture of leafy vegetables[132], they should focus on maximizing production with vertical farming in abandoned buildings[133], well connected to the road's networks. Whereas, when the will of a company is to create a unique, "experiential" product, then the "best practices" could be to create small cultivation areas in the city center, like the case of Farm.One (or InFarm, among the case studies)

These examples have been useful in explaining the trivalent relationship, now the economic components that contribute to the success of the farm will be analyzed. Among them, the most impacting are:

- The market strategy
- The branding and communication strategy
- The jobs creation

The market strategy

Lufa farms have managed to create a virtuous market strategy, by producing and becoming a food hub for other partnered organic farms. The pivotal point of its "b2c" strategy is also the "home delivery" distribution. Lufa farm customers can choose their products through the website, and have them delivered directly to their homes, thanks to the "eco" delivery service with electric vehicles. The decision to create this new service for the citizen, the willingness to provide certified high-quality organic food, as well as the choice to diversify production through partnerships with other farms has been the winning strategy. This distribution

[131] He is the co-Founder of FarmedHere, a former vertical farm in Chicago, that now is closed. He has attended as panelist the conference "Aglant: An Examination of Shuttered Vertical Farming Facilities", hold in Atlanta on the 19th February 2017

[132] Herbs, flowers, leafy greens, microgreens, are the most appropriate crops and the most profitable plants for hydroponic indoor and vertical farming(Arnold, 2017).

[133] According to his previous experiences, Mike Nasseri, - speaker at the mentioned panel "An Examination of Shuttered Vertical Farming Facilities"- suggests choosing cheaper urban area, like industrial ones, for commercial operation since more economically advantageous.

model is detached from the traditional supply chains of grocery stores and renews the traditional CSA[134] model.
The example of Gotham green, on the other hand, demonstrates how success can be achieved through collaboration with large retailers. This company, in fact, secured its profit by becoming the first supplier of leafy vegetables, basil and other herbs to the Wholefood grocery chain. Both strategies shown are considering increases production and in the number of customers in the following years. This same model is used by other types of farms like Aerofarms, which has decided to devote itself entirely to large-scale distribution and also creating partnerships with airline companies, as Singapore Airline (Fitzpatrick, 2019).
The last model is the "niche market", as in the case of Farm.One. This choice greatly reduces the number of customers (mostly restaurants which require premium quality products but in less quantity[135]), becoming very elitist, however, its profit derives from the sale of rare and sought-after products, with excellent qualities.

The branding and communication strategy

The branding and the communication strategy of commercial urban farms – together with a strong social media presence- is important to reinforce local food ad a lifestyle choice (Proksch, 2016, pag. 169). Successful urban farms know how to communicate their storytelling, their products and to motivate consumers to buy them, through a careful and well-studied communication plan based on social interaction (Instagram, Facebook, Twitter) and the web page by which informs on event and news[136]. Many farms rely heavily on the "parochialism" of their production with the slogan as "Made in Brooklyn", "Grown in London", etc.

The jobs creation

In addition to generating wealth, these small economies have produced a fair number of new jobs (Benis & Ferrão, 2018; Gorgolewski & Straka, 2017a) although obviously not comparable to industry. Thanks to mechanization, many processes have been speeded up. However, many activities (such as the harvest) still take place through human activity. Precisely the cost of labor influences the delicate financial statements. For this reason, the research is aimed at robotizing many production steps, to the detriment of manual work. The types of jobs present in a Z-farm are different from traditional agriculture where no particular academic

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[134] Community Supported Agriculture

[135] This has been expressed by Matt Liotta and Mike Nasseri during the conference "Aglant: An Examination of Shuttered Vertical Farming Facilities", hold in Atlanta on the 19th February 2017

[136] Lufa farms, for instance, communicate through social and have an active website by which is possible not only order the food but also have information on how use the products thanks a blog with recipes or information on the seasonality of fruits and vegetables. For further info: https://montreal.lufa.com/

knowledge is required. Engineers, chemists, and agronomists are among the professional figures required by the Z-farm market, as well as unqualified but trained personnel on this new type of production. The size of the farm and the type of distribution and the market strategy influence the number of employees. Small-sized Z-farms tend to have no more than 5-10 operators, as in the case of Farm.One, Skyvegetables, GrowUp. For the larger Z-farms, the number increases, thanks also to the business that creates (communication and marketing office, distribution, partners for the CSA model, retailers, etc.), for example, Lufa Farms employs over 140 people. Consequently, in terms of impact on the number of workers, medium / large z-farms obviously have larger numbers.

The environmental impacts

Since there has been a great deal of discussion about the sustainability of these new farms, environmental impacts have been assessed in relation to the urban context. Mostly all the z-farms reduce the food chain, compared to the traditional one. In fact, the food produced is directly sold to the customer or through a directly connected intermediary to avoid food miles or prolonged use of the cold chain. For this reason, proximity to retailers or distribution centers and the creation of a green distribution network (see Lufa Farms' delivery service) are important points to consider as best practices.

The reuse of a building (in whole or only in part as the roof) has to be considered a "best practice" as it avoids the land consumption (Benis & Ferrão, 2018) as well as redeveloping a structure and generating a small urban economy. Moreover, in many cases, the creation of a Z-farm has led to improving the energy performance of the building (for examples wall insulation, improved performance of windows, etc.). This is especially true for the Z-farm rooftop greenhouse. The rooftop greenhouse type has to be considered among the best practices, as it reduces dispersion, increases the insulation (both in summer and winter) (Dubbeling, Orsini, & Gianquinto, 2017; Gorgolewski & Straka, 2017a) of the building below (thanks to the "buffer zone" effect, typical of the greenhouse) and creates, in some cases, a synergy and a recirculation of resources. Therefore, there is a reduction in consumption both for the building below and for the greenhouse, despite it is an energy-intensive element in some situations (extreme cold as in North America or hot environment). Another benefit of the Z-farms rooftop greenhouse compared to the indoor vertical farming typology[137] is that it reduces the heat island effect, decreasing the temperature of the surrounding area (compared to the effect of a traditional flat roof). Moreover, many of the cases of rooftop greenhouse Z-farm

[137] For this reason, the score "Reducing heat island effect" of the indoor VF Z-farms in the table is zero

recover rainwater, which is then reused for cultivation. Some Z-farms rooftop greenhouses also generate resources through solar panels (see Gotham Greens), this is certainly to be considered as a best practice for future projects. Indeed, the creation of resources is fundamental for future projects, especially as regards the indoor buildings Z-farms, because they would allow outweighing the disadvantage of the lack of solar energy (Shamshiri et al., 2018).
Finally, from an environmental point of view, the production in greenhouses allows the cultivation of more varieties of plants (tomatoes, aubergines, courgettes, etc.) favoring the creation of a "biodiversity" and greater CO2 storage compared to indoor building cultivation where only leafy vegetables and herbs can be cultivated.

Evaluating the social impacts

The cases presented are dedicated exclusively to the commercial production purpose, however, in some cases, they have social repercussions., Among them there is the access to organic and local food at competitive prices (accessibility vs. niche product), as in the case of Ferme Abatoir, where products can be purchased at grocery stores (GrowingUnderground, GothamGreen) or at farmers' markets or farmers fair (such as Skyvegetable or Aquagreen at Artscape Wychwood Barns, Toronto). These projects are usually private (although in some cases sponsored by investments, including public ones) and therefore do not involve the creation of public spaces. However, some of them include spaces open to the public or for activities or events (see UrbanFarmers in The Hague). Some Z-farms organize periodically activities and visits open to the public for educational purposes (Open day or Friday for school at Lufa Farms, guided visits to GrowingUnderground, at Ferme Abattoir, etc.). this attitude can be considered a best practice for several reasons: it educates and informs the population about new technologies in the agricultural field, it gives visibility to the farm, it creates a clearer relationship with the customer (who sees how food is grown), it makes the citizens more involved to the neighborhood life.
Finally, some farms have developed not only products but also service, such as home delivery. This service is useful for those who have mobility problems but also for those who wish to spend their expenses directly at home. This is a plus value much appreciated by customers of Lufa Farms. Lufa Farms, in addition to that, offers to associations for social vegetables gardens (or sells for paltry amounts to other consumers) compostable resulting from their cultivation.

6.2. A possible market: urban z-farms as a driver of a new food-retail revolution

"If quality attributes related to appearance, flavor, and aroma, and nutritional well-being can be manipulated and controlled by the spectrum of growth light, specialty crops produced with specific light prescriptions may have competitive advantages in the marketplace with field-grown produce shipped from afar. This form of value added goes beyond 'local grown' and 'freshness' and is an area of intense research interest" (Mitchell & Stutte, 2015). This apparently simple affirmation has given rise to a discussion on which are the possible consequences that a product, that becomes "sought after", can generate. In fact, if Z-farming product is considered an asset, that due to its intrinsic characteristics does not compete with others similar (food) because it is completely different since is sought as such, then there could be the prerequisite to modify the current food system or generate a parallel one, as Lufa Farms aims to do.

As a result, it could be a revolution for the conventional food store typologies, both for the existing buildings and for future new developments; in fact, the future grocery models could adopt new architectural shapes or integrate a growing area in their own volume. As a consequence, building codes must be reviewed to integrate farms in the urban environment and regulate the design and construction of these structures, as well as the management of flows (internal goods, processes, resources such as energy, water, and air). Currently, the difficulties are mostly related to the creation of an external volume (a greenhouse on the roof), due to structural deficits or the impossibility of using external spaces (roof) because of building regulations as well as zoning roles, while apparently there are no complications in integrating a growing area (vertical farming in boxes) in existing food shops (as in InFarm, in Germany).

Figure 50 Vertical farm module by InFarm, Berlin, courtesy of Infarm

Figure 52 Eye Bird view of Wholefood. Source: https://gbdmagazine.com/2015/whole-foods-market-brooklyn/

Figure 51 Whole Food Grocery + Gotham Greens, Brooklyn, Maicol Negrello

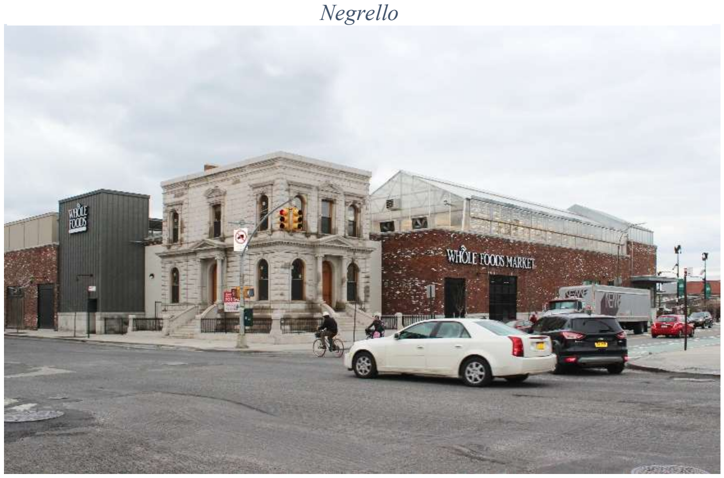

Figure 53 Whole Food Grocery + Gotham Greens(street view), Brooklyn, Maicol Negrello

However, in this last case it would be a production for an "experiential" food for the customer (who buys the product that has been cultivated under his eyes), rather than a real commercial production with a wider choice that could derive from the use of a greenhouse (such as Lufa Farms, Gotham Greens, etc). The integrated design process has been partly tested in the Gotham Greens Z-farm project, on the roof of the grocery Whole foods, in Brooklyn. Although this was a first experimentation of integration "production+retail", it is an excellent starting point to think about which the needs for this type of architecture are. Thanks to a survey conducted by the author, it was possible to notice which are the design elements that need to be implemented in order to reach optimal design guidelines. The pictures (24,25,26) show the building at present. As can be seen, the volume dedicated to farming is positioned on the roof next to the bar/restaurant. There are no elements of union between the two bodies, separated by a small terrace accessible only to the staff. The two parts share the vertical distributive element (stairs and elevator with the function of freight elevators for goods). The lack of distributive spaces reserved for the connection between production and retail is problematic because customers intercept the goods and the comings and goings of boxes, materials, and staff. The future project should consider the idea of creating a dedicated connection just for the farm. It could also be interesting to develop an area dedicated to the transformation of raw materials for preparations such as salads, sauces, pesto instead of transporting the raw materials, grown in a greenhouse, to another building and then being returned to the grocery store. Furthermore, it would be appreciated for communication and educational aims, if consumers could be allowed to observe directly the farming process through physical barriers (a glass partition wall) ensuring a clearer way to produce. In this way, the consumer could learn and be more interested in buying a certificated product. It must be said that it is understood that the consumer has a basic knowledge of correct nutrition, however, this layout of the spaces could also have positive repercussions both from an educational, but above all economic point of view: people who see what their food is made of are more motivated to buy the product continuously. The use of energy resources is one of the elements that have a greater impact on the economy of the farms. For this reason, it is appropriate to design (where possible) rainwater recovery systems and solar panels. The aforementioned exemplary case exploits the supermarket's large parking lot to create solar covers that provide for the farm's electricity needs and also provide the supermarket. In this way, the farm becomes independent of the other urban resources, thus becoming in synergy with the environment of the city. new projects must take into consideration the creation of solar farms where possible, in addition to the construction of heat pumps for heating or cooling the greenhouse and the building.

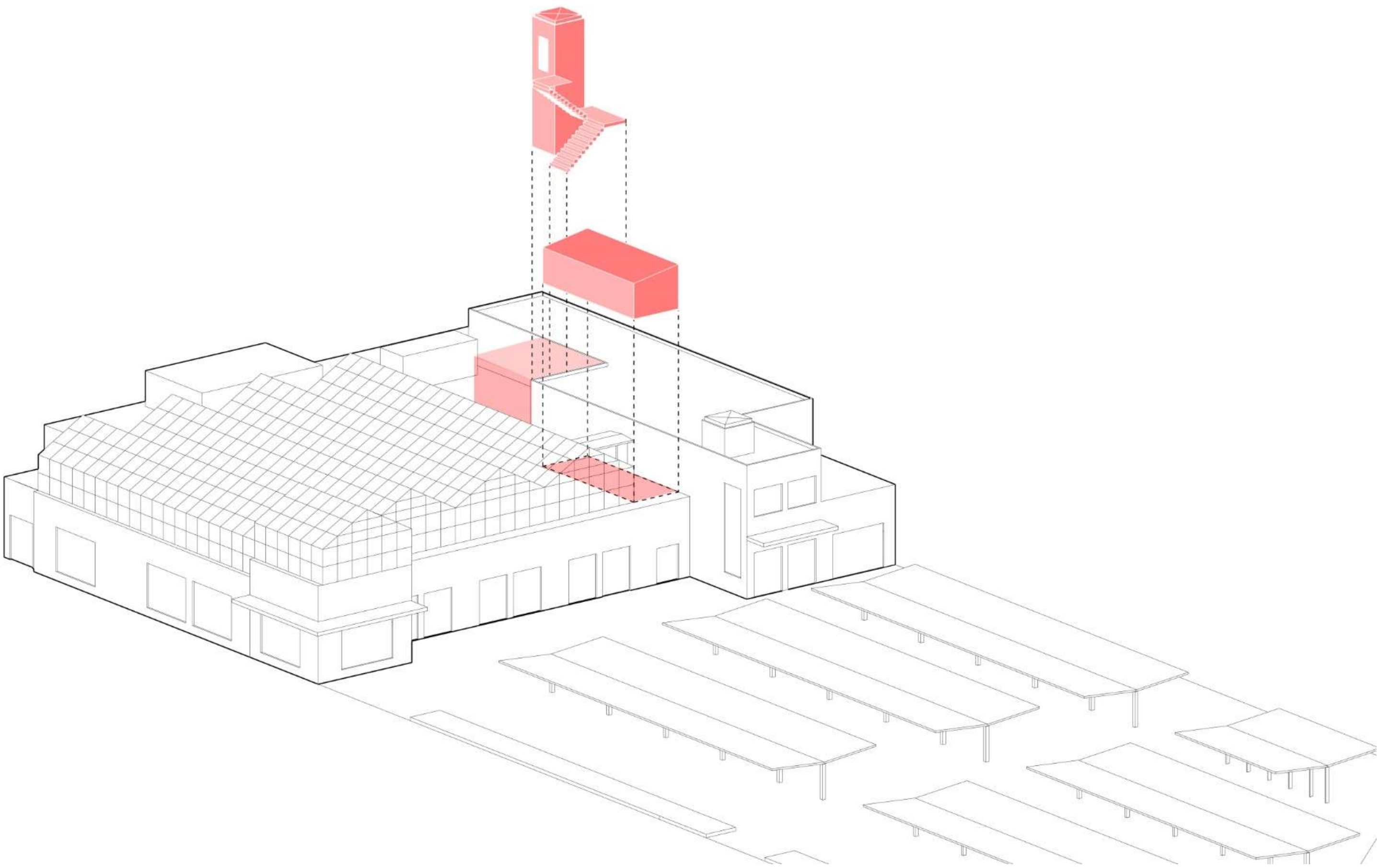

Figure 54 Elements of improvement, illustration by Maicol Negrello

6.3. Adapting existing spaces for new productions: the toolkit

As mentioned in the first chapter architecture at the beginning of Z-farms, has given extraordinary visions of futuristic - as utopian – farms. However, soon it has been demonstrated that those scenarios, although interesting, could not be real, but just a “placemaker”. Back to the real world, agriculture has tried to adapt to the urban environment through Z-farms by using urban voids, underused areas, abandoned structures. Thanks to interviews with architects, contractors, entrepreneurs, professors, urban planners[138], it was possible to identify what are possible future scenarios to regenerate spaces and architectures for agricultural production.

First of all, it is important to understand which type of farm to adopt in relation to the urban location and the structure of the host building (if it is integrated into a building[139]). Furthermore, the roof lease needs to be long enough (Fesquet, 2015) to be able to ensure the development of the activity. Other aspects to take into consideration are municipal planning, zoning requirements and building codes that can have impacts first on the location(Gorgolewski & Straka, 2017b), then on the architectural shape.

Rooftop greenhouse Z-farm

After choosing the location, the process flows for the creation of rooftop greenhouse Z-farm start with:

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[138] Among them Michael Grove, Chair of Landscape Architecture, Civil Engineering, & Ecology at Sasaki (http://www.sasaki.com), Sabine Karsenti, Sale Director for Le1420 Boulebard Mont-Royal, Jacques Besner, urban planner and consultant for Société de transport de Montréal, City of Shanghai and General manager of ACUUS (Association des Centres de recherche sur l'Utilisation Urbaine du Sous-sol), Carolee Kakola a planner, urban designer and currently director of Enterprise Operations at Bubbly Dynamics, LLC / The Plant, June Komisar, associate professor in the Department of Architectural Science at Ryerson University, Mark Gorgolewsky Chair of Ryerson’s Department of Architectural Science, Joe Nasr, Centre for Studies in Food Security, Ryerson University, and others.

[139] Since this part is focused on the creation of a best practices / toolkit, it will be directed to the description of the creation of an integrated rooftop greenhouse (i-RTG) Z-farm, which it is considered the best example of resource efficiency compared an isolated greenhouse rooftop (no exchange with the building below). In fact, the integration of building’s water flow (such as rain water and greywater)with the farm can avoid water waste, thanks to a closed system (Sanyé-Mengual, Rieradevall, & Montero, 2017). In addition, the building can also reutilizes the surplus of heat or cool from the greenhouse to improve the thermal comfort of the building by reducing energy requirements(Sanyé-Mengual et al., 2014) and residual CO_2 from the building can improve plants growth. However, it is not always possible to integrate the flows (water, energy, CO_2) into the metabolism of the host building as this also depends on its use (residential, public, industrial, retail, etc).

1. the creation of a virtual model, called Urban Building Energy Modeling (UBEM), a digital twin of the area in which the farm is inserted to evaluate urban performances, also in accordance with the research conducted by Benis, Ferrão et al. (2018; 2017b). The studies have shown the importance of considering the surrounding city setting of a farm in order to evaluate energy demands[140] and, consequently, from productivity.

2. the structural analysis is crucial to understand the resistance of the floor and, if necessary, provide for the construction of reinforcement structures.

3. the analyze the hosting building energy performances through virtual simulation (Building Performance Simulation) for a preliminary pre-sizing of the heating and exhaust air recovery systems, and for all the building energy flows. This aspect is fundamental because the energy cost impacts on the project economy[141] .

4. the check for the availability and accessibility of resources (if the building is connected with public electricity and water infrastructure), and if it is missing, provide the connections. Check the availability of internal spaces in the building for any water and nutrient recovery tanks.

5. the knowledge of the uses of the common areas and the habits of the other building tenants to avoid problematic situations between farmers and other occupants.

These first steps represent preliminary analyzes of the site. It is assumed that economic evaluations have been discussed, but it will not be taken into account in this architectural / design analysis.

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[140] The energy demands, in the case of a roof greenhouse, are subject to the amount of solar gains (related to the geographical coordinates) because greenhouses must have maximum transmission of natural light(Montero, Baeza, Muñoz, Sanyé-Mengual, & Stanghellini, 2017), on the shading of other building, on the percentage of surrounding green area (since in a dense urban area the temperatures are warmer due to the urban heat island effect, that plays an important role in reducing heat demand).

[141] It is important to evaluate and quantify the impact of this intervention especially if the greenhouse and the host building are of different owners. In fact, the construction of the greenhouse will significantly reduce the heat loss of the roof and therefore an economic return to the owner of the host building, in addition to its roof being retrofitted.

The architectural process is made by different steps, after the resolution of zoning issues[142].

1. Orientation: according to some scholars, the preferable orientation is the East-West which would guarantee greater light transmission (Bot, 1983).

2. Roof slope: this affects the percentage of light absorption. The slope of the roofs also depends on the geographical coordinates and it is regulated (limited) by building codes. As reported by Montero et al. (2017, pag. 85), an inclination of 30° is recommended both from the point of light performance and from that of construction costs.

3. Greenhouse framework: again, this is depending on the building codes that require high (and higher compared to rural ones) coefficients of security for wind and snow load, fire and hail resistance, etc. As a consequence, structures are must very solid but at the same time, they do not have to be too thick, as they can reduce the light supply due to their shadings. So, it is preferable that the structure would be white painted to reflect the light. It must be considered the presence of other structures on the rooftop (or avoid the wrong placement during the integrated design), such as stairs, elevator room, building's equipment, that could partly cover the farming area and reducing crop growth (as it happens in Skyvegetable farm in the Bronx, New York City).

4. Materials: usually galvanized aluminum is used to guarantee greenhouse strength in order to limit the weight on the host building. The dimensions of the beams depend on the area (length and width) of the greenhouse, the climatic conditions and geographical position that contribute to increasing the requirements (e.g. snow load, wind resistance, earthquakes), the type of coating (double glazing, or other plastic materials), building code requirements. It is advisable to paint the white structures because they reflect the light more inside the structure.
   Rooftop greenhouses need to be cover by a material with a high transmissivity for sunlight (hence low reflective) and able to absorb and keep far infrared radiation inside the greenhouse to guarantee a better photosynthetic process and maximize the production.
   Also, provide for the inclusion of mobile thermic barriers (curtains) to

[142] Local planning and zoning requirements and building codes vary with each location and with the type of building and its use (Gorgolewski & Straka, 2017b)

prevent overheating during the summer and to reduce heat loss during the winter and reduce energy cost till 50%, especially in harsh climates (see Lufa farm).

5. Windows: in order to natural ventilation in spring/summer periods electronic windows are required both on the sides and on the roof. usually, the positioning of cooling systems with water and fans is provided near the openings.

6. Vertical connections: create a vertical connection (stairs and elevator) for the exclusive use of the farm (see Sky Vegetable), appropriate for move goods and material, in order to avoid interferences between users and farmers (see Gotham Green, Brooklyn). It is advisable to realize a connection (elevator) that links the production area (on the roof) with the "sorting area" / loading docks. This connection is strongly recommended because, usually, the use of the lobby elevator is forbidden for these activities (or accessible during a limited period of time, as at Lufa Farms, Ahuntsic-Cartierville, Montréal). These issues should be considered since the first design stage (Gorgolewski & Straka, 2017b). Furthermore, it is expected that safety ladders are built in case of emergency.

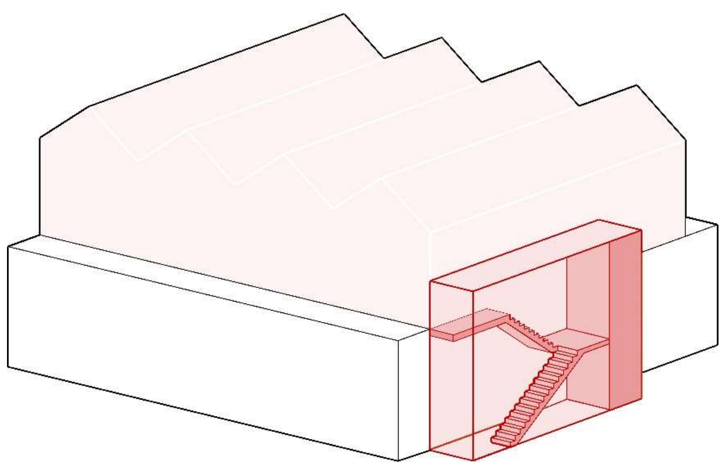

Figure 55 Example of optimal vertical connection, illustration by Maicol Negrello

7. Horizontal distributions: trolleys and forklifts require sufficient “manoeuvre areas” and corridors, this also depends on the size of the greenhouse. However, it is enough to provide space for manoeuvre

inside the greenhouse and corridors, between one row and the other, about 80/100 cm wide.

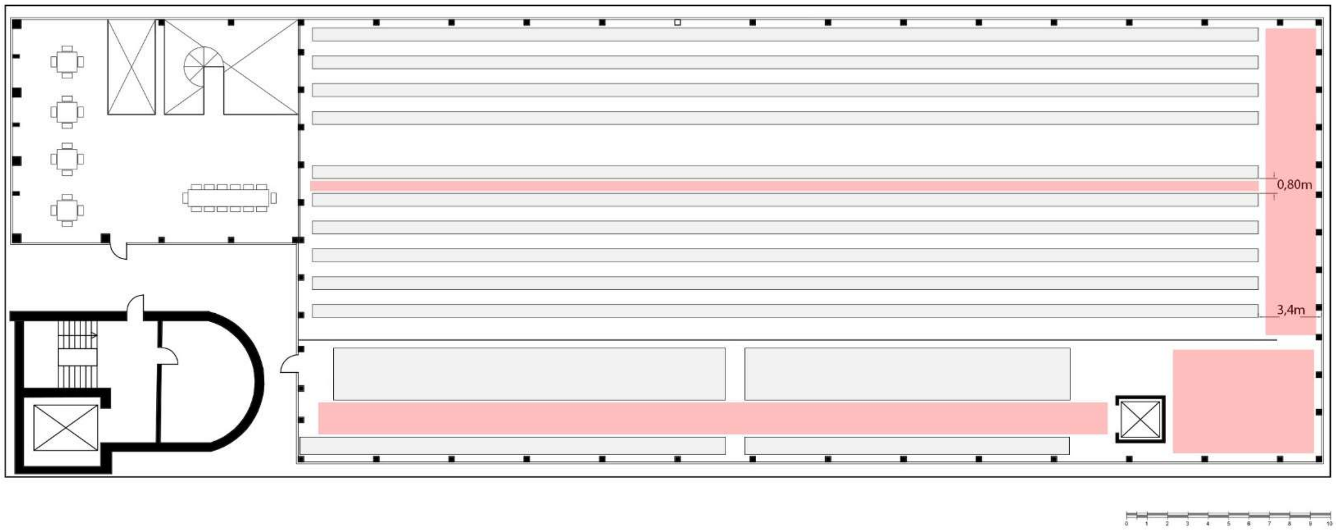

Figure 56 Urban Farmer The Hague, Space&Matter Studio, re-drawing by Maicol Negrello

8. Packaging area: it depends on the strategy of the farm, for instance, Lufa farms collect the vegetables from the rooftop that are brought to the basement where they are placed in the baskets. Since this space is a hub where other products from other farms are brought to be sorted, the dimensions are very high (around 1500sqm).
   In the case of medium/small farms, the packaging area is from 5 to 25 square meters.

9. Water and nutrients tanks: consider space for rainwater collection tanks and nutrients. This, in turn, will be connected to machinery for pumping and pressurizing water. Usually, it can be located in the basement. This space can also be dedicated to the treatment of compost, as in the case of Lufa farm, from which they profit.

10. Retrofitting: this point represents the maximum ambiance from a project of this type. The efficiency of the envelope through the creation (where possible) of the exterior insulation and finishing system (EIFS) makes it possible to minimize heat losses and passively heat the farm (Benis & Ferrão, 2018).

Cultivating in spaces where normally it could never have possible, it is the greatest benefit of innovative technologies such as LED and hydroponic systems. These have given the opportunity to re-evaluate and exploit unused urban spaces. According to some stakeholder interviewed in this research, it has been possible to define some scenarios of possible reconversion and of the uses of spaces[143] for indoor agricultural production. Michael Grove from Sasaki predicts that for example in cities where mobility will become increasingly public, many underground parking lots will be gradually abandoned, and these may be an optimal environment for developing this agricultural production. The same idea of re-appropriation of underground spaces seems to be positively welcomed by other stakeholders such as Michel Boisvert (urban planner and consultant for Société de transport de Montréal) and Sabine Karsenti (Sale Director for Le1420 Boulevard Mont-Royal). The first believes that abandoned spaces such as underground subway tunnels can be an excellent environment for growing plant varieties (even marijuana, now legal for recreational use in Quebec)[144]. Karsenti sees the future of indoor agriculture even in luxury real estate operations, where the underground floors become niche areas of strawberries, leafy greens, and refined herbs, as in the redevelopment project “The 1420 Boulevard de Mont-Royal”, or similar example such as Farm.One in Manhattan (New York City). The urban underground space seems to be more attractive as it is a limited and circumscribed space in which only a few activities can adapt (due to the lack of windows) and the intervention costs seem to be lower. Otherwise, industrial areas (although they have serious problems with pollutants) have much more possibilities for re-development through different uses, more profitable than the agricultural one.

In the case of former industrial structures, new companies used them as a shell and reconverted these structures with few architectural interventions, although expensive. As in the previous case for RG, after ascertaining the possibility of building the farm after having ascertained the possibility of creating the farm, the architectural process adopts the following steps:

1. Reclamation of the area from polluting materials, if are presents.

[143] Abandoned industrial facilities, basements of buildings, covered / underground parking, underground spaces, etc.

[144] It is considered to be a more profitable investment than leafy greens/salad, as well as plants for pharmaceutical uses.

2. Securing the building and making connections to water and electricity networks.

3. Provide internal insulation in order to ensure the airtightness of the entire building and avoid heat loss to the outside.

4. Choice of the technologies (hydroponic, dryponic, aeroponic) and construction of support structures for crops (towers or shelves). According to stakeholders involved in VF, the use of the multi-layered systems with grow beds reaching to the ceiling is not advisable[145]. A better solution is Zip typology since it optimizes the space, avoids overheating in each layer, improves air recirculation and, above all, facilitates control and crop collection operations.

5. Depending on the typology of growing structure (growing beds or vertical tubes), it must be considered spaces for corridors between shelf units or vertical ducts. Usually, for high size farms with high ceilings and multilayer beds (where scissor lift is required) corridors are up to 1,5 m, whereas for small size farm corridors are tighter enough for employees to perform their operations. Multilayers beds usually are placed 40 cm from each other.

6. Depending on the farm size, calculate space for packaging and temporary storage (it could be refrigerated in summer) before delivering.

In conclusion, it should be remembered that the choice of these typologies that are best suited to the structure in which they are inserted/positioned derives from an understanding of the factors mentioned in chapters 4 and 5.

Limits, and applications of the toolkit

The toolkit represents an idealized tool, which draws its reflections from the observation and analysis of case studies, through a process previously illustrated. However, it remains an ideal tool whose reproducibility depends on several variables. The first fundamental point to take into consideration is whether reproducibility represents a need, the desire to create a new business or the desire

[145] See paragraph 5.1 (maintenance cost). “Scissor lifts are not an ideal solution” states Nasseri, because use it is not practical/ ergonomics and not efficient for manual work (it takes more time, hence higher labor cost).

to experiment with this type of production in places that are still virgin (countries where this production has not yet developed). In the first case, reproducibility makes sense in inhabited areas where food resources are scarce (extreme climates such as the Arab Emirates or Nordic territories) and where the resources required by this practice are available or where the costs of goods produced locally are lower than the imported ones (excluding the question of nutritional values). The second point sees the question of reproducibility only from a commercial point of view. The need for this production does not derives from a primary lack of a good but from the desire to create a business for a new market. This usually happens when you want to create a market sector, niche.

Once this point has been exceeded, the limits of reproducibility are therefore the problems that have already been highlighted in the previous chapters. Urban policies (chapter 5.2), construction costs, management costs and resources to reproduce what already exists in nature are the greatest limits that this activity must face. In detail, this toolkit provides guidelines for the project of a Z-farm, however, there are gaps regarding ecological management (quantitative energy consumption) and the economic aspects of this business.

From these two assumptions comes my consideration: in places where the difficulty of finding fresh food, such as in large and dense cities (as Asian metropolitan area or Americans ones) or in territories with extreme climates (extreme cold/warm, with long cold winter or hot harsh summers), the reproducibility of these examples is justified by the lack of a primary good on site, in all other situations and geographical contexts it is necessary to verify the feasibility of the intervention, before the application of the toolkits. For these reasons, indoor urban farming commercial projects may have a future in areas such as northern Europe (including Iceland), where the climate allows limited cultivation periods. In Mediterranean areas, on the other hand, this type of production is likely to be poorly profitable since the costs of high-quality goods (grown organically and on the ground) would be lower than the costs of a Z-farm product, which requires greater resources and processing costs. However, this production, which is still struggling to develop in Europe, could be hypothetically successful if placed in commercial / recreational / educational contexts (market hall + educative course for urban agriculture + workshop + others activities) or for rare, sought-after or niche crops.

“Academic/didactic experimentations" have been carried out during the research process to test the design of those strategies. Through the design work elaborate by the students of the design atelier "*Costruire nel costruito*" (2017), where I took part as teaching assistant, and, in particular, by the research project[146] of Monica Dogliani, graduate student in “Architecture, Construction and City” (2018), that I supervised with tutor Professor Roberta Ingaramo and I, it was possible to trial my

[146] Dogliani, M., (2018), FEEDING THE CITY A Food Hub for Lisbon: proposal of industrial reuse, tutor Ingaramo R., Negrello, M., Politecnico di Torino

previously cited hypothesis to design of urban farms integrated with existing buildings and activities (commercial, educational and others).

Conclusion

This thesis aims to be a contribution in analyzing a complex contemporary urban phenomenon, which has seen its intensity grow over the last 10 years.
The topic of this research has been analyzed through historical research, understanding the processes that led to generating this idea, as it was the first questions. In fact, the overview on urban agricultural space shows how this was linked, in some cases, to factors such as periods of war, Liberty Gardens (1917-20), then Victory garden (between 1941-45) or crisis (like the energy crisis of the 70s), in others, connected to utopian visions of an urban-rural world as in “Broadacre City” (1934–35) by Frank Lloyd Wright, “New Regional Pattern” (1945–49) by Ludwig Hilberseimer or in Andrea Branzi’s "Agronica" (1993–94). Subsequently, the role of urban agriculture and its spaces evolve and are enriched by other functions, such as recreational, social education, in rare economic cases. Around the 2000s the idea of urban agriculture changed thanks to the advent of innovative technologies. Thus, in some cases, it becomes an activity considered almost an indoor "light manufacturing". These activities, first, should have been hosted in utopian projects, initially called vertical farms or skyfarms (as the Despommier projects), then, due to their complexity related to feasibility, they started to occupy urban (unused and already existing) spaces and architecture. Further, this thesis answers the question of how the term has evolved from Skyfarms to a more appropriate definition: the “Zero Acreage farm”[147]. This research attributes among the reasons for the genesis of the Z-farms the need to rethink the agricultural production system, closer to the consumer (that is now mostly disconnected (Proksch, 2016)) able to respond to environmental problems (pollution of soils and aquifers, air), to climate change, and to the forecasted urban growth (therefore food consumption).

The second objective achieved by this thesis is the definition of the spatial and architectural characters of the indoor z farms. After the description of selection criteria for the cases (geography, indoor and commercial typology), the data were collected and analyzed through a table with parameter that test the different characteristics of the farms. Starting from the results on an urban scale, it was noted that, in most cases, the farms are mainly located in industrial urban areas, directly connected to the downtown, to retails or to logistic/distribution centers thanks to the proximity to the urban infrastructure. The choice is not accidental, in fact, the low rental costs and the availability of built space (often abandoned such as former

[147] Farms that do not occupy fertile soil but develop above or within buildings thanks to the use of innovative technologies (hydroponic, dryponic, aquaponics and LEDs)

factories or warehouses) or underused (such as rooftop) are the elements that most influence the location. In some cases, the position is more central – downtown (see. Farm.one) and this depends on the type of product and business model.

From an architectonical point of view, the results show that there are two main typologies of farms: the building integrated agriculture (that are rooftop greenhouse linked with a host building) and the – so-called - vertical farm. These categories represent two different approaches (that in some cases can coincide). The first one is the addition of a structure – the greenhouse- above the building, with which it creates a sources synergy, whereas the second one is the insertion of the productive part inside a controlled environment as an insulating shell, such as a warehouse, former factory o an underground space.
From the analysis of the case studies, it is found that rooftop greenhouses (BIA) occupy in the 62,5% rooftop of industrial buildings because their concrete structure can support higher loads, the 25% are housed respectively on commercial buildings and 12,5% on residential one. Since in industrial areas the buildings have usually uniform heights, there are no shading problems, so they are suitable to host rooftop greenhouses. Whereas, for vertical Z-farm the 90% of them are hosted in a former industrial facility because are mostly medium/large scale farm and required spaces. Among the result, there is no direct relation between dimension and success. Data showed that 38% of rooftop greenhouses Z-farm are over the 3000 sqm, 34 % between 1000-2000 sqm, and 25% less than 1000 sqm. While vertical Z-farms, the 33% has an area greater than 6000sqm, most of them (50%) are under 1000sq.m, 17% has a surface between 1000 and 6000sq.m.
The survey finds out that there is a trivalent bound between location, architectural type and product (see paragraph 6.1). For instances, fruit vegetables as tomatoes, aubergines, cucumber, etc., require for growing a great amount of solar radiation, that is possible just with the use of a rooftop greenhouse (and a lightening system to overcome the lack of light in winter), otherwise it would extremely expensive and, above all, environmentally unsustainable, cultivate them with LED. Whereas, products such leafy and micro greens, flower, and special herbs are suitable for vertical farming since they are small (so they can be piled on shelves), therefore any type of closed environment that has connections with electricity and water. It can be said that the architectural aspects have a great economic footprint (construction cost), however, the success of these farms in most cases depends on the business model. Talking about success, usually, media tend to exalt successes and enhance some qualities. Moreover, scholars underline the how Z-farm can contribute to producing part of food for city inhabitants(MacRae et al., 2010; Nasr, MacRae, & Kuhns, 2010) reducing – partly - the impact on agricultural lands and

food miles[148], and contribute to be a more sustainable and complementary food production (Pinstrup-Andersen, 2018).

This research, therefore, refutes these statements, highlighting also the real problems that lie behind the common communicational-image of the Z-farms. In fact, this research illustrates which are the main reasons that caused the failures occurred in recent years. Among them, urban location and distribution model, competitive uses, market target, construction costs, and maintenance and labor costs, zoning and building code issues, questioning on the social acceptance of these models and on the real sustainability of Z-farm, generally can contribute to unsuccess.

The pieces of evidence previously mentioned have generated critical debate on the possible adaptation proposals to facilitate the inclusion of these activities in an urban environment. Therefore, chapter six represents a sort of conclusion of the research and the analysis process, that is expressed through design strategies for solving the problems mentioned in chapter 5. Indeed, the architectural approach strategies are defined in consideration of a corollary of aspects that derive not only from architecture but from all the typical variables[149] of the contemporary urban environment, and above all case specific (Benis & Ferrão, 2018).

In conclusion, this study led me to review the image of the Z-farms, very often represented as the only future for agriculture. Surely the impact of these realities will increase in the future, but it will not be the ”cure-all for hunger” (Mandel, 2013, p. 3) and to feed 10 billion people, since most of the products (especially for vertical farms) are low-calorie vegetables (Haßler, 2018b). Z-farms can ensure an urban fresh food supply, above all the rooftop greenhouses, but it cannot entirely substitute field farming, however, it would rather be complementary (Haßler, 2018a). It could represent a great supply for locations with scarce local production (due to extreme climate condition such as Emirates or north remote regions as Nunavut and Nunavik) and totally depending on import. Moreover, Z-farming represents also a possible future for other sectors as medical and pharmaceutic and food services integrate with farming[150].

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[148] Even if, in the research, it is shown that “food miles alone are not the best way to judge whether the food we eat is sustainable” (McKie, 2008).

[149] Among the variables we find the problems arising from zoning and building code, in many cases obsolete. Municipalities should update the regulations to facilitate these activities, as some cities like Boston, NY and Paris (with the project “Parisculteur”) are doing.

[150] From the academical and design point of view, I had the opportunity to experiment with these strategies thanks to the thesis work of some students of the Master degree in "Architecture, Construction and the City", among which I mention the project for "The Lisbon Farm Food Hub" by Monica Dogliani. Moreover, during the Design Atelier "Building in the Built", I collaborate with prof.Roberta Ingaramo and the students for the realization of Z-Farm integrated with Food services, by reusing and adapting former industrial buildings. These projects can be found in the article: Negrello, M. (2018). " Agricultural factory": industrial reuse for innovative production towards more sustainable cities. In *International Symposium on Greener Cities for More Efficient Ecosystem Services in a Climate Changing World 1215* (pp. 165-170).

Another last reflection is dedicated to the transfer of these knowledge and technologies to the areas of greatest demographic growth (and where it has been envisaged), in order to use Z-farms for the high populated areas, especially for low-income countries.
Since the need to improve the food system and make it accessible to most people was among the first ideas at the base of Z-farms, it may seem discordant that currently, this practice is active in the major developed cities of the northern hemisphere. However, an explanation to this can be given by excerpt "Cities First – Rural Development Later" by Jane Jacobs from her "The Economy of the cities"(1969), concerning technology and knowledge transfer from cities to rural world. Here a short excerpt:

"Modern productive agriculture has been reinvented by grace of hundreds of innovations that were exported from the cities to the countryside (the rural world) transplanted to the countryside or imitate in the countryside. […] Innovations created specifically for farming depend directly upon earlier development of city work. […] great innovations were added in cities and only after they had been developed and proved out there were they received into the agricultural world" (Jacobs, 1969, pp. 3–10)

A more contemporary vision of this reading could consider the "new" rural world as all those underdeveloped realities whose growth forecast in the coming years will be exponential. The cities of developed nations are currently the incubators of this new type of production, which tomorrow could - become cheaper - be available to everyone and spread worldwide.

Possible future research scenarios

Due to the recent spread, and the future expected one, of commercial Z-farms in major cities worldwide (Benis & Ferrão, 2018; Nasr, Komisar, & De Zeeuw, 2017), after the effective cases of commercial Z-farms especially in Nord America (the USA and Canada)(Specht, Weith, Swoboda, & Siebert, 2016), it would be opportune to address further studies for all types of Z-farm in both economic (reducing cost in technologies, labor hence price for products) and environmental fields (limiting energy consumption, improving synergy with buildings, improving efficiency of the technologies)(Banerjee & Adenaeuer, 2014; Marston, 2019; Michael, 2017a, 2017b; Specht et al., 2014; Wong, 2017), also under different climates[151] (Benis & Ferrão, 2018; Goldstein, Hauschild, Fernández, & Birkved,

[151] Reference is made to the studies conducted on rooftop greenhouse Z-farm by Benis & Ferrão (2018) under Mediterranean climate.

2016) to be able to validate the strategies and feasibility, especially for large-scale commercial developments (Shamshiri et al., 2018). The first step would be to develop more “open sources” and less individualistic shared strategies. In fact, Pinstrup-Andersen (2018) underlines that the lack of collaboration in the entire sector to develop common strategies slows down the progress of the Z-farms, and I could personally ascertain this statement from my onsite researches and from the interview that I conducted in USA and Canada with some stakeholders. Furthermore, if the sector continues to expand, it may be necessary for the creation of a new professional figure capable of managing the Z-farm design and processes.

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Chapter 1
Overview of the evolution of urban spaces for agriculture

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Chapter 4
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Chapter 6
Designing a possible future: the z-farm toolkit

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Interviews

During the PhD research I have conducted interview to professors, researcher, architects, consultants, farmers and professionals of the sector.

North America

- **Boston**
  Connie & Shawn Cooney, Cornerstalk Farms
  Local farmers at Farmers'Market Boston
  Michael Grove, Chair of Landscape Architecture, Civil Engineering, & Ecology at Sasaki Architects Boston

- **Chicago**
  Carolee Kokola, Director of Enterprise Operations, Bubbly Dynamics-Plant

- **Detroit**
  Ann Perrault, Avalon International Breads and part of urban organic agricultural movement

- **Toronto**
  Gustavo Macias, Aqua Greens – farmer market Toronto
  Joe Nasr, Associate Researcher – Ryerson University/ Centre for Studies in Food Security
  June Komisar, Associate Professor -Ryerson Department of Architectural Science
  Mark Gorgolewski, Chair of Ryerson Department of Architectural Science

- **Montréal**
  Sabine Karsenti, Sales Director at 1420 Boulebard Mont-Royal
  Laurence Hamelin, former Comunication office at Lufa farm
  Vikram Bhatt, McGill University, faculty of Architecture

- **New York City**
  Henry Gordon-Smith, Agritecture consulting
  Yara Nagi, Agritecture consulting + Skyvegetables (Bronx)
  Wythe Marshall, PhD and lecturer Harvard

Europe

- **Milan**
  Luca Travaglini, Travaglini Farm Tech, Cinisello Balsamo
  Mark Oshima, Co-founder of Aerofarm NY (Seeds&Chips food event, May 2017)

- **Paris**
  Mélanie Collé, Chargée de mission agriculture urbaine chez Exp'AU – AgroParisTech

- **Turin**
  Giorgio Quaglio, Agronomist at Seacoop
  Luca Ciardossin, Giro di Vite Farm, former architect at InFarm (Berlin)

- **Basel**
  Mark Durno, former menager at UrbanFarmer Basel