VERTICAL FARM: PERSPECTIVE OF DEVELOPMENT

Introduction: One concept for different realities

PREMISE

4. The integration between architecture and urban agriculture in the vertical dimension

INTRODUCTION

A unique concept for different realities

Strictly speaking, the concept of "vertical farm" refers to the practice of producing food in vertical, integrated or not in other facilities specially built or preexisting. In this perspective the vertical farm is therefore predominantly urban agricultural company, or placed in urban areas, which develops vertically and uses specific cultural, organizational and commercial techniques.

Recent trends, however, tend to extend the concept to many and different production methods, which share the choice of using the space vertically, to four fundamental and incontrovertible evidences:

- the deterioration of agricultural soils, linked to intensive production techniques;
- the growing demand for food due to the steady growth of the world population, which increases at the rate of 80 million people a year;
- the continuing growth of the urban population: it is estimated that in 2050 nearly 80% of the earth's population will reside in urban centers, resulting in exponential expansion of soil artificialisation;
- the rapid climate change, which causes the increase of desertification and the rising of sea levels, which could decrease the arable land.

Therefore fall into the category of vertical farm also all those cultivation methods based on the exploitation of the vertical dimension, as the vegetable gardens on the rooftop, green wall and vegetable gardens implemented on balconies or terraces of varying width.

Said that, each of them requires owns techniques and organizations, responding to different needs and a different historical and operational development, in the present

work we take into consideration their specific problems, with particular attention, however, to the industrial vertical farms, trying to put light on whether and to what extent they can be a real sustainable response to the growing need for food, as their most important theoretical, the American Dickson Despommier, states. The illustrious professor of microbiology and Public Health at Columbia University in New York, with his book *The Vertical Farm* (2010), laid the theoretical foundations of the innovative urban vertical farming methods designed to «feeding the world in the 21st Century».

The question is whether the enthusiastic optimism Despommier can find concrete and advantageous embodiment and if the vertical farm can actually become «the next big thing for food and tech», as defining the business television channel CNBC, capable of representing a possible solution of the problems highlighted, or remain a fascinating, but not sustainable idea.

PREMISE

The "philosophical" presuppositions of vertical farm

1. **The soil consumption**

While the world's population could reach 8.5 billion people in the year 2030 (UN estimates) and 11 billion at the end of this century, the availability and fertility of the soil for agricultural production will be alarmingly reduced. As the vice president CONAF Rosanna Zari has shown opening the World Day of the Soil held in Rome on 5 December 2015[1], the fertile soil area available for global agricultural productivity is just 11%, a percentage that is rapidly decreasing because of climate change,

[1] Event organized by the Consiglio dell'Ordine dei dottori agronomi e dei dottori forestali (CNAF), AISSA, ISPRA, European Commission (JRC), Slow Food e Legambiente.

desertification, erosion, salinization (of soils and irrigation water) and artificialisation. These aspects affect agriculture in a way that it loses 10 million hectares of arable land each year, to which are added 20 million hectares abandoned because the quality of the soil is too degraded, largely because of intensive agricultural techniques and the consequent loss of organic substances necessary for physical, chemical and biological soil fertility[2].

Great part in the erosion of agricultural land is also the urban sprawl, the exponential growth of urbanization. A report[3] of UN estimates that in 2014 metropolitan areas lived 54% of the world population (compared to 30% in 1950), with a growing trend. The dynamic that induce more and more people prefer to live in urban areas is also found in Italy, as evidenced by the data provided by ISTAT, confirming the gradual decrease of the population living in rural areas in our country[4].

To get an idea of soil consumption trends, just consider that while between 1950 and 1981 the total cultivable area increased from 587 million hectares to 732 million hectares, in 2000 the acreage has dropped to 656 million hectares, against a constant increase of the population (2.5 billion in 1950 to 6.1 billion today).

Soil consumption is accompanied by the reduction of fertility, the deterioration of biological, chemical and physical properties of agricultural land, which is manifested by reduced availability of nutrients and decreasing soil water retention capacity, resulting from the destruction of its structure, determined mainly by intensive

[2] For organic substance, considered a key component of a healthy soil, means all living organisms in the soil and the remains of their ashes in different stages of decomposition, rich of organic carbon. The sources for organic matter are crop residues, animal and plant compounds and fertilizers. The decline in organic matter, the main cause of land degradation, is generated by the reduced presence of decaying organisms, or by the increase in decomposition rate determined by the alteration of natural or anthropogenic factors.

[3] Consultable in: http://www.un.org/en/development/desa/population/publications/pdf/trends/Concise%20Report%20on%20the%20World%20Population%20Situation%202014/en.pdf. In it we read also: «More than half of the world's population now lives in urban areas. While the number of large urban agglomerations is increasing, approximately half of all urban dwellers reside in smaller cities and towns. The number of young people has grown rapidly in recent decades and is expected to remain relatively stable over the next 35 years. In contrast, the number and proportion of older persons are expected to continue rising well into the foreseeable future».

[4] See: http://www.istat.it/it/files/2012/01/Allegato-statistico-DEF.pdf?title=Consumo+del+suolo+-+23%2Fgen%2F2012+-+Allegato+statistico.pdf; http://www.camera.it/temiap/temi17/suolo13_istat.pdf.Usefull also data provided by ISPRA: http://www.isprambiente.gov.it/files/pubblicazioni/rapporti/Rapporto_218_15.pdf.

processing. It is evident that land degradation affects the growth of plants and hence agricultural production in quantity, quality and biodiversity.

2. The "natural capital"

The analysis of the Vertical Farm first theorist, Dickson Despommier; is included in the observation that currently the nature has become "natural capital", as well as the man became "human capital", resulting in the monetization of both[5]. Even ecology, he stresses, has assumed considerable economic value: «... it is estimated that all the ecological service on earth may be worth as much as 560 trillion». [6]

However, there are many financial analysts and management complaining insufficient financial and economic attention to the "natural capital", as is clear, for example, from the report Accounting for Natural Capital (2014) of the British Chartered Institute of Management Accountants (CIMA): «While accountants have developed ever more sophisticated ways of accounting for financial capital, and the efficiency with which a business is able to transform this into commercial value, natural capital is still largely hidden from view and absent from the corporate narrative. This situation is no longer acceptable if organizations are to become truly sustainable. […] We lack the frameworks and systems needed to account for the relationship between natural capital and business strategy and performance».[7]

Beyond the ethical aspects linke to the monetization of nature, the hoarding the last meter of land and the last drop of available water, Despommier points out that today,

[5] The British Ecological Society define the Natural Capital in this way: «Natural capital refers to both the living (e.g. fish stocks, forests) and non-living (e.g. minerals, energy resources) aspects of nature which produce value to people, both directly and indirectly. It is this capital that underpins all other capital in our economy and society. Natural capital can often be confused with ecosystem services. However, whilst similar concepts, they are fundamentally different. Natural capital refers to the actual stock (living and non-living parts) that provides value whereas ecosystem services refer to the flow of benefits that this stock provides. Essentially, natural capital is about nature's assets, whilst ecosystem services relate to the goods and services derived from those assets» In http://www.britishecologicalsociety.org/public-policy/policy-priorities/ecosystem-services-and-valuing-natural-capital/

[6] D. Despommiers, *The Vertical Farm, Feading the World in the 21 st Century*, Picador, New York 2010, p. 140.

[7] In http://www.ey.com/Publication/vwLUAssets/Accounting-for-natural-capital/$File/EY-Accounting-for-natural-capital.pdf.

to the point we have arrived, it is crucial to invest in the preservation of the environment and in reduction of the exploitation of the nature: «Some who feel the need to put a dollar figure on the very processes that keep us alive».[8]

The need for action to restrain the exploitation of ecological resources appears confirmed by the calculations of the Global Footprint Network, which give an idea of its size and its growth rate introducing the concept of Ecological Debt Day (EDD), also called Earth overshoot Day, the day on which humanity exhaust global nature's budget for the year, set for the 15th of August 2015 (it was the 17th of August in 2014, the 20th of August in 2013 and so on until the 23rd of December in 1970).[9]

Even putting a grade of incertitude on the calculations, it remains clear that humanity's consumption of earth's natural resources has reached alarming levels, such as to endanger the earth's capacity to regenerate them.

Among the most significant factors in the overexploitation of land resources is undoubtedly that of soils, previously put in evidence, that fits between the causes of what Desmonnier defines as a true "suicide" of civilization. Hence the need to increase «the capacity of adavanced reasoning and creativity, ad use these two intellectual attributes to invent farming, and eventualy the rest of tecnology-driven world».[10]

3. The verticality as a solution: a piece of history

It has been estimated that in order to meet the food needs of the growing population, the arable land should raise by about 10 billion hectares.

To this basic critical points are added those of an ecological nature, that have stimulated the search for sustainable agricultural strategies - such as biology and bio-dynamic farming, permaculture and “kilometer 0” - oriented to the preservation of the soil and the organic value of the products, but also to a rationalization of the distribution with

[8] D. Despommier, cit. p. 140.
[9] For further details, please refer to:
http://www.footprintnetwork.org/en/index.php/GFN/ (web site of Global Footprint Network)
http://www.overshootday.org/about-earth-overshoot-day/ (web site illustrating the calculation methodology of EDD)
[10] D. Despommiers, cit. p. 139-140.

the reduction of transport costs (environmental and economic) from rural production areas to urban centers.

Trying reacting to this requirement, since the Sixties-Seventies the architecture began to design urban multi-storey buildings equipped with roof gardens, in which it became possible to grow vegetables, as well as ornamental plants, in order to increase the urban verse with undoubted positive effects on the quality of urban air. All projects that inevitably recall the Hanging Gardens of Babylon (Figure1), one of the seven wonders of the ancient world, the ziggurats of ancient Mesopotamia (4th millennium BC-600 BC), the *Villa dei Misteri* in Pompei, which had an elevated terrace where plants were grown, and the Renaissance roof gardens, which had both decorative and functional purposes, refreshing and perfuming air with medicinal and aromatic plants.

Figure 1: Reconstructions of Hanging Gardens of Babylon

To go back to a more recent epoch, among the first and most significant multi accomplishments provided with roof gardens, we can remember Habitat 67 (Figure 2), a housing complex built in Montreal (Canada), designed by architect Moshe Safdie and built for the Expo 1967, and *Les Etoiles* (figure 3), designed by architect Jean Renaudie

in Ivry (France) between 1969 and 1982, in which the large terraces allowed even limited food self-production together with ornamental plants.

Figure 2: Figure 2: Habitat 67 di Moshe Safdie a Montréal (Canada)

Figure 3: Les Etoiles di Jean Renaudie a Ivry (France)

Goes in this direction also the installation of vertical gardens, whose originator is considered the Parisian botanist Patrick Blanc. After his first speech that dates back to 1994, when he introduced the green wall at the *Festival International des Jardins de Chaumont-sur-Loire*, and the subsequent green walls for the *Parc Floral* in the Bois de Vincennes, his operations in the urban space have multiplied, decorating also public buildings of Paris, the *Orangerie of the Palais du Luxembourg*, the *Musée du Quai Branly* (Figure 4) and the latest Living Wall in the oasis of rue d'Aboukir.

Figure 4: The vertical wall of the Musée du quai Branly, Patrick Blank (Paris)

Figure 5: Dezeen oasis of Rue de Aboukir

Born into the Blank's intentions as a decorative and ecological element, the idea of vertical gardens has been transferred in the realization of vertical cultivation, thanks to which you can grow some vegetables in the urban space. We will see later in this specific production the specific characteristics of this "artisan" system, which is catching on in many Italian cities as well.

Falls into the vertical space utilization strategy also the rooftop garden, methodology that can finds origins in the *Fustat palaces*, a city that was the capital of Egypt after the Muslim conquest in 641, and that, according to the descriptions of the traveler philosopher Nasir Khusraw of the early 11th century, was equipped with many high-rise buildings up to 14 stories, with roof gardens on the top, accompanied by ox-drawn water wheels for the irrigation.

4. The evolution of the idea of vertical farming

The first antecedent of a tall building in which food is cultivated is considered an article published in Life Magazine in 1909, in which appears a drawing depicting vertically stacked homesteads set amidst a farming landscape. The idea is taken up by Rem Koolhaas in his utopian book *Delirious New York A Retroactive Manifesto for Manhattan of 1978*[11], in which he considers the skyscraper «as utopian device for the production of unlimited numbers of virgin sites on a metropolitan location».

The first architectural designs that enroll in this vision of "green architecture" can be the *Immeuble villas of Le Courbousier* (1922), which provide "*unité d'habitation*" multilevel with garden terraces destined also to domestic crops, those of the School of Gardeners in Langenlois (Austria) and the present glass tower in the Vienna International Horticulture Exhibition 1964.

More specific is the idea developed by John Hix in his book The Glass House of 1974[12], which paved the way for "greenhouses", structures covered with a transparent or translucid material, in which cultivate plants with environmental conditions that can be modified or controlled.

The birth of the real vertical faming is still traced back to the towers for the hydroponic cultivation realized in Armenia in 1951[13]. In the same year was published by J. Sholto

[11] Italian pubblication: R. Koolhaas, *Delirious New York*, Mondadori Electa, Milano 2013.

[12] John Hix, *The Glass House*, Phai-don, London 1974.

Douglas *Hydroponics: The Bengal System*, considered the seminal text for the development of this methodology[14]. And it is precisely in the Fifties which opened the debate on hydroponics culture practiced in vertical structures, demonstrating that the discussion and the first achievements of vertical farms existed more than 40 years prior to contemporary discourse on the subject.

From the beginning the debate has seen two opposing positions. Supporters of vertical farm saw it as a means to meet the demand of reducing the energy costs needed to transport foods to consumers and minimize climate change produced by excess atmospheric carbon. His detractors instead emphasized the excessive burden, due to the high costs of the additional energy needed for artificial lighting, heating and other vertical farming operations, which would outweigh the benefits of the building's close proximity to the areas of consumption.

Moving to a time closer to us, the Malaysian architect Ken Yeang is considered the first to have designed and built the "bioclimatic skyscrapers", multi-storey buildings based on low-energy and passive-mode on a wide presence of green spaces and crops (including rooftop gardens), as the Roof-Roof'House of 1985 and the *Menara Mesiniaga* of 1992, both edified in Kuala Lumpur. From this idea it develops the mixed-use integrated architecture, combining areas for cultivation to those destined to housing.

However, as mentioned, Dickson Despommier is the one who gave the greatest contribution to the idea of vertical farming, when already in 1999 began to work on the subject, stimulating the interest of scientists, architects, and investors worldwide turning the concept of vertical farming into a reality. The development of architectural designs and inspired multidisciplinary team approach, systematized in his book, *The vertical farm* in 2010, has then allowed to give concrete realization of his purposes, providing technical solutions regarding energy, illumination and water balances. The

[13] Mentionated in James Sholto Douglas, *Hydroponics: the Bengal system : with notes on other methods of soilless cultivation*, Oxford University Press Delhi 1951.

[14] James Sholto Douglas, *Hydroponics: the Bengal system : with notes on other methods of soilless cultivation*, cit.

growing interest of the mass media on the subject, already documented in 2007[15], shows how the always considered utopian system is watched today with curiosity and favor by the public.

WHAT ARE VERTICAL FARMS?

1. Vertical farms according to Despommier

«By applying state-of-art controlled environmental agricultural technologies as an integrated system contained within a multistoried building – vertical faming – the world could rapidly became a much better place to welcome the next generation of humans».[16] With this optimistic hope Dickson Despommier deals with the concept of Vertical farm, with which reference is made to the practice of producing food in vertically dimension in a closed stacked system – in stacked layers, in vertically inclined surfaces and/or integrated in other structures – as a component of urban agriculture and on the basis of Controlled Environment Agriculture (CEA) technology. The author is sure about the usefulness of this innovative practice at various levels:«Implementation of the vertical farm employing large-scale hidroponics and aeroponics inside the cityscape is a potential solution for two problems: production of food crops to feed a growing urban population without further damaging environment, and feeding up farmland and allowing it to return to its ecological setting»[17].

[15] In 2007 articles have appeared in numerous more or less specialized publications, such as, among others, *The New York Times*, *U.S. News & World Report*, *Popular Science*, *Scientific American* and *Maxim*, as well as radio and television features.

[16] D. Despommier, cit, p. 142-143.
[17] D. Despommier, cit, p. 145.

In this statement of Despommier emerge four main aspects of Vertical farms:

- their ability to produce food in the urban area for a growing population;
- their ability to reduce the environmental impact and resulting in their placement within the green economy;
- the opportunities they offer to re-enter within cities that productive activity which has gradually been expelled;
- the two main cultivation techniques which can be implemented, the hydroponic and aeroponic.

At these aspects he adds another implicit one, the fact that the traditional farming practices are not sufficient to meet the growing demand for food, as well as are insufficient the common agricultural strategic choices more adopted until now. In this regard it was found that 15% of the land suitable for raising crops has been laid waste by poor management practices[18]. Hence the need to innovate the methods of cultivation by activating the «capacity of adavanced reasoning and creativity», to avoid the impending disaster. Now let's see in more detail the analysis of the points highlighted by Despommier, starting from the strictly tecnica ones.

1.1. The structure of industrial vertical farm

The industrial vertical farm may show different types of structure and can be made with special buildings or in any type of building that has sufficient space to hold the racks in which the plants are placed.

As shown in Despommier, those specially constructed are made by a complex of building costructed in close proximity to one another. In addition to the space for the crops, which must be separated from the other structures, it is expected:

« - offices for management;

[18] Sources FAO and NASA.

- a separate control center for monitoring il funzionamento della struttura;
- a nursery for selecting and germinating seeds;
- a quality control laboratory to monitor food safety, document the nutritional status of each crop, and monitor for plante disease;
- a building for the vertical farm workforce;
- an eco-education/tourist center for the general public;
- a green market;
- and eventually a restaurant.

Aquaculture and poultry will be housed in adjacent but separate building with no physical connection to vertical farm building to ensure safety of the plants».[19]

In the Despommier's idea, the vertical farm are real urban farms, conceived as places of vegetables and poultry production, but also as centers of education and social integration, able to create a spirit of community, as well as poly research aimed at safeguarding the quality of food and its ecological sustainability production.

The vertical farm so conceived is thus a radical innovation compared to companies who practice hydro-stacker vertical hydroponic growing systems, characterized by the stacking hydrostackers. Even agreeing with the hydroponic companies the premises of soilless cultivation and some specific production techniques, the vertical farm differs in the vision of the different functions it intends to integrate, and in the assumption of operating within a complex urban buildings specially designed and built to meet these functions.

1. 2. Soilless culture systems: hydroponics and aeroponics

The hydroponic growing system produces plants without soil, by feeding directly into all the nutrients necessary for their growth. Hydroponics is easy and simpIe way to grow plants, considered by many more advantageous than the cultivation in soil

[19] D. Despommier, cit., p. 179.

because it make possible to give plants maximum levels of the exact nutrients they need. Precise control of nutrient uptake allows reap higher yields faster.

The first hydroponics applications in the modern sense [20] dates back to 1929 when the Californian William F. Gericke of the University of California at Berkeley began to promote this solution for agricultural crop production[21]. After have created a sensation by growing tomato vines twenty-five feet high in his back yard in mineral nutrient solutions rather than soil, Gericke had to face the skepticism of administrators of his University, who denied him use of the university's greenhouses for his experiments. The publication of his book, *Complete Guide to Soil less Gardening* [22] in 1940, go hand in hand with the growing interest in the technique proposed by him, so that his system was used by the US Army to supply fresh vegetables troops during the Second World War.

Since the 80s, the use of plastic and peat in the receptacles substrate gave new impetus to the technology of hydroponics, thanks to the ongoing scientific research conducted in the Netherlands, England and Japan, countries where the reduced availability of arable land has stimulated a greater interest in this farming methodology. Later, also East Asia, Spain and Israel have increased the implementation of hydroponic farm, while NASA has developed a research program for a system hydroponic food production to be used in space missions. [23]

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[20] The word "hydroponics", introduced by Gericke in 1937, is a neologism that refers to the term "Geoponica" (literally "worked the land"), formed by the replacement of the root -geo (earth) with the root -hydro (water).

[21] It is believed that the first hydroponics systems have been made in the hanging gardens of Babylon and the floating gardens of the Aztecs of America, who grow vegetables in wooden rafts called Chinampas, described by William Prescott in the eighteenth century«Wondering Islands of Verdure, teeming with flowers and vegetables and moving like rafts over the water». Floating Chinese gardens are also described by Marco Polo in his famous journal. We must get to the seventeenth century to find the first recorded scientific approach to hydroponic crops, when Belgian Jan van Helmont showed in his experiments that plants obtain substances from water.

A prestigious written reference to the growing terrestrial plants without soil technique appears instead in the Francis Bacon's book *Sylva Sylvarum*, published in 1627, which aroused considerable interest in this technique. In 1699 John Woodward, a fellow of the Royal Society of England, published his water culture experiments with spearmint, through which he found that plants in less-pure water sources grew better than plants in distilled water. The compilation, in 1842, of a list of nine elements believed essential for plant growth, and the discoveries in the years 1859-1875 of German botanists Julius von Sachs and Wilhelm Knop (considered the "father of water cultures") favored the development of the cultivation of terrestrial plants without soil.

[22] William F. Gericke, *Complete Guide to Soil less Gardening*, Prentice-Hall, Inc., New York, 1940.

[23] NASA has already designed food supply systems for the astronauts, during eventual missions to Mars.

The installation of vertical structures has given a further impetus to hydroponics, for the possibilities they offer to provide a solution to increased environmental pollution and land degradation caused by intensive farming.

Hydroponic cultivation is considered an effective tool for controlling the growth and production of plants especially for the several advantages that produces:

- the reduction of the time of development: in a hydroponic system the plants grow faster than in the traditional system on earth as there is greater control of the supply of nutrients and a richer supply of oxygen to the root system. Breathing more easily, the plants speed up their metabolism and take less time to grow. Furthermore, with the shortening of the growth cycle, the chances that the plants develop diseases decrease;
- better working conditions from the plant to the collection, even with strict control of the effective cultivation needs;
- higher productivity per meter, thanks to the highest density of seedlings and the elimination of the attack by the soil-borne pathogens;
- increasing product quality in post-harvest: vegetables produced hydroponically does not contain the remains of chemicals used for geo-sterilization[24], are cleaner, and do not differ with products grown in soil from the nutritional point of view;
- reduction of the amount of water for irrigation compared with a traditional crop (about 90% less thank to recycle too);
- environmental compatibility, since the hydroponic crops do not provide sterilization and it is reduced the use of water and fertilizers.

Currently, however, are still many people who believe that hydroponics cultivation is an unsustainable systems, for several reasons:

- it requires large investments of capital;
- it requires a large quantity of water and fertilizers, especially in the case of the open system;

[24] "Geo-sterilization" means the soil disinfection against harmful organisms (nematodes, soil insects, weeds) implemented by physical (water vapor) or chemical means(fumigants).

- still has high operating costs.

In Italy the plant species mainly dedicated to this type of cultivation are some types of flowers (such as the rose and the gerbera), tomato and strawberry.

The other technique reported by Despommier for crops in vertical farms is that aeroponics, which consists in process of growing plants in in a closed or semi-closed environment without the use of soil or an aggregate medium, by spraying the plant's dangling roots and lower stem with an atomized or sprayed nutrient-rich water solution.

In nature there are many species that grow in an areoponic mode, mainly in tropical climates as different quality of orchids and tillandsie and many epiphytic plants.

Techniques for growing plants in the air and in absence of substrate first developed in twenties by botanists who used primitive aeroponics to study plant root structure.

In 1966, Bruce Briggs, considered the aeroponic cultivation pioneer, succeeded in inducing roots on hardwood cuttings by air-rooting. In fact he discovered that air-rooted cuttings were tougher than those formed in soil and concluded that the basic principle of air-rooting is sound. He discovered then that air-rooted plants could be transplanted to soil without suffering or setback to normal growth, differently by how it was observed in hydroponic transplants, in which is normally observed transplant shock. But it was in the seventies that the research and use of aeroponic systems developed in a large scale. In 1976 the British researcher John Prewer carried out a series of aeroponic experiments near Newport, Isle of Wight (U.K.), in which he made grown in 22 days lettuces from seed to maturity in polyethylene film tubes made rigid by pressurized air supplied by ventilating fans.

carried out a series of aeroponic experiments near Newport, Isle of Wight (U.K.), in which he made grown in 22 days lettuces from seed to maturity in polyethylene film tubes made rigid by pressurized air supplied by ventilating fans. It was then the Mee Industries of California to supply the equipment used to convert the water/nutrient into fog droplets. After remaining part of the experiment, the aeroponic system had its big

public debut in 1892, when was opened "The Land", pavilion at Disney's Epcot Center. In the same year in Israel L. Nir began to evaluate the commercial value of the aerofoni system, with which he obtained a succeful production of tomato, eggplant, cocumber, lattuce and pepper. Nir registered a patent for an aeroponic apparatus, "Apparatus and Method for Plant Growth in Aeroponic Conditions", in which «plants are supported by a support member above the root portions thereof and the root portions are subjected to a nutrient mist directed thereto, with control and timing means for controlling the time and sequence of application of the mist. Nir utilizes a high pressure pump or pneumatic pressure to deliver a nutrient solution to suspended plants, held by styrofoam, inside large metal containers. Alternatively, Nir provides for the spraying of tap water from a water tap. However, such tap water spray does not include nutrient»[25]. In 1983 also Richard Stoner filed a patent for the first microprocessor interface to deliver tap water and nutrients into an enclosed aeroponic chamber made of plastic. Stoner developed different companies for aeroponic hardware, interfaces, biocontrols and components research, for commercial aeroponic crop production. After had used, in 1984, a different design of aeroponics system to grow strawberry plants in association with John Prewer, a commercial grower on the Isle of Wight, nel 1985, Stoner's company, GTi, has been the first company to manufacture, market and apply large scale closed-loop aeroponic systems into greenhouses for commercial crop production, specially of strawberries. The system perfectionated by Stone was particularly appreciated by customers, especially for the cleanliness, quality and flavor of the fruits. It was very appreciated also by NASA, which in 1990 funded a project related to a small aeroponics operation: Stone's great effort lead to developments of numerous advanced materials for aeroponic cultivations[26].

[25] In *Method and apparatus for aeroponic propagation of plants*, in http://www.google.fr/patents/US4514930

[26] Demonstrating the efficiency of aeroponic system characteristics that make it an efficient means of growing plants, especially in future scenarios in earth and space, NASA has activated plans related to Mars missions, providing for the construction of structures in which the aeronauts should spend 60% of their time on the red planet farming to sustain themselves.

To stay in the technical aspects of this method, the elements that qualify are:

- the closed environment (aeroponic chamber or grow room or grow box), constituted by a suitable structure and as isolated as possible from the outside so that the necessary parameters are monitored and controlled to the growth of the plant, which are:
  - the lighting, which is substantially the same for all indoor crops;
  - the temperature, whose optimum range is between 21 and 28 degrees centigrade, which is monitored through simple measuring instruments such as thermometers or thermo hygrometer; there are several ways to reduce it (like vacuum cleaners or extractors ari) or improve it (electric heating preferably powered by renewable energy sources);
  - aeration, ventilation and carbon dioxide
  - moisture, which must always be around 50 - 60%, and should never be excessive;

- the radical apparatus in the air suspension and of the leaves, which is supported by suitable perforated panels for different type and shape according to the cultivation choice;
- the lack of land, which allows you to cancel the exposure of plants to pests and pathogens, thereby facilitating their development;
- the radical apparatus nebulization, which is periodically sprayed with nutrients diluted in water using nebulizers matched to a high pressure pump and a timer splashing at regular intervals the solution directly onto the roots, obtaining an air / nutrient solution by remarkable effect that benefits to the plant;
- the recovery of nutrients and water from the bottom of the structure.

Among the most products in aeroponic methods vegetables, which supporters consider more advantageous than hydroponics for the greater savings of substances and water, there are various types of radicchio and lettuce, chicory, spinach and potatoes. The industrial aeroponics is considered one of the most recent and promising research

frontiers in the field of vegetable and flower crops sector, which, as hydroponics, has supporters and detractors.

Among the advantages that are reported by its supporters, there are:

- the possibility of significant quantitative and qualitative increases in production, without depending on seasonal changes;
- cost reduction, guaranteed by the significant reduction in the use of manpower and energy consumption;
- saving substances and water, which are retrieved from the bottom of the structure and recirculated;
- lesser possibility of formation of a suitable environment for the growth of molds, viruses or bacteria such as salmonella;
- drastic reduction in pesticide treatments;
- 90% reduction of fertilizers, with the total elimination of those most responsible for air pollution (such as methyl bromide);
- reduction of pollution of environment and groundwater, guaranteed by the recovery of substances used;
- greater culture exchange rate and elimination of transplant stress;
- independence from water not suitable for cultivation;
- elimination of waste material to dispose of, except the organic residues due to the change of cultivation;
- nitrate reduction in the leaves;
- long life of the materials used for the cultivation;
- reduction of maintenance time;
- possibility of producing organic and certifiable vegetables;
- possibility to produce vegetables throughout the year (you can make 20 cuttings per year against 5-6 of the cultivation ground).

Despite all these benefits, those who have a more skeptical position and who think aeroponics is «a great system for small premises»[27] highlight those disadvantages:

- the difficulties in the utilization of this technique for the traditionally extensive crops (wheat, maize, etc) and of crops of plants which require a large vegetative development;
- the need for a substantial expenditure of system to activate the cultivation;
- lack of certainty about the possibility of reduction of pathogens;
- the dependence on the system, as in aeroponics system is made up of high pressure pumps, sprinklers and timers: if any of these break down, your plants can be easily damaged or killed;
- the need for greater technical knowledge amounts of nutrients required for the growth and health of the plants;
- the need for regular cleaning of the root chamber, that must not be contaminated or else diseases may strike the roots;
- lower quality of products grown with indoor systems.

1.3 Illumination

«The sunlight –Despommier writes – is the main source of energy to grow the crop, then the vertical farm should be made as transparent as possible. The designer/architect has many choices of transparent material to chose from. Glass is cheap to manufacture and durable, albeit a bit on the fragile side and heavy.[…] A current trend in modern building design advocates for total transparency. […] It is now even possible to create an all-glass structure without any metal at hall in the building by using special adhesives. The caveat here is that, as of this writing, he new glues used to attach sheet of glass together have only been tested for a year's worth of wear. Insulating an all-glass building is a big problem, and employing double-glazing to provide energy-

[27] In http://www.gardeningsite.com/aeroponics/aeroponics-benefits-and-disadvantages/ are presented all the advantages and disadvantages of aeroponic cultivation.

saving adds huge amount of weight and expense to the equation. One solution is to abandon glass altogether in favor of high-tech plastics that are much lighter in weight and more durable. Recycling transparent plastic (bottle, etc.) into clear panels used for windows and modular construction of eco-friendly structures has spawned a new industry for building materials».[28] Thus we can say that the vision of Despommier of the vertical farms starts from that of the traditional glass houses.

In addition to the transparency of the surface, Despommier also thinks of his form, which should preferably be curved to take full advantage of natural sunlight and to follow the progression of the sun across the horizon. In this way the indoor cultivation can reduce the lighting gap with respect to the outdoor one.

Good sun exposure is important but not essential for plant growth, as in the vertical farm natural lighting is complemented by various artificial systems, which increase the natural sunlight with metal reflectors or integrating that with artificial lighting.

In fact, the growing systems in the indoor environment require the application of additional, at least supplementary, light sources to ensure the photosynthesis and so the plant growth.

One of the most efficient illumination system is the one of light-emitting diodes (LEDs), considered the new artificial illumination border because they never overheat, requiring very low energy consumption and offer a great choice of colors. About their efficiency it’s very useful to read the article published in 2014 in the journal "Royal Society", which underlines: «the photosynthetic processes are often modified in plants grown under artificial lighting, because lamps do not usually mimic the spectrum and energy of sunlight. Agronomically, new lighting technologies such as LEDs have the potential to cover fluence and wavelength requirements of plants, while allowing specific wavelengths to be enriched, thus supplying the light quantity and quality

[28] R. Despommier, cit. pp.188-189.

essential for different phases of growth. The biomass and metabolic products of cultivated plants can therefore be modified» [29].

The same article claims that this illumination technique can sustain normal plant growth: «Among artificial lighting systems, LEDs present the maximum PAR efficiency (80–100%; see the electronic supplementary material, table S1). LEDs emitting blue, green, yellow, orange, red and far red are available and can be combined to provide either high fluence (over full sunlight, if desired), or special light wavelength characteristics, thanks to their narrow-bandwidth light spectrum. The high efficiency, low operating temperature and small size enable LEDs to be used in pulsed lighting and be placed close to the leaves in interlighting and intracanopy[30] irradiation. Their long life expectancy and ease of control make them ideal for greenhouses in use all year round. The LED technology is predicted to replace fluorescent and HID lamps in horticultural systems and to revolutionize controlled growth environments» [31].

The article ends with these considerations about the LED application in the vertical farm too: «The lighting industry needs to offer energy-efficient, ecologically sustainable lamps adapted to the changing requirements of consumers. LEDs equipped with driver chips could provide the additional benefits of operational flexibility, efficiency, reliability, controllability and intelligence for greenhouse lighting systems. However, the acceptance of solid-state LED lighting in niche applications in horticultural lighting will depend on improvements in conversion efficiency and light output per package of LED light and the cost of lumens per package. It is predicted that horticultural cultivation under controlled environmental conditions (horticulture industry) will expand in the near future, as was presented in the workshop on Challenges in Vertical Farming[32]. The new technologies provide possibilities for

[29] Eva Darko, Parisa Heydarizadeh, Benoît Schoefs, Mohammad R. Sabzalian, *Photosynthesis under artificial light: the shift in primary and secondary metabolism*, 3 March 2014, in the Royal society web site, http://rstb.royalsocietypublishing.org/content/369/1640/20130243

[30] The canpoy is the aboveground portion of a plant community or crop, formed by the collection of individual plant crowns.

[31] Ibidem.

[32] Reference to the workshop of the University of Maryland the 26 of seprember of 2012. See: http://challengesinverticalfarming.org/

economically efficient consumption of light energy for horticultural cultivation of crops both on Earth and in space in the near future, and may contribute to feeding the growing human population and maintaining outdoor (principally forest) ecosystems and thus to the protection of the Earth»[33]. For artificial lighting of indoor cultivation, in addition to LED lamps there are other types of media, such as fluorescent neon lamps, which have the advantage of being intense and constant, and the resumption of lights very similar to the natural ones, achieving the revival of extremes of red and blue of the solar spectrum. However they present certain problems, for the intensity of brightness, which is not suitable for all types of plant.

Also the CFL energy saving lamps, very similar to fluorescent lamps and capable of guaranteeing energy savings without emitting heat, are very appreciated by farmers, especially "craft" ones.

The HID (High Intensity Discharge), widely used in hydroponic crops, provide excellent light intensity but tend to consume to much and to emit heat.

Among other lamps there are the MH (Metal Halide), which produce a predominantly blue light, ideal for the vegetative growth stage, and HPS (High Pressure Sodium), which provide light predominantly red, great to illuminate during the flowering/fruiting stage.

The choice of material to be used for the artificial lighting depends of course on the type of crop and on the type of plant, since each one has its own needs and characteristics.

Very important in the lighting of an indoor cultivation is also the positioning and the height of the light sources. Are then necessary sliding systems to follow the growth of the plants always maintaining an optimum distance.

Since the plant growth cycle includes an alternation of day and night, different times of exposure are provided to light both the different plants and the different stages of growth. It is necessary the use of timers to prevent irregularities in lighting, which can

[33] Eva Darko, Parisa Heydarizadeh, Benoît Schoefs, Mohammad R. Sabzalian, *Photosynthesis under artificial light: the shift in primary and secondary metabolism*, cit.

cause serious damage to the life cycle of plants.
Decisive for a sustainability perspective is also the manner in which the artificial lighting system is fed, for which Despommier indicates the geotherm, tidal[34] and wind energy, choosed in base of the vertical farm geographical position. To these he adds the energy of fire, that is obtainable from the burning of farm waste materials: «It is good to keep in mind that the fact that the word "waste" does not appear anywhere in the ecosystem's dictionary. It's all a part of the same natural loop of energy recovery aiding in the regeneration of life. If the vertical farm is to behave like an ecosystem, then the roots, stems, and leaves of crops, and the entrails of flow and fish, all need to find their way back onto energy grid. Incineration is the most practical way to proceed». [35]

So the Despommier's indications go in the direction of an energy self-sufficient vertical farm, able to use photovoltaic, biogas made from waste, geothermal or other renewable sources to derive heat and power energy.

It is right underline that there are some open discussions about the real energy savings that can be achieved in vertical farms, as there are many doubting it.

1.4. Fertilizers

Given the sustainable vocation of vertical farm, fertilizers used must to be organic.

As for hydroponics, growing interest is having for the use of fish scrap to provide the plants organic nutrition necessary for their development. The water from the tank of the fish is pumped into the plants one, which filter and clean that, so it can be reintroduced again in the fish tank. This makes it very advantageous combination of hydroponics and fish breeding.

Another innovative fertilization system is that of "liquid earth", called "biponia" and brevetted by William Texier, who registered the brand "BioSevia™, Grow & Bloom"

[34] Tidal energy is a form of hydropower that converts the energy of the tides into electricity or other useful forms of power. Tidal energy is therefore an entirely predictable form of renewable energy.
[35] R. Despommier, cit., p. 196.

as 100% organic fertilizer. To be bioponic a fertilizer should be liquid or soluble in water, it should not contain too large particles and must be rapidly available and degradable. Combined with other products, such as the "Trichoderma harzianum" and the silicate powder, biponia can recreate a nutrient solution with all the relevant elements for the plant, making even the function of humus contained in the soil and thus reproducing the natural fertility of the ground conditions.

It must be stressed that, while the US products from hydroponics are certified as organic (USDA Certified Organic), in Italy they cannot be certified as such, since the recognition of "organic" does not extend to soilless cultures.

In this regard William Texier, in a recent interview to mark the Italian publication of his book, *Hydroponics for Everybody - All about Home Horticulture*, he replied to the question: «You have also invented bioponics (hydroponic and organic farming). Do you believe that this may be the future of farming?

Probably not, especially because the impossibility to obtain an organic certification for a product that is not grown in soil. When we do bioponics, we respect all the rules of organic farming, with the added advantages of hydroponics, but still there is a widespread mentality which considers "bio" only what is "ground-in dirt". We have some clients that use this technology on a commercial scale in the world, but I can not say that it is spreading in massive way, for now remains essentially a niche crop. The thing that makes me optimistic is that all of these trading operations are highly successful, so I think that, over time, slowly but surely this technology is destined to occupy a more prominent place»[36].

As regards in general the fertilizer for hydroponics, it should be recalled that all have generally bio-mineral origin and that they must have a balanced ratio between the primary elements - nitrogen (N), phosphorus (P) and potassium (K) -, secondary elements - calcium (Ca), sulfur (S) and magnesium (Mg) - and trace elements - boron (Bo), copper (Cu), iron (Fe), chlorine (Cl), cobalt (Co), manganese (Mn), molybdenum

[36] In http://www.dolcevitaonline.it/intervista-a-william-texier-autore-di-idroponica-per-tutti/

(Mo), silicon (Si) and zinc (Zn), equally necessary for the crops in soil. In addition to containing all the necessary salts, fertilizer must be adapted to the used water, hard or soft, perfectly soluble and free of heavy metals and pollutants.
Because in the US products from soil-less cultivation can be certified as organic, in this country it is possible to use organic fertilizers even in an aeroponic systems, provided that they are readily soluble and have a particulate that does not occlude the tiny holes in the spray heads of high pressure aeroponic systems.

Chapter 2 The different types of vertical farms

2.1. The vertical farm designed

Dickson Despommier's researches about vertical farm, in which all environmental and productive factors can be controlled (humidity, temperature, gases, fertilization…), has been inserted in an increasing interest by architects, engineers, garden designers, agronomists and researchers environmentalists, who have created operational teams that combine their knowledge to design and build structures directly or indirectly inspired by this innovative farming methods. It is so open a phase of design fervor favored also by the ten-day workshop organized in May 2008 by Despommier, at which were invited also several European students aimed at producing visualizations of his theoretical work on vertical farms.
We will see in Chapter 3 how the project activity necessarily implies the estimate of the costs as a fundamental element in a position to attract the investment needed to turn ideas into reality.

It is probably because of the uncertainty about their feasibility and cost-effectiveness that many of the projects have remained on paper for now.

There is no doubt that the many research done for plan implementation contributes significantly to compose a "science" of vertical farm that could favor their creation in an environmental sustainability, productive and economic perspective, or to convince the stakeholders (public administrators, investors etc.) to abandon it. As we'll see in Chapter 3, there are environmental and geographic conditions that may make it more advantageous the construction of vertical farms, as demonstrated in the case of Japan, in which the presence of radioactivity in soils, especially in some zones, makes this methodology a rational and efficient response to the demand for uncontaminated products.

Among the most significant projects we list some, that stand out for their futuristic design, by their originality and in many cases for their exact level of feasibility analysis.

1. **La tour vivante - The Living Tower (Rennes, 2005)**

Project hold by SOA architects (Augustin Rosenstiehl and Pierre Sartoux), the Tour Vivante, conceived as an "ecologic autonomous machine", is a vertical farm of 30 floors mixed with housing and offices programs. Two large wind machines, directed towards the dominant winds, are located at the top of the building, produce electricity facilitated by the height of the tower: their electric power production is estimated about 200 to 600 kWh per year. These wind machines are also used as station of pumping in order to ensure the circulation and the recycling of rainwater recovered in roof and for the urban development of the complex. «The concept of the Tour Vivante aim is to associate the agricultural production, dwelling and activities in a single and vertical system. This system would allow to make the city denser meanwhile a greater autonomy could be gained reliance in agricultural plains, reducing the need of transportation between urban and extra-urban territories. The yet unusual superimposition of these programs finally makes it possible to consider new practical

and energetic relations between agricultural culture, tertiary spaces, housing and trade inducing a very strong energy saving»[37].

Figure 6: The tour vivante by SOA

2. Vertical Farm by Chris Jacob (New York)

Converted to the concept of vertical farm from the encounter with Depommier, architect Chris Jacob conceived for New York a cylindrical building thirty floors, topped by a huge satellite dish, for the production of vegetables, also generating clean energy and purifying wastewater. «Primarily, an agricultural shift towards vertical farming, away from traditional horizontal field farming, would have a twofold affect: controlled crop production and reforestation. Food production would fall completely under human control as all farming would be relocated indoors within controlled environments, preventing crop failure, eliminating pesticide and fertilizer usage, allowing for direct distribution of harvests, and permitting year-round production. And with farmlands no longer needed for crop

[37] In http://www.ateliersoa.fr/verticalfarm_fr/pages/images/press_urban_farm.pdf

production, countless acres could be reforested, restoring untold amounts of hardwood forestry to temperate and tropical area»[38].

Figure 7: Vertical farm by Chris Jacob

3. Sky Farm by Gordon Graff (Toronto, 2007)

Designed by Gordon Graff, a student in the Master of Architecture program at the University of Waterloo and considered one of the pioneer of vertical farms, this project, proposed for downtown Toronto's theatre district, is a tower of 58 floors and 2.7 million square feet of floor area and 8 million square feet of growing area, that can produce as much as a thousand acre farm, feeding 35 thousand people. «A vertical farm – Graff writes – must be able to produce enough food to cover the cost of its day to day operations and, ultimately, the capital cost of the building's construction (or renovation). While this is clearly dependent on some factors outside the realm of architectonics, such as the market price of food and current state of grow-lighting technology, the physical arrangement of the

[38] In http://www.greenandsave.com/green_news/green_building/towers_of_imagination_chris_jacobs_and_vertical_farming_in_theory

building can have a profound impact» 39. In the project Graff calculated also the operation cost, which was supposed to amount to about $110 million, against a hypothetical sale of 25 million heads of lettuce per year into the local market.

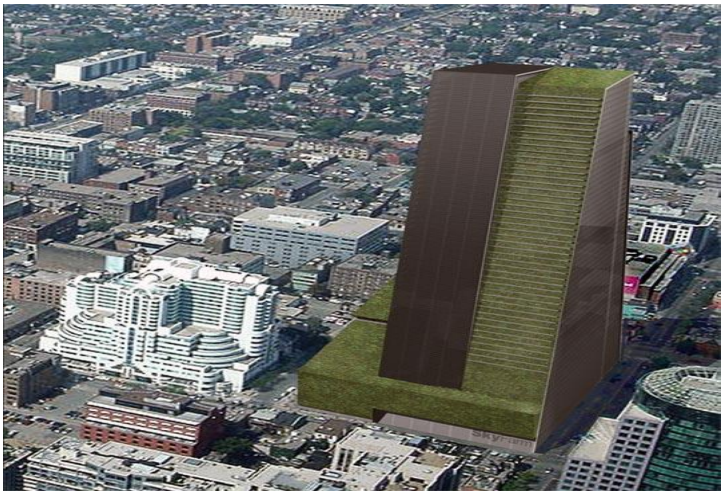

Figure 8: Sky Farm by Gordon Graff

4. Urban Epicenter/NYC (New York, 2009)

Project at Graduate School of Design, Harvard University Project Advisor by the architect Jungmin Nam. The prototype provides a high building, whose twist is aimed at maximizing the solar light, which «is not only for the food production but also for the productive urban living, as it works as a tool for social change; a sustainable way of consuming, food distribution, job creation, healthy food source and civic space for local community. It will reshape urban life style as being manifestation on how the urban life can be in the future from a day-to-day impact on our cities» 40.

[39] In http://www.treehugger.com/green-food/gordon-graff-demonstrates-that-vertical-farms-can-actually-work.html
[40] See the offical web site: http://www.worldarchitecture.org/architecture-projects/mzme/urban-epicenter-nyc-building-page.html

Figure 9: Urban Epicenter, NYC

5. The Living Skyscraper (Chicago, 2009)

Prototype designed to be placed on the surface of the sea, created by Blake Kurasek – today Project Architect at Dattner Architects of New York – while he was a graduate student at the University of Illinois at Urbana-Champaign. The concept places urban farms on the outer fringes of residential apartments. Some floors are enclosed for year-round production of greenhouse crops, while others include terraces for seasonal items such as orchards. The ground floor would contain a farmers' market where residents could sell to one another and the general public. Interessante, nel suo progetto, il disegno assonometrico della struttura dell'edificio, che presenta una precisa descrizioni degli elementi funzionali di una vertical farm.

Figure 10: The living Skyscraper, by Blake Kurasek

6. Dragonfly (New York, 2009)

Designed by the Belgian architect Vincent Callebaut on model of the wings of a dragonfly for the Roosevelt Island of New York City, this visionary urban farm of 600 meter high comprehends 132 floors and 600 vertical meters, and can accommodate 28 different agricultural fields for the production of fruit, vegetables, grains, meat, to facilitate the solution of food mileage and shortage problems. A combination of solar and wind power makes the building 100% self-sufficient.

Figure 11: Dragonfly project, by Vincent Callebaut

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7. Seewater Vertical (Dubai, 2009)

The project of the Seawater Vertical of the Italian architects *Studiomobile* provides for five cocoon-greenhouses fixed to five branches that also transport and nebulize the seawater creating a humid and cool flow, ideal for the plants, like the environment of the equatorial forest. In these conditions crops need very little water as they are not stressed by excessive transpiration. Besides this suggestive design, this vertical farm utilizes the seawater, purified with special evaporators, to cool and humidify greenhouses, and to irrigate the crops.

Figure 12: Seawater Vertical, Dubay

8. EVF Experimental Vertical Farm (Santiago del Cile, 2011)

EVF Prototype Building, designed by Claudio Palavecino Llanos, professor at the Universidad de Chile, School of Architecture and Urbanism, it provides 4 high cylindrical tower with a sloping roof, conceived as an artificial ecosystem food-producer with minimum energy and resources consumption, which comprises full agricultural production process, from plantation, harvest, process, packing until dispatch for public consumption. «The main design fact – is written in the project – is about how to concentrate the traditional agricultural framework in a very simple process into only high-performance building; and how this is integrated to urban flows (energy, matters, transportation) and landscape. These actions have sense into an integral sustainable development framework (social, economic and environmental), based on a management plan what put in context this project as a possible action in current urban and market requirements, in this case, based on Chilean current situation»[41].

[41] See the official web site: http://www.archiprix.org/2015/index.php?project=2926

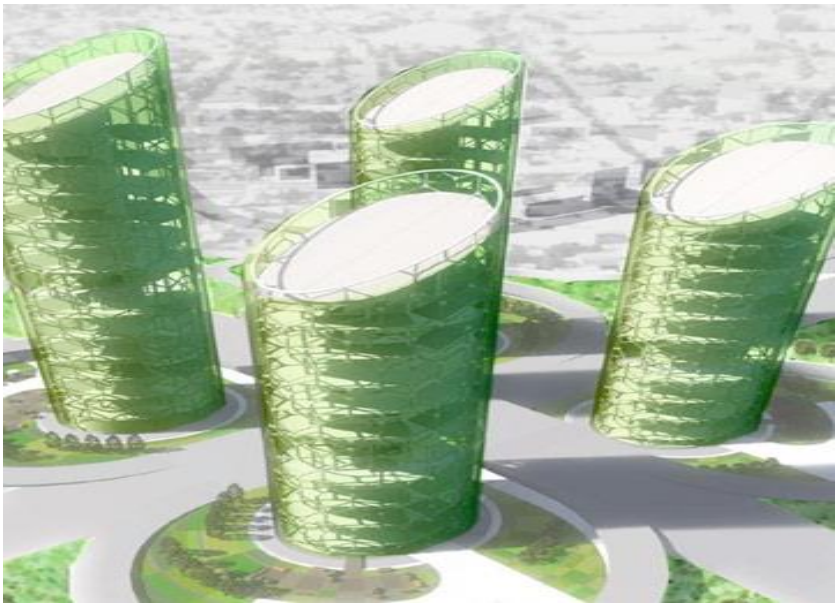


Figure 13: The Experimental vertical farm, by Claudio Palavecino Llanos

9. Vertical Farm Design (Paris 2009)

Architect Charlotte Avignon project, this prototype of vertical farm is thought to be located in a park-like environment and would Provide fresh, local food for Parisians. The sail-shaped building intends to give to Paris a seductive historical iconic infrastructure that represents the new eco-friendly vocation of the city.

Figure 14: Vertical farm project, by Charlotte Avignon

10. The Harvest Tower (Vancouver, 2009)

This prototype, designed by Canadian study Romses, won the "Vancouver's Challenge 2030", competition dedicated to the best projects to address climate change and reduce carbon emissions.«The urban design strategies for the proposal are predicated on the view that urban food and energy harvesting needs to be "fore-grounded' into strategic and highly visible locations in the city, such as transit hubs along arterials. The "Harvest Tower" will act as a landmark vertical marker for the development and surrounding neighborhood, while the commercial/office podium roots the development to the surrounding arterial street-wall context.

The concept of "harvest" is explored in the project through the vertical farming of vegetables, herbs, fruits, fish, egg laying chickens, and a boutique goat and sheep dairy facility. In addition, renewable energy will be harvested via green building design elements harnessing geothermal, wind and solar power. The buildings have photovoltaic glazing and incorporate small and large-scale wind turbines to turn the structure into solar and wind-farm infrastructure. In addition, vertical farming potentially adds energy back to the grid via methane generation from composting non-edible parts of plants and animals. Furthermore, a large rainwater cistern terminates the top of the "Harvest Tower" providing on-site irrigation for the numerous indoor and outdoor crops and roof gardens»[42].

[42] In http://www.evolo.us/architecture/the-harvest-tower-is-a-sustainable-vertical-farm-romses-architects/

Figure 15:The Harvest Tower realized by Romses Architects

11. Pyramid Farm (USA, 2009)

The iconic pyramid shape was chosen by architect Eric Ellingsen of the Illinois Institute of Technology and by the same Dikson Despommier to address the needs of a swelling population on a planet with finite farmland. It's conceived as «a self-sufficient ecosystem that does what other vertical farms are intended to do, but the difference here is that apart from raising vegetables and fruits indoors, the ecosystem utilizes waste to produce fish and poultry as well. The design is so efficient that it would just use 10% of the water and five percent of the land needed by farm fields»[43].

[43] In http://www.ecofriend.com/eco-agriculture-pyramid-farm-vertical-farming-reinvented.html

Figure 16: The Pyramid Farm by Eric Ellingsen and D. Depommier

12. Vertical Farm Type O2 (Australia, 2010)

The vertical farm of Olivier Foster consists of a broken cylinder, as if to show the "natural" soul of the building, composed by the access ramp and by structures that recall a tangle of twisted branches. The architect's goal is to «make maximum use of a small amount of space by filling glass houses, with plant beds stocked high one above other»[44].

[44] In http://verticalfarmingaustralia.blogspot.it/

Figure 17: Vertical Farm Type O2 by Olivier Foster

13. Oasis Tower for Zabeel Park Vertical Farm (Dubai, 2010)

The Oasis Tower for Zabeel Park a Dubai, designed by Rahul Surin, is a self-sufficient tower, composed by three twisted spiral cylindrical buildings, assembled in the form of a hexagram, which is seen as the combination of the negative and positive pushes nullifying each other and thus claiming equilibrium. Its facade's renewable energy systems will be optimized for maximum energy generation. It is conceived to provide a solution for urban farming and sustainable housing in arid conditions. «Architect Rahul Surin believes that the Oasis Tower will be able to provide enough food to feed 40,000 people and use renewable energy technologies to meet the whole building's energy demands. The exterior of the building would be lined with air-filled pockets made from ethylenetetrafluoroethylene, which help protect it from the environment by providing optimized shade to minimize heat absorption. The tower would also be

powered by vertical axis wind turbines placed in between the floors of the central tower»[45].

Figure 18: Oasisi Tower by Rahul Surin

14 Skyland, ENEA (Milano, 2009-2015)

The project was presented at the Expo 2015 in Milan, from a collaboration between ENEA, who developed the project structure, *Agrimercati*, who provided advice on agro-side, and the Department of Health of Milan. It was first edited by dr. Mauro Basili and architects Gabriella Funaro and Julius Mizzoni. This prototype of a green skyscraper energetically self-sustainable, and designed to grow organic agricultural products for 25 thousand people, is imagined as «a place where it can be produced healthy food, where it's made research to ensure food safety, where you can learn and taste. A place thought to hold quality, for the care of the person, that does not pollute and does not waste, not far from our homes»[46]. In the intentions of the designers, Skyland should integrate in one location the entire food chain, from indoor soilless production (hydroponic and aeroponic), through the marketing of products with installation within the area of services sectors to sell the products, both to large distribution level and to retail level. It

[45] In http://www.futuresparks.org.au/media/34559/bright_ideas.pdf

[46] In http://webtv.sede.enea.it/index.php?page=listafilmcat2&idfilm=277&idcat=22

should also comply with the parameters "five zeros": zero emissions, zero waste, zero distance, zero power, zero pesticides. Implicit is the reduction of soil consumption, since Skyland exploits the height, with which one hectare is equivalent to 4-5 hectares of traditional crop fields.

The structure is composed by the building, 150 meters high, and consists of a 30-storey main body designed to contain the greenhouses on a total productive area of 4.2 hectares. It provides a side tower in which are placed the connecting carriers (lifts and elevators), the service of production facilities, the shopping area and catering and it is composed by smaller bodies in which they develop service activities, research, wholesale and retail trade. Are then foreseen terraced bodies, arranged along the height, destined to catering and recreation/cultural functions.At the top there is a terraced body with a sailing coverage with auditorium functions.

There will also be two underground floors for parking and utility rooms, and an outdoor covered parking for the public.

For the energy supply of the building is expected the use of photovoltaic panels and GHP (Geothermal Heat Pump), thermodynamic energy conversion plants inverse and extraction of biogas from waste.

2.2. Realized vertical farm

From projects that have been talked, emerges a vision of vertical farm in which predominates the architectural aspect. The imagined buildings are often mixed-use skyscrapers that require great investments and challenging urban interventions. Most of the realized vertical farm are greenhouse multi or single floor (even called PFALs, Plant Factories with Artificial Lighting) used exclusively for the cultivation of plants.

Their implementation depends on many factors. We list a few:
- agro-climatic factors for food production: for example the desert region of Middle East and North African countries have not enough soil resources to produce food; comparable situation in the Taiga and in the mountain regions, or Nordic countries, which do not have suitable conditions for agriculture;
- elevate urban population: the mega-cities have environmental problems linked to the production, logistic and quality of food;
- the eco-friendly attitude of the public administration: their policies can both facilitate and hind the vertical farm construction;
- the available investments: to activate a VF it's necessary an initial capital, which entity depends by the dimension of the system implementing. The technological systems used in VF often imply high initial and functioning costs;
- the potential market of products destination: if the purchasing power of local consumers is not high enough and if there are not the facilities able to activate a large scale market, it's impossible to implement a VF;

It is these factors that determine the transition from design to implementation, and that have moved towards the construction of small scale VF, such as, for example, that of the *Paignton* Zoo (United Kingdom), activated to produce food to feed the animals of the bio-park, reducing personal spending and avoiding CO2 emissions due to the movement of goods. Solutions such as this could have a large following, requiring low investment and optimizing resources.

Figure 19: Paington Zoo food production system

Many VF were activated in Asia and in USA, in addition to that of Newark, about which we will give a more detailed description, where have arisen high-tech facilities for indoor cultivation in Chicago, Detroit, Buffalo (NY) and New Buffalo (Michigan), and many more are being born.

Figure 20: the Green Spirit VF of New Buffalo, Michigan

We think that among the Vertical Farms realized, a mention must be done for that presented by ENEA within the "Future Food District" at the Expo 2015 in Milan, a small prototype that was meant to give visibility to this type of indoor cultivation. It was a metallic structure of 3x3 meters base and 4.5 meters high, covered with transparent glass panels (extra-clear tempered glazing) on the east and west sides,

and insulation panels (glazing reflective matt) on the north and south sides. On the north side it was inserted a LED screen, while on the south side there was the back door. The flat roof of the structure also served as a support structure for air conditioning of the greenhouse plants, inside which there were shelving consisting of 6 levels with the function of supporting tanks at ebb and flows of water containing nutrients and crops (multilayer cultivation system).

Also among the VF that have seen the light, we choose some that may be emblematic of the various existing and different geographical are types.

Figure 21: ENEA's VF, (EXPO 2015)

2.2. Realized vertical farm

2.2.1 The Sky Greens vertical farm

The Sky Greens vertical farm, realized in 2012 in Singapore to help the city grow more food locally and reducing dependence on imported produce, is considered the first commercial vertical farm. With a population of five million crammed on a landmass of just 715 square kilometers and only seven percent of food grown locally, the tiny republic of Singapore has been forced to find a system to feed its many

inhabitants and to make some areas of the mega-city self-sufficient from the productive point of view.

The solution has been found in the form of a public-private partnership, with the creation of what has been hailed as the "world's first low-carbon, water-driven, rotating, vertical farm" for growing vegetables in an urban environment, result of a collaborative agreement between the Agri-Food and Veterinary Authority of Singapore (AVA) and a local firm, Sky Greens.

The vertical farming system was ultimate and tested by the engineer Jack Ng and by "Go-Gro", a professional potting mix manufacturer, which created a series of aluminum towers – some up to nine meters high – each containing 38 tiers equipped with troughs for the vegetables production. To ensure the Sky Greens's environmental sustainability, the water used to power the rotating towers and to grow the vegetables is recycled within the system. Each tower consumes only 60 watts of power daily, about the same amount as a single light bulb, thanks to the consistent sunlight that reaches the plants through the transparent facades, reinforced also by the slow rotation of the vertical structure: «The multi-layered vegetable tower rotates very slowly, taking some eight hours to complete a full circle. As the plant travels to the top it absorbs ample sunlight and when it comes back down it is watered from a tray that is fed by the hydraulic system that drives the rotation of the tower. The closed cycle system of the farm is easy to maintain and doesn't release any exhaust»[47]. La farm is able to produce two tons of fresh veggies every day, which are sold in local supermarkets.

Sky Green is therefore a system of production modules inside which are placed vertical structures used for the cultivation. This model have inspired many farms in various countries, who have developed the arable land in the vertical dimension.

[47] In http://www.ipsnews.net/2012/12/farming-in-the-sky-in-singapore/

Figure 22: the Sky Greens farm of Singapore

2.2.2 Vertical farm di Newark, New York

A Newark (New Jersey) it is being built what is considered the largest vertical farm in the world, obtained from the renovation of a former disused factory of 69,000 square foot, thanks to the investments of RBH Group, Goldman Sachs Urban Investment Group and Prudential Financial Inc.

AeroFarms is the foundator, an urban agricultural company, which have foreseen a 39 million $ cost. According to the builders, the production should be of about 900.000 kg of vegetables per year, destinated to local New York and New Jersey communities and partially cultivated with the aeroponic system. In the structure will be installed plants of photovoltaic panels for energy production, which will fuel efficient LED lights.

The AeroFarms CEO David Rosenberg how this project, which is scheduled for completion in 2016, is insert in a global vision: «We set out to build AeroFarms not to build one farm, not to build a farm for just the rich, but to really change the way we source of food for humanity»[48].

[48] http://www.npr.org/sections/thesalt/2015/08/05/429345848/green-pie-in-the-sky-vertical-farming-is-on-the-rise-in-newark

The urban farm has been greeted with fervor, but not without some criticism. Some worry that don't make sense to build this kind of farm in areas with high real estate prices or high labor costs. Others state that the vertical farm is not suited to growing many types of vegetables, such as tubers or fruit.

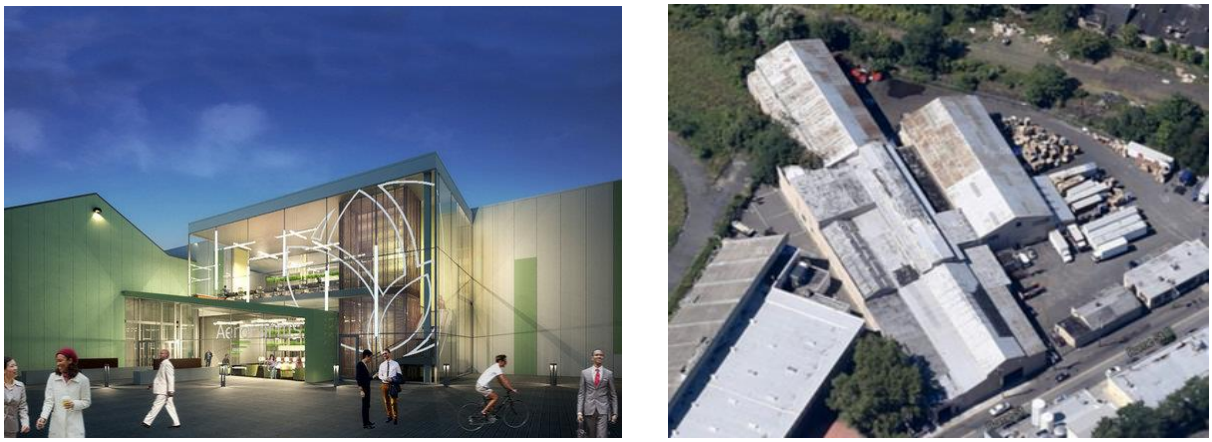


Figure 23: Newark VF project

2.2.3. Vertical farm of Suwon, South Korea

Korea attempted its first vertical farm in the city of Namyangju in Gyeonggi Province in 2009, but the plan was stopped when it was not considered cost convenient, as the Ministry of Agriculture, Food and Rural Affairs official Lee Young-sik said in a report on the farms: «Normal vinyl houses cost 200,000 won ($182) to 300,000 won ($273) per pyeong (3.3058 square meters) to build. Glass greenhouses, meanwhile, cost one million won ($911), whereas a vertical farm costs 10 million won ($9,110). Despite the differences in the costs of building the farms, the crops' prices were all similar, so cost-effectiveness wasn't good for the vertical farm»[49].

[49] In http://www.koreatimes.co.kr/www/news/nation/2015/04/116_177084.html

In the Asian country, since 2012 was activated in Suwon, a city 30-kilometers south of the capital Seoul, a "smart vertical farm" prototype built by the Rural Development Administration, constituted by a three floors plant.

Journalists Fabian Kretschmer and Malte E. Kollenberg, after have visited the farm described that in Spiegel Online: «Inside the building, heads of lettuce covering 450 square meters (4,800 square feet) are being painstakingly cultivated. Light and temperature levels are precisely regulated. Meanwhile, in the surrounding city, some 20 million people are hustling among the high-rises and apartment complexes, going about their daily lives.

Every person who steps foot in the Suwon vertical farm must first pass through an "air shower" to keep outside germs and bacteria from influencing the scientific experiment. Other than this oddity, though, the indoor agricultural center closely resembles a traditional rural farm. There are a few more technological bells and whistles (not to mention bright pink lighting) which remind visitors this is no normal farm. But the damp air, with its scent of fresh flowers, recalls that of a greenhouse.

Heads of lettuce are lined up in stacked layers. At the very bottom, small seedlings are thriving while, further up, there are riper plants almost ready to be picked. Unlike in conventional greenhouses, the one in Suwon uses no pesticides between the sowing and harvest periods, and all water is recycled. This makes the facility completely organic. It is also far more productive than a conventional greenhouse.

Choi [*Choi Kyu*-hong, agrarian scientist] meticulously checks the room temperature. He carefully checks the wavelengths of the red, white and blue LED lights aimed at the tender plants. Nothing is left to chance when it comes to the laboratory conditions of this young agricultural experiment. The goal is to develop optimal cultivation methods - and ones that can compete on the open market. Indeed, Korea wants to bring vertical farming to the free market»[50].

[50] In http://www.spiegel.de/international/zeitgeist/vertical-farming-can-urban-agriculture-feed-a-hungry-world-a-775754.html

Korea intetests to this kind of production has grown always more, based on the hope that in the near future the technology will expand and be capable of feeding the entire nation. In 2015 the Seoul government says the reason for the vertical farms is not commercial gain, but to develop new technology and expertise in this method of agriculture.

Figure 24: VF of Suwon, South Korea

2.2.4. PlantLab, Netherland

Located in Den Bosch, Netherlands, PlantLab[51] is currently under construction and is based on a smaller prototype that has been running for several years.

The plants are grown by red and blue LED lighting in a closed environment, quite sealed.

The plant has a control software that monitors parameters 163 830 per second in order to create the ideal environment for each type of crop. With the software are adjusted the temperature and the brightness to achieve the desired product in a shorter time and to have a lower waste of resources compared to the traditional greenhouses, and also is controlled the water cycle, which is recycled in the

51 PlanLab is a consortium of Dutch engineers, who have developed the technology to optimize plant growth.

evaporation, with a consumption equal to 10% of water used by a traditional greenhouse.

Loyal to its eco-friendly vocation, PlantLab does not use pesticides, no genetically modified plants and tries to limit human intervention as much as possible.

According Gertjan Meeuws, spokesperson of the firm, PlanLab will get a harvest three times higher than that of a traditional crop, with less consumption of the same output power.

His belief is that the advanced technology implemented - which saves 90% water, triples the crop and can grow any type of plant - can be effectively used in every part of the world.

Figure 25: PlantLab (Netherland)

2.2.5 Vertical farm Nuvege in Japan

Vertical farming has been booming in Japan after 2011, when Fukushima nuclear disaster irradiated a significant portion of the nation's arable land. Born to face this huge problem, Nuvege (also called "Green Green Earth") is a hydroponic vertical farming company based out of Kyoto, currently producing lettuces in a hydroponic system innovative, unlike any other conventional hydroponic system that exists today, as its creators say: «Nuvege's proprietary lighting network (NLN) uniquely increases the yield rate of vegetable growth by equalizing light emissions that also

advance photosynthesis through increased levels of carbon dioxide. Our lettuce products, grown in our protected "Vertical Farming Environments" with our patented technology, are unaffected by erratic weather, climatic events, bacterial disease, and remain unthreatened by contaminants of any kind.

The result is a form of extraordinarily healthy, organic produce that is unmatched anywhere in the world for its quality and content.

Nuvege - is the healthy, sustainable business model for the future of the world's food supply. [52]

The farm is housed in a 4 story quanset hut-like building, the size of a 747 hangar (2851 square meters) 30.000 horizontal square feet, and utilizes more than 57.000 of vertical square feet of growth environment in the same space. Naoki Matsumoto, of the SPREAD company, is the one that activate the plant, convinced that Nuvega is going to improve: «We produce only lettuce, but the variety of produce grown in plant factories is increasing»[53].

The company intent is that their innovative vertical farming techniques will provide a universal model for the rest of the world. Nuvege's corporate goals actually include efforts to establish branch operations throughout Asia and United States.

Always in Japan, precisely at Aizuwakamatsu, city of the Fukushima district, a only 113 miles from the Daiichi Nuclear Power Plant, Fujistu, a Japanese multinational company began to experiment a fresh cultivation system using advanced artificial lighting in a factory that could produce 3,500 heads of lettuce per day.

[52] In http://agritecture.com/post/27440882258/nuvege

[53] In http://scitation.aip.org/content/aip/magazine/physicstoday/news/10.1063/PT.5.4002

2.2.7 Plantagon Greenhouse (Svezia)

In the Sweden city *Linköping* is being build an industrial-scale multifunctional vertical farm projected by Plantagon, an international company leader in the sector of urban agriculture**.**

Hans Hassle, CEO of Plantagon, explains so his happiness about the start of the project: «We are excited that the Plantagon Greenhouse has been given the green light by Linköping's Administrative Board, and we are of course very eager to get started. The vertical greenhouse in Linköping will be a landmark in several ways. It is the first building of its kind in the world. It is also the result of combined efforts from several actors, like SWECO, Tekniska Verken and The City of Linköping, working together with us to realize this project»[54].

In the greenhouse of 60 meters high will be space reserved for urban agriculture and in the inner part of the construction will be a 16-story office building that can be used for many different functions (hotel, office or school). Plantagon's head office will host on one floor, while in the others floors there will find the offices of other companies, institutions and start-ups.

The entire building is thought to minimize the use of water and the demand for artificial lighting, and to gain the most possible homogeneous light levels.

[54] In http://www.mynewsdesk.com/plantagon-international/pressreleases/plantagon-to-build-unique-vertical-greenhouse-for-urban-agriculture-in-linkoeping-sweden-1100765

Plantagon Greenhouse should so become a mixed-use skyscrapers, and not a vertical farm only used to cultivate.

2.2.8. Vertical Harvest, Jackson, Wyoming (USA)

Under construction from November of 2014 in the heart of the city of Jackson, Wyoming, this greenhouse is built by Show Construction with a public/private partnership to fill an increasing market demand for locally fresh agricultural products. It is a 3-storey building built on a surface of 13,500 sq. ft., within which they will be implanted hydroponic systems.

«The greenhouse – we ca read in the web site of the farm – will utilize a 1/10 of an acre infill lot to grow an annual amount of produce equivalent to 5 acres of traditional agriculture.

With 95% of its product already under pre-purchase agreements, Vertical Harvest will grow and sell vegetables year-round to the Jackson area via restaurants, local grocery stores and directly to consumers through on-site sales. Vertical Harvest will also donate fresh produce to anchor institutions such as St. John's Medical Hospital to go towards nutritional programs, like the Diabetes Program. Vertical Harvest will provide these businesses and programs with a stable, consistent source of produce at competitive prices year round.

In addition to fresh lettuce and tomatoes, Vertical Harvest produces jobs. Vertical Harvest will establish an innovative model to employ an under-served Wyoming

population: adults with developmental disabilities. Current statewide statistics show an unemployment rate of 78% among Wyoming's employable developmentally disabled residents»[55].

With an estimated cost of $ 3,700.000, the farm should provide up to 100,000 lbs of produce each year, without using pesticide and a water consume about 90% less than conventional farming.

Figure 26: Project & construction of Vertical Harvest in Jackson, Wyoming

[55] In http://verticalharvestjackson.com/the-greenhouse/

Chapter 3

Analysis of advantages and disadvantages of vertical farm agricolture system: an open discussion

3.1. Advantages and disadvantages compared

Strong supporter of vertical farms, Dickson Despommier has been spreading the seeds of his radical idea through conferences, lectures and his web site. However this idea has been questioned by many critics, who have pointed out that «dreams need to be brought down to earth».

To answer the skeptics in his book The Vertical Farm Despommier analyses 11 advantages of vertical farm:

« 1. Year-round crop production
2. No weather-related crop failures
3. Eliminates agricultural runoff
4. No agricultural runoff
5. No us of pesticides, herbicides or fertilizers
6. Use of 70-95 percent less water
7. Greatly reduced food miles
8. More control of food safety and security
9. New employment opportunities
10. Purification of gray water to drinking water
11. Animal food from postharvest plant material»[56].

To those brought to light by Despommier you can add other more general benefits:

1. Great reduction of use of fossil fuels (farm machines and transport of crops)
2. Possibility to use abandoned or unused properties
3. Mayor sustainability for urban centers thanks to transport reductio

[56] D. Despommier, cit., pp. 154-146.

4. Energy saving allowed by the use of methane generate from the combustion of inedible parts of crop plants
5. Risk reduction of infection caused by agents transmitted at the agricultural interface
6. Returns farmland to nature and restore of ecosystem functions and services
7. Less use of agricultural soil

Despite these positive aspects, however, are many who highlight the negative ones:
- Use of a lot of electricity: excluding the vertical farm implemented fully equipped with walls of glass structures (as greenhouses), there's few sunlight that can reliably capture with a vertical farm, so it's necessary to rely a lot on artificial light, and this is expensive in term of money and of resources use, if the farm does not have an efficient and advanced renewable energy systems;
- pollination problem: if the vertical farms is an insect-free environment, pollination will have to be done by hand, and this will ask more cost;
- problem of the cost of urban surfaces, that is greater than that of rural areas, and the problem of the renovation of existing buildings costs to be converted back into vertical farm;
- problem of the overall cost required by the creation of such complex systems, which, in addition to the construction costs, include those for lighting, for the control of environmental temperature, to the apparatuses for the nutrient delivery system, for the platforms for plant growth along with artificial growing medium and interior elevators (for people, various products and materials).
To examine the weaknesses of a vertical farm very usefull is the report of Germans *Chirantan Banerjee e Lucie Adenaeuer, Up, Up and Away! The Economics of Vertical Farming*, publicized on *"Journal of Agricultural Studies"* of *Macrothink Institute,* a private organization dedicated to scientific research and publication di Las Vegas. The purpose of the report was to investigate the economic feasibility of a vertical farm of 37 floors high, designed and simulated in Berlin by the

Engineering Study initiated by DLR Bremen, and to estimate the cost of production and market potential of this technology. This is the resume of the weaknesses highlighted:

«Crops require space, light, carbon dioxide and water, which is available freely in nature. In case of Vertical Farming all these need to be supplied at a cost. Structures need to be built for the nutrient delivery system and platforms for plant growth along with artificial growing medium, generating additional costs. This could be a weakness compared to conventional agriculture; greenhouse agriculture on the other hand has similar requirements. Taking this into consideration, Vertical Farming is logically viable only in places where agriculture is necessary but agro-climatologically difficult to be practiced in the open, like in desert nations or mountainous nations lacking flat arable land. This might also be justified as a space saving approach in Mega-cities where real estate demands hinder setting up of parks and botanical gardens.

Light in Vertical Farming towers has to be supplied artificially. Although it opens up the opportunity to regulate the wavelengths, intensity and photo-period to optimal levels, and can be held comparable to greenhouse agriculture, it still remains a cost that needs to be taken into consideration. The justification of incurring this extra cost lies in areas where light intensity is too low or the photo-period incompatible for crop cultivation, as in case of higher latitudes or where the intensity is too high for cultivating sensitive salads, fruits and vegetables, as in sub-tropical deserts»[57].

The importance of the location of vertical farms to assess the favorability is also underlined by Augustin Rosenstiehl – a french architect who worked with D. Despommier, associated with the group SOA in Paris. He is strongly convinced that every vertical farm project needs to be adapted to a specific place. In 2008 he said so: «We cannot do a project without knowing where and why and what we are

[57] Chirantan Banerjee, Lucie Adenaeuer, *Up, Up and Away! The Economics of Vertical Farming, Journal of Agricultural Studies of Macrothink Institute,* Vol 2, No 1, 2014. Available in http://www.macrothink.org/journal/index.php/jas/article/view/4526.

going to cultivate. For example, in Paris, if you grow some wheat, it's stupid because we have big fields all around the city and lots of wheat, good wheat. There's no reason to build towers that are very expensive»[58]. In realtà nel 2012 la stessa SOA ha progettato *Urbanana*, a banana plantation just in the heart of the French capital[59].

An important aspect of this innovative farming type is the exploitation of verticality, connected with the increase of urban density. As shown by the eastern megacities, vertical building is considered the only solution to keep the city within acceptable territorial dimensions, to reduce the time and transportation costs, and increase the value of urban land. The idea of vertical farming is so into this trend to carry out more and more self-sufficient city of towers because they are able to enclose within them all the functions necessary to the life of their inhabitants.

To complete the discussion on the advantages and disadvantages analysis, is worth recalling that, in the vision of Despommier, the vertical farms are not only facilities for the production of food, but activators of energy at various levels, the importance of which must be counted of their overall economies:

«Indeed, the Vertical Farm is not merely about food, but about the unseen circuits of energy and materials, labor and resources, capital and infrastructure, technology and politics upon which our cities depend; food is only a single component of the Vertical Farm, the most visible part, the market and marketable part […]; food, the only part of farming which consumers see while the rest of the industrial process remaining invisible, unquestioned, absolved by sheer ignorance»[60].

There is another important benefit highlighted by Despommier: the social one. He believes that vertical farms could become «important learning centers for future generations of city-dwellers, demonstrating our intimate connectedness to the rest

[58] Cited in The New York Times, 15 june 2008, in http://www.nytimes.com/2008/07/15/science/15farm.html?_r=0

[59] See the projectin: inhabitat.com/urbanana-is-an-urban-renovation-concept-that-would-bring-banana-farming-to-paris/

[60] D. Despommier and Eric Ellingsen, The vertical Farm – The origin of 21st century Architectural Typology, CTBUH Journal, 2008, in http://global.ctbuh.org/resources/papers/download/449-the-vertical-farm-the-origin-of-a-21st-century-architectural-typology.pdf

of the world by mimicking the nutrient cycles that once again can take place in the natural world. These traits re-emerged as the result of returning land
Back to the natural landscape» [61]. Hence the vision of vertical farm as poles of ecological education and social gathering, so necessary especially in megacities, but also desirable in smaller urban centers. The question arises to what extent this social aspect can arouse the interest of public authorities and investors.

3.2. Cost analysis

Vertical farming is steadily becoming a subject discussed in industrial and scientific communities of many countries. There are a lot of centers (more than 150 for Christine Zimmermann-Loessl of the Association for Vertical Farming[62]) working on realization, realization and on their physical, economic and structural feasibility: ThanetEarth (UK); NewYork-Sunworks (USA); Omega-Garden (Canada); Levenston (Canada); PlantLab (Italy); VertiCrop (Canada); Plantagon International AB (Swedish), ENEA (Italy); Sky Greens (Singapore); The Plant (USA), Mirai Co. (Japan), Aerofarms INRA-AgroParisTech (French), German Aerospace Centre (Germany), Urban Pastoral Collective (USA), EcoGeek (USA), SOA (France); ODA architecture (USA), to name just a few. There are also numerous universities that foster research in this area: in addition to Columbia University (USA) in which D. Despommier, we mention a few other: Clemson University Institute of Applied Ecology (USA); Faculty of the Architecture Department in Partial Fulfillment of the Requirements for the Degree of Master of Architecture Savannah College of Art and Design (USA), Politecnico di Torino (Italia), School of Architecture, Dalhousie University, Nova Scotia (Canada), *Università La Sapienza di Roma* (Italy) and the *Università di Perugia* (Italy).
The construction of a vertical farm requires a prior and detailed cost analysis of start-up costs and operation costs, based on accurate quantification of all items of

[61] Ibidem.
[62] The Association for Vertical Farming is an internationally active nonprofit organization focusing on advancing Urban and Vertical Farming technologies, designs and businesses. Site: https://vertical-farming.net/

expenditure and revenue, to check if it holds the promise of enabling more food produced with less resources use, but especially if the capital expenditure for construction and the annual variable costs can have a yield as to encourage investment in this sector.

Obviously, the quantification of costs depends on different scenarios of each specific realization, which can present significant changes in relation to the type of structure (height and width, technologies used, type of cultivation, energy used and produced etc.) and to the geographic area in which it is implemented.

Interesting detail is the cost analysis performed for a "*tesina de especialitat*" by Marc Prades Villanova of the *Escola de Camins* (Universitat Politècnica de Catalunya, BarcelonaTech) on the project to change the west façade of the *Mies Van der Rohe's Seagram Building*, in New York, with the substitution of the existent façade with a Double Skin Façade where, between the two glass surfaces, many plants could grow with hydroponic system. The accurate quantification of all items of expenditure of this original system leads to the following conclusion: «This first approximation offers some valuable results. Even with suboptimal circumstances (using default window glass), the energy savings from implantation would still be substantial»[63]. That confirms that the use of glass walls is a decisive variable for the economy in terms of energy saving.

3.2.1 Cost analysis of Singapore vertical farm

Regarding the importance of the geographical area in which is implemented a vertical farm, it is interesting to the analysis made by Luckily JJ Reidy, CEO of the Urban Pastoral Collective, which highlights the basic conditions that have made the construction advantageous the vertical farm in Singapore:

[63] Marc Prades Villanova, *Vertical Farm Façade First approach to the energetic savings applied to the Seagram Building in New*
York.http://upcommons.upc.edu/bitstream/handle/2099.1/23367/Vertical%20Farm%20Fa%C3%A7ade%20%28Marc%20Prades%29.pdf

« - Dense and urban population (Singapore is an island a little more than 3 times the size of Washington, DC with a population of 5.6 million people. Their population is 100% urbanized).

- Production proximity to market (New, government-sponsored industrial parks allow companies to build their businesses on the island)

- Existing infrastructure (Singapore is a developed, high-tech country whose purchasing power parity ranks 41st in the world)

- Cheap energy (Energy is reliable and affordable, especially when supplemented with renewable resources)

- Legislative Support (Singapore's government not only has the laudable sustainability goals of 20% self-sufficiency in the coming years, but also established a 20 million dollar fund to boost domestic food production. This helps enormously in the face of insane vertical farming start-up costs.)

- Local Demand (Expensive imports from China and Japan currently fill Singapore's supermarkets. Singapore only produces 7% of the produce it consumes)»[64].

Luckily JJ Reidy notes that «doing this analysis in Singapore was important for two reasons: first, because Singapore's government is so dedicated to increasing their self-sufficiency, they aren't going to put unnecessary legislative blocks on vertical farm projects and instead will let market forces decide what succeeds; and second, there were two vertical farms competing with very different models for the same concentrated market»[65]. An important factor highlighted by Luckily JJ Reidy is the legislative one, which can weigh significantly on the feasibility of vertical farms.

[64] In https://urbanverticalproject.wordpress.com/2014/08/08/the-first-vertical-farm-showdown-why-you-need-to-know-whats-happening-in-singapore/

[65] Ibidem.

3.2.2. Case: total cost analysis of a vertical farm simulation, in Berlin

In the mentioned report *Up, Up and Away! The Economics of Vertical Farming* of *Chirantan Banerjee e Lucie Adenaeuer* we find an accurate costs analysis based, as we say, on the simulation of a vertical farm in Berlin, considered a megacity with a sufficient market potential for implementing such a structure. This is the designed vertical farm:

«In order to support 15,000 people with enough food the tower is planned to have the following configuration: A Vertical Farm of 0.93 ha (roughly the size of a city block) with a total of 37 floors, 25 of them solely for the purpose of crop production and 3 for aquaculture. Further, uniformly distributed floors are for environmental regulation and 2 in the basement for waste management. In addition there is one floor for cleaning of the growth trays, sowing and germination, one for packing and processing the plants and fish and one for sales and delivery at the basement. This configuration results to a total building height of 167.5 meters, with a length (and width) of 44 meters, giving an aspect ratio of 3.81. A freight elevator big enough to allow a forklift truck was planned in the center of the building, allowing for harvest and waste to be transported down to the respective floors. [….] It yields about 3,500 tons of fruits and vegetables and ca. 140 tons of tilapia fillets, 516 times more than expected from a footprint area of 0.25 ha due to stacking and multiple harvests»[66] .

The costs analysis simulation brings us to conclude that the investment costs add up to € 200 million di euro, and it requires 80 million liters of water and 3.5 GWh of power per year, with the produced food costs around between € 3.50 and € 4.00 per kilogram.

The 200 million euros computation has been so obtained:

[66] Chirantan Banerjee, Lucie Adenaeuer, *Up, Up and Away! The Economics of Vertical Farming*, cit..

Production Costs

Fixed Costs	**(€)**
Building (incl. Site)	111 581 994 €
Equipment	90 382 192 €
Total Costs	201 964 186 €
Variable Costs	
Personnel	12 050 000 €
Power Demand	5 390 941 €
Plant Seeds	44 406 €
Water (recycled)	0 €
Nutrients	424 919 €
Fish Food	127 020 €
Total Costs	8 037 286 €

The study ends to the conclusion that «to tap the economic, environmental and social benefits of this technology, extensive research is required to optimize the production process»[67], also because if the produced food costs are between 3.50 € and 4.00 € per kilogram, we can establish that from this analysis emerges a substantial economic unsustainability of the considered vertical farm. So the conclusion is that «to tap the economic, environmental and social benefits of this technology, extensive research is required to optimize the production process. […] This work started with reasonable doubts that food grown in Vertical Farms might be exorbitantly expensive to ever become a practicable solution. This work has shown, however, that it is a possibility which needs to be further investigated»[68].

[67] Ibidem.
[68] Ibidem.

3.2.3 Cost analysis of Skyland project, Milano

The cost of energy is considered the most specific of a vertical farm, as it differs that from the one in traditional soil culture, which does not need to expenses for lighting, heating and cooling, and the operation of the production apparatus (lifts and hoists). It is therefore a crucial voice in determining the sustainability of this type of agricultural buildings (see the interview of the architect Gabriella Funaro, ENEA, in the appendix).

For the quantification of the energy costs of a vertical farm is very useful the thesis *Bilancio energetico di una vertical farm* presented at the Turin Polytechnic, Faculty of Engineering, Degree in Civil Engineering from David Wüthrich in October 2010.

In this work, the graduate has performed a thorough analysis of Skyland costs, the vertical farm designed by ENEA, which has been discussed in Chapter 3, for the cultivation of leafy plants, fruit plants and tuber plants.

The verification work was requested by the ENEA, in order to check the facilities of the structure and assess its energy self-sufficiency.

To do this analysis of consumption expected during operation for Skyland, David Wüthrich has used Design Builder[69], a software Energetics of Buildings Simulation, applied to a virtual model of the structure, observing as much as possible the constructive provisions.

The results were then compared with those developed by ENEA.

« When considering Skyland as a whole, in order to verify consumption - writes Wüthrich – we prefer to divide the skyscraper in different environments depending on their intended use. Each room has a distinct behavior, resulting in consumption and energy balances different from area to area and in order to simulate as closely

[69] The software Design Builder used in the calculation of the energetic balances is a commercial interface which utilizes Energy Plus, whole building energy simulation program that engineers, architects, and researchers use to model both energy consumption - for heating, cooling, ventilation, lighting, and plug and process loads -and water use in buildings. Its development is funded by the U.S. Department of Energy Building Technologies Office.

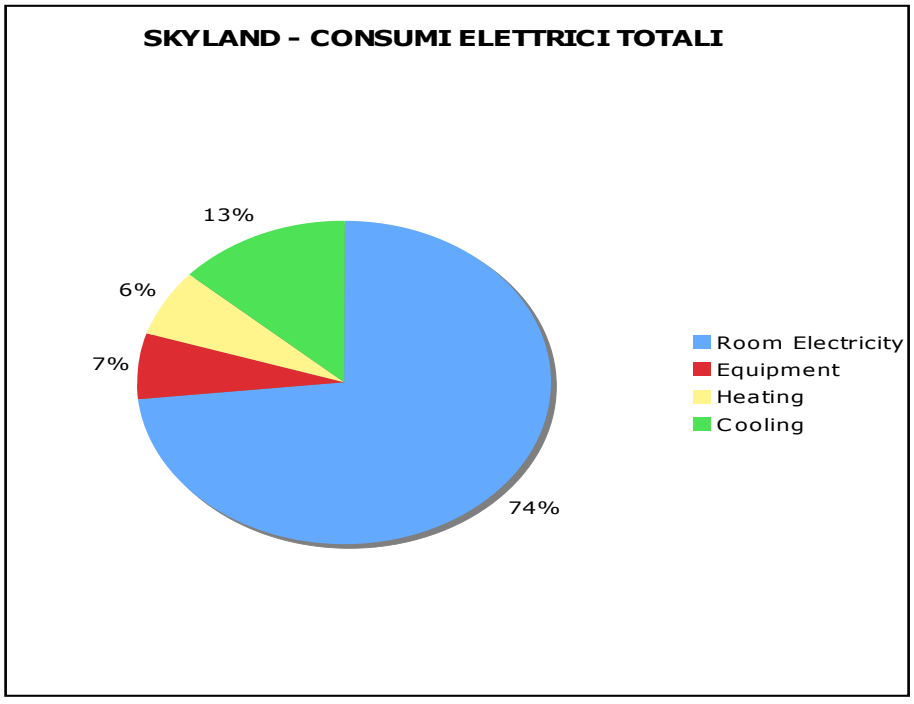
as possible the service life of the building in question, to all parts of the structure were assigned very specific characteristics, typical for that destination user.
Simulations have been made both for total energy balance, related to the whole structure, and for the partial of each zone identified in the skyscraper. It was also possible to plot an hourly trend of temperatures and relative humidity in various environments; this last graph is indispensable in the area turned into a greenhouse for hydroponic cultivation of plants, which must be kept constant temperature and humidity.
For each environment we are then derived the consumption on an annual scale and the expenses required under the least favorable conditions, so for the hottest day of the year (July 15) and the coldest day of the year (January 15). The financial statements in the less favorable conditions are used to size the systems that need to be able to guarantee a maximum of comfort even under poor working conditions.
The experience aim was to obtain an energy balance of the whole structure under examination, Skyland, to verify the installations»[70].
The calculation was made by dividing the area of the greenhouses consumption and the services area, which present extremely heterogeneous technical characteristics and therefore a different energetic grade.
According to data provided by the agronomist ENEA, it is expected that the density of plants per cubic meter reached within Skyland is the following:

PRDUCTIVE PARAMETERS	**LEAF PLANTS**	**FRUIT PLANTS**	**TUBER PLANTS**
Plant density [plants/m^3]	*70*	*4*	*12*

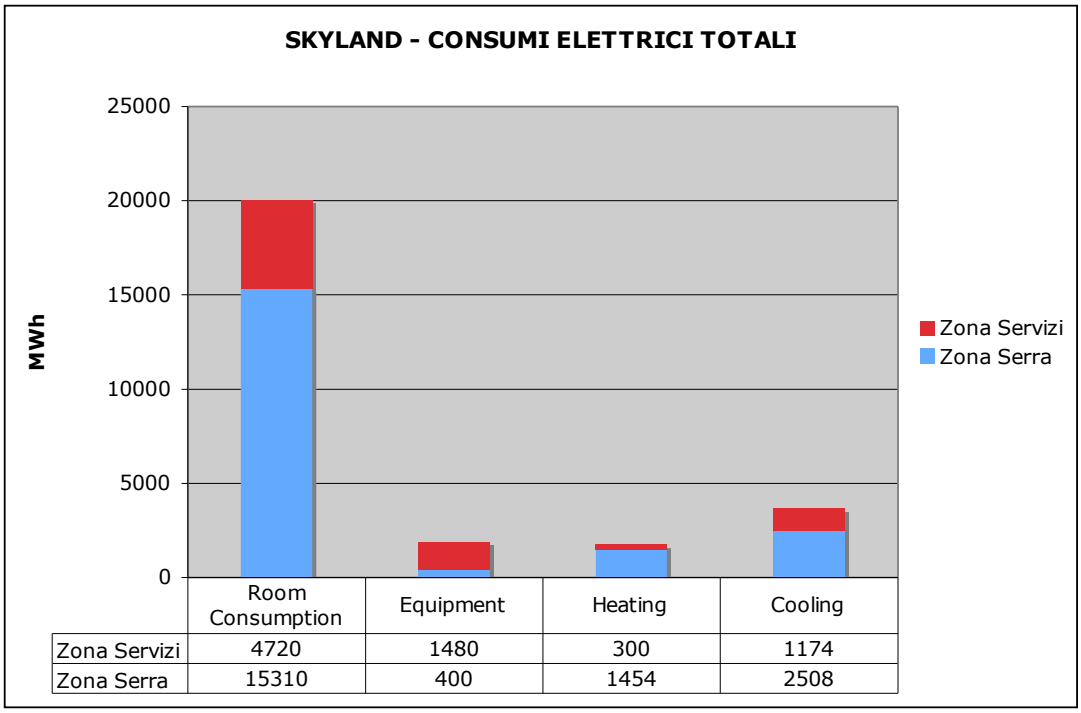
[70] Davide Wüthrich, *Bilancio energetico di una vertical farm*, final tesis preseted to the *Politecnico* of Tourin, *Facoltà di Ingegneria*, *Corso di Laurea in Ingegneria Civile*, octuber 2010, p. 37.

To grow and mature plants under optimal conditions, the greenhouses should be monitored according to various parameters - temperature, relative humidity, circulation and exchange of air, lighting, day and night cycles of light - each of which has consumption characteristics energy specifications.

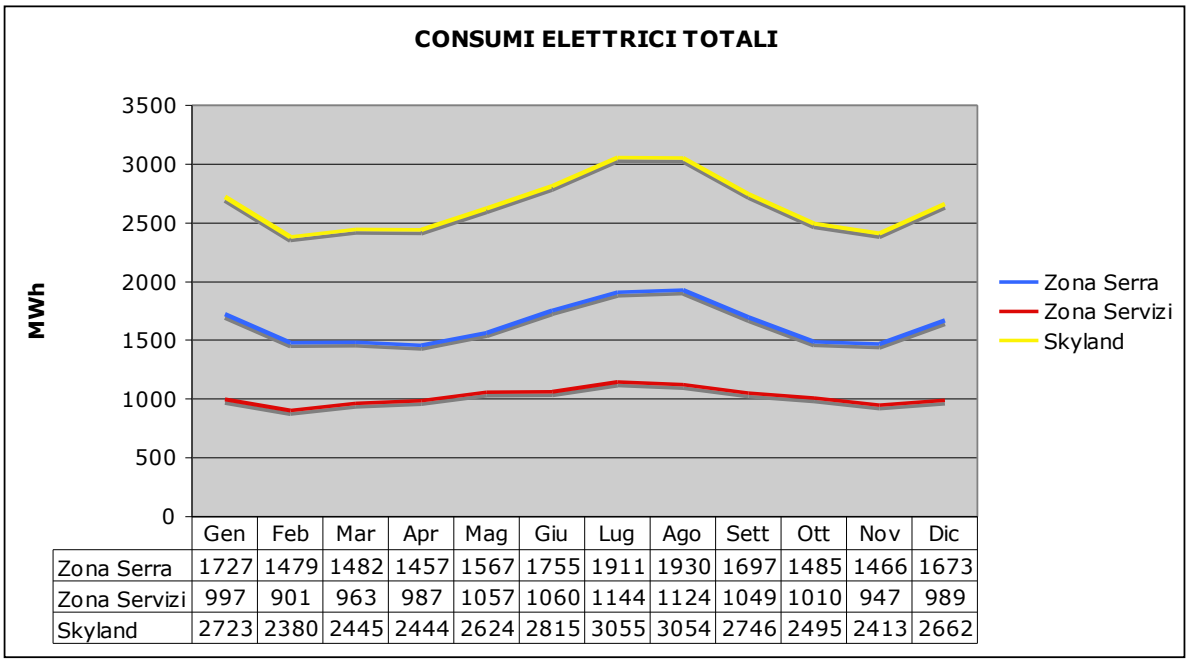
The calculation made by David Wüthrich in his thesis were summarized in a series of graphs. The following example shows the different incidence of total electrical consumption values divided into different uses. From them it is clear that the higher consumption is related to the illumination system.



The following graphs instead shows the total electricity consumption set, divided by areas, and for months.



	Room Consumption	Equipment	Heating	Cooling
Zona Servizi	4720	1480	300	1174
Zona Serra	15310	400	1454	2508



	Gen	Feb	Mar	Apr	Mag	Giu	Lug	Ago	Sett	Ott	Nov	Dic
Zona Serra	1727	1479	1482	1457	1567	1755	1911	1930	1697	1485	1466	1673
Zona Servizi	997	901	963	987	1057	1060	1144	1124	1049	1010	947	989
Skyland	2723	2380	2445	2444	2624	2815	3055	3054	2746	2495	2413	2662

In the thesis emerges that the producible energy in the building is insufficient to meet the total energy needs, estimated at 27.35 GWh per year, and that the self-

reliance of the structure remains a critical point of the project. The values provided directly by ENEA are in fact the following:

- photovoltaic energy: the total energy that can be produced by photovoltaics is 3.6 GWh/year
- biogas energy: the producible electrical energy from municipal solid waste is 5 GWh/year
- from geothermal energy: the electricity produced by geothermal heat pumps is approximately 7 GWh/year.

Concluding his scrupulous studies, David Wüthrich comes to the following conclusion:

«The fact that as a result of this simulation, and through the use of these systems currently envisaged we are not able to achieve energy self-sufficiency of the complex does not imply that the project is not feasible, indeed we must take this simulation as a point of start and a cue for further research and find a solution to this problem that makes the entire building self-sustainable from an energy point of view. So this is a very interesting and very challenging technological challenge that, thanks to the most innovative systems, will be surely able to win»[71].

[71] Ibidem, p. 82.

Chapter 4 The integration between architecture and urban agriculture in the vertical dimension

4. 1. Towards an architecture always greener

At the EXPO 2015 in Milan it was organized the traveling exhibition A.A.A. Agriculture Alimentation Architecture, dedicated to new trends in green architecture, in order to stimulate architects, engineers and agronomists to share their knowledge and leave the precincts of the interests of the category to turn the design into a new and great opportunity for urban development. «Today – the PromoVerde[72] president Gianluca Cristoni says – we have a unique opportunity to ensure that the culture of the project makes a step forward. Architects and engineers have to learn about plants, worth the loss of commissions and money. And the agronomists, growers and the whole of the green supply chain must understand the world of architecture and see it for what it has become for them: a new and great opportunity for professional development».[73]

This initiative forms part of the growing awareness of green architecture, seen as the future of environmental sustainability and able to create (or recreate) a fruitful symbiosis with the Food and Agriculture also part of the urban dimension. Expelled from the city by the process of industrialization, agricultural production appears to have now the opportunity to reconnect to the housing centers in order to overcome the problems posed by their growing food needs and also the necessity to reduce costs (economic and environmental) transport.

As we have seen (see the Premise) since the Sixties and Seventies we have made buildings that have combined housing solutions with the expansion of green spaces located in the buildings. In the eighties, instead, the intent of integrating green and architecture it is decidedly moved in the direction of urban verticality. Among the

[72] PromoVerde, *Associazione per la Qualità del Paesaggio e del Florovivaismo*, based in Rome, aimed to coordinate non-profit network of professionals, companies, associations, institutional bodies, higher education and research institutions, individual citizens to promote a new relationship with Green, Agriculture, Architecture, Food and the landscape in all its forms.

[73] In Press release: http://www.assoarchitetti.it/doc/aaa.pdf

precursors of this design choice is reckoned the Korean architect Ken Yeang, who, with his Bioclimatic skyscraper and its eco-architecture, has placed ecological sustainability and aesthetics at the center of its vertical urban design.

With buildings as the *National Library* of Singapore, thought as a "vertical linear park" with an ecologically-linked vegetated pedestrian walkway ramp punctuated by sky garden terraces located at each of the building's corners, and further linked to the uppermost-level roof gardens. Also with the successive, the *Solaris* in Hong Kong, conceived as "ecocell" (a green integrative device), Ken Yeang has paved the way to an eco-architecture designed to meet a growing interest, especially for the possibility of integrating the agricultural function in that housing.

Have so grown up the projects of mixed-use skyscrapers, in which the plant should be cultivated in open air or in indoor system.

The orientation towards ecologically sustainable architecture cannot be separated from speculative aspects related to real estate transactions, which can be seen in the increase in green urban strategies inspired by the new frontier for increasing the real estate market taking advantage of the growing awareness (and demand) to homes with space-garden in the urban dimension. Because to build houses is required capital injections, the financial aspect is essential to the evolution of the "green friendly". The question is whether the inclusion of space-garden in the cities, in big cities or in megacities can be considered only a trend, a profitable business or a particular need for environmental reasons. The same question is asked by some for vertical farms.

4.1.1. Green architecture projects

Interest in green farming has infected famous architects, who explore the possibility to experiment with a new idea of the urban dimension. The SPARK study, based in London, Singapore and Shanghai, has carried out numerous projects aimed at systematic integration between residential areas and spaces for the growth

and care of vegetation, such as Homefarm in Singapore, «a conceptual proposal for the next generation of urban retirement housing. It presents a living and farming typology for Singapore (or elsewhere) that combines apartments and facilities for seniors with vertical urban farming. Seniors live in a high-density garden environment created by a vegetable farm, where they may find employment. SPARK's aim is to generate discussion about the many potentials that can emerge from the mixing of two typically separate realms. The research-based design addresses two pressing challenges faced by Singapore: how the city state might support a rapidly ageing society, and how it might enhance its food security (90% of which is currently imported) »[74] . The project includes balconies with tanks for fish farming, which waste can be used as fertilizer for vegetables grown with hydroponic system. On the upper floors are designed earth filled containers in which to grow various kinds of plants and herbs, while in the center of the building is drawn a collective vegetable garden, which could produce up to six tons of vegetables per month.

Inspired by the same principles are also the SPARK Orchid road projects, always designed to Singapore, and the Nanchang Vanke Haishang Chuanq.

Another green project of particular interest is the residential tower *East 44th Street* in Manhattan, designed by ODA study, whose intention is to give the opportunity to enjoy all the advantages of a house in the suburbs in the city center. The project provides for real gardens suspended between one floor and the other and open plant levels accessible directly from the apartments, which offer a scenic and relaxing space to the inhabitants of the structure.

To demonstrate the attention towards these architectural perspective, the New York-based magazine *Metropolis* has launched a competition for urban architecture, which in 2015 was won by two English architects, Sean Cassidy and Joe Wilson, with Organic Grid +. The project provides for the inclusion on the

[74] In http://www.sparkarchitects.com/work/homefarm#1

outer facade of a office tower, 50 meters above the ground, a greenhouse high 3 floors. «The Organic Grid+ – says Sean Cassidy – sets out to create a completely unique approach to creating a healthier workplace which embraces technology and the current urban environment. The scheme seeks to reuse existing office spaces and them fully adaptable to any business using a flexible grid system. Through the use of augmented reality delivered via a contact lens, employees can manipulate any surface or space to be a usable working environment, forming both private and collaborative areas»[75].

One of the most spectacular realization of green architecture is the Parkroyal Hotel on Pickering di Singapore, a tower complex cut through by a wild patch of tropical forest, designed by WOHA, a Singapore-based architecture practice founded in 1994 by Wong Mun Summ e Richard Hassell. With this complex the designers have materialized their intention to demonstrate «how they were able to not only conserve greenery in a built-up high-rise city center, but multiply it vertically in a manner that is architecturally striking, integrated and sustainable»[76]. The complex is constituted by a group of towers suspended above a green zone of flora and palm trees that grows in the tropical climate. The vegetation runs long some curved terraces that are fixed to the towers' glass facades.

The "vegetalization" of urban spaces has established itself in Italy and found one of the most significant achievements in the *Bosco Verticale* made by Boeri in Milan, recognized in 2015 as the most beautiful building in the world.

A recent real estate transaction of green footprint is also the *25 verde*, project realized in Turin by Luciano Pia and Ubaldo Bossolono, with a rich and complex system of terraces, overhangs, tubs and window boxes that give the building the image of a pleasant suspended garden.

[75] In http://cassidy-wilson.com/organic-grid/
[76] In http://www.archdaily.com/217121/parkroyal-on-pickering-woha

4. 2. New green urban space

The green architecture and vertical farm are part of the more general concept of urban agriculture, within which there are very different realities, even with more modest dimensions, such as greenhouses and urban gardens, green roofs with also food use and gardens and vertical allotments intended for domestic cultivation of ornamental plants or vegetables, united by the exploitation of arable areas within cities.

«Urban agriculture - explains Francesco Ferrini - seems to overcome some limitations of the industrial food system, being an industry highly adaptable to different contexts, able to free themselves from dependence on fossil fuels, taking efficiently advantage of the high density of human and material resources in the present in the urban environments. These areas without a precise destination could provide productive uses, compatible with these ambits. If in certain cases of land close to road infrastructure and of contaminated soils is not desirable to the cultivation of edible plants, it is nevertheless possible, for example, use these areas for arboreal plants for CO2 emissions offsets. The impact of the suburban part of the green areas on the seizure of carbon dioxide and other atmospheric greenhouse gases appears also to be considered on the basis of the wide surface which, as said, these areas occupy in the territory, and in order to identify economic and technology strategies needed to reduce the negative effects of global change on the welfare and human health as well as on biodiversity structure in general»[77].

4.2.1. The green roofs: sky garden

The possibility of exploit the buildings' roofs for the cultivation of the plants has received a great success. The green-roof fans sustain the numerous advantages, in

[77] Francesco Ferrini, *Vertical farming": un'idea affascinante ma troppo poco sostenibile*, in Georgofiliinfo, http://www.georgofili.info/detail.aspx?id=594

fact this method can be very useful, by absorbing rainwater, providing insulation, reduce heating, combating the urban heat island effect (UHI)[78], creating a habitat for wildlife, helping to lower urban temperatures, to provide a more aesthetically pleasing landscape and, obviously, recovering surface to produce food.

Despite these positive aspects, we must also mention the problems linked to their implementation, which depends very much on the kind of roof garden. Despite the initial cost of installing a green roof completely recovered by vegetation, which demands a really efficient waterproofing system to isolate the roof and a constant attention, considering also that the additional mass of the soil substrate and retained water can weigh in problematically on the structural support of a building. That because a lot of buildings have not been designed to support such a large amount of added weight. Different is the concept of a building designed from the beginning to be able to support such weight.

Another problem can be represented by the insects which could infiltrate a residential building through the windows.

Green roofs can be only partially covered by vegetation (roof garden), or entirely covered: this is the case of the green roof made for the purpose of insulation, traditionally found in certain geographical aere.

The green roofs – also called eco-roofs, oikosteges or vegetated roofs –

Are divided into *intensive*, which are thicker, with a minimum depth of soil of 12.8 cm and can support a wider variety of plants but are heavier and require more maintenance, and *extensive*, which are shallow, ranging in depth from 2 cm to 12.7 cm, that require minimal maintenance. Advances in green roof technology have favored the development of new systems that bring the most advantageous qualities of both extensive and intensive green roofs.

[78] The urban heat island (UHI), a phenomenon already described in 1810 da Luke Howard, makes reference to all metropolitan area that is significantly warmer than its surrounding rural areas due to human activities.

Another distinction is between the flat green roofs and the pitched green roofs, which reduces the risk of water penetrating through the roof: this distinction is linked to the living typology of the different geographic areas.

Currently in urban areas has increasingly been developed the roof garden, often with real greenhouses for hydroponic or pot, although there are numerous studies for re-enacting the traditional principles of green roof in buildings covered with tiles of various materials.

Since the seventies have been made several studies on green roof and on roof gardens, especially in Germany, where Berlin is considered as one of the most important centers of research, togheter with the more recent ones of USA and of other countries, as Australia, Canada, Costa Rica, France, UK, Greece, Israel, Switzerland, Sweden and Egypt.

Between the greatest realization of roof gardens in multi-floor buildings we can mention the *Centro Congressi Library Square* di Vancouver, placed in the city center; the *Roof garden of the Rockfeller Center* in Manhattan (NY); the *Chicago City Hall Green Roof* in Chicago; the *Sky garden* from the 34 to the 37 floor of the *20 Fenchurch Street*, a commercial skyscraper in London; the roof of the *Palais de Tokyo* in Paris; the *Eagle Street Rooftop Farm* in Brooklyn (NY), real farm that produces organic crop on a roof of more than 500 square meters.

Since you can activate a roof garden even in small portions of the roofs of buildings, there is a growing number of buildings in which they are created small gardens on the roofs in which you can recreate the natural growth process of plants and vegetables.

It is worth mentioning also the innovative eco-friendly handicraft practice, spread mainly in Canada, Japan and France, to launch or shoot handfuls of seeds of certain plants with appropriate tools on small tiled roofs portions, to make grow small flowery spots only with the rainwater intake.

4. 2.2. The green walls

Starting from the intuition of Patrick Blanc, many architects and garden designers have begun to design vertical gardens (or vegetable walls) in urban areas and suburban, with aesthetic and ecological purposes.

It is necessary first of all to clarify the difference between green walls, that have growing media supported on the face of the wall, and the green facades, that have soil in a container or in ground only at the base of the wall.

There are various system to realize the green walls, which can be indoor or outdoor, of differenet measures and with freestanding supports or attached to an existing wall. They are generally built with modular panels hold by growing media, which can be of different type: shelves, bottles, containers, bags, sacks, or supports as coir fiber, felt mats, semi-open cell polyurethane sheet that are easily handled for maintenance and replacement. From the artisanal point of view are made creative green wall with various media fantasy, giving the green an original tone.

In addition to their high decorative value, the green walls offer several environmental benefits, as they improve the thermal insulation of the building to which they are combined, help to capture the fine dust, reduce noise pollution and glare, as they absorb the sound and light waves.

Species of ornamental plants suitable to be used for green walls change depending on climate and environmental factors in which they are: the most usual are the microthermal (fescue, perennial lolium, poa pratensis etc…) and macrotherm, indicated for warmer climates (such as couch grass), but many others can be chosen according to their color rendering. Suffice to say that Patrick Blanc for Oasis d'Aboukir Paris has used **7,600 plants** of **250 different varieties** on an area of 25 meters.

Typically they prefer varieties with low maintenance, needing little care and sporadic interventions during the year.

Recently in the major cities it has spread the interest in domestic vertical gardens, which give the possibility to produce vegetables even when you do not have land

available. A vertical garden makes it possible to grow plants in quite small places using the height of the outdoor spaces. There are many plants that we can grow, to be chosen according to the weather conditions: herbs, lettuce, radicchio, arugula, berries, but also kale, cabbage, broccoli, beans, peas, tomatoes, and even melons.
At the Expo 2015 in Milan the United States have realized in their pavilion a vertical garden of the length of a football field and designed by a team of architects led by James Biber.

4.2.3. Green roofs and the *Bosco Verticale*

The growing tendency to put the green in architecture, not as an appendix but as an important element of environmental sustainability, has increased the design of the green roof, placed on building terraces. The real estate market rewards this trend, for the greater appreciation for the units equipped with areas dedicated to the cultivation of ornamental plants, but also eatable.
It is especially in large cities that are designed and built buildings with terraces "*vegetalized*" ever wider, some of which create a "green" impact of great charm.
It is part of this trend the project *Forwarding Dallas*, winner pin May 2009 of a competition in which the designers were call to design the most sustainable city block possible at the most low prize, that was the chance to see that design come to life. Designed by the Atelier Data and MOOV, the building include vegetation-covered hillsides, apartments, a cafe, a gym and many other public spaces.
Currently pending construction, but not yet started to be built, is the *EDITT Tower* in Singapore, thought to become a paragon of “Ecological Design In The Tropics”. The building of 26 floors, doted by numerous hanging garden (quite half of his surface area will be wrapped in organic local vegetation), was designed by TR Hamzah & Yeang and sponsored by the National University of Singapore. It will boast photovoltaic panels, natural ventilation and plants for the biogas generation and for collect rainwater and integrate a grey-water system for both plant irrigation

and toilet flushing, with an estimated 55% self-sufficiency. Publicly accessible ramps will connect upper floors to the street level, in which will find place shops and restaurants.

Already achieved is the spectacular ACROS, building with hanging gardens raised in Fukuoka (Japan), the structure of which reaches a height of about 60 meters and contains 35,000 trees of 76 different species.

Designed by Argentine architect Emilio Ambasz and opened in April 1995 after more than three years of construction, the building houses inside a concert hall, conference rooms, a cultural information center aimed at tourists, public and private offices, and an art gallery. The south-facing facade is characterized by a series of terraced gardens covered by dense vegetation, which makes this building one of the most significant ecological architecture models.

Also in Singapore was recently built *Pinnacle*, a large complex of towers jointed each other on the 26th and the 50th floor balcony of a bridge, with hanging gardens and rooftop garden at altitude.

One of the most successful examples of buildings with real hanging gardens is the *Bosco Verticale* (Vertical Forest), built in the historic center of Milan and designed by the architect Stefano Boeri, whose idea it was to build a «Tower for trees wich incidentally haused human beings»[79].

The Vertical Forest is made up of two buildings housing 400 residential units: the E Tower is 26 floors and 111 meters high, the D Tower is 18 floors and is high 78 meters. A kilometer and 700 meters of vessels go along the steel-reinforced concrete baconies - designed to be 28 cm thick, with 1.30 meter parapets - were placed 730 trees (480 large, 250 small), 5,000 shrubs and 15,000 between vines and perennials; groundcover was placed on the facades of buildings.

«It took months of research and experiments – writes Boeri – conducted with a group of outstanding experts in botany and sustainability to solve problems that

[79] Stefano Boeri, *A vertical forest – un bosco verticale*, Corraini edizioni, Bologna 2015.

architecture had never before had to deal with: how to prevent a tree being broken by the wind and falling from a height of 100 meters, how to ensure continuous and precise watering of trees planted at heights where conditions of humidity and exposure to sun are very different; how to prevent the life of the trees being jeopardized by the personal choices of the owners of the apartments»[80].

Whit this greening of the two skyscrapers Boeri has set out to change the relationship between trees and men, promote a new idea of the city and «reduce energy consumption thanks to the filter that a façade of leaves exerts on the sunlight plus the microclimate that is created on the balconies»[81]. But not only. The leaves of the trees can absorb, in addition to carbon dioxide, fine particles of urban traffic, helping to clean the air of Milan.

According to Boeri himself says, the Vertical Forest Project refers to Garden city mouvement, a method of urban planning that was initiated in 1898 by Sir Ebenezer Howard in the United Kingdom, in the period in which there were growing the big European metropolis. Howard's idea, systemized in *A Peaceful Path to Real Reform*, was to create self-contained communities surrounded by "greenbelts", containing areas for residences, industry and agriculture. From here the proposal to create garden cities that would house 32,000 people on a site of 2,400 ha.

«A century later – writes Boeri – the proposal for the creation of a worldwide system of "Urban forest" consisting of buildings that are homes to nature within their own structures is facing a different scenario, yet the part of the world where the urbanization of large number of peasants will for many years yet be an unstoppable process. This scenario sees agriculture – agriculture that is versatile and full of variety, finally able to produce food for the different urban social groups – again becoming a key resource for large metropolitan areas»[82].

For its spectacular "green" impact in the heart of the city, the Vertical forest, defined by Boeri «a project for the environmental survival of contemporary cities»

[80] Ibidem, p. 12.
[81] Ibidem, p. 8.
[82] Ibidem, p. 18

[83], received two prestigious rewards: on November 2014 won the International Highrise Award, international competition bestowed every two years, honoring excellence in recently constructed buildings that stand a minimum of 100 meters (328 feet) tall; on November 2015 the *Bosco Verticale* was chosen by the Council on Tall Buildings and Urban Habitat (CTBUH) Awards Jury as the overall "**2015 Best Tall Building Worldwide**" at the 14th Annual CTBUH International Best Tall Building Awards Symposium, celebrated at the Illinois Institute of Technology of Chicago.

[83] Ibidem, p. 110.

Conclusions

In the name of progress, man is turning the world into a fetid and poisonous place (and this is "anything but" a symbolic picture). It is polluting the air, water, soil, animals ... and himself, to the point that it is legitimate to ask whether, in a hundred years, you can still live on earth

(Erich Fromm)

We already have the statistics for the future: the growth in percentages of pollution, overpopulation, desertification. The future is already in place

(Gunter Grass)

Mi sono simpatici gli ecologisti. Ma hanno programmi costosi. Non si può essere più "verdi" delle proprie tasche

(Gianni Agnelli)

The population growth rate of world forces us to rethink how we eat and where it comes from what we need to live: it is estimated that in 2050 there will be need for an area of approximately two planets to feed the world population.

The future of nutrition and agriculture is becoming a central issue at the international level, focused on the search for sustainable production systems with low "environmental costs".

Among them there are surely the vertical farms, whose mission is to move the crops in buildings specially constructed, realizing a farming intensive "soft" version. In this way, vertical farms, and more generally the urban farms, present a solution to a number of unavoidable environmental issues - such as desertification and depletion of soil, water scarcity, pollution and urban overpopulation - by transferring agriculture in the urban space and taking advantage of the vertical dimension, considered the figure of the contemporary metropolis. So is back in the city that agriculture expelled progressively during the centuries, with the process of industrialization and urbanization, to respond now to the needs of eco-sustainability.

Do we expect so a future in which the heart of big cities will grow farms similar to skyscrapers to feed their inhabitants?

The answer seems to be negative, at least in the short term and in certain geographical areas. For sure we don't miss pharaonic projects of mega vertical buildings for cultivation or mixed use (greenhouses, homes, offices), but it can be assumed that their achievement is not at hand, because for now they are too expensive, also in terms of energy, and they have not found political and financial support to be translated into reality.

All cost analysis of vertical farms considered in this paper, which explore large-scale projects (vertical farm in Singapore, simulation of a vertical farm in Berlin and Skyland project of Milan), confirm their excessive economic burden, but at the same time indicate the need for further research and wish a technological development that can improve their energy performance and therefore their feasibility. Emblematic is the fact that large investors have not given credence to these great projects, which for now remain as fascinating as unfulfilled.

More practicable has been instead the construction of vertical farms of small scale, greenhouses of more or less large size intended exclusively for agricultural production with hydroponics and aeroponics systems, and also breeding. Many of them have been implemented and many are under construction in various parts of the world, being particularly attractive in certain habitats: desert areas or very cold, mountainous regions without arable land, areas with highly contaminated soils (ex. by nuclear radiation as in Japan) or megacities, in which the high density of the population poses considerable problems of production, marketing and transport of food.

The key to success of these vertical farms is mainly due to their ability to save energy by using renewable sources (photovoltaic, wind, geothermal, biogas etc.) Or by recycling water and waste. To facilitate their implementation are however also other factors, such as the type and the amplitude of the structure (for example the glass facades allow greater use of the solar light), the possibility of having profitable

markets in which to place the products and the existence of favorable policies by the government.

In other words: the idea is good, but under certain conditions.

A growing interest is having the choice to adapt urban spaces in disuse (abandoned factories, abandoned warehouses crafts etc…) into plant structures for air culture and hydroponic vegetables. It is a convenient solution, because it allows you to recover urban land and to provide food at kilometer zero or with a short chain, with lower installation costs.

The existence of more than 150 companies worldwide specializing in the implementation of vertical farms and many universities engaged in research in this area suggests a productive segment in expansion and attest a growing interest in this new (and for some revolutionary) agricultural technique, which is viewed with great attention also by the media.

About the Italian situation, it should be emphasized that the lack of recognition of organic certification to the soilless cultivation (hydroponic or aeroponic) arises for now as a serious obstacle to the realization of these structures, which are characterized precisely for organic food production. Another huge hindrance is represented by our extraordinarily expensive cost of electricity.

The theoretical vision of vertical farm Dickson Despommier to bring the green in the city is part of a general trend line oriented to give an ever greater value to urban vegetation, which after being sacrificed in the name of overbuilding now returns to take on an increasing importance also in the real estate market. Asserting a sensitivity towards environmental sustainability, which goes hand in hand with urban pollution worsening, stimulates demand for homes with green areas: roof gardens, green walls and hanging gardens thus become the new frontier of desire to have a campaign flap in the heart of the city and help lessen the environmental degradation of the metropolis. Given the high value of urban land, which helps to erode the green areas to the ground (parks, gardens) in favor of cementing, the

solution to create spaces for the plants inside buildings may seem a small consolation, but it could be the only feasible in front of the propensity of the public sector and real estate speculators to build.

Reconciling the cement with vegetation and relocate agriculture in the urban space today is not a chimera. According to FAO, there are currently 800 million people in the world who cultivate small portions of urban spaces (like vegetable gardens, flower beds etc.), helping to meet the food needs of the cities, to aesthetically improve the space and to decrease environmental pollution.

To address the need for grow vegetation in the city has created a synergy between ecologists, architects, botanists and gardening companies in order to create an architecture "green" now established itself worldwide. One example is the *Bosco Verticale* of Stefano Boeri, built in the heart of Milan and thought of as come «a project for the environmental survival of contemporary cities», emblematic confirms that it is opening a highway to an architecture capable of being eco-friendly.

If it's a trend, motivated only by speculative intent and a logic of monetization of "natural capital", or a forced choice, only time will decide. Everything suggests, however, that there are two possible solutions: either we can reverse the impressive growth of megacities and to stop the global concreting processes that destroy the green, or we can try to relocate green inside of urban areas, destined to be more and more overcrowded.

Vertical farm buildings and 'green' urban architecture are definitely part of a process of artificial state of nature, which many lead back to what Vanni Codeluppi called "bio-capitalism" and others designate by the term "eco-capitalism" (conceptualization of the ecological problem as an economic problem). But it is equally certain that the complex interaction between man and nature is based on complex systems evolving, with dynamics that mutually change and affect one or the other over time. The current technical and scientific developments oblige to ask

ourselves about what today is “natural” and to explore the possibility of containing environmental degradation thanks to science and technology.

There is also another aspect to be reckoned with. The vertical farms of small size and community management of urban green spaces offer the opportunity to create social sharing spaces and the re appropriation from the "bottom" of the production and commercial chain of vegetables, which can re-open the road to a united vision of the relationship with nature, integrating it into a size of more conscious life experience.

Climate change is the most urgent threat facing our entire species and we need to work collectively and stop procrastinating

(Leonardo Di Caprio)

APPENDICE

INTERVIEWS

Interview with Professor

Dickson D. Despommier

Emeritus professor of microbiology and Public Health at Columbia University. Considered the most important exponent of the vertical farm project worldwide, being part of the Association of Vertical Farm.

Professor Despommier, shall you tell me the reasons why you are giving so much efforts in order to make succeed the vertical farm project worldwide?

It's a very long answer to a very short question. My main reason for wanting to see vertical farms succeed is so that outdoor land can be returned to its proper ecological function, because now as we speak more and more land is being obtained from nature in order to produce food, that land is usually hardwood forest, not always, sometimes is grassland but mostly it's grassland and hardwood forest. We have a horrible problem today because we have too much carbon dioxide in the atmosphere and we have no way of bringing it out of the atmosphere, back to hearth. So that's called the carbon "think", we are busy removing the carbon think from the heart, mostly by farming. So if you had to ask me the main reason why vertical farming has a purpose is not only to supply food of course but to allow the possibility for taking outdoor food production and allowing that land to return to forest. Now I know this is not going to happen anywhere and I know it might not even happen to the 50% mark of the amount of land that is now on use, if the 50% would go back to hardwood forest this would be a remarkable return of wilding to the hearth, and it would have a fantastic effect on the planet, but even a 10% or a 20% would be a huge difference compared with what we

have today. Climate change is my big problem and vertical farming is the potential partial solution to that problem.

Is it very recent the progress of the vertical farms, especially for the commercial ones?

Yes, I mean, 5 years ago the only vertical farm in the world was Skygreen, but today there are many vertical farms and commercial too. Most of them are located in Japan, and they don't call them vertical farms, they call them plant factories, but they're still taller than a single storing building, but as long as they're taller than a single storing building that's a vertical farm, and they are about 200 now in Japan. So Japan has the most, and there is a book that just came out that is called Plant Factory that is produced by some Japanese indoor growers and they listed 146 vertical farms but the book is a year old so I am going to assume now that they are from 50 maybe a hundred more than what they list. If you go to Taiwan they list 45 vertical farms, just in Taiwan, if you go to Singapore, where Skygreen is, there are 3 other companies now that are classified as vertical farms, and one of them is run by Panasonic but a worthy vertical farm in Japan is run by Toshiba, so big industry has been invited in, now whether they stay in contact with vertical farms or not I don't know; but as we speak today two big Japanese companies have elected to try their hand at vertical farming. China has many vertical farms, but they're not saying where they farm. I do know that there is a company in Portage, Indiana, their name is Green Sense Farms, they have been inspired to China to make 20 vertical farms, the same as they have in Portage Indiana and they claim to be the biggest in their firm. Green sense farms in United States is very big. There is one in Panama city (of all places in Panama, no kidding), it's a 3 story (floors) vertical farm. There are many vertical farms in United States, most of them in the Chicago area. There are few, this one in Jackson, WY, that is about to open, called Vertical Harvest, there is one in Irvine, California called Urban Produce and by the

way Urban Produce belongs to one hundred urban vertical farms just like what they have. So there is a lot of activity. The biggest one is now being opened in Newark, New Jersey and is called AeroFarms. There is an association for vertical farming, called The Association for Vertical Farming, and if you join that organization they will give you a big list of where all these vertical farms are, and CEOs and how much they grow and what they grow.

What do you think about the social aspects of vertical farm?

It's interesting that you asked that question, I've recently returned from Paris where that city wants to make urban agriculture as part of the scene for Paris and they want to do it not only because it will supply fresh products for people living in the inner city but also it will supply jobs opportunities. So the job opportunity is a big social reason for wanting this to happen, there a lot of people in cities that have no jobs whatsoever, and there's a lot of abandoned properties within the city limits that are not being used for anything. It's very easy to convert a warehouse to a vertical farm, the technology is already there and the best example is a warehouse in Bedford Park in Illinois, which is just north of Chicago, and the company is named FarmedHere. It is a commercial farm and it took over an abandoned electronics factory and it converted it to this vertical farm. So the social reasons for wanting to do this relate to unemployment, training people, skill jobs like growing, harvesting, packaging, delivering, marketing, and those other things that can all be done in vertical farm operations. The one in Jackson, Wyoming that's being built has another social program which is equally important and is to find place in the world for people that are mentally disadvantaged, it helps also people, with other varieties of birth defects that prevents them from fully functioning, to find a job. So the vertical farm in Jackson, Wyoming is hiring these people because they can be trained, and they found out that they're very useful people and grateful for the opportunity, and so that's a big deal. The farm group in Bedford Park hires newly

released people from jail. As they get out from the jail they offer them to work with them, they offer to pay them a decent salary and they reintroduce them in the society by working. They are very busy expanding that, they just don't want to be in one place, they want to be in 5-6 other places as well, so the social program is very strong and very useful.

What do you think about people who are against the vertical farm project?

There are two kinds, one is the people that say the quality of the food produced indoors is not good and is not nutritious (etc..) and then there is another group that says the quality of the food indoors is very good, it's as good as the food produced outdoors, but it's too expensive because it requires too much energy.
Let's start with the first group.
Hydroponically produced food has been going to markets for maybe 40 years, and no one objects to it and no one says it doesn't taste good or it does taste good, they don't have opinion, because frankly they don't know from where it comes from.
To say right off the bat because they're against something they will make up a reason why you shouldn't be in favor of that also, and telling you that it's not nutritious and it doesn't taste good, is stupid. You should probably talk about things that are true and that would be better to use as reasons if you're not doing something. So the group that talks about energy used to have a good point because the cost of electricity hasn't changed much over a 10 years period but the efficiency of the LED grow lights has changed. So 10 years ago it would be impractical to use indoor growing systems that require artificial light. So, the Skygreen for instance, in Singapore, is transparent, it's all glass and has a special system for rotating the plants across the windows to make sure that every plant in his growth system receives the same amount of sunlight. And that's done with an engineering trick, and he is a very good engineer I've met him, and he knows what he's doing, and his plants grow very well and in fact Skygreen used to

be a 2,000 square foot farm and now it is a 20,000 square foot farm and it will be bigger than that yet again because he's been very successful. But he doesn't use grow lights. So the places that use grow lights have only come on line over the last 5 years basically, and because the efficiency of LED lights has got so much better, going from 20-25% efficiency to a currently 68% efficiency. The lights that are available, that you can buy are about 40% efficient and that's still enough to make this economically viable in terms of setting up a business plan and convincing a bank that you will not only break even, you're going to make money at this, because the grow lights are not the major grain of the economic expense that you have to worry about. Mostly, it's personnel, it's either salaries, or internal benefits or health benefits and very often they'll get a deal from the city, if you use this abandoned warehouse for the next 5 years we won't charge you any property taxes.

So there's a choosing sentence from the part of some cities to make sure that these abandoned warehouses that used to be very useful for companies like Wall-mart, EJ Corvette, K-mart (these are some companies that are no longer have a large presence in the United States, well Wall-mart is still big but those other companies are mostly out of business) and they just left the warehouses, they just walked away from them; so these abandoned warehouses are available for use for other reasons, and vertical farming turns up to be very very good re-use of an abandoned property. The criticism in the past was the cost of energy but they can no longer make that claim, that's no longer true. A lot of interplant factories in Japan use grow lights. Now, remember Japan has another reason for wanting to do this because they had this horrible tsunami after the Fukushima event, and people would not eat the food grown on Japans soil, so we are having to import all of Japans food and that's not acceptable, you can't run a county like that. So this technology of vertical farming was hard to be explored by a cheap university, and the government just poured a lot of money into it and got it to speed up pretty fast so that's the reason why Japan is the world leader in vertical farming today.

In your opinion, could the vertical farm actually save resources such as soil or water?

So let's go back to Skyfarm, that guy uses soil and that's pretty primitive, you don't have to use soil, in fact it is preferable not use soil. About half of the plant factories in Japan use hydroponics and the other half uses a combination of acquaponics and aeroponics or acquaponics and hydroponics, so there's a nice loop that you can create, and indoor loop, a reuse of water by going fish and then taking away the fish and using to feed the plants, that's the aquaponics link. So a lot of indoor farms use that as their storing material and of course they end up being to sell fish too.

What is, in your opinion, the future of vertical farm? Do you think that will take root even in major European cities?

Well I think that the thing that's holding it back right now is the lack of awareness, so more people need to know more about this in order to get this adopted throughout the world, most big cities have some form of urban agriculture going on right now, like London, New York, Paris, Berlin and other large cities; these cities are very active which regards to people wanting to grow their own food.
So their right for instituting vertical farming within the city limits, and that's happening.
I would make a bold statement to say that in 10 years from now, virtually every city will have at least one operational vert prom, but maybe some cities will have hungers and I can already tell you which cities are going be, that is Seul in Korea. Seul (South Korea) right now wants to put vertical farms on every flat roof in the city, and would be a big "wow", because we are considering very large flat roofs; and I am going to tell you right now how many people live in Seul: 10. 117, 909 people.

Every country would have a different answer for you, so for instance Japan it is an island country, so they are more or less obliged to live within their own means, and that's the reason why the country has gone in that direction, because of the vertical farming is the immediate answer that they can give to their people, and they can raise most of the leafy green vegetables within these buildings, so that's basically what they are doing.

And I've already discussed the social benefits, of course people can trust where food comes from, and they also feel like they're supporting local farmers because indeed that is exactly who is producing the food.

So every country has this desire, so France, you can't find a fussier country in the world, when it comes to food than France. Paris is the epicenter for that and the cuisine that came out of Paris from these wonderful Michelin chefs, those ingredients have to be carefully selected and yet at the same time here is the mayor of the city saying "we have to institute vertical farming throughout Paris" that's a remarkable statement in itself.

Interview with Professor

FRANCA MIANI

Professor of Political-Economic Geography. Currently with the Department of Economics Parma where he teaches Urban and Local Policies, in the Master of Science in International Business & Development.

Already implied in lecturer organization and regional planning at the Faculty of Architecture of Parma.

What is your thought about the green architecture?

The idea of green architecture is not so recent. The architect Ambasz[84] with a study in NY has worked everywhere, already since the 90s, to make green architecture. Initially it was designed to build having less impact on the landscape as possible. He has worked very hard in Japan, especially for a "green" restauration of railway stations. At Expo 2015 they have made it look like the novelty of the century, but it had been done 30 years ago. In the north of Japan islands were constructed buildings with glass windows recreating a tropical climate inside. Ambasz also worked to beautify many squares in Spain. In Italy however he has not managed to achieve anything concrete because we're always the last in makng the innovations of this kind, especially to not modify our historic centers. In Puglia, Ambasz designed a "hidden" holiday village, practically invisible from the sea, without ever realizing it.

So you seem skeptical about this latest urban greening?

[84] See: http://ambasz.com/

I agree on the idea of green inside the buildings, such as in offices, because we spend most of our time at work, than at home.
Instead I am against the attempt to revive the real estate market by adding the green without the proper knowledge of the facts. Often, in fact, landscapers are impractical and un realistic. An example is the *Bosco Verticale* of Boeri, where a friend of mine bought an apartment recently. I have warned her about the difficulties that might arise with buildings of this kind. For me, they are not sustainable. The trees on the terrace should be maintained, pruned, changed, etc... And this is a condominium questionnaire. They will surely be nice and bright, but not practical.
Another example is the pilotta square, in Parma, where the lawn is difficult to maintain, due to our climate. We're not in England and the green should be done where it is manageable, feasible and truly sustainable including maintenance. Before making these works, we should analyze the environment, land and climate. For example, in Parma, humidity makes it difficult to build some type of construction. Like the wooden houses that were designed around the year 2000. They would not last long.
The green in the city is therefore to be taken very carefully. It seems to me made more to beautify and fashion the constructions, than for real practical purposes. You cannot resolve in this way the known problems of pollution and urban green.
My advice is to better keep and organize the green already existent, rather than insisting in making new. The first example that comes to mind is that of the botanical garden (always in Parma), cared little and badly, in which ultimately collapsed trees, very dangerous for children's rides.
Serve targeted investments, better maintenance and more control for security. We surely should invest to increase the wellbeing of citizens, also through green architecture, but it must not be done to improve the value of the buildings or to make casually something green only to clean the conscience of people.
It could seem a drastic point of view but I think that it’s impossible to solve geological and environmental problems in this way.

Interview with Arc.

GABRIELLA FUNARO

From 2011 he carries out its activities at the ENEA Central Unit Studies, taking care of sectoral studies for sustainable construction, eco-friendly urban design and vertical farms design.

Architect Funaro, are you collaborating with Enea since a long time?

Yes. I have been a dependent of ENEA for over 30 years and I have developed the vertical farm prototype that was presented at EXPO 2015. In particular I am developing, as a researcher, the vertical farm projects for ENEA, which, as a result of our presence at EXPO, had the opportunity to arouse various attentions. Let's just say that I am the referent of ENEA regarding vertical farms.

So you designed and you will work on the Skyland project that should rise in MILAN?

Yes, it's still me to handle it. Let's say that the Skyland project, which unfortunately has not yet seen the light, wanted to be the first study to understand how could run a building contemplating the whole food chain, from production to marketing, to the consumption of products grown with these indoor cultivation systems. We therefore say that although Skyland remains for now only “white paper”, the six months of EXPO of the prototype tests have definitely gave positive results, regarding the functionality of this system.

Can we say that if Skyland is still in theoretical form this is due to the fact that Italy has always been reluctant to accept innovations of this kind?

We can say that from this point of view we are always a little 'back (laughs).

Can you give me some information about the Cost-Benefit analysis of Skyland?

Let's say that we started with the idea of making it totally self-sufficient, but it is not so simple, for now. In fact, despite the exploitation of renewable energy, including solar and bio-gas, the cost of production remains very high, at around € 1,200 per square meter. The great use of LED lights for growing and the energy required for the air-conditioned increase electricity costs to the point that make it for now an unsustainable project.
So we put the Skyland project aside for the moment, concentrating on the EXPO prototype and on other projects such as the restoration of existing buildings for vegetable productions always with indoor systems.

Some of these projects are you talking about have already been completed?

No, for now no, but there is a project that is now ahead of all. In fact, we are working to build a vertical farm commissioned by a private customer, hoping to arrive soon to the true realization phase.

We know that over the world the vertical farm phenomenon has already in place, particularly in Japan but also closer to our country, such as in France. Are you convinced that it is only a matter of time before all countries, including Italy, adopt these production systems? If yes, what are the reasons?

Surely, it is the agriculture of the future and will become unavoidable with time. That's for various factors, including the growing world population, the increasing industrialization and therefore the reduction of arable land, also due to climate factors that make the once a time fertile lands, today impossible to cultivate. Then there is the consideration about the depletion of the phosphate mines that produces most of the fertilizers used today. The case of Japan underlines the problem of polluted soil, from which the spread of indoor cultivation in vertical farm across the country.
All these factors therefore suggest that the outdoor cultivation in the future will be replaced by indoor growing, though not entirely, because some products, such as wheat, continue to be cultivated in the "classic" fields.
In the world there are already many examples of vertical farm, although some, not having all the correct features, are only "masked" by vertical farm. For Vertical farm we mean in fact completely closed systems, acclimatized and with LED lights. Those not totally closed, which use sunlight or other types of illumination cannot be placed in the category.

In Italy, through our prototype at EXPO, we have launched the first stone. A new market is going to begin, despite the obstacle presented by energy costs. If you do not break down these costs will be difficult to implement indoor cultivation on a large scale. In the future, I think, the shortage of arable land will increase the price of the same to the point that it will be inevitable that we have to use these new methods. You must then prepare to the question whether. This is our policy and our thinking.
Another very important thing is the quality of the product. Thanks to the closed-loop hydroponic systems the product is of the highest quality and, given the non-use of

pesticides and the absence of any air pollution agent or other polluting factor normally present in the air, the products are considerable healthiest than BIO.
Then the possibility of being able to grow on overlapping planes allows six-fold the average output per square meter of surface.

Another factor to consider is *water*, a factor in exhaustion that is gaining more importance than the oil. With hydroponic, water consumption is greatly reduced. The difference is abysmal, we talk about two liters per cubic meter of lettuce against 40 of the normal crops.

With the passing of the time all these factors will equalize the costs and for this we are more than convinced about the success of vertical farming. It remains only to convince the traditional farmer to take these street, fighting against the general skepticism that we hope goes thinning thanks to the success of existing specimens.

APPENDICE 2

Vertical and Urban Farming Events

The list of events organized in matter of the vertical farms theme is provided by the Association for Vertical Farming (AVF), founded the 18 July 2013 a Munich (Germany) and diffused since 2015 all over Europe, in Asia, in USA, in Canada and in the United Kingdom. «This internationally active non-profit organization unites growers and inventors to improve food security and the sustainable development of Vertical Farming. The AVF also focuses on advancing vertical farming technologies, designs and businesses by hosting international info-days, workshops and summits. They developed a glossary to bring consistency to the industry and plan on helping to standardize the technologies. […] The mission of AVF Mission is foster the sustainable growth and development of the Vertical Farming movement through education and collaboration.

One of the primary objectives of the Association for Vertical Farming is to bring together experts, policy makers and newcomers towards collaboration in Vertical and Urban Farming. Currently we do this through the following three event formats:

- Vertical Farming Info Days
- Agritecture Design Workshops
- Association for Vertical Farming Summit» (in https://vertical-farming.net/).

Events 2016

14/06/2016 - 16/06/2016	GreenTech 2016 - Amsterdam *RAI Amsterdam, Amsterdam*
13/06/2016	AVF Summit 2016 - Amsterdam *RAI Amsterdam, Amsterdam*
10/02/2016	Open Forum - Vertical Farming (Ghent, Belgium) *Faculteit Bio-ingenieurswetenschappen UGent, Gent Belgium*

05/02/2016 - 06/02/2016	Agritecture Fresno Collaborative Design Workshop *Ideaworks Fresno, Fresno CA*

Events 2015

17/11/2015	AVF Annual Meeting 2015 *German Aerospace Center (DLR), Bremen*
02/11/2015 - 03/11/2015	Vertical Farming Conference Bangalore, India *The Taj West End, Bangalore*
12/10/2015 - 17/10/2015	NYC AgTech week *New York City, New York, NY 10022, USA*
24/09/2015 - 25/09/2015	Agritecture Minneapolis Collaborative Design Workshop *University of Minnesota – Humphrey Institute, Minneapolis MN*
18/09/2015 - 19/09/2015	Agritecture Atlanta Collaborative Design Workshop *Georgia Tech, Atlanta GA*
09/05/2015 - 10/05/2015	Association for Vertical Farming Summit Beijing *Chinese Academy of Agricultural Sciences, National Agricultural Science & Technology Demonstration Park, Beijing*

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