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The Vertical Farm - The origin of a 21st century Architectural Typology

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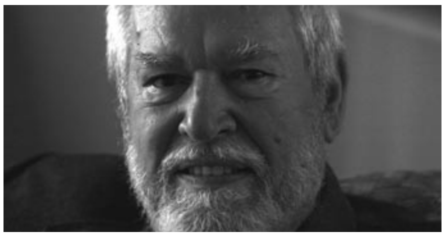

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"While no one questions the value of farming in getting us to this point in our evolutionary history, even our earliest efforts caused irreversible damage to the natural landscape, and are so wide-spread now that it threatens to alter the rest of the course of our life on this planet."

Though often bandied about by architectural form chasers, the invention of typologies are rare. The fortuitous resultant of social imperatives, cultural and economic necessity, intractable environmental pressures and technological prodigality, architectural typologies, like real paradigm shifts, are mostly nothing more than UFO sightings: stories dreamt up in bars and wishfully elaborated for credibility in digital manifestoes.

"The duct is one of the most monumental [innovations] in the history of environmental engineering."

Reyner Banham (Banham, 1969)

However, one such occurrence can be noted at the opening of the 20th century, which did not appear as visibly among all the wonderful—indeed they are extraordinary!—avant-garde manifestoes. It is the modern hospital as a new architectural typology and the untold (and not adequately told here) history of the duct (think of the Vertical Farm as Reyer Banham might, a history of the near future).

In 1906 the Royal Victoria Hospital, by Henman and Cooper, opened in Belfast, Ireland. (Banham, 1969). It was the first modernized, air-conditioned building in the world, and launched the hospital as an apparatus that simultaneously reached across multiple scales of engagement. It addressed and organized the internal needs of a person and the internal control of a building environment, to the mediation of an external population of individuals and the external conditions of the natural environment. It was the functional relationship between parts, rooms, program, mechanical and natural systems of exchange and circulation that allowed the hospital to become a finely tuned and controlled instrument of beauty, very literally an organon of change. (Organic has Greek roots from Organon: instrument, tool. (Rykwert, 1992)). At that moment architecture evolved as a modern enterprise, not merely a structural revolution, but the material embodiment of a networked, technical, spatial assemblage where 19th century structural revolutions of the steel frame could be enmeshed with mechanical technology, the individual, the microbe, the city. It was near this time that the surgical suite replaces the anatomical theater, and the natural environment is linked together in a living mechanical architectural system, which addressed social, societal, political, biological, and individual needs. It was the duct which permitted the reinvention of the hospital, which had been in existence since 4000BC. Thus a mechanism of exchange and environmental controls becomes the impetus for both new typologies, and a new breed of architecturally mediated and controlled environmental possibilities, pressures, and constraints, possibilities which leaps and mutates from the hospital and proliferated into variations at every architectural scale, from house to office, studio to indoor stadium.

The Vertical Farm is a correlate of the modern city, offering stability while embracing the change. Far from fantasy, the Vertical Farm scoops up the available ducts and technologies at the opening of the 21st century, organizing and redistributing otherwise unrelated parts, grafting together everything available, from NASA Biosphere control systems to Greenhouse technology. What is crucial to understand at the outset is that the Vertical Farm is a complex system rather than a single building. In other words, the Vertical Farm is not merely a building where you grow tomatoes and shortened corn situated in the milieu of an urban setting; rather, the Vertical Farm is a functional part of the urban system itself. The Vertical Farm is not merely a skyscraper with farm plots chopped up like strips of turf and rolled into FAR [foot to area ratio] rationed floorplates. 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 (imagine the politically marketable 'greenness' of a 1000ft luscious cornicopic living transparent zone of fertility next to the black steel and glass skyscraper in your city); food, the only part of farming which consumers see while the rest of the industrial process remaining invisible, unquestioned, absolved by sheer ignorance. Essentially, the Vertical Farm allows us to address in one ambitious but realistic strategy, the precarious and tricky crisis of modernity between the individual and the city, which French philosopher Paul Ricour stated so poignantly, it allows us to participate in the local place and global flow at the same time, to embrace modernity and simultaneously return to our roots." (Ricour, 1965) Those roots simply exist 1000 feet above the ground. (A ground which would be better served by forests than by feed-stock, as it turns out.)

The Vertical Farm, as perceived by the public, is choreography of food visibility. Food is the most dynamic and complex of systems in the 21st century, requiring a web of interrelationships. Yet we often forget, as Wendell Berry states, that "eating is an agricultural act." (Berry, 1990) Therefore, the first thing the vertical Farm does is mediate the visibility of the production of food. The Vertical Farm helps you realize that your engagement with the world, particularly in terms of what you eat, has consequences.

As you approach the Vertical Farm from a distance, you witness transparent shelves of color and texture cantilevered off the structural core of the living system (see Figure 1). The shelves are agricultural programmed boxes, each striated with modern fields of ripe agricultural foliage: vegetation, fruits, etc. (Note: the particular foods in each shelf would be controlled to cancel the foods traveling the most miles to your now truly sustainable city, and, be selected around the individual dietary and cultural palette of the community). Also, springing from the structural core, you notice residential apartments set like seeds into the more hermitically sealed laboratories in which the agricultural systems would be researched and initially cultivated for control purposes and finally deployed, by way of the core, into the shelves. Apartments to both scientists and students, the Vertical Farm also contains program for private residences, and for those residents, gardens and vertical parks linking the outside of the shelves with the living and the labs (see Figure 2). As you look closer you will notice that some of the programmatic shelves contain grazing colors, which seem to be in motion. Upon closer inspection (see Figure 3) you notice pigs and chickens, not the sour image via noisome smell of the factory farm hidden out of site and attempting to evade the eye, but rather sterile and proud public animal production. Finally, you will notice two systems of tanks; one system comprised of smaller pools filled with fish and shrimp, the other much larger tank linked into a waste water and bio-solid treatment facility, looking much like active industrial

Figure 1. The Vertical Farm model from above as seen in the Museum of Science and Industry, Chicago.

Figure 2. The Vertical Farm Park at base of model

Figure 3. A vertical Farm in Dubai. Design by Eric Ellingsen and Dickson Despommier. Image by Eric Ellingsen, Homero Rios, and Mo Phala.

monuments decorating the country side as silos and refineries which, when preserved and remediable like at Gasworks Park in Seattle, or documented so wonderfully well by the German photographers Bernd and Hilla Becher. That's what you'll see from a distance across the city.

You will be walking to the Vertical Farm to join your colleagues for lunch at a restaurant on the second floor of the tower (see Figure 4). On the way up you will stop through the park (Figure 8) and listen to the public performance by local undiscovered buskers that afternoon scheduled to take place each day (much like Music Under New York: http://www.mta.info/mta/aft/muny/). After lunch, you will dip through the Vertical Farmers market and pick up the fresh organic tomatoes and honey which you need for the dinner party the next night. And at that dinner, when your locavore friends lament the agricultural sores which Michael Pollen repeatedly drives home, like the fact that agriculture is above all in the 21st century an industrial act. and that agricultural acts are as egregious to the health of the environment as our industrial foods are to our bodies, you will finally have a more palatable conversation. Because, you will see and live and experience through the Vertical Farm the real links between our food and our city as perhaps the most intense and complex network of interrelationships in the 21st century.

As of January 2006, approximately 800 million hectares of arable land were in use, allowing for the harvesting of an ample food supply for the majority of a human population now in excess of 6.4 billion. These estimates include grazing lands (formerly grasslands) for cattle, representing nearly 85% of all land that could support a minimum level of agriculture. Farming also produces a wide variety of grains that feed millions of head of cattle and other domesticated farm animals. According to the US Department of Agriculture, in 2003 nearly 33 million head of cattle were produced in the United States. In order to support this large a scale of agricultural activity, millions of hectares of hardwood and coniferous forest (temperate and tropical), grasslands, and wetlands were sacrificed, or at the very least severely reduced to fragmented remnants of their former ranges. In either case, significant loss of biodiversity and disruption of ecosystem functions on a global scale has been the result (Wilson, 1992).

While no one questions the value of farming in getting us to this point in our evolutionary history, even our earliest efforts caused irreversible damage to the natural landscape, and are so wide-spread now that it threatens to alter the rest of the course of our life on this planet. The silt-laden soils of the floodplains of the Tigris and Euphrates River valleys serve as a good example in this regard. This region was the cradle of western civilization attributable solely to the early invention of food growing technologies (mostly wheat cultivation). The land was soon degraded below a minimum level of food production due to erosion caused by intensive, primitive farming practices that rapidly depleted the earth of its scant supply of nutrients, while mismanaged irrigation projects were often interrupted by wars and out-of-season flooding events. Traditional farming practices (i.e. non-high tech) continue to this day to produce massive loss of topsoil, while excluding the possibility for long-term carbon sequestration in the form of trees and other permanent woody plants (Williams, 2003).

According to the IFA (International Fertilizer Industry Association), Agrochemicals, especially fertilizers, are used in almost every commercial farming scheme due to the demand for cash crops that require more nutrients from the substrate that it can provide. Fertilizer use is expensive and encourages the growth of weeds, making herbicide use almost a requirement. In commercial ventures, farming involves the production of single crop species, most of which are vulnerable to attack from a wide variety of microbes and arthropods (Carson, 1962; Zupan, 2003). The agrochemical industries have, over just a short period of time (fifty or more years), responded to these biological pressures, producing an astounding array of chemical deterrents that have, up to very recently, been able to control these unwanted guests attempting to sit at our table. The regular application of pesticides and herbicides has facilitated an ever-increasing agricultural bounty, but many arthropod and plant species have developed at least some level of resistance to both classes of compounds. As the result, higher and higher doses of these products are needed to do the same job as the year before, thus making agricultural runoff the single most damaging source of pollution. In the majority of intensive farming settings following even mild rain events, a toxic mix of agrochemicals leaves the fields and contaminates surrounding ecotones with predictable regularity. The ecological consequences of runoff have been nothing short of devastating. Furthermore, human health risks are also associated with high exposures to some agrochemicals (Molyneux, 2003). However, many chemicals manifest their toxic effects in the human body in ways far more subtle than, say for instance DDT and the thinning of birds of prey egg-shells, making them difficult to implicate in the disease process (Stromquist, Burmeister, 2003).

Farming itself is an activity fraught with health risks. The mechanisms of transmission for numerous agents of disease (e.g. the schistosomes, malaria, some forms of leishmaniasis, geohelminths) are linked to a wide variety of traditional agricultural practices (e.g. using human feces as fertilizer, irrigation, plowing, sowing, harvesting). These illnesses take a huge toll on human health, disabling large populations, thus removing them from the flow of commerce, and this is especially the case in the poorest countries. In fact, they are often the root cause of their impoverished situation. Trauma injuries are considered a normal consequence of farming by most who engage in this activity and are particularly common among "slash and burn" subsistence farmers. It is reasonable to expect that as the human population continues to grow, these problems will worsen at ever increasing rates.

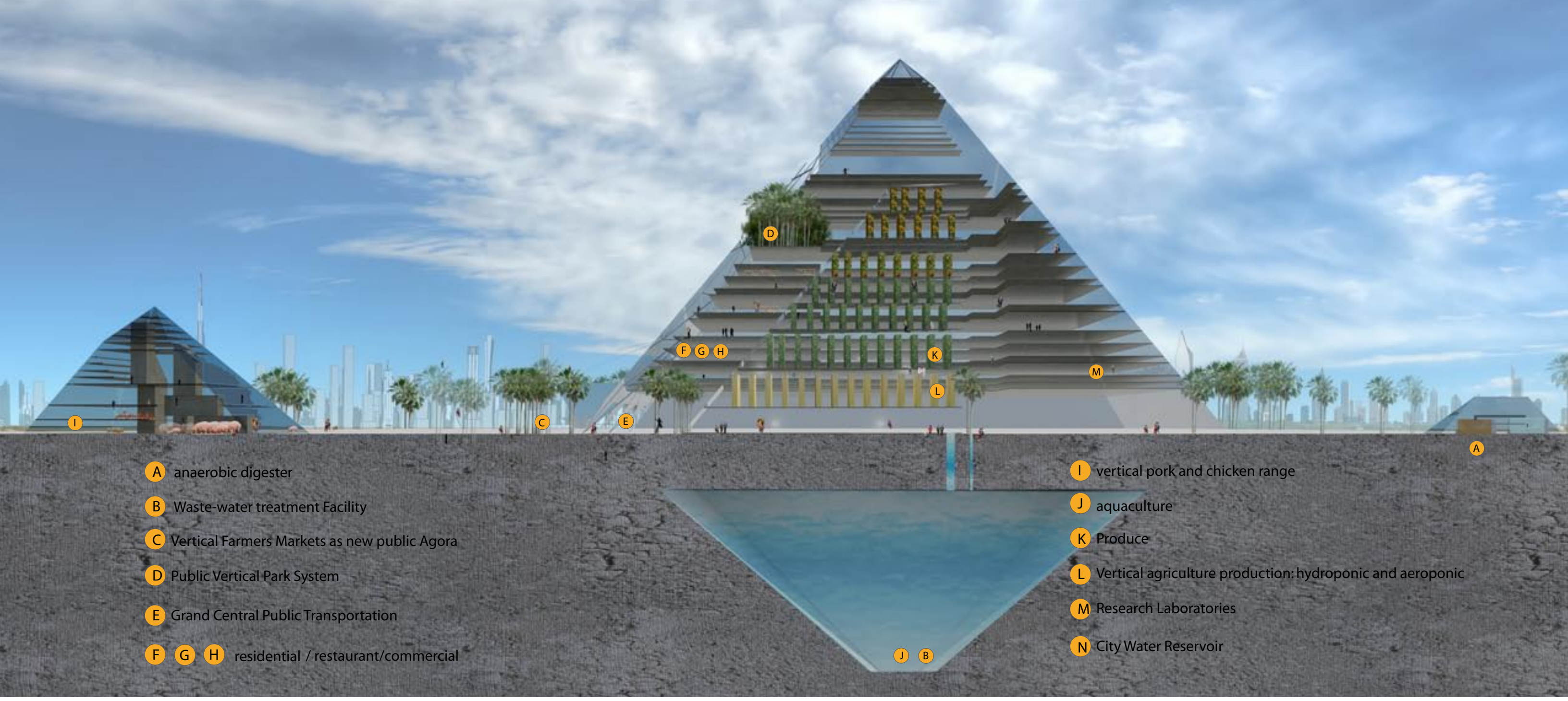


Figure 4. Section of the various components of a vertical Farm in Dubai. Design by Eric Ellingsen and Dickson Despommier. Image by Eric Ellingsen, Homero Rios, and Mo Phala.

To address these problems and those perceived to soon emerge onto the horizon, an alternate way of food production was proposed; namely growing large amounts of produce within the confines of high-rise buildings. This idea appeared to offer a practical, new approach to preventing further encroachment into the already highly altered natural landscape. The Vertical Farm Project was established in 2001, and is an on-going activity at the Mailman School of Public Health at Columbia University in New York City. It is in its virtual stages of development, having survived 4 years of critical thinking in the classroom and worldwide exposure on the Internet to become an accepted notion worthy of consideration at some practical level. We have identified an extensive list of reasons why vertical farming may represent a viable solution to global processes as diverse as hunger, population growth, and restoration of ecological functions and services (e.g. returning land to natural process, carbon sequestration, etc.). If vertical farming (VF) were to become widely adopted, then the following advantages would most likely be realized:

1. Year-round crop production; 1 indoor acre is equivalent to 4-6 outdoor acres or more, depending upon the crop (e.g. strawberries: 1 indoor acre = 30 outdoor acres).(Note: for further examples see WIRED magazine, 16-11-08, "The Future of Food" p.188-205)

2. VF holds the promise of no crop failures due to droughts, floods, pests, or other periodic natural phenomena.

3. All VF food will be grown organically employing chemically defined diets specific to each plant and animal species: no herbicides, pesticides, or fertilizers.

4. VF eliminates agricultural runoff.

5. VF would allow farmland to be returned to the natural landscape, thus restoring ecosystem functions (e.g. increased biodiversity) and services (e.g. air purification).

6. VF would greatly reduce the incidence of many infectious diseases that are acquired at the agricultural interface by avoiding use of human feces as fertilizer for edible crops.

7. VF converts black and gray water into potable water by engineering the collection of the water realized through evapo-transpiration.

8. VF adds energy back to the grid via methane generation from composting non-edible parts of plants and animals.

9. VF dramatically reduces fossil fuel use (no tractors, plows, shipping.).

10. VF eliminates much of the need for storage and preservation, thus reducing dramatically the population of vermin (rats, mice, etc.) that feed on reserves of food.

11. VF converts abandoned urban properties into food production centers.

Vertical Farm as urban agricultural armature:

With the Vertical Farm, there is no waste in waste.

A crucial component of the Vertical Farm mega-structure is the anaerobic digester (A). Human and animal waste serves as decentralized input energy source as a feedstock on an urban scale. The Vertical Farm complex also includes chicken, hen, and hog production (I), and aquaculture (J) tanks for raising shell-fish to tilapia; all waste in the form of animal manure will be phytore-mediated through the plants root systems and re-routed into the anaerobic digester generating biogas such as methane and as re-used as fertilizer. Water from plant evapotranspiration and from the aquaculture tanks will be recycled into the waste-water large water treatment facility (B) and finally, a potable urban reservoir (N). The Vertical Farm will also grow fruit and vegetable produce (K) year-round. The produce palette will be chosen by the local diet desires and needs, as well as by offsetting the imported foods which travel the furthest to arrive in our cities (usually an average of 2000km+). This produce will be grown in controlled environments using hydroponic and aeroponic systems (L). Active Research Laboratories (M) will be a crucial component to the Vertical Farm complex, as will be the residential living (F) units, restaurants (G), and commercial (H) programs.

Above the ground on the exterior of parts of the Vertical Farm, a public park system (D) is woven into the skyscraper. Whereas most skyscrapers are merely visual stimulants to the inhabitant of the city, in the Vertical Farm a new relationship between nature and the public space interior to skyscrapers will be created. Furthermore, the base of the Vertical Farm offers a wide range of public amenities as cultural catalysts, such as out-door street level vertical farmers markets and public agoras (C), and a grand central station (E) hub. The Vertical Farm will collect, intensify, filter, layer, merge, and finally re-distribute the urban energy.

...vertical farms

> “What if “eating local” in Shanghai or New York meant getting your fresh produce from five blocks away? And what if skyscrapers grew off the grid, as verdant, self-sustaining towers where city slickers cultivated their own food?”
>
> *Quote by Bina Venkataraman, reporter for the New York Times, Sciense section. Dickson Despommier, professor of public health at Columbia University, discusses the concept of the 'Vertical Farm' in the city. From 'Country, the City Version: Farms in the Sky Gain New Interest.' The New York Times, July 15th, 2008.*

12. VF creates sustainable environments for urban centers.
13. VF creates new employment opportunities.
14. VF could provide year round production of medically valuable plants (e.g. the anti-malarial plant-derived artemesinin).
15. VF could be used for the large-scale production of sugar (sucrose) to be used in the revolutionary new method for the production of non-polluting gasoline.

Thus, the Vertical Farm is an apparatus of capture (Deleuze and Guattari, 1987) a filter which helps regulate the flows of urban energy in the forms of water and waste management, redirecting those problematic outputs as energy inputs and agents of change for the production of our daily caloric needs. Vertical Farms also act as cultural catalysts, allowing unique pockets and authentic food fields particular to the diverse ethnic diets and populations of place to match and coordinated with the place where food is grown to the lives where people that are going to eat and prepare that food live (your vegetables don't have to travel the 1500 hundred miles on average to get to your plate). Thus, on an urban scale, waste literally fuels urban services rather than becoming an urban liability. All the while, re-tuning the cities infrastructural systems provides the urgent de-stressing of local and global natural resources like our forests, waterways and mineral reserves.

Indoor farming (e.g. hydroponics and aeroponics) has existed for some time. Strawberries, tomatoes, peppers, cucumbers, herbs, and spices grown in this fashion have made their way to the world's markets in quantity over the last 5-10 years. Most of these operations are small when compared to factory farms, but unlike their outdoor counterparts, they produce crops year-round. Japan, Scandinavia, New Zealand, the United States, and Canada have thriving greenhouse industries. Freshwater fishes (e.g. tilapia, trout, stripped bass, carp), and a wide variety of crustaceans and mollusks (e.g. shrimp, crayfish, mussels) have also been commercialized in this way. Fowl and pigs are well within the capabilities of indoor farming, and if we were to proceed to do so, offers some interesting advantages in addition to providing the world with a convenient food supply. For example, if chickens and ducks were to be raised entirely indoors, then the current epidemic of avian influenza might well have been aborted, or at the very least, significantly reduced in scope. None have been configured as multi-story entities. In contrast, cattle, horses, sheep, goats, and other large farm animals seem to fall well outside the paradigm of urban agriculture.

What is proposed here differs radically from what currently exists; namely, to scale up the scope of operations, in which a wide variety of produce is harvested in quantity enough to sustain even the largest of cities without significantly relying on resources beyond the urban footprint. Our group has determined that a single vertical farm with an architectural footprint of one square New York City block and rising just 30 stories (approximately 3 million square feet) could provide enough calories (2,000 cal/day/person) to comfortably accommodate the needs of 50,000 people, and mainly by employing technologies currently available. Constructing the ideal vertical farm with a far greater yield per square foot will require additional research in many areas – hydrobiology, material sciences, structural and mechanical engineering, industrial microbiology, plant and animal genetics, architecture and design, public health, waste management, physics, and urban planning, to name but a few.

Yet, despite the obvious enthusiasm for the idea, there are cautions to consider. High-rise food-producing buildings will only succeed if they function by mimicking ecological process; namely, by safely and efficiently re-cycling everything organic and re-cycling "used" water (e.g. human and animal waste), turning it back into drinking water. Most importantly, there must be strong, government-supported economic incentives to the private sector, as well as to universities and local government to fully develop the concept. Ideally, vertical farms must be cheap to construct, durable and safe to operate, and independent of economic subsides and outside support (i.e. show a profit at the end of the day). If these conditions can be realized through an ongoing, comprehensive research program, urban agriculture could provide an abundant and varied food supply for the 60% of the people that will be living within cities by the year 2030.

Waste management and urban sustainability

Today, we face the challenge of trying to understand enough about the process of ecological balance to incorporate it into our daily lives (i.e. do no harm). Our willingness to try to solve problems that we ourselves have created is a measure of our selflessness and altruistic behavior as a species. Thus, the second most important reason to consider converting to vertical farming relates to how we handle waste (Malkow, 2004; Eckenfelder, 1999). Current waste management practices throughout the world, regardless of location, are largely detrimental to public health and social welfare, and exposure to untreated effluent often carries with it serious health risks. However, even in the best of situations, most solid waste collections are simply compacted and relegated to landfills, or in a few instances, incinerated to generate energy. Liquid wastes are processed (digested, then de-sludged), and treated with a bactericidal agent (e.g. chlorine) before being released into the nearest convenient body of water. More often in less developed countries, it is discarded without treatment, greatly increasing the health risks associated with infectious disease transmission due to fecal contamination.

All solid waste can be re-cycled (returnable cans, bottles, cardboard packages, etc.) and/or used in energy generating schemes with technologies that are currently in use. A major source of organic waste comes from the restaurant industry (Wie, 2003). Methane generation from this single resource could contribute significantly to energy generation, and may be able to supply enough to run Vertical Farms without the use of electricity from the grid. For example, in New York City there are more than 21,000 food service establishments, all of which produce significant quantities of organic waste, and they have to pay to have the city cart it off. Often the garbage sits out on the curb, sometimes for hours to days, prior to collection. This allows time for vermin, including cockroaches, rats and mice, to dine out at some of the finest restaurants in the western hemisphere, albeit second-hand. Vertical farming may well result in a situation in which restaurants would be paid (according to the caloric content?) for this valuable commodity, allowing for a greater measure of income for an industry with a notoriously small (2-5%) profit margin (Mann, 1999). In New York City, on average 80-90 restaurants close down each year, the vast majority of which are precipitated by inspections conducted by the New York City Department of Health. A common finding by inspectors in these situations is vermin (mouse and rat droppings, cockroaches) and unsanitary conditions that encourage their life styles.

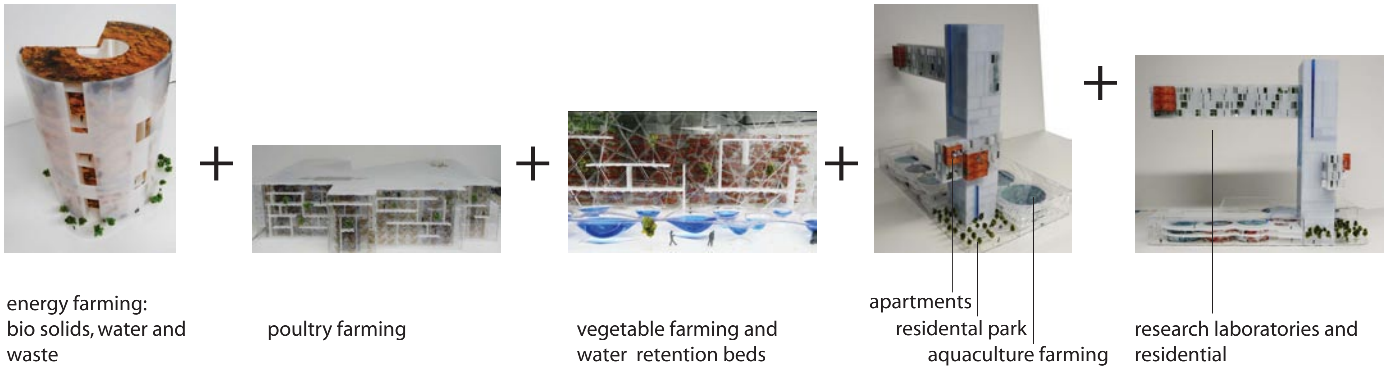
Waste management issues are equally dire in the rural setting. Agricultural runoff despoils vast amounts of surface and groundwater (Foster, 2003; Holt, 2000). Vertical farming offers the possibility of greatly reducing the quantity of this non-point source of water pollution. In addition, it will generate methane from municipal waste currently being funneled into water pollution control facilities. The concept of sustainability will be realized through the valuing of waste as a commodity so indispensable to the operation of the farm that to discard something –any thing - would be analogous to siphoning off a gallons' worth of gasoline from the family car and setting it on fire. Natural systems function in a sustainable fashion by recycling all essential elements needed to produce the next generation of life. This way of doing business is being incorporated by NASA engineers into all future programs that focus on colonizing outer space. If we are to live in closed systems off the surface of the earth, then the concept of waste becomes an outdated paradigm. Unfortunately, this goal has yet to be fully realized by NASA or by the ill-fated Biosphere 2 Project (Allen, 1997). If we are to live in a balanced extraterrestrial environment, we must somehow learn how to do it here first.

Sludge, derived from waste water treatment plants of many, but not all cities throughout the US, and treated with a patented process referred to as advanced alkaline stabilization with subsequent accelerated drying, is being turned into high grade topsoil and sold as such to the farming community at-large by N-Viro Corporation, Toledo, Ohio. The limiting factor in using municipal sludge for farming appears to be heavy metal contamination, mostly from copper, mercury, zinc, arsenic, and chromium (Scancar, 2000). Vertical farms will be engineered to take in black or gray water, depending upon availability, and restore it to near drinking water quality using bioremediation (Bonaventura, 1997) and other technologies yet to be perfected. Fast growing inedible plant species (e.g. cattail, duckweed, sawgrass, Spartina spp.), often referred to collectively as a living machine (Todd, 1994; Todd, Josephson, 1996) will be used to help remediate contaminated water. They will be periodically harvested for methane generation employing state-of-the-art composting methods yielding energy to help run the facility. By-products of burning methane – CO 2, heat, and water – can be added back into the atmosphere of the vertical farm to aid in fostering optimal plant growth. The resulting purified water will be used to grow edible plant species. Ultimately, any water source that emerges from the vertical farm should be drinkable, thus completely re-cycling it back into the community that brought it to the farm to begin with. Harvesting water generated from evapo-transpiration appears to have some virtue in this regard, since the entire farm will be enclosed. A cold brine pipe system could be engineered to aid in the condensation and harvesting of moisture released by plants. Nonetheless, several varieties of new technology will be needed before sewage can be handled in a routine, safe manner within the confines of the farm. Lessons learned from the nuclear power plant industry should be helpful in this regard.

Some "proofs of concept"

1. Year round crop production

Traditional farming takes place over an annual growth cycle that is wholly dependent upon what happens outside. Significant deviation (e.g. drought or flood) for more than several weeks away from conditions necessary for insuring a good yield has predictable, negative effects on the lives of millions of people dependent upon those items for their yearly food supply (Cairns, 2000). Every year, somewhere in the world, crops suffer from too little water and wither on the spot, or are lost to severe flooding, hailstorms, tornados, earthquakes, hurricanes, cyclones, fires, and other destructive events of nature. Many of these phenomena are at best difficult to predict, and at worst are impossible to react to in time to prevent the losses associated with them. Climate change regimens will surely complicate an already complex picture with respect to predicting crop yields (Tilman, 2001).



The components of the Vertical Farm model

In addition to losses due to bad weather events, an unavoidable portion of what is grown spoils in the fields prior to harvest time. Another large portion of harvest, regardless of the kind of plant or grain, is laid waste by a variety of opportunistic life forms (i.e. fungi, bacteria, insects, rodents) after storage. In Africa, locusts remain an ever-present threat (Abate, 2000), devastating vast areas of farmland in just days. Finally, armed conflict halts all normal human activity in any given war zone. Faming usually suffers greatly during those stressful times, with crops being burned or otherwise made unavailable by those wishing to severely limit the opposition's access to a reliable food supply.

Vertical farming obviates all external natural processes as confounding elements in the production of food. Growing food within urban centers will lower or even eliminate the consumption of fossil fuels needed to deliver them to the consumer, and will eliminate forever the need for burning fossil fuels during the act of farming. So where does the energy come from that is needed to run the vertical farm? Ideally, they will take full advantage of technologies centered around methane digestion of the inedible portions of what is grown (i.e. biogas production). Solar, wind, and tidal power could also contribute to reducing their dependence on fossil fuels. Iceland and other geologically active regions (e.g. Italy, New Zealand) will have the distinct advantage of harnessing geothermal energy, which they have at their disposal in abundance.

2. No-cost restoration of ecosystems: the principle of benign neglect

Converting most food production to vertical farming holds the promise of restoring ecosystem services and functions. There is good reason to believe that an almost full recovery of many of the world's endangered terrestrial ecosystems will occur simply by abandoning farmland and allowing the countryside to "cure" itself (Gunderson, 2000). This belief stems, in part, from numerous anecdotal observations as to the current biological state of some regions that were once severely damaged either by now-extinct civilizations or by over-farming, and, in part, from data derived from the National Science Foundation-sponsored long-term ecological research program (LTER), begun in 1980, on a wide variety of fragmented ecosystems purposely set aside for study subsequent to an extended period of encroachment. One of the most intensively studied of these fragmented ecozones is Hubbard Brook in northern New Hampshire (Likens, 2001; Likens, 1970). The area is a mixed boreal forest watershed that has been extensively harvested at least three times in modern times (1700s-1967). The Hubbard Brook LTER lists its research objectives as: vegetation structure and production; dynamics of detritus in terrestrial and aquatic ecosystems; atmosphere-terrestrial-aquatic ecosystem linkages; heterotroph population dynamics; effects of human activities on ecosystems. A portion of the watershed was clear-cut and the trees left in place, in contrast to farming regimes in which trees are removed to make way for crop production. Re-growth of some plants (shade intolerants) occurred within 3 years. By 20 years, the trees (shade tolerant plants) grew back to the same density as before the experiment was begun. These data give credence to the hypothesis that if vertical farming could replace most horizontal farming, then ecosystem services that reinforce a healthy life style (e.g. clean water, clean air, carbon sequestration) would be restored.

3. Urban sustainability

Natural systems function in a sustainable fashion by recycling all essential elements for the next generation of life (Eugene, 2005). One of the toughest challenges facing urban planners is trying to incorporate the concept of sustainability into waste (both solid and liquid) management. Even in the best of situations, most solid waste collections are compacted and relegated to landfills. In a few rare instances they are incinerated to generate energy (Ragossnig, 2005). Liquid wastes are processed, then treated with a bactericidal agent (e.g. chlorine) and released into the nearest body of water. More often than not in less developed countries, it is discarded without treatment, greatly increasing the health risks associated with infectious disease transmission due to fecal contamination (Khosla, 2005). From a technological perspective, all solid waste can now be efficiently re-cycled (returnable cans, bottles, cardboard packages, etc.) and/or used in energy generating schemes with standard methods that are currently in use (Malkow, 2004). Incorporating modern waste management strategies into the vertical farm model should work the first time out without the need for new technologies to come to the

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commercial and restaurant

vertical farmers market and public park

Vertical Farm model

The Vertical Farm model is a 23' interactive model, featured in the Fast Forward exhibit at the Museum of Science and Industry, Chicago, IL. The model was designed and built by Eric Ellingsen and TJ McLeish; Student Design and build team: Homero Rios, Ryan Szanyi, Stephanie Herrera, Sabine Kollwitz, Adie Rios, William Hutchison, John Castro, Mahdieh Salimi Consulting and Dickson Despommier.

rescue. It must be emphasized that urban sustainability will only be realized through the valuing of waste as a commodity, deemed so indispensable that to discard something –anything - would be analogous to siphoning off a gallons' worth of gasoline from the family car and setting it on fire.

Since agricultural runoff despoils vast amounts of surface and groundwater (Stalnacke, 2001; Fawell, 2003; Foster, 2003), any water that emerges from the vertical farm should be drinkable, re-cycling it back into the community that brought it to the farm to begin with. Harvesting water generated from evapo-transpiration appears to have some virtue in this regard, since the entire farm will be enclosed. A cold brine piping system could be engineered to aid in the condensation and harvesting of moisture released by plants. The only perceived missing link is the ability to easily handle untreated human and animal wastes in a safe and efficient fashion. Several varieties of new technology may be required. Perhaps lessons learned from the nuclear power industry in handling plutonium and enriched uranium may prove helpful in designing new machinery for this purpose.

4. Social benefits of vertical farming

The social benefits of urban agriculture offer a rewarding set of achievable goals. The first is the establishment of sustainability as an ethic for human behavior. This ecological concept is currently only a property of the natural world. Ecological observations and studies, beginning with those of J. Teal in Georgia (Teal, 1962) showed how life behaves with regards to the sharing of limited energy resources. Tight knit assemblages of plants and animals evolved into trophic relationships that allowed for the seamless flow of energy transfer from one level to the next, regardless of the type of ecosystem in question (Ricklefs, 2000). In fact, this is the defining characteristic of all ecosystems. In contrast, humans, although participants in all terrestrial ecosystems, have failed to incorporate this same behavior into their own lives. If vertical farming succeeds, it will establish the validity of sustainability, irrespective of location or life form. Vertical farms could become important learning centers for future generations of city-dwellers, demonstrating our intimate connectedness to the rest 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.

Finally, hydroponic and aeroponic technology has increased yield potential by more than 23 times while decreasing water usage by well over 30 times; LED's (Light Emitting Diodes, the kinds used in many traffic lights) and sulfer-mircrowave lamps are being employed as alternative light sources in agricultural environments which grow and harvest within 'biomass production systems' and 'plant research units' by the Bioregenerative Life Support Project at Dynamac, Inc., at the Kennedy Space Center. These are constantly regulated, environmentally maintained, and hermetically controlled completely sustainable agricultural solutions which we have at our disposal today. Nourishing Vertical Farms right within the intolerably impoverished regions of the world's largest urban settings, such as Ethiopia, India, Central African Republic, the Gaza Strip, etc. is not only realistic, it's practical. Taking these ideas from outer space and deploying these strategies in the space of our cities is not only rationally feasible, it may be one of the best vehicles we have to take on agricultural challenges of the near and distant future.

CONCLUSION:

Our lives, actions and activities don't happen in the city—they ARE the city. The city is not the skyscrapers and tall buildings; it is the living and dynamic material and economic networks that makes these technological sequoias possible. Our cities are desperate for something that is simultaneously global, international, modern, and, local, unique, particular to the identity, identification, and individuals that are the place. The Greek urban planner, Doxiadis, in the 60s called this a Glocal economy: global + local. What the Vertical Farm offers, among other benefits like re-growth of forests and carbon sequestration, is a local food economy, a shortened route from producer to consumer, a self-dependant autonomy rather than a 1500 mile on average delivery from field to plate, and, a deeper, more meaningful, living typology rather than merely a thin iconic, visual typology. Chicago, for example, claims that being a sustainable city is one of its highest priorities, in fact it speaks in all superlatives—the MOST. But a green roof on the city hall doesn't cut the longest yard. A Vertical Farm offers a real Millennium iconic production, not merely an Millennium iconic symbol; not some urban planning, boiler-plate cultural import star-architect trick. Rather, the Vertical Farm offers a brand new architectural typology as a local and global solution to a 21st century crisis.

Architects must be informed by this active understanding of how nature works and how our cities need to work, rather than merely what nature and a broad shouldered city looks like—an aesthetic shoplifting really both of the image of 'nature' and the image of a 'modern city' that, in the end, is merely racing to build taller. But our view of nature meshed with a more dynamic view of the performance criteria of our city can both inform one another in robust and deep ways. How do natural systems, for instance, constantly change and yet constantly perform and stabilize in that change? How can we feed and grow and grow and grow simultaneously? Our cities must perform like this, and the Vertical Farming will help. On the one hand Vertical Farms will be like hospitals for food, but they will also be eco-services to our cities, which are in desperate need of infrastructural renovations, like our strangled waste management systems and hydrological services, storm water management, etcetera. Vertical Farms will allow flexibility and stability at the same time. Our cities are starving for better answers to a 21st century urbanism; the Vertical Farm needs to be on the menu.

...economic analysis

“very provocative - but it requires a rigorous economic analysis… Would a tomato in lower Manhattan be able to outbid an investment banker for space in a high-rise? My bet is that the investment banker will pay more.”

Armando Carbonell, chairman of the department of planning and urban form at the Lincoln Institute of Land Policy in Cambridge, Mass., explains how he feels about Dr. Despommier's vertical farm visions. From 'Country, the City Version: Farms in the Sky Gain New Interest.' The New York Times, July 15th, 2008.

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