VERTICAL FARMING AND ITS SYSTEM BORDER

by Daniel Podmirseg

The question of scale

The integration of agriculture into discussions about architecture and urbanism is actually experiencing a revival. Concepts on urban farming from Ebenezer Howard to Frank Lloyd Wright and Le Corbusier are well known and documented. Vertical Farming as a substitution of traditional soil based agriculture or a supplement in food production is increasingly becoming an integral part of research works, theses, design projects and competitions dealing with urbanism in general[1] [2], smart cities[3], productive cities[4] [5] or Hyperbuilding cities[6].

All these contributions must be kept in mind while reading Dickson Despommier's manifesto on Vertical Farming[7]. Urban (vertical) agriculture in public perception is as emotionally perceived as traditional or conventional agriculture. Depending on the perspective it is placed somewhere between Eutopia and Dystopia. But it is well known, experienced and distributed practise all around the globe - for centuries now. What is new is the scale of the vision of a stacked greenhouse. But aside the typological question which potentials and challenges recently have been highlighted[8], three helpful scales for analysis have to be considered and critically evaluated before design proposals should emerge.

1 VIE:BRA - Vienna-Bratislava-City, urban strategies: http://www.dieangewandte.at/jart/prj3/angewandte/main.jart?rel=en&reserve-mode=active&content-id=1234966513566&AktId=4493, retrieved 31.10.2015
2 http://milliardenstadt.at. University of Technology, Vienna. Project initiator: Lukas Zeilbauer
3 LIM CJ, ED LIU. 2010. Smartcities + Eco-warriors. Oxfordshire (first published), New York. Routledge.
4 NELSON, N. 2009. Planning the productive city. Available: http://www.nelsonelson.com/DSA-Nelson-renewable-city-report.pdf. Delft Technical University, Wageningen University and Research, NL
5 http://www.futurarc.com/index.cfm/competitions/2013-fap/. Addressing „adaptation of existing building typologies for agriculture (...) urban networks for production [and] distributions (...)
6 CODY, B. 2014. Form Follows Energy - Die Zukunft der Energie-Performance, energy2121, Bilder zur Energiezukunft, Klima- und Energiefonds, Vienna, omninum, p. 121 ff.
7 DESPOMMIER, D. 2010. The Vertical Farm, New York, St. Martin's Press.
8 PODMIRSEG, D. 2015. up! Contribution of Vertical Farms to increase the overall Energy Efficiency of Cities. Dissertation, Graz University of Technology, Austria

The structure and the system

The complexity of the food sector undoubtably is compareable to the complexity of human society. Dependent on where the observer draws the system border of the food sector, specific types of analysis are possible. Big picture studies on world agriculture from different organization are as well obtainable as specific numbers on daily energy demand for humans regarding the basal metabolic rate. This means, we know how much land we use to cover our daily nutritional value and its impact on a global scale - on average for the single individual as well as for the world population as a whole.

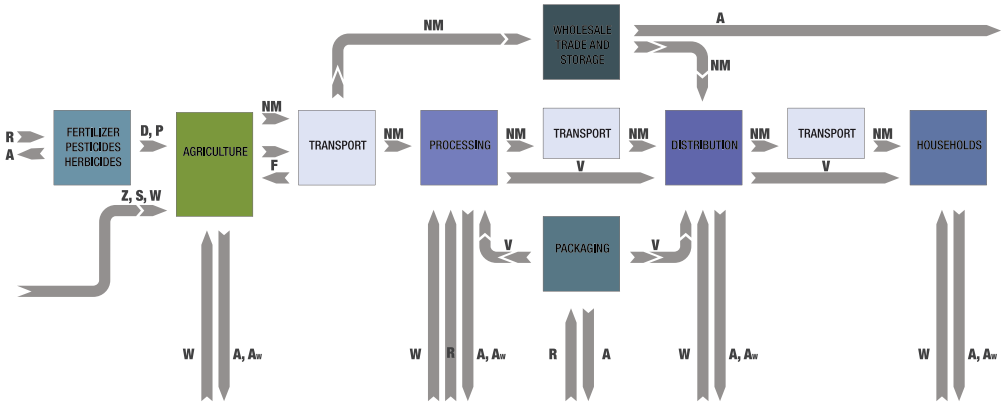

Fig.1. Systemborders of the food sector (A=Waste, Aw=Wastewater, D=Fertilizers, F=Feed, P=Pesticides, NM= Food Products, R=Resources, S=Seeds, V=Packaging Material, W=Water, Z=Growth) - based on FAIST, 2006.

The research field on energy- and material flows on an urban scale is some smaller and thus therefor should be investigated more intensively[9], not just because on every square meter of built up land ten squaremeters of agricultural land are needed to feed the urban population[10] - an important insight in times with exponential population growth.

To support the development of the typology of Vertical Farms it is thus helpful to define different levels of complexity to obtain reliable data, foundation for an expedient design process. The definition of these levels are obtained from sociology: the definition of systemborders on a micro, meso and macro level. As the Vertical Farm must be defined as a structural element of an urban system, the look on it as an „individual“ or an isolated typological prototype would hide all its potentials which emerge with the reunion of a 11,000 years old idea which got weakened some fifty years ago.[11]

9 An important work in this context should be mentioned: WATKISS, P., SMITH, A., TWEEDLE, G., MCKINNON, A., BROWNE, M., HUNT, A., TRELEVEN, C., NASH, C. & CROSS, S. 2005. The Validity of Food Miles as an Indicator of Sustainable Development: Final report produced for DEFRA. AEA Technology.

10 PODMIRSEG, D. 2015. up! Contribution of Vertical Farms to increase the overall Energy Efficiency of Cities. Dissertation, Graz University of Technology, Austria, p.91

11 MC.KINNEY, M. et al. 2012 „Environmental Science: Systems and Solutions“, Burlington, Logan Yonavjak Jones & Bartlett Publishers. p. 35 ff.

Micro

The Vertical Farm in its heart is a verticalized greenhouse where its volume is developed for optimum plant growth. Plant needs, physiological processes, photosynthesis are in the centre of the investigation. It is the daily action, the continuous interaction of the crop itself with the created environmental conditions. This is the most intimate level, the direct interchange between the growing plant with all essential elements needed for a healthy plant growth. On an architectural level of primary interest are all factors which directly influence photosynthesis and photomorphogenesis such as light and temperature, water and carbon dioxide. Multidisciplinary acting is needed where plant needs and thermal simulation and energy modeling lead to the design.

Fig.2. Paignton Zoo, Devon: Photo of the production volume

Meso

This mid-scale approach offers the possibility to re-interpret system borders of the food sector. The system border can either be defined as the border of the building itself or phenomenologically sketched as the *Vertical Farm-gate*.
The building shape is the geometrical description which defines the optimized architectural answer to communicate between the plant‘s need on the micro level and the environmental and climatic conditions such as the built urban context, the climate zone where it is situated and the sunstand along the year round changes.

Today‘s world agriculture is dependent from a global food transportation network, where the production of macronutrients, the agricultural land, processing, wholesa-

le, storage and distribution are spatially detatched from each other and are therefor responsible for remarkable costs, not only on an energetic level.[12]
Disassembling the food supply chain for specific crops and the analysis of its different items enable the opportunity to programmatically enlarge the function of the verticalized greenhouse, to redefine the system border in food production - to define what items are placed within the Vertical Farm gate.
The identification of additional functions is based on its potential to reduce the impact in both energy- and material transport between the urban area and the country side, placed somewhere on the globe. Processing, small scale storage are as well thinkable to happen within a Vertical Farm such as the re-establishment of local social and economic interdependencies carried by market- and trade areas within and around the farm.

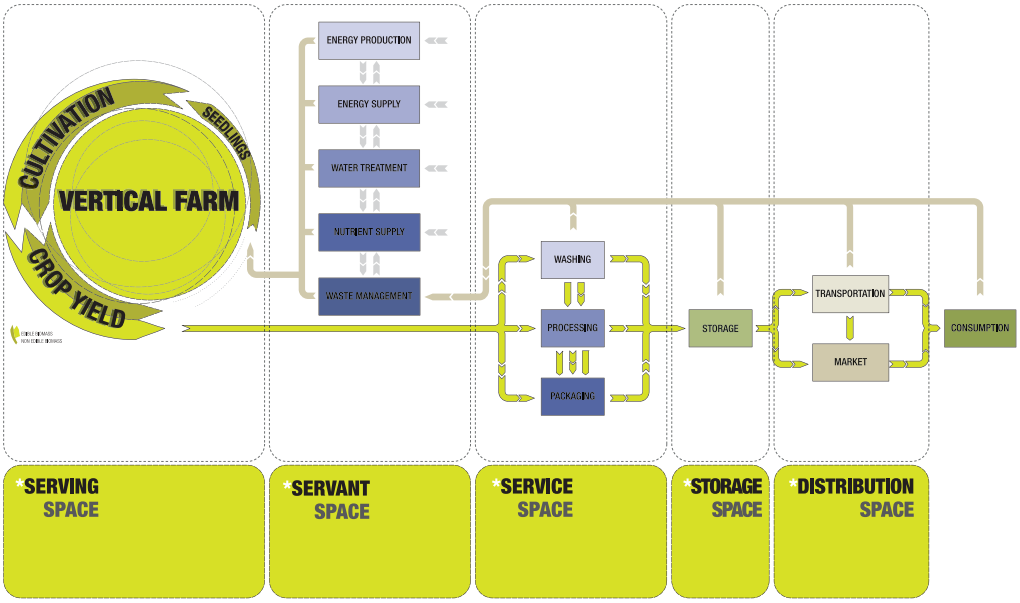

Fig.3. Ideal systemborder of a Vertical Farm

Macro

The global food sector is responsible for a third of the overall energy consumption, responsible for 70% of all renewable water withdrawals, impacts on emissions and as a consequence on climate change are notable. Global agricultural land today covers more than 30% of the global land mass with tendency to grow, especially through slash-and- burn practises used to convert forests to productive land. Since the 1980s

12 WATKISS, P., SMITH, A., TWEEDLE, G., MCKINNON, A., BROWNE, M., HUNT, A., TRELEVEN, C., NASH, C. & CROSS, S. 2005. The Validity of Food Miles as an Indicator of Sustainable Development: Final report produced for DEFRA. AEA Technology.

global numbers are continuously published, studies and methodologies are compareable and deleve this often brutal impact on our natural habitat.[13]
On an urban scale, in this context the macro level energy- and material flows are interesting to be drawn. Every human every day needs a specific amount of food mass which has to be produced and distribute. If the concept of metabolism is adequate to be adaptable to urban analysis, impacts of Vertical Farming can be drawn, its advantages and challenges.

The principle of Vertical Farming on a macro level, the value and meaning it contains – its raison d'être – is primarily to dependent on four factors:

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reduction of needed additional land conversion for the urban population

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A reduction in land use up to 50 times can be achieved by comparing year round yield from Vertical Farms to soil based agriculture.[14] Since the 1980s roughly 80-90% of the additional land for agriculture came from forests. Today, this is still an ongoing practice. One hectare of forest every year binds more than 11 t of CO_2[15] and it would release up to 737 t of CO_2[16] which, by converting it into agricultural land, would be released by current slash-and-burn practices.

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renewables substitute hydrocarbon

Crops with high lighting demand challenge typological developments. The city as a whole has to be considered, smart energy grids have to support energy demands of Vertical Farms, the system border in providing energy now is the city and the peri-urban zone. „Industrial symbiosis" have to be considered.[17] Waste from biomass production entity has to be defined as energy source. The choice for adequate crops with tenable support in artificial lighting has the highest potential to reduce the energy demand.

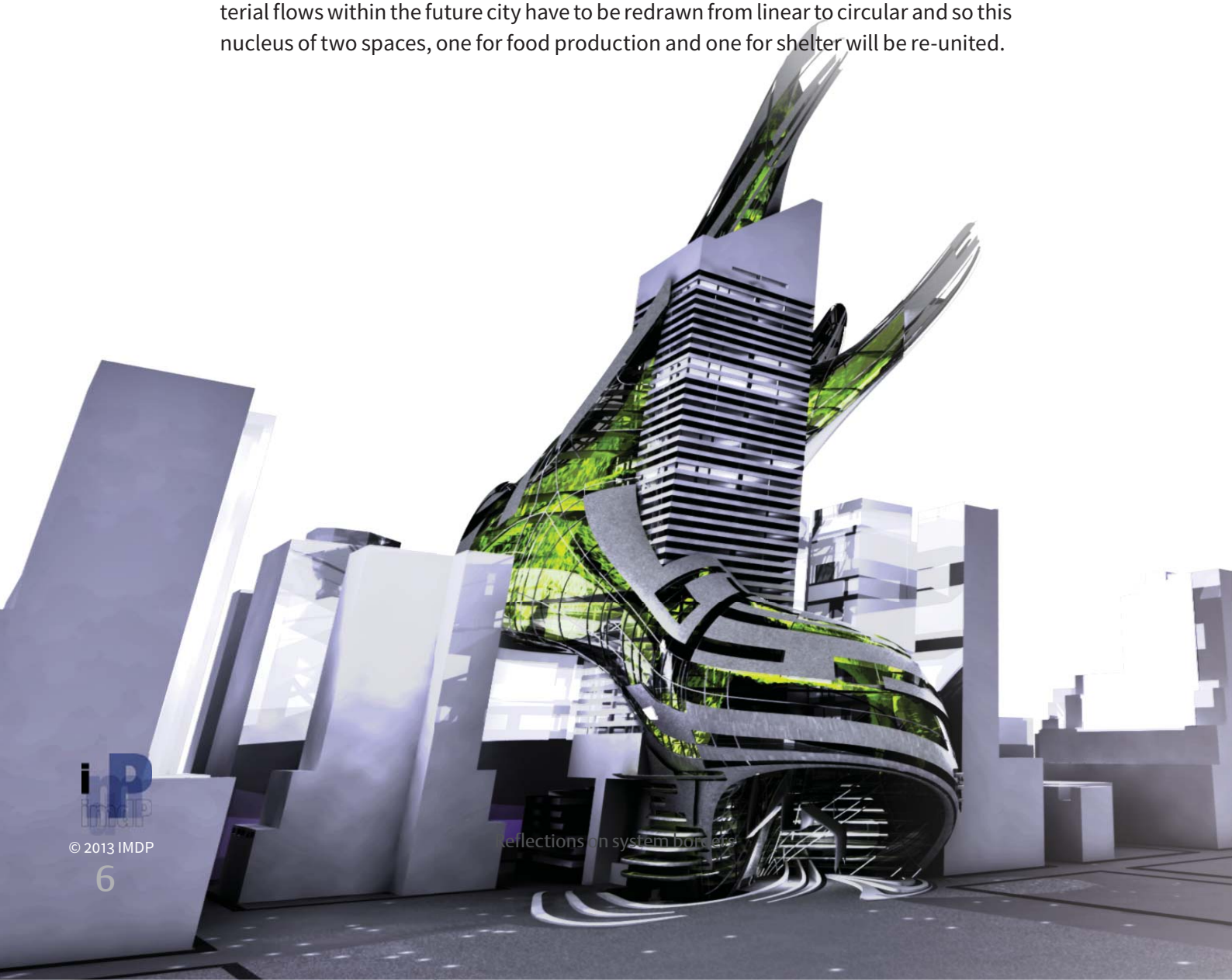
13 FISCHER, G., VELTHUIZEN, H. V. & NACHTERGAELE, F. O. 2000. Global Agro-Ecological Zones Assessment: Methodology and Results. International Institute for Applied Systems Analysis, FAO., Executive Summary, p. xii
14 PODMIRSEG, D. 2015. up! Contribution of Vertical Farms to increase the overall Energy Efficiency of Cities. Dissertation, Graz University of Technology, Austria, p.306
15 SMIL, V. 2008. Energy in Nature and Society, Cambridge, Mass., MIT Press. p.69
16 http://pubs.iied.org/pdfs/16023IIED.pdf. p.10
17 http://plantagon.com/urban-agriculture/industrial-symbiosis, retrieved 12.12.2015

the site affects the typology

Solar analysis studies and morphological investigations determine and detect potential sites and thus influence the building envelope. The context defines the typology and the potential crop produced, from the centre to the peri-urban zone. Buiding heights, solar availability and natural energy grids as well as existing transportation hubs locate Vertical Farms.

ecological symbiosis between agriculture, society and architecture

If world population in urban areas continues to grow, and this is most likely to happen, then future cities must be prepared to be resilient. Cities must minimize their impact on our natural habitat outside the urban area. The Neolithic Revolution implemented a nucleus of spaces for food production and cities. This development has drastically changed within the last decades. The city has to be understood as a system, and the Vertical Farm as an integrative structural element of it. Energy and material flows within the future city have to be redrawn from linear to circular and so this nucleus of two spaces, one for food production and one for shelter will be re-united.



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Article written on December 8th 2015 and selfpublished on researchgate.net

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Contribution of Vertical Farms to increase the overall Energy Efficiency of Cities

First Edition November 2015:

Selfpublishing

Print:
Graz University of Technology
Print- and Copycenter

ISBN: 9-783299-043824