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Addressing Food, Water, Waste and Energy Locally Yields in Urban Regenerative Environments

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An Introduction to ATINER's Conference Paper Series

ATINER started to publish this conference papers series in 2012. It includes only the papers submitted for publication after they were presented at one of the conferences organized by our Institute every year. The papers published in the series have not been refereed and are published as they were submitted by the author. The series serves two purposes. First, we want to disseminate the information as fast as possible. Second, by doing so, the authors can receive comments useful to revise their papers before they are considered for publication in one of ATINER's books, following our standard procedures of a blind review.

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Abstract

Our cities are built dependent on centralized systems of water and waste management, food and energy production. This practice has proven efficient for a while; nonetheless as our cities expand with immense speed and population increases, severe issues of food access, waste accumulation, floods, water contamination and increased energy demand reveal the obsolescence of those systems. The solution does not lie anymore only in conservation and precautionary measures but in a diverse way of thinking and redesigning existing infrastructures. Through this research, several systems of urban agriculture, decentralized water management and treatment, as well as energy production from waste were identified and studied through literature and actual case studies. The ultimate goal was to create a toolkit for urban regenerative environments, which will be used to introduce those systems to designers. The key component of the toolkit is the quantitative link between the spatial demands of each system and its efficiency.

The process of the work is defined by three phases. The first phase was to delineate the different systems through literature review and data collection of recent or ongoing case studies. The second phase was to analyze, classify and document the case studies for the Toolkit of Urban Regenerative Environments. Finally, as a proof of concept of the usability of the Toolkit as well as a way of investigation of the potentials of the systems presented, a design exercise was realized in a neighborhood in Philadelphia. Different systems were selected and applied in an area considered as a food desert in Northern Liberties, close to downtown Philadelphia. Through this exercise the applicability of the Toolkit was tested and the potentials of the systems were identified.

This paper presents the results of the proof of concept, highlighting the benefits and potentials of decentralized food, water, waste and energy systems.

Keywords: Urban regenerative environments, sustainable design, food production, water treatment, energy from waste, decentralized infrastructure, urban resiliency

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Introduction

Urban density constitutes a critical part of the sustainable communities. Denser cities have reduced per capita use of resource, due to the limited needs in commuting. (Calthorpe, 2011) Nowadays, 28% of the energy consumed in US is due to transportation, (U.S. Department of Energy, 2011) hence it is really important to reduce commuting distances. Dense urban areas minimize commuting long distances, and therefore reduce the carbon footprint of a community. However, the idea of minimizing long distances and using local resources comes in conflict with the current model of globalization and the open global market. Consequently, working within a global framework we have to come up with local ideas.

In this global framework, cities and dense urbanized areas are expanding with immense speed, creating controversies about the quality of space produced. In 2000, China announced her intention to create 400 new cities, (an urban area as big as 24 times the size of the metropolitan area of London) until 2020 due to the intense immigration of rural population to the cities. (Katrini & Ventourakis, 2008) Under those terms, air and visual quality, human comfort and health, as well the connection to nature are often being compromised.

Cities are created with no local solutions for food supply and waste management. We spend 10.2 quadrillion Btus annually in the food production and distribution sector. (Heller & Keoleian, 2000) From the above energy consumption, 14% is consumed for transportation. (Hill, 2008) In the U.S. fresh produce is estimated to travel 1,500 miles from the growers to the consumers. (Hendrickson, 1996) The food transportations by airplanes, trucks and other means lead to increasing emissions of greenhouse gases and air pollution. For example the imports of fruits and vegetables in California in 2005, only by airplane, led to more than 70,000 tons of CO_2 to be released in the atmosphere. (NRDC, 2007) A main reason for food transportation is also the ability to provide certain types of fresh produce year round. However, in order for this fresh produce to stay intact while travelling, pesticides and toxic preservatives are added, which are harmful both to human health and the environment. Despite that, fresh produce still loses important part of its nutritious value from the moment it is produced to the moment it gets delivered.

Unfortunately, apart from being energy demanding, our current food system is full of contradictions. Based on the energy consumed and food miles travelled, it could be implied that food is being uniformly distributed and available to everybody. Nonetheless, that lies far away from the truth. In 2009, there were more than 23 million people in U.S. who live in food deserts. (Bornstein, 2012) A food desert is defined by US Department of Agriculture (USDA) as “a low-income census tract where substantial number or share of residents has low access to a supermarket or a large grocery store”. (USDA, 2012b) Food deserts are the aftermath of the disconnection between food production and actual demand. Food is mass produced far away from the cities where the actual demand is. That leads to problems of increased food production, bad distribution and consequently unmet demand. That means that we produce more food than we actually need, and a great part of us still stays hungry.

It is estimated that 1/3 of the food produced in the US is being thrown away before it is even eaten. (Martin, 2008) In 2010, 34,000,000 tons of food waste was created and almost all of it was thrown to the landfills. Each person produces 1 pound of food waste every day, leading food scrap to the second place as the largest source of waste to end up in landfills. (US EPA, 2010) On the other hand, the number of landfills in the US is diminishing significantly every year. From 1991 to 2007, landfills have been reduced by 2/3, creating issues of waste management and treatment. (US EPA, 2008) As landfills become fewer, waste has to travel greater distances to get treated. After March 2001, when Fresh Kills, the landfill of the City of New York closed, the waste produced by 8,175,133 people cannot be treated locally anymore and has to be transported to Ohio, Pennsylvania to get disposed, costing approximately as much as $67.50 per ton. (Lipton, 2000) Moreover, the concentrated waste in specific areas leads to air, water and ground pollution, which compromise the health of the residents in surrounding areas. Neighboring regions of landfills can suffer up to 13.7% decrease of residential property values due to pollution and odor problems. (Ready, 2011).

The current practices of urban development and structure have an effect on the hydrological cycle. The impermeable, concrete, dense urban clusters provoke environmental issues of climate change; with increasing floods and urban heat island effects that pose threats on human life. One of the major problems in dense urban centers is the incapability to retain the storm water. The expansive impermeable surfaces of concrete and asphalt along with the dense built environment result in flooding and polluted surface water. Flooding incidents are getting more and more frequent; only in 2004 there were more than 80 flood events in the US. (US DOE, 2008) Apart from the obvious risks that they include, they cause damages with great costs for infrastructure. It is estimated that floods cause an annual cost of damage of about $6 billion. (National Geographic, 2012) Moreover, the repercussion of those floods is the overflow of the sewer systems, which in the case of approximately 772 cities in the US, which have combined sewer systems, leading to the contamination of the watersheds. (NPDES, 2012)

Finally, the buildings themselves contribute even more to the above urban complications. The construction industry, by creating buildings on a first cost base, ignores their performance, creating a high energy-demanding landscape. In the U.S., buildings are responsible for the 42% of the total energy consumption, resulting in greenhouse gas emissions which account for the 30% of the U.S. total. (EPA, 2011) (Figure 1 A) The greenhouse gases emissions are due to the way we produce energy; through combustion of mostly coal or natural gas. Producing electricity through combustion and then distributing it through the grid, leads in serious energy losses that consist the 2/3 of the initially produced energy. (U.S. EIA, 2011) (Figure 1B)

The above examples question the efficiency of centralized systems. The emerging hypothesis from these statistics that was analyzed is; *Will addressing food, water, waste and energy locally yield in urban regenerative environments? If it does, how designers and people related to the building industry can be updated about such environmentally sustainable decentralized systems?*

Methodology

Scope of work

The scope of this research project was to identify technologies and case studies of urban food production, stormwater management, decentralized wastewater treatment and energy production from waste and present them through a comprehensive method. The representation of the case studies through the Toolkit for Urban Regenerative Environments aims at creating a link between the size of the systems, their performance and capability to a district, neighborhood or building level.

Research process

The process of the work is defined by three phases. The first phase was to delineate the different systems through literature review and data collection of recent or ongoing case studies. The second phase was to analyze, classify and document the case studies for the Toolkit of Urban Regenerative Environments.

The classification of the case studies selected was realized based on three parameters (Figure 2):

1. The type of the system: food production, stormwater, wastewater treatment and energy from waste.
2. The location of the system: landscape, rooftop, window, whole building
3. The scale of the system: building, neighborhood, district

Each case study has been documented with the following details (Figure 3):

1. Background story
2. System Description
3. Key dimensions
4. System capacity or annual production
5. Plan with graphic scale and general dimensions
6. Supporting information, diagrams and images

The ultimate goal of this process is to provide the users of the toolkit with the ability to estimate the potential use of such a system in their projects based on their available space, building typology, community characteristics and other project demands.

Finally, as a proof of concept of the usability of the Toolkit as well as a way of investigation of the potentials of the systems presented, a design exercise was realized in a neighborhood in Philadelphia. Different systems were selected and applied in an area considered as a food desert in Northern

Liberties, close to downtown Philadelphia. Through this exercise the applicability of the Toolkit was tested and the potentials of the systems in another neighborhood were identified.

The Toolkit for urban regenerative environments

The purpose of this toolkit is to make designers aware of various innovative and forward-thinking strategies related to food production, stormwater management, wastewater treatment and energy production. The toolkit for urban regenerative environments is a tool for the design team during the preliminary design phase. It illustrates spatial requirements and quantitative benefits of these strategies with the goal of pushing the team towards a new way of thinking. Considering the toolkit as a “Green Infrastructure for Dummies”, it could actually help the design team during the schematic phases. Due to ongoing technological advances, the intent is not to showcase best practices, but present current practices. Consequently, the toolkit is not meant to be a static best practices book to refer to, but a constantly evolving and updated database.

Additionally, it can become useful in another part of the design process; the charrette. It is an easy way to showcase several case studies to people from different backgrounds, as both the illustrations and the texts are presented in a simplified manner to be useful to a wider audience. Through the case studies, the toolkit also provides convincing evidence to the clients by correlating the space needed and the potential benefits of the systems being considered.

The different systems presented through the toolkit are for food production; geoponics, hydroponics, aeroponic towers, aquaponics, greenhouses, for stormwater management; wetland, bioswale, stormwater planters, for wastewater treatment; living machine, membrane bio-reactor and for energy from waste; anaerobic digester and incinerator.

The toolkit includes 2 introductory cards, 4 cards with general information about the four system categories; food production, stormwater, wastewater treatment, energy from waste, 19 cards presenting different case studies, a references’ card and a CD. (Figure)

The first two introductory cards present how the toolkit is structured and how it is used. The instructions card, gives the necessary information or references to the design team on how to calculate the following data, based on the number of residents of a certain project:

1. How much fresh fruits and vegetables they consume
2. The runoff volume generated from the area of the project
3. The wastewater produced by the residents
4. How much food waste is produced by the residents

Based on the above data, and the space availability of the certain project, the design team can decide which system from the case studies that follow is more appropriate. On the second introductory card the classification index of the case studies is presented. All the case studies are classified based on the system, the location of action and the scale of the project.

The systems introductory cards are found before the related case studies cards. They present the benefits of the system and a short description of the different current technologies. Each case study card has the same structure that helps the user understand the project, its basic information, the system and its requirements. On the front side, there are images, the title, the classification of the system (
Figure) and a short paragraph about the background of the project. The back side is dedicated to the presentation of the system. On the right there are all the main information about the system; the system description, its key dimensions, its capacity, how much it yields etc. For all the case studies, there is always a description of the system and key dimensions category, as well as a category where shows the yield or capacity of the system. Consequently, the spatial demands of each system presented are correlated with its quantitative benefits. On the right side, there is the supporting graphic material along with the plan of each system presented as a “stamp”. The idea of the stamp is to outline fully the system and its key dimensions. The design team could literally recreate those stamps on their development plan and multiply accordingly to calculate the yields. However, as the design process is not being done anymore by hand, a digital version of the case studies “stamps” is provided as an Autocad file in the CD. Hence, the design teams can now “copy-paste” the stamps on their project file following the same concept. Moreover, as the scales of each case study and system vary from building to district, it would be impossible to create all the stamps in a certain scale. Nevertheless, a graphic scale and a North arrow indication are provided on each stamp.

Proof of Concept

The Neighborhood

In order to test how the toolkit will be used in an actual design process, a design exercise was realized as a proof of concept in the city of Philadelphia. (Figure 5) The design was based on the information gathered in the case studies. Even though the city consists of an urban dense area, food deserts are found within its limits. According to the United States Department of Agriculture’s ‘Food Desert Locator,’ there are three basic areas currently defined as a food desert (U.S. Department of Agriculture, 2013); one of those was selected as the study example. The implications of limited food accessibility in communities, especially areas considered as food deserts, often influence the health and economy of the community and its residents. (Wrigley, Warm, Margetts, & Whelan, 2002) (Pothukuchi, 2004) The selected neighborhood is located in the general area of Northern Liberties and Fishtown. It has 2171 residents, and all of them are considered to have low access to fresh food. (USDA, 2012a) There are 951 housing units and the total area of the development is 142 acres.

The Design Actions

Firstly, availability of space for food production in the neighborhood was investigated. Vacant lots, industrial and commercial rooftops were considered as possible spaces to grow edible plants. It was assumed that 80% of every vacant lot and 62% of every industrial and commercial rooftop will be used for urban agriculture. (Grewal & Grewal, 2012) That led to a total of 25.7 acres of land. As far as wastewater was concerned a Membrane Bio-Reactor was implemented in the neighborhood that has the capacity to treat about 100,000 gallons of water per day. The spatial demands of such a system were about 0.06 acres. Finally, the neighborhood will host an anaerobic digester that will treat organic waste and produce biogas. The biogas can be used as a renewable natural gas for cooking and heating purposes in the residential units.

The above design actions resulted in the following quantitative and qualitative benefits:

Quantitative Benefits

Food Produced: Supply 50% of the residents' needs for fresh fruits and vegetables (1085 residents).

Wastewater treated: With the implementation of the Membrane Bio-Reactor 100% of the residential wastewater produced gets treated on site.

Waste treated: The neighborhood will host the anaerobic digester which will treat the residential food waste of 12 neighborhoods of the same size.

Energy Produced: The anaerobic digester produces annually 5,860 MMBtus of gas which satisfies 7% of the neiborhood's gas demand (66.5 Housing Units).

Qualitative Benefits

Education: Workshops and educational programs are organized in the local farms for students. Informational Center of the digester brings 'human waste to human scale'. Residents are learning how organic waste is digested and how energy is being produced.

Job opportunities: Creation of job opportunities and support of local economy through on site farms and food processing businesses.

Community: Creation of green spaces with activities that can bring the community together.

Reducing food miles travelled: Food is becoming accessible in the neighborhood reducing the miles travelled. Moreover the local food production industry can supply other areas of Philadelphia without travelling great distances, as they are within a 5 miles radius.

Waste diversion: Every year 5,000 tons of organic waste is diverted from landfills and about 70,629,334 ft3 of methane is being captured.

Conclusion

As mentioned in the introduction above, several problems related to food access, water management and energy supply arise due to the attempt of satisfying the cities' needs only through centralized infrastructures. Such massive global systems, which follow economical and political trends, face fluctuations on their efficiency. That means that often enough they might fail to satisfy everybody's needs. The great advantage of decentralized systems, such as the one presented through the toolkit, is that they can become back-up mechanisms minimizing the failure risk of the centralized systems.

Moreover, if we imagine the community as an organism or a system, the decentralized infrastructure act as the system's balancing feedback loops. In particular, every community has inputs and outputs. It imports food, energy and water by using the centralized networks; it has energy losses and exports waste and wastewater. The decentralized systems use the outputs of a community in order to generate food, energy and water supply. Consequently, the demand for external input is reduced while reducing waste and losses. (Figure 61, Figure)

Creating opportunities for decentralized systems of food, water, waste and energy in communities in combination to the greater networks can increase urban resiliency and efficiency and eventually create urban regenerative environments.

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Figures Appendix

Figure 1. A. *Left: 2011 Energy Consumption estimates by sector [Source: Energy Protection Agency (EPA) Data] / B. Right: Electricity Flow Chart [Source: U.S. Energy Information Administration]*

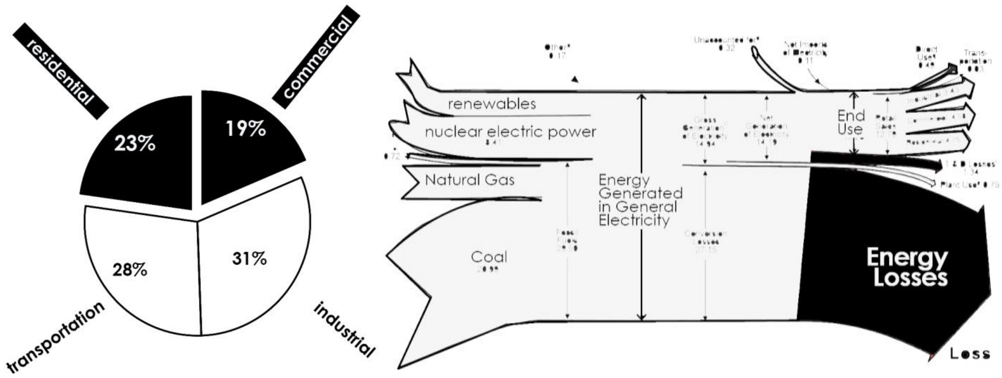

Figure 2. *Case studies classification keys for different systems, locations and scales*

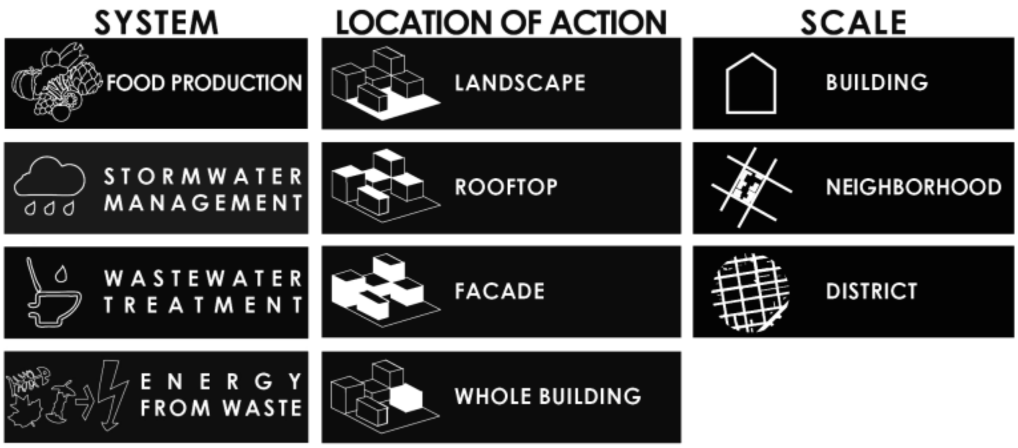

Figure 3. *Documentation of case studies (Sample Card of Toolkit)*

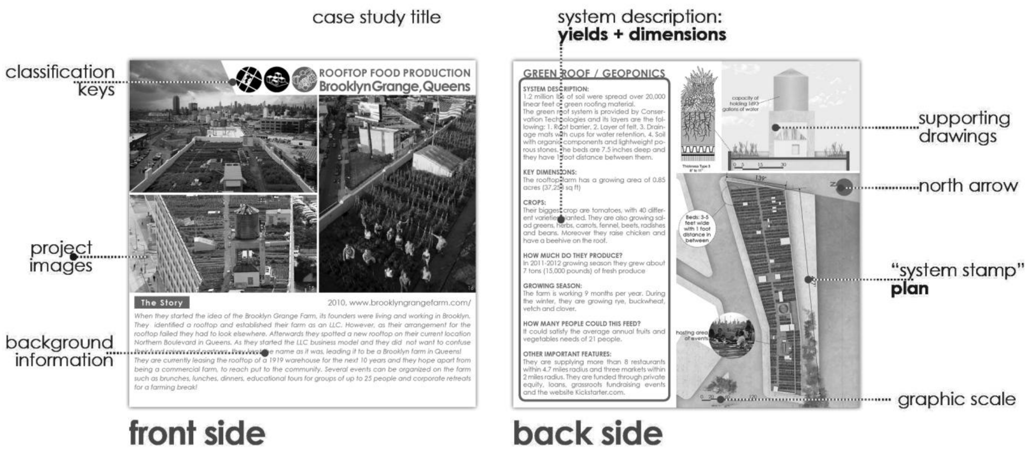

Figure 4. *Toolkit for Urban Regenerative Environments*

Figure 5. *Map of the Northern Liberties area*

Figure 61. *Model of energy, water, food and waste flows through a typical community served by centralized infrastructures*

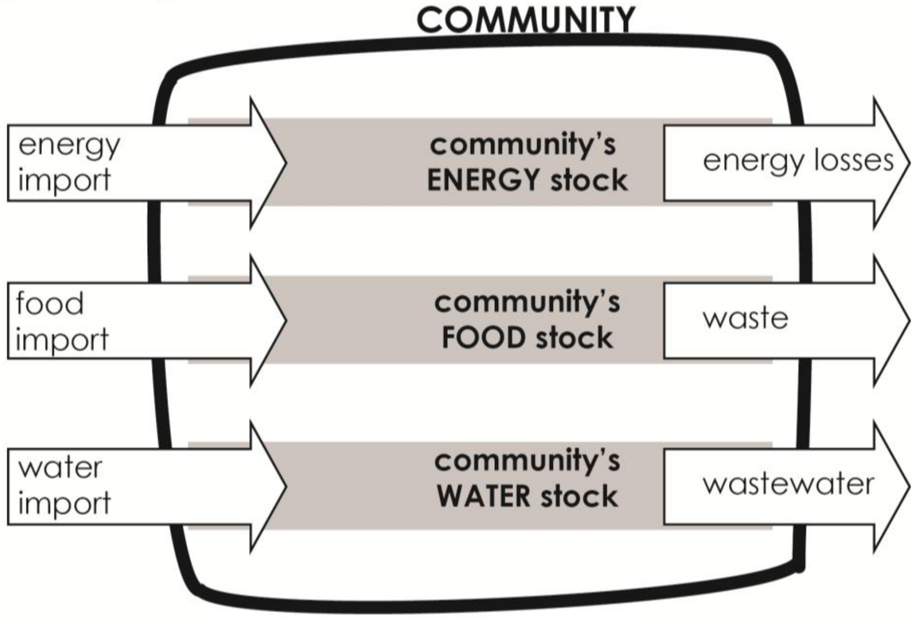

Figure 7. *Model of energy, water, food and waste flows through a community which uses decentralized systems as back-up mechanisms. Reduction of inputs and outputs is noticed*