Energy-Water-Food Synergy Possibilities in Housing Environment

Patrycja Haupt

1 Cracow University of Technology, Faculty of Architecture, Institute of Urban Design, Chair of Housing Environment, ul. Podchorążych 1, 30-084 Kraków
phaupt@pk.edu.pl

Abstract. Strategic directions of development of contemporary cities, according to emerging master plans and policies are providing appropriate technical, spatial, social and economic conditions for the inhabitants in a sustainable way. In order to improve the urban areas' performance and to minimize the negative environmental impact there are new solutions introduced to save energy, water and food resources. There are actions undertaken to educate and activate community that also appear in the way of designing housing environment, especially public spaces accompanying residential areas. Therefore there are experimental forms of buildings and urban spaces designed to meet the demands of community serving the environment at the same time. There have been a variety of solutions implemented successfully in housing environment to solve either the problems of energy or water management, and also bringing up the food production problem especially in the contact areas between the buildings and their surroundings. Nowadays we are searching for a new type of housing environment, a home for the resilient community capable of independent development. In order to create that kind of space there is a need of new solutions providing synergy between energy, water and food management and production. There is a need of identifying the new type of architecture that is capable of satisfying the contemporary community demands. The search for those solutions is the main subject of research. The paper is an attempt to classify the implementation of synergy solutions in housing environment. It also refers to the significance of natural elements of composition in achieving energy, water and food independence. The trends in architectural design of contemporary residential areas are described based on contemporary investments and future city concepts.

1. Introduction

Strategic directions of development of contemporary cities, according to emerging master plans and policies are providing appropriate technical, spatial, social and economic conditions for the inhabitants in a sustainable way. Under the influence of forecasts concerning the increase in the number of city populations, as well as global warming, rising sea and ocean levels threatening contemporary metropolises, there has been a development of ideas in the area of various fields of knowledge aimed at indicating guidelines and developing development strategies securing the fate of future generations. A number of integrated assessment models have appeared to understand the linkages between climate, land, energy, water, and food as referred to the term nexus. This kind of simulation model thinking in urban development has a variety of influences the system analysis work of The Limits to Growth Meadows et al., 1972 [1]; Bazilian et al., 2011[2]; Foran, 2015[3]; A. Rothwell, et all, 2015 [4]. Some
of the results have shown that the actions should be taken in order to prevent and in some cases even reverse the negative impact processes.

The interdisciplinary search for the idea of shaping cities and setting the directions of their development has begun, as an effect of the further escalation of negative phenomena (Zachariasz [5]; Lehmann [6]). These concepts concern both the spatial and social structure of the city, which in this case is understood as sociological phenomena. The field of shaping the image of the city is taken from the 1960s by the city researchers and theoreticians (Lynch [7]; Jacobs [8]; Tołwiński [9]; Krier [10]; Wallis [11]; Wejcher [12]; Norberg-Schulz [13]; Gehl [14]). Contemporary visions of the city's development and directions of urban transformation are presented by theoreticians, as well as practicing architects (e.g. S. Holl, MVRDV).

One of the aspects of this problem is the contemporary importance of nature in urban spaces. Its presence is considered indispensable for shaping the environment of human life through its functional qualities - used to improve the quality of water and atmosphere, but also because of its aesthetic properties that affect the satisfaction of the residents' needs.

2. Understanding the linkages in housing environment

2.1. In search for the new housing environment

Europe is now facing rapid urbanization. According to statistical data, by 2050, nearly 10 billion people will live on Earth. In Europe, gradual disappearance of rural areas is observed, caused by urban sprawl. These trends will be intensified by climate change. Another urgent issue to be addressed are the demographic changes associated with the process of the population growing old. The basic social unit, the family, goes through a period of redefinition. These phenomena cause the increasing percentage of people with specific housing needs within the population. In recognition of these processes in many countries actions are undertaken to prepare the residential environment for those changes. There are policies developed to achieve resilience through the design and community actions. The research conducted in order to find a new type of dwelling [15], the results are various in this never ending process but some main assumption can be made basing upon the undergoing scientific findings.

The urban sprawl and free access to information technologies - especially social media lead to declining the sense of community and the impoverishment of interpersonal relationships. Accordingly, the demands for a high standard of living, aesthetics and comfort are increasing. The challenge that we are facing is creating a new model of housing environment for the redefined social structure including the results of ageing and migration, that would be capable of adapting to the changing user demands. Synergetic model including the interactions between energy-water-food consumption and production is considered to be the solution.

2.2. Energy, water and food dependencies

One of the means of achieving effectiveness in sustainability as well as environmental resilience is understanding the linkages between energy, water and food production. The dependencies shown by United Nations Economic Commission for Europe 2016 can be adapted also for urban areas, for the growing interest in environmental quality by introducing green infrastructure, water management, and urban farming within the city area to serve its community. All of the three major concerns – energy, water and food production and consumption are equally important in the urban areas, for they apply to the building and community performance.

The dependencies between those three factors in the built environment can be a clue for sustainable and resilient urban and architectural design. Nowadays the most significant requirements for architectural and urban design are energy management issues. According to targets set in 2007 the
2020 package is a set of binding legislation to ensure the EU meets its climate and energy targets for the year 2020. The package sets three key targets: 20% cut in greenhouse gas emissions (from 1990 levels), 20% of EU energy from renewables, 20% improvement in energy efficiency. The new 2030 climate & energy framework from 2014 sets the new three key targets for the year 2030: at least 40% cuts in greenhouse gas emissions (from 1990 levels), at least 27% share for renewable energy, at least 27% improvement in energy efficiency. These regulations have their reflection in UE countries’ building codes. There are conjugated interactions between all three nexuses. The building industry tends to put forward the energy aspect. There is special attention paid to the requirements for energy consumption and production. As for water and food resources, there are only regional requirements, especially in the areas suffering from disasters.

However, to improve building performance there is a need for holistic vision of future urban development. The cooperation between the building and its immediate neighbourhood is needed to eliminate the negative impact of the urban development on the environment, e.g. reducing the CO₂ emission as well as the heat island effect, improve the water performance as well as reduce the energy consumption for food delivery. There is a need to study the dependencies between energy, water and food in urban areas.

---

Figure 1. Energy, Water & Food Synergy in urban development graph

---

1 Energy Efficiency Directive of the EU Parliament 2012/27/EU of 25 October 2012 and the later updates
2.3. Working with nature

Today, due to the rapid urbanization processes, the most important area for transformation is city space. The urban landscape has become a place for interaction, for blending architecture with nature. This relationship is set on three main factors deriving from the building performance and the community needs. These are energy, water and food demand for each of the inhabited units. All of them may be satisfied by balancing the building impact with a proper setting, working with nature to improve building performance.

Through the ages the perception of the role of nature would change. There may be five stages of this process distinguished of defining this relationship: adapting the natural landscape, imitating it, then creating cultural landscape as the transformation of nature, modern city - opposing nature and contemporary - mimicking forms of nature, both in spatial form as well as in performance [16]. Following this scheme, there may be an assumption set, that the future city buildings can be described as organisms, working independently for the community of its inhabitants adaptable to outer conditions. Working with nature - instead of in opposition to it - may be an important factor of becoming more resilient and coming back stronger after disruptive natural events. It is even more important to understand the significance of everyday performance of the building and the urban environment for its impact on the ecological and human health.

Observing contemporary urban landscape, the tendency reveals that natural elements of composition whether as integral parts of the buildings such as green roofs or walls, or the building's intermediate surroundings. There is a new form of synergetic system of dependencies developing between the constructed structures, the city green infrastructure and even with community in some cases. The need of protecting the natural resources has triggered the cautious and balanced type of design using the possibilities of natural elements of urban and architectural composition to improve the building performance reducing energy and water demand and reducing the negative impact on the environment, supporting the water management and air quality.

Understanding the dependencies in urban environment leads to the need of spreading this symbiosis. The food production fulfilling the rapidly growing cities has become a concern since the urban sprawl process has been constantly moving the agricultural areas away from the centres. The mass food production not only causes the high energy demand in the phase of production as well as in storage and transport. Therefore in many cities of Europe and United States the public spaces of the cities as well the open access integral parts of the buildings are used for popularization of the new forms of recreation such as urban farming initiatives. This movement evolved from the idea of improving the status of the urban poor, to projects supporting sustainable urban development strategies [17]. The forms of farms are varied, from independent adapted green areas, as is the case in Battery Park in New York through on ground cuvette gardens provided for in residential complexes in the Lyon district of Le Confluence (figure 2, 3), or the roof garden of Cité de la Mode et du Design (Figure 4) managed by the local community. Their objective is mainly educational but the urban environment and community benefits from reducing heat island effect, improved water management and healthy food in minor scale. The next step would be an independent residential complex capable of self-food production incorporated with the building infrastructure system.

![Figure 2, 3 Lyon district of Le Confluence](image1)

![Figure 4. Roof garden of Cité de la Mode et du Design](image2)
2.4. Experimental designs

In order to come up with the various synergetic models there are experimental designs developed. Their main objective is to discover the new innovative types of dwelling supporting the needs of the community of inhabitants by the bioclimatic and productive performance of the unit. The most common in contemporary cities are the models utilizing the land, greenery, water and air movement potential to support the building.

The residential tower, completed in 2012, designed by the Périphériques architectes office is one of the structures that may be considered as an example of this kind of synergetic model (figure 5, 6). The designers' assumption was to create a self-sufficient and energy-efficient structure, at the same time providing residents with contact with nature, introducing the form of vast green area to the center of Paris. The form of vertical, compact quarter referring to the historical buildings of the city was chosen in order to create the public green space. In this area wind turbines are set up, that together with photovoltaic cells on the facade of the building create a system of collecting renewable energy. The shape of the building supports the use of solar collectors that provide a source of energy for central and water heating. The rainwater is collected at the site and reused within the system. Surrounded by greenery, the building allows you to maintain the proper microclimate of interiors, and also a form of preventing the effect of the urban island of heat [18].

The pilot example of the model combining natural and architectural elements in order to create self-sufficient housing environment, which also provides a cultivation area, is the EVA Lanxmeer residential complex (Figure 7, 8).

![Figure 5, 6 The residential tower designed by the Périphériques architectes](image)

It was founded on the outskirts of the Dutch city of Culemborg in cooperation with the EVA foundation, municipal authorities and with the participation of future residents [19]. It was referred to as an "artificial ecosystem" because it combines the elements of the pristine rural landscape to be protected and green areas for recreational and agricultural use, where the residential buildings were located. The architecture is varied, but semi-collective and terraced houses predominate. Each of them has access to natural areas that serve recreation, gardening activities and water management of buildings. The complex is surrounded by a water reservoir, which collects rainwater and gray water,
which is then purified in a natural way and reused. All residential buildings have been equipped with a double water and sewage system. Gray water is treated in water reservoirs, black water along with other waste is treated in a local biogas plant. The natural elements, along with the aesthetic function of the picturesque foreground for architecture, create a landscape that is an integral part of the environmental technology systems that are provided for in the buildings.

Figure 7, 8 EVA Lanxmeer residential complex

The project that look into the future such as RegenVillages by Tech-Integrated and Regenerative Residential Real Estate Development by ReGen Villages Holding, B.V. are even more oriented on self-sufficiency. In this case not only the building performance is supported, but also the needs of community are planned to be satisfied. The research on large-scale non-traditional agriculture forms enterprises such as urban farms (vertical, roof, underground) have shown that they create a high demand for energy and water and also experience higher risks of environmental contamination. In addition, they also generate more costs than traditional agriculture. [20] Considering those issues smaller scale experiments such as Regen Villages are undertaken. The project was announced during the Venice Biennale in 2016, and right now it is progressing as the pilot programme in Almere, the Netherlands. The first 194 homes within the area of Oosterwold District Master Plan are to be completed by the end of 2018. The model residential unit consist of power positive homes comprised of renewable energy, water management, and waste-to-resource systems. The main objective of the complex is to create a home for resilient family that can be multiplied around the world. The surplus of energy and food production can amortize and reduce mortgage payments for the inhabitants to be independent also in the economic status [21].

The above mentioned models are characterized by the large impact in the range of the complex. They improve the microclimate, support rainwater management system, and can provide means to acquire renewable energy. They also sustain the comfort of building interiors, as well as can affect the façade thermal performance. Nonetheless the experimental designs affect the ecological condition of the city but in the minor way by the introduction of biodiversity in the form of ecological corridors, reduction of the urban heat island effect, the creation of green infrastructure, and can also be part of
the natural disaster protection system. They also serve organic food production. The main benefit is the integration of the societal, sustainable and social needs in the model such as elimination of social and cultural exclusion in creating the residential environment by adjusting the community behaviour pointing out the need of common efforts towards increasing performance of the unit.

3. Energy water and food dependencies for sustainable and resilient design

The synergetic models are developed to meet the contemporary need for sustainable and resilient design. One of the main concerns in this field are the demographic changes in the societies and its impact on the urban environment. [22] Therefore the most important field is everyday resilience in normal performance, for its largest scale impact in the global scale. The research on society of the future should be undertaken prior to design cities and shape man’s housing environment while thinking about the architecture of the future. Only therefore, it is possible to forecast tendencies in the development of tomorrow’s housing architecture as well as the formation of new forms of residence–basing on current searches and experiments in this field [23].

City, as well as housing environment of the future should not only limit the effects of emergency situations. To follow the development of civilization it should create an attractive environment and shape the space for humans’ life by using terms such as urbanity and identity [24]. However achieving a certain level of energy, water and food independence may provide a tool for emergency resilience. In the certain regions of the world prompt to extreme conditions it is also important to prepare the city for disasters - fires, infrastructure and power outages, the effects of seismic movements, extreme temperatures and weather phenomena such as storms, hurricanes and flooding.

One of the first interdisciplinary interventions that not only relay on large scale engineering structure was the Thames Barrier Park opened in November 2000 in London. The green public space supports the engineering building located on the opposite side of the river protecting the city from flood. Previously, it used to be a port area, one of the most polluted areas of London, the location of PRChemicals chemical plants. The idea of the winning project was to regain this area and give it a recreational function. An important part of the original design was also to preserve the memory of the port heritage of these areas. This was achieved by situating the park below the terrain level, in the depressed area of the remnant of the dock. The geometrical composition of greenery, in the form of undulating bands, offered by Alain Provost and Patel Taylor, resembles water, referring to the identity of this place. The goal of this type of resilient landscape planning and design is to retrofit our communities to recover more quickly from extreme events, now and in the future. In an era when disasters can cause traditional, built systems to fail, adaptive, multi-layered systems working with nature can maintain their vital functions and are often the more cost-effective and practical solutions.

As events become more frequent and intense due to climate change, communities must adapt and redevelop to reduce risks and improve ecological and human health. The resilient communities movements try to seek the answer to work on the emergency resiliency in a smaller scale. Their main objective is to achieve the ability to anticipate risk, limit impact, and bounce back rapidly through survival, adaptability, evolution, and growth in the face of turbulent change. The main activities of those movements are creating social bonds within the community to work together in each stage of the building life - design, construction, performance and demolition in order to create a self-reliant urban environment. Community resiliency can be described as the ability of individuals and neighborhoods to support each other before, during, and after a disaster or crisis, strengthening community ties and relationships and developing holistic support systems placing value on equity, access, participation, common ownership and social health [25]. The Resilient Communities & Cities Partnership Program is supported by the United Nations Partner organizations and it is developed around the world.

4. Conclusions

The designers today stand at the verge of transformation. The traditional division between urban and landscape space are merging. The built environment becomes more of a complex system combining built and natural elements. The experiments are undertaken to change the basic residential unit in order
to provide everyday sustainability and resiliency in the bottom up projects. The new type of housing environment should be based upon identifying the user needs especially in context of demographic and migration challenges as well as facing the climate changes.

The research should be undertaken in multiple scales and environment in order to find best solutions for residential architecture of different density and spatial shape to come up with a model unit for the future city. Interdisciplinary cooperation is crucial in order to test the energy consumption and production, water and waste management together with food supply to support not only the built structure but also the community. The adaptability to changing population and climate conditions is the clue factor for achieving the assumed everyday and crisis resiliency.

In an age of rising waters and temperatures on top of diminishing budgets, the inspiration for the defences shall be seek in nature. Determining the potential of the residential unit, including the increase in the quality of the housing environment, predicted social behaviour of the inhabitants, adaptation to climate change and linked risk, and the impact on the city performance provides the means for assessment and improvement of the urban environment.

References
[1] D. H. Meadows, D. L. Meadows, J. Randers, W.W. Behrens III, "The Limits to growth", Universe Books, 1972.
[2] M. Bazilian, H. Rogner, M. Howells, S. Hermann, D. Arent, D. Gielen, ... K. K. Yumkella,"Considering the Energy, Water, and Food Nexus: Towards an Integrated Modelling Approach", Energy Policy, 39 (12), 7896-7906, DOI: 10.1016/j.enpol.2011.09.039, 2011.
[3] T. Foran, "Node and regime: Interdisciplinary analysis of water-energy-food nexus in the Mekong region", Water Alternatives 8(1): 655-674 2015
[4] A. Rothwell, B. Ridoutt, G. Page, W. Bellotti, "Feeding and housing urban population: Environmental impacts at the peri-urban interface under different land use scenarios", Land Use Policy", 48 (2015), p.377-388.
[5] A. Zachariasz, "Zieleń jako współczesny czynnik miastotwórczy ze szczególnym uwzględnieniem roli parków publicznych", Wydawnictwo Politechniki Krakowskiej, Kraków 2006 (in Polish).
[6] S. Lehmann, "The Principles of Green Urbanism; Transforming the City for Sustainability", Earthscan, 2010.
[7] K. Lynch, "Obraz miasta. The image of the city", Wydawnictwo Archivolta, Kraków 2011 (in Polish).
[8] J. Jacobs J., "Śmierć i życie wielkich miast Ameryki, Death and life of great American cities", Fundacja Centrum Architektury 2014 (in Polish).
[9] T. Tołwiński, "Urbanistyka t.3. Zieleń w urbanistyce. Urban planning v.3. Greenery in urbanism", Warszawa 1963 (in Polish).
[10] L. Krier, "Rational Architecture: Reconstruction of the European City", 1978, za: N. Ellin, Postmodern Urbanism, Princeton Architectural Press, Nowy Jork 1999
[11] A. Wallis, "Ameryka – miasto. America - the city", Krajowa Agencja Wydawnicza, Warszawa 1987.(in Polish)
[12] K. Wejchert, "Elementy kompozycji urbanistycznej. Elements in urban composition", Wydawnictwo Arkady, Warszawa 1984.(in Polish)
[13] Ch. Norberg-Schulz Ch., "Bycie, przestrzeń, architektura. Existence, Space and Architecture", Murator, Warszawa 2000 (in Polish).
[14] J. Gehl, "Life between Buildings. Using Public Space", Island Press, London, 2011.
[15] M. Skaza, "Is there a house of tommorow?", Środowisko Mieszkaniowe = Housing Environment – 2013, 12, s. 138-141, ISSN 1731-2442.
[16] A. M Szymski, "Percepcja krajobrazu kulturowego w teorii i praktyce. Perception of culture
landscape in practise", Technical Transactions, Czasopismo Techniczne seria Architektura 2007 z. 5-A, Wydawnictwo Politechniki Krakowskiej, s. 169-171.

[17] A. Palej, "Farmy miejskie – przedsięwzięcia wspomagające strategie zrównoważonego rozwoju miast. Urban farming - the enterprises supporting the sustainable development of the cities", Technical Transactions, Czasopismo Techniczne Architektura nr 6A-2010.

[18] P. Haupt, "Naturalne elementy kompozycji w kształtowaniu współczesnej przestrzeni miejskiej. Relacje budynku z otoczeniem. Natural elements of composition as factors shaping contemporary urban space. Relationship between the building and its surroundings": Wydaw. PK, 2015, ISSN 0860-097X ; 514

[19] E. Kusińska, "Woda w założeniach architektoniczno – urbanistycznych. Water in architectural and urban complexes", Wydawnictwo Politechniki Krakowskiej, Kraków 2009.

[20] P. Harrington, R. D. Lacewell, C. R. Taylor, "Non-Traditional Agriculture: Path to Future Food Production?", https://www.sciencedirect.com/science/article/pii/S0264837715001957, access: 22.03.2018.

[21] RegenVillages, https://www.effekt.dk/regenvillages/, access: 22.03.2018.

[22] K. Racoń-Leja, "Tomorrow's estate in the face of predicted demographic changes", Środowisko Mieszkaniowe = Housing Environment 2013, 12, s. 99-103, ISSN 1731-2442.

[23] A. Orchowska, "The city of the future" Środowisko Mieszkaniowe Hosuing Environment. 1731-2442. Nr 12 (2013), s. 30-33.

[24] W. Seruga, "New forms of residence in a sustainable housing environment", Środowisko Mieszkaniowe = Housing Environment – 2013, 12, s. 114-133, ISSN 1731-2442.

[25] Principles of the Resilient Communities Program, https://www.newamerica.org/resilient-communities/resilient-futures/principles-resilient-communities-program/, access: 22.03.2018.