ADVANCED FOOD PRODUCTION DESIGN FOR CIRCULAR NEIGHBORHOODS

IMPROVING CIRCULAR FLOWS OF FOOD WATER, ENERGY AND NUTRIENTS IN HIGHLY DENSE URBAN DISTRICTS

Abstract:

Urban Agriculture has seen a growing interest in recent years and planners, engineers, and architects joined agronomists in proposing farming projects within the cities' boundaries. The reason for the recent success of UA is not only to be found in its ability to increase global food production but also in its possibility to implement targeted circular flows of resources in urban areas, offering new opportunities for sustainable city development. Indeed, due to climate changes, population growth and the already high urbanization, resources like energy and water are becoming scarcer and scarcer, as their cost keeps rising up. In this sense, promoting UA up-cycling projects in urban areas might be fundamental to recover these finite resources while fostering a new typology of green architecture. Furthermore, today more than ever, shifting towards new circular and sustainable food systems is crucial as industrial agriculture is the most resource-consuming human activity on this planet, with 70% of freshwater usage, 50% of global habitable land usage, and 26% of global greenhouse emissions. In this regard, modern off-soil agro technologies represent a big opportunity to bring part of the agricultural production right within the cities' boundaries, reducing soil, water, and energy consumption, creating metabolic flows of resources between the urban built environment and the food production systems. In this scenario, food production should be considered a full-fledged new paradigm of green urban planning.

Starting from these considerations, the aim of this research is to answer the question of how it is possible to re-use residential buildings' resources for urban food production, specifically focusing on water, energy and nutrients recovery. As a result, this research will propose green building design strategies that facilitate the construction of a metabolic architecture through the integration of hydroponic systems as a tool for a fully-integrated urban food production.

The framework of reference:

With the majority of the world's population already living in cities and the urbanization trends confirming the increasing curve over the next 30 years, cities are at the core of the climate change response. The need to make cities more sustainable was discussed at the Paris Agreement in 2015 where parties recognized them as important stakeholders, capable of mobilizing strong and ambitious climate actions [1]. The important role of cities in achieving sustainable development is also reflected in the SDGs, in particular in SDG 11 *Make cities inclusive, safe, resilient and sustainable*, where most targets are directly linked to greenhouse gas (GHG) emission reductions, focusing on the implementation of sustainable transportation systems, green buildings and the reduction of the environmental impact of cities [2]. The urge for new planning policies to make cities more sustainable is justified by the recent reports of the Intergovernmental Panel for Climate Change (IPCC), which have estimated that urban areas account for 67-76 percent of global energy use and 71-76 percent of global energy-related carbon dioxide (CO2) emissions [3]. Furthermore, a 2017 report from UNFCCC [4], reported that 20% of the worldwide anthropogenic GHG emissions come from urban infrastructure such as buildings and transportation (of which buildings and construction account for about 70% and transportation for about 30%). In this scenario, the rapid expansion of the urban population equals mass expansions of urban infrastructure. In developing countries the growth rate will be exponential, while in cities in the Americas, Europe, and Oceania, which are not experiencing the same rapid rates of urbanization, it will be fundamental to reduce infrastructure gaps, replacing old aged infrastructure. A 2016 report by McKinsey Global Institute showed that historical underinvestment and the public spending cuts adopted to face the 2008 financial crisis resulted in an infrastructure shortfall of 350 billion dollars per year, most of which concentrated in industrialized European and American countries [5]. Additional investments are then required to meet SDGs goals, and directing infrastructure investment towards low-emission options offers significant mitigation potential and should be ensured [4].

Furthermore, in addition to climate change and urbanization trends, our current industrialized food system will also have to face the important challenge of how to satisfy the rising demand for food, while its productive land is constantly decreasing. The environmental impacts of modern industrialized agriculture are proven to be unsustainable, nonetheless, the need of satisfying a rising food demand could result in making the same mistake of keep relying on intensive food production, implementing the use of chemicals and GMOs to further increase yields of agricultural products [6]. Moreover, food crops are not only competing for land but also water, nutrients, and other resources. In this context, horizontal and vertical surfaces in the city, such as rooftops, facades, squares, and interior spaces, can host a large-scale urban food production, taking off pressure from agricultural land [7]. Cities have resources like land, labor, energy, water, and a ready-made market for food production [8], therefore, it makes sense to produce in urban areas where citizens are not only the final users but also the producers.

The need for new urban green infrastructures, as well as new sustainable solutions for food productions, brought part of the international scientific community to believe that Urban Agriculture may be one of the solutions to climate change adaptation, playing a crucial role in making cities healthier and greener [7]. In this sense, UA should not be considered just as a food-related practice, but instead, as a tool for planners and practitioners to boost cities sustainable development [9]. New urban planning strategies should then be carried on with our food needs in mind. Moreover, reducing CO_2 emissions, and implementing new green infrastructure call for a new innovative form of architecture and urban design. Nowadays, it is possible to integrate food production within and on buildings, recycling and reusing resources passing through them while shortening the food chain. New technologies, allowing plants to grow on media instead of soil, permit to harvest of crops in high densely built-up areas where the availability of space often limits the size of the production unit [10]. In this context, architects should consider new off-soil production systems as new construction technologies, understand UA applications, and implement green architecture projects with the integration of the proper food systems.

The research project:

This research project will specifically target resource recovery in building-integrated Architecture, setting the research in the Global North with specific focus on industrialized European countries. The research will mainly contribute to the foreseen tasks and activities of the following EU projects:

- H2020 Food Systems in European Cities (FoodE, www.foode.eu), GA 862663
- H2020 FOOD and Local, Agricultural and Nutritional Diversity (FOODLand, https://foodland-africa.eu/), GA 862802
- Erasmus+ Innovative Indoor Farming Applications for Future Urban Farmers (InnoFarming, https://site.unibo.it/innofarming/en), 2019-1-FR01-KA202-062337

Therefore, this research will be divided into three steps, each of a duration of four months:

1) The first step concerns the design of modular and scalable districts for urban food production. The design of the prototypical districts will take into consideration the possible demand of food of a certain area, the specific dietary requirements and the production capacity of the integrated food system in order to size the off-soil production spaces. Based on different needs and cultures this research aims to develop a methodological design that can be applied to different climates and contexts and that could be easily scalable. The expected outcomes of this first step are:
   - Define the best population densities to allow an optimal resource recovery from the building in order to minimize external inputs for food production.
   - Assess the amount of energy, water and nutrients that can flow from the building to the production systems and vice-versa.
   - Design of the modular structures of the buildings that compose the district in order to assess their range of scalability.

2) The second step concerns the in-depth analysis of the flows that can be exchanged by the buildings and the production systems. This step will focus on two main topics: i) energy (as in heating, cooling and CO_2 exchange), and ii) wastewater (as in reclaimed water for irrigation and nutrients recovery). The expected outcomes of the second steps are:
   - Define the amount of energy saved by using active sources for energy production and applying passive solutions that foster the recirculation of heating and cooling between the greenhouse and the building.
   - Determine the amount of water and nutrients recovered from wastewater, specifically analyzing the potential loss in productivity of the chosen food systems.
   - Determine the possible presence of harmful bacteria in reclaimed water and refer to the best available technologies to exclude potential health-related risks.

3) The third step concerns a thorough assessment of the construction costs including the architectural and the required installations for resource recovery and transformation. The expected outcomes of the third steps are:
   - Determine the architectural costs of the construction systems and the designed modular structure.
   - Assess the costs of all the installations required to extract nutrients from the reclaimed water and to disinfect the remaining wastewater.
   - Assess energy costs of the whole production system including energy operation costs of the installed machines for wastewater treatment.
   - Estimate the potential savings on nutrients, water, and energy costs by recirculating resources from the building to the production systems in order to assess the economic feasibility of the research.

Methodology and tasks:

The research will mostly be carried out in Bologna at the Department of Agricultural Sciences, with possible interactions with experts on architectural construction and modular design, specifically

referred to the Academic Discipline ICAR12. The research will also include the participation to international conferences and periods of practical research both at the University of Bologna and foreign institutions whenever required or specified.
Practical outcomes of the research will be at least 2 scientific articles to be published in international peer-reviewed journals, as well as participation in public calls for the development and design of buildings and districts with regards to urban regeneration connected to urban farming practices.
The candidate is expected therefore to take part in the elaboration of proposals in European tenders of the new European Green Deal and the new Horizon program related to the research, with the creation and coordination of wider consortiums with international experts, institutions and associations.
The candidate will also have to commit to the organization and management of the UrbanFarm International Student Challenge intended as an activity related and complementary to the proposed research.

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