Chapter

Experimental Living and Housing Forms: Cities of the Future as Sustainable and Integrated Places of Food Production

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Abstract

Population growth and urbanization are progressively leading to an increase in the global food demand within cities resulting in a rise in global greenhouse gas (GHG) emissions, land consumption, resource depletion, and social tensions. The key challenge for future decades is to feed a growing population in an ethical and socially, economically, environmentally sustainable way. Traditional city and housing models are no longer capable of providing a compelling solution. The urgency of providing dynamic responses in terms of integrated urban solutions must coexist with a medium- to long-term perspective in which production is gradually embedded within the urban structure. Since the relationship between places of production and consumption is a critical node in food policy, it is essential to strengthen this link within a more globalized and interconnected economy. This essay investigates two different strategies: on the one hand, agri-cities and communities as an experimental social-business model that places the production once again at the center of housing design, and on the other floating potential for food production in delta and coastal cities, as a zero-land footprint strategy. In both approaches, cities and the way they work must be reimagined with a view to making them locally productive and globally connected.

Keywords: productive city, agri-city, land scarcity, urban farming, floating potential

1. Introduction

Changing global housing conditions due to recent climate hazards, migration, war, pandemic events, and globalization are further exacerbated by the rapidly unfolding economic global crises [1]. Today, we are witnessing two seemingly opposing phenomena: on the one hand, an inevitable increase in the world's population and on the other, a constant inexorable aging and decrease in the Western population [2]. Global population growth implies an increase in the demand for food production, especially that related to animal-derived protein consumption, which will have a significant impact on the whole production chain. According to the World Resources Institute, the global consumption of meat and dairy products is expected to rise by about 70%

between 2010 and 2050, with beef consumption increasing by more than 80% [3]. The United Nations (UN) Food and Agriculture Organization (FAO) projects that annual global meat production will rise from 228 to 463 million tons by 2050 to meet the rising demand, with bovine production expected to increase from 1.5 to 2.6 million tons, and sheep and goat products from 1.7 to 2.7 million tons [4]. The global food system, besides being one of the greatest threats to the planet's biodiversity, accounting for 80% of global species and habitat loss, is also one of the most polluting sectors [5]. Agriculture accounts for 24% of worldwide greenhouse gas (GHG) emissions [6]. Intensive livestock production is a major source of GHG emissions in this sector, accounting for 14.5% of total emissions [7]. Furthermore, according to the UN report "The World Population Prospects 2019: Highlights," the global population will reach 9.7 billion people by 2050, rising to nearly 11 billion by the end of the century [8]. Without a radical change, these emissions are expected to rise as the world's population and food demand increase. Traditional city and housing models are no longer capable of providing a compelling response to these emerging and unavoidable social and environmental challenges [9]. The threats posed by climate and socioeconomic changes, as well as the resulting alterations in environmental balances, require immediate mitigation and adaptation measures. In urban areas, these strategies affect not only land use, but also lifestyles and production. Half of the world's population and three-quarters of Europe's population live in urban areas. Cities are key contributors to rising environmental pressures, with significant withdrawals of natural resources and pollution emissions. Moreover, increasing environmental pressure has serious implications for public health and safety. As a result, cities play a crucial role in achieving the sustainable development goals (SDGs) [10]. Goal 11 of the UN 2030 Agenda [11] lays the groundwork for integrated sustainable urban solutions. The SDG 11 declaration statement emphasizes the most compelling need for an integrated and systematic management of all potential dimensions of contemporary life on earth [12]. According to the UN, the world is falling behind in reaching the SDGs, and the efforts made thus far are completely inadequate. A radical shift in lifestyles is needed to achieve these goals in the shortest amount of time. The urgency of providing dynamic responses [13] that are adaptable to unpredictable challenges [14] has largely contributed to the development of renewed housing cultures that are more inclusive and shared [15]. The dynamic responses and new housing cultures must coexist with a medium- to long-term view, in which the development of creative innovative community forms serves as a means of empowering end-users. This radical is supported by citizens' increasing awareness of the use and importance of autonomous and decentralized food and energy production models.

1.1 The challenge of combining housing and food production

Food and related activities—production, processing, distribution, consumption, and postconsumption—are key contributors to urban-scale unsustainability in environmental, social, and economic terms [16]. The current food production system has optimized food supply chain management, lowering product costs but with major negative consequences [17]. These impacts not only affect the natural environment (loss of agricultural and natural biodiversity; increased competition for land, land grabbing, and new forms of food colonialism), but especially cities, which are becoming increasingly distant—not only physically—from places of production. The main related issues include environmental pollution (waste, land consumption; reliance on fossil fuels and GHG emissions, traffic, and water consumption for production), social tensions, food crises, and the soaring increase in diseases related to obesity and unhealthy eating habits, particularly among low-income groups [18].

Cities are currently considered as the major engines of economic progress. As a result, rural places are assigned a marginal role. This polarity leads to the widening of the gap between cities and their territorial contexts (including supply), disrupting the material and immaterial flows that connect them to rural areas [19]. Already in the nineteenth century, Marx had theorized a fracture in the metabolic interaction between humanity and the rest of nature as a result of capitalist agricultural production and the rising divide between town and country [20]. This fracture is known as the metabolic rift. More precisely, this rift results in the loss of biodiversity, depletion of natural resources, and environmental degradation in urban environments [21], drawing attention to the need to rethink sustainable local agri-food systems and thus redefine relations and a balance between the city and the countryside.

Since the relationship between places of production and consumption, between city and rural, metropolitan and peri-urban areas, is a critical node in food policy [22], it is essential to strengthen this link within a more globalized and interconnected economy. The significance of physical and organizational proximity in different social, cultural, and economic relationships must be rediscovered. The emphasis on production, the traditional urban–rural dualism, and an increasingly global and de-territorialized agri-industrial system has resulted in the disappearance of food from reflections on urban development, after having shaped and molded the form and substance of cities for centuries [23]. Indeed, in cities, there is (little) awareness of the act of consuming, whereas the other phases of the supply chain tend to be overlooked [24].

To reverse this trend, as early as 1997 the European Commission began advocating for a "more versatile, sustainable, competitive, and widespread European model of agriculture." The Farm to Fork EU Strategy is at the heart of the European Green Deal and aims to accelerate our transition to a sustainable food system. It addresses comprehensively the challenges of sustainable food systems and recognizes the inextricable links between healthy people, healthy societies, and a healthy planet. This model has found application not only in a wide variety of farm facilities, land cultivation systems, and range of products, but also in the spread of new multifunctional rural and urban settlements. The new patterns of productive settlement have led us to rethink the role of agriculture in urban areas and to refine the design and implementation of experimental housing-productive settlements, characterized by a long-term gradual transformation of living and housing models.

Food Trails is a European Union (EU)-funded Horizon 2020 project, bringing together a consortium of 19 European partners, including 11 cities, 3 universities, and 5 organizations. The project is rooted in the Milan Urban Food Policy Pact (MUFPP), an international mayors' agreement, and aims to enable cities to reimagine, develop, and implement sustainable, healthy, and inclusive food policies. Each partner city runs a pilot project, a "Living Lab," which seeks to codesign and co-implement food actions integrated with other local sectoral works and aligned with the Farm to Fork EU Strategy and the priorities of the EU-FOOD 2030 Policy: nutrition, climate, circularity, and innovation. Grenoble-Alpes Metropole, for instance, has a unique food system linked to its geography. Around 15% of its mountainous territory is covered by farmable land, and the local government sought to capitalize on it to improve diets, sustainability and create short food chains. The Metropolitan Agricultural Strategy 2015–2020 implemented by the Metropole aims to re-territorialize its food system, promoting sustainable and high-quality farming in rural municipalities while connecting them to other metropole cities via short supply chains, supporting farmers in adapting agriculture and food production to climate change, and reducing the environmental impact of local horticulture in order to reduce GHG emissions by 2050. Moreover, it seeks to develop a participatory scheme from a Food and Agriculture Policy and Strategy (FAPS) toward a Common Food Policy.

Considering the current transformations cities are experiencing, the key challenge for future decades is to feed a growing population in an ethical and socially, economically, environmentally sustainable way [25]. Therefore, the search for an alternative food paradigm through food policies based on relocation, critical consumption (fresh, local, organic), and nutrition education is necessary. Relocation does not mean achieving complete food self-sufficiency, but rather producing locally a greater portion of the basic food demand. This purpose underlies policies such as urban and peri-urban farm protection and promotion, alternative food networks, optimization of distribution and logistics stages in a short supply chain perspective, and public procurement.

The EU Joint Research Centre report "Farmers of the Future" [26] reflects on the future of agriculture in the coming decades and what characteristics farmers will have in 2040. It highlights "the emergence of more diverse and experimental agriculture models to address environmental challenges and respond to different consumption patterns."

This change toward a wider range of housing types integrated with extensive agricultural facilities, in addition to having strong implications for governance, requires adaptation of farming and livestock systems to local specificity. Three factors must be considered in terms of producing food for consumption: assessment of socio-ecological changes, interpreted as typological-spatial variation in housing and settlements; recognition of multifunctionality and supply of public goods as intrinsic tasks associated to housing; and creation of a suitable governance framework capable of systematizing all aspects of production (energy, labor, agriculture, and livestock) integrated into experimental housing models.

2. Food-producing communities as dynamic urban laboratories for sustainable living

Modern agroecology proposes a new multidisciplinary, intersectoral, and multiscalar approach to redefining the relationship between production, cities, and land, both by providing a more current vision of agriculture, which influences the development of new management, monitoring, and planning tools, and by offering a different perspective to restructure the relationship between agriculture and society [27]. In contrast to the assumptions of a standard agricultural management and the concept of a one-size-fits-all agricultural model, experimental agri-urban models developed in recent decades emphasize the importance of the management of all resources involved in agricultural production processes and emphasize the need to promote diffuse management and production systems. Such models ascribe to food production not only the ability to sustainably cope with the growing food demand from a short supply chain perspective—thus reducing critical factors associated with long-distance transportation such as GHG emissions and food waste—but also the ability to improve living conditions by increasing the degree of multifunctionality, supply of public goods, ecosystem quality, and even microclimate conditions. Indeed, bringing nature into cities through urban farming not only provides high-quality

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zero-mile products and a variety of social functions, but it also has the potential to mitigate many of the polluting phenomena that affect highly urbanized territories. Food-producing cities are livable cities: they create new connections on a social, ecological, and economic level.

Against this backdrop, cities must seize the opportunity to renew themselves through the adoption of a new business model that places the production once again at the center of housing design. Not just production of fresh food, materials, and energy, but a production of intangible value in the transition to a more sustainable future. As a result, cities and the way they work must be reimagined with a view to making them locally productive and globally connected.

In recent decades, the use of the term agritecture has grown in popularity as a means of transforming and reinventing the food supply of future cities. In the productive city concept, places of agriculture or food production can shape new peri-urban contexts or find space along the edges of sub-urbanization or within established urban fabrics, in existing buildings, in public spaces, in residual spaces, even on terraces and courtyards, in a comprehensive redesign of the metropolitan landscape. Several experts highlight how awareness on the interaction between urban agriculture and contemporary urban space has increased in recent years [28, 29]. Areas intended for farming are being reclaimed and regenerated in abandoned or in-transition urban and peri-urban contexts. Agritecture takes several forms, especially as innovative agricultural models, integrated into buildings. Applications are mainly classified as follows: hanging gardens and/or intensive green roof systems designed to grow fruits and vegetables using soil-based production methods; rooftop greenhouses, "vertical farms," "plant factories," or "indoor farms" that use multistory vertical systems for food production that rely on controlled environment agriculture (CEA) methods that aim to optimize crop growth and space occupied through above-ground growing techniques such as hydroponics, aquaponics, and aeroponics.

Thus, food production takes place in close proximity to consumers, with the possibility of using urban waste as an input for food production in a circular system. The recovery of rainwater, wastewater, waste heat, and organic waste, for example, provides a valuable opportunity to supply water, energy, and nutrients to food production systems while reducing the load on the respective urban drainage and treatment systems.

On the other hand, the progressive recognition of the importance of food in urban development patterns, as well as increased awareness of the impact and externalities of the agri-food system, particularly at the socioeconomic level, have led local governments in recent years to regain responsibility for food and actively engage in the development of urban food policies. Food policies, in fact, place (or relocate) food at the center of urban policy agendas, capitalizing on existing experiences and initiatives and fostering relationships and synergies between various groups of stakeholders (public, private, third sector and associations, citizens) and the different policy domains that food intersects (environment, production activities, logistics and transportation, education and training, economic development and employment, culture and tourism, health and social welfare) in a holistic and integrated vision [24].

Within this perspective, the citizen is assigned an active role, becoming a prosumer (from the crasis of producer and consumer) rather than a passive. By producing food, prosumers attempt to bridge the gap between production and consumption in cities as well as in rural communities.

Bringing agri-food production into housing (or vice versa) can thus include designing and implementing new suburban or peri-urban districts conceived of as laboratories for sustainable agricultural production, housing and social interaction, innovation, education, employment, among other things.

"ReGen Villages," a Stanford University spin-off firm envisioning the future of living in regenerative and resilient communities, has developed an innovative program-planning technique. This is a new visionary model for the establishment of integrated and resilient off-grid ecovillages that blend technology, innovation, circular economy, and self-sufficiency, including especially food. Positive energy housing, renewable energy production and storage, high-yield organic food production, aquaponic/aeroponic farming systems for vertical agriculture, water management, and waste-to-resource systems are among the innovative concepts embraced by the concept. In the new village concept, from the standpoint of a circular economy, the outputs of one system are actually the inputs of another. It also integrates artificial intelligence (AI) and machine learning (ML) to identify, create, and manage regenerative neighborhoods that promote long-term health outcomes for residents and communities. Moreover, these villages are planned for global replication and scale in collaboration with established industrial partners, universities, governments, and sovereign wealth and pension funds, enabling an optimistic green transition. Several architecture/engineering firms and companies in Europe have embraced this philosophy and collaborated with the US-based start-up to develop, propose, and experiment with new city and living models. According to White Arkitekter, Sweden could become the first country with circular and self-sufficient communities. Over the past few years, ReGen villages has met with several Swedish municipality administrations, landowners, real estate developers, and stakeholders with the aim of initiating, with the support of the Swedish architectural team, a pilot project in the country.

Naturbyen (Nature Village) is a similar experimentation (**Figure 1**) that was launched in Denmark in 2020 because of a shared desire among the municipality of Middelfart and a number of local communities to design an alternative future through a participatory process coordinated by the Danish design firm EFFEKT.

This collaboration led to the design of a housing area, conceived of as an international demonstration archetypal project of how sustainable housing development may be integrated with ambitious reforestation, improved biodiversity, and a circular approach to resources in suburban and peri-urban regions. Furthermore, housing contributes to agricultural output by creating healthy, socially integrated areas.

A total of 220 new residences located inside a newly planted forest outside big cities represent an alternative to the traditional terraced and parceled housing options that are still the most common housing typology in Denmark. The new municipality-led residential expansion project aims to become a laboratory for residential and agricultural development in suburban and peri-urban areas, with the goal of becoming an iterable intervention in similar realities and assisting Denmark in meeting its ambitious goal of covering 20% of its land area with forests by 2100.

A different approach is being pursued by the city of Shanghai. With a population of about 24 million people and a severe lack of agricultural land for food production, the Chinese megacity has envisioned a unique urban agricultural zone of roughly 100 ha.

The Sunqiao Urban Agricultural District, designed by Sasaki in collaboration with various stakeholders from both the public and private sectors, aims to meet the region's growing agricultural demand while also serving as a living, dynamic urban laboratory for research and innovation, social interaction, and education. In the new district, agriculture is introduced on a large scale through diffuse and punctual vertical farming interventions that take advantage of hydroponic and aquaponic cropping systems that have higher spatial-productive efficiency and a significant reduction in

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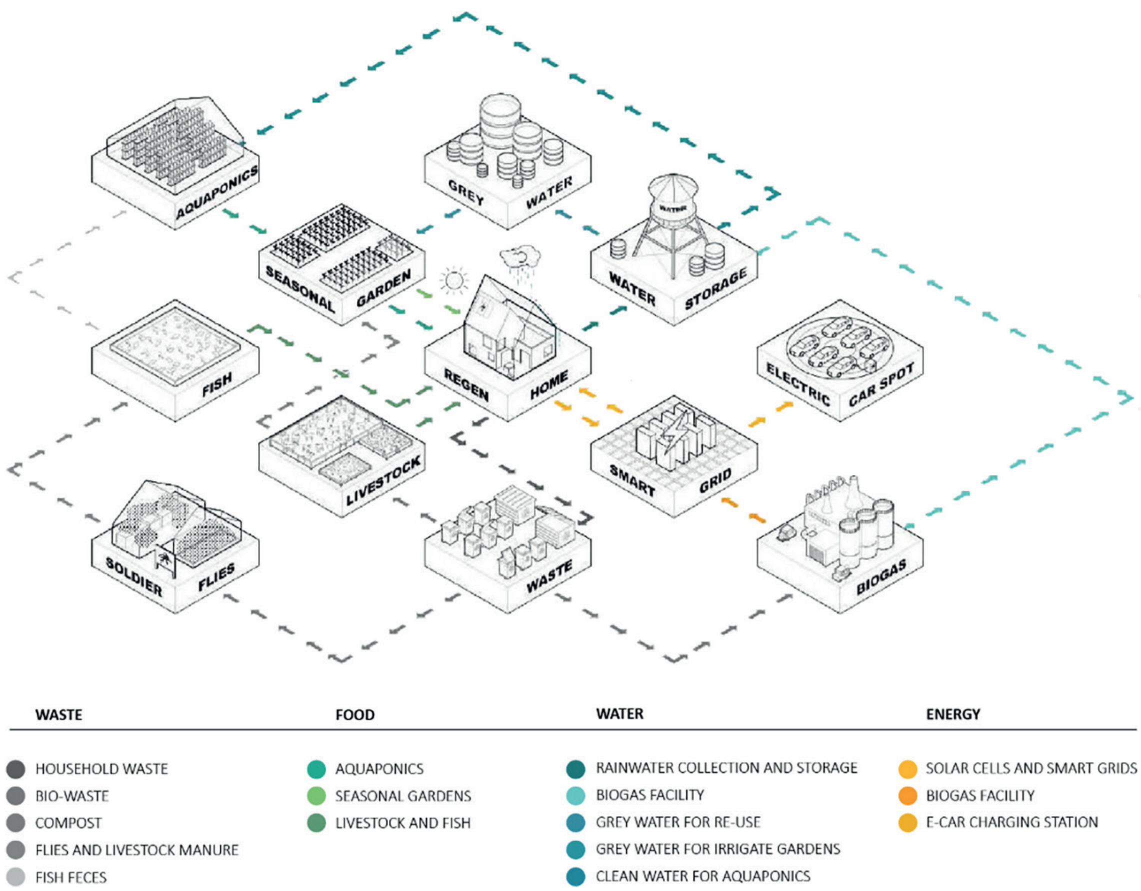

Figure 1.
Layout of an agri-city on the model of Naturbyen by Studio EFFEKT.

water and soil consumption. However, Sunqiao is more than just a food-production district. In fact, the intervention has a high social value and prioritizes agriculture as a key driver for urban growth. An interactive greenhouse, a science museum, and a market represent an attempt to educate future generations about conscious food consumption. Public spaces and facilities, offices, and houses represent the desire to create a mixed-use, dynamic, and active environment, far from the traditional concept of an agricultural district.

3. Floating potential for urban embedded food production. A zero-land footprint strategy

In recent decades, we have witnessed two related trends: land occupation on the one hand, and soil sealing on the other, both of which are the result of city growth and expansion of urban areas characterized by high building density ratios. Due to scarcity of available empty land within cities, agri-food production systems often play a marginal role in temporal (transient), spatial (interstitial), social (e.g., women and low-income groups), and economic (e.g., financial crisis, food shortage) terms. Indeed, urban farming and food production in cities are currently limited to the transformation of brownfields, residuals, and urban voids into micro-farming, private rooftop cultivation, urban community and institutional gardens, small-scale urban farming, urban aquaculture and aquaponics, urban forestry, and hydroponic and aeroponic vertical farming systems. In response to scarcity of land and/or water resources, the spread of vertical farming in cities has grown significantly, allowing for the combination of housing and farming within a single building inside the city.

Recently, a zero-land-footprint strategy that takes advantage of the continental and tidal hydrographic network for food production has gained popularity. This strategy entails the use of floating structures along rivers, lakes, or coastlines to house greenhouses and farms within urban centers.

Water proximity has always been a crucial component in the establishment and development of human settlements [30]. Many cities were built up along coastlines or at the mouths of large rivers because they served as collection points for raw materials coming from the inner areas, they were supplied by an efficient water transportation network and were guaranteed with access to clean water. Cities lacking permeable and underused soil but located near rivers, lakes, or coasts could easily host water-based food production facilities. The hydrographic network or the sea itself provides a huge potential for the floating development of food producing facilities in cities characterized by high building density. More precisely, floating farming facilities can provide several environmental and sustainability advantages [31], including: reducing the burden on freshwater by using seawater desalination techniques or collecting and storing rainwater; introducing new cultivable or breeding surfaces where permeable land and freshwater are scarce, particularly in high density urban areas; providing complete and self-sufficient farming systems in terms of automated planting, harvesting, processing, and export, drastically reducing transport costs; and providing the possibility of relocation in more appropriate sites when a given location is no longer suitable for any reason (environmental or pollution risks, political conflicts, and urban population shifts). Furthermore, floating greenhouses or breeding farms could be designed as multilevel vertical systems to increase overall farming surface and yield, ensuring the economic viability of the floating farm concept.

Floating agriculture is actually a vernacular soilless practice widely spread over Southeast Asia (Lake Inle Kay La floating village with farming and fishing arrangements), Middle East (Al-Tahla floating Islands in the southern wetlands of Iraq), and South America (Totora reed floating islands in Lake Titikaka, Peru). Different low-tech systems have been used for thousands of years and have allowed farmers to grow crops in flood-prone areas, wetlands, or lakes, where no other land use was conceivable. These systems usually consist of plants on rafts made of composted water weeds piled up on water bodies, by simply stripping nutrients released from decomposing organic material [32]. These systems are now seen as a strategy to cope with the combined effects of urbanization, land consumption, cementification, and climate change in areas that are more vulnerable to sea-level rise and coastal erosion, where flooding prevents land from being used for agriculture for extended periods of time [33] or where there is no available land for agri-production.

Floating Farm 2.0, designed and built by Goldsmith Studio, is the world's first floating dairy farm, located in the port of Rotterdam. The Floating Farm Dairy is a compact and efficiently stacked urban farm with a strong public and educational character. The building combines technical installations, storage, production, and processing of dairy on board. The farm produces fresh dairy products from its 40 cows. All raw dairy products are processed on-site and delivered across the city as fresh milk and yogurt. Floating Farm 2.0 is designed according to a circularity concept to employ leftover goods produced by the city, such as grass from public parks and food waste, to feed animals and return fresh milk to the city. This circular approach not only finds a new effective use for leftover products, but it also reduces food transportation costs and pollution by keeping food production and consumption tightly linked. Throughout a highly sustainable closed loop, cow manure is reused to produce fertilizer for public spaces within the city. The concept is envisioned for a future in which rising sea levels make farmland increasingly unusable due to flooding. The goal is to consider a new approach to bring agriculture back to the city while minimizing resource depletion and environmental impact and building resilience to climate change in a time-based design conception.

Another example of integrated agri-food production in the city is the Jellyfish Barge (**Figure 2**), a floating greenhouse module that aims to minimize energy, water, and soil footprint. Jellyfish Barge uses hydroponic cultivation with 70% water savings compared to traditional agriculture. The barge is made of recyclable materials and uses solar distillation to collect and purify 150 l of salt water per day. Fifteen percent of the seawater is returned to the water to improve the mineral content and nutritional value of the crops. One module is around 70 m^2 and can grow between 1400 and 1600 plants per month. One hectare could host more than 120 apartments.

Of course, these strategies do not expect to address the problem of city feeding by minimizing transportation and producing all consumed foods locally. Given the population figures, this scenario is inconceivable if only the continental hydrographic network is used as a new farming surface. But, as future visions suggest, one could even consider close offshore waters as farmland.

The Forward Thinking Architecture firm is branching out and transforming the way we think about agriculture and water. Its smart floating farm (SFF) concept is at the heart of this new way of thinking, and it is a real and already buildable construction. The floating farm is an offshore three-story floating facility that will host large hydroponic crops and fish farms beneath them. It is designed to be built off the coast of a city to produce both fish and vegetables using a simple system of linkages between different operational layers. The structure's composition is inspired by traditional Asian fish floating farms, but it also features two additional layers, one for growing any type of plant and another to supply the needed energy through solar energy conversion. Aside from the actual growth of plants (automated hydroponics) and hatching of fish, water-access points and a desalination plant (to convert ocean water to freshwater and then use it for farming) are provided, as well as an abattoir for the fish and a packaging facility. Solar panels, wind turbines, and wave energy converters have the potential to convert natural forces into useful electricity. It has the ability to produce 8.1 tons of fruits and vegetables and 1.7 tons of fish per year. The factory would be almost completely automated using sensor systems to capture data and fine-tune the

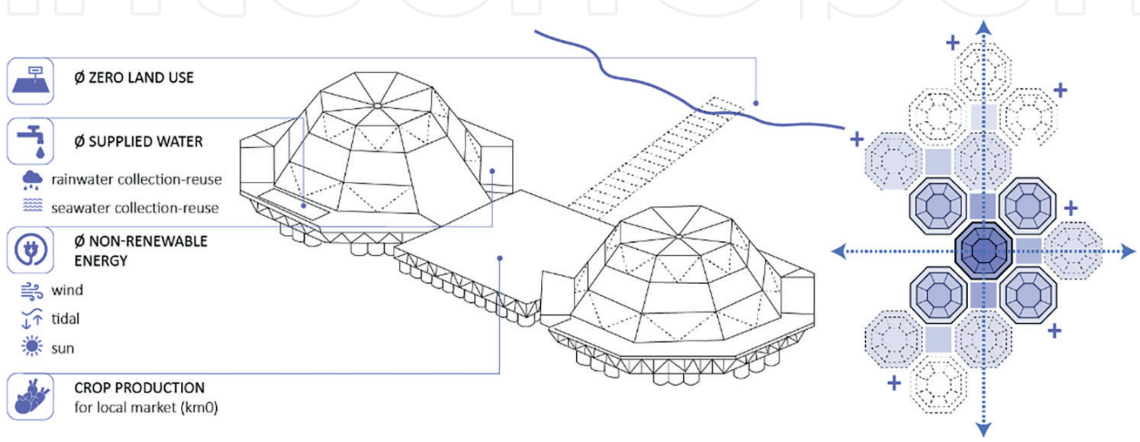

Figure 2.
Diagram of floating food production system on the example of Jellyfish Barge.

farms to work as effectively as possible. At the moment, it's an extremely ambitious concept. Yet, it raises a significant point: we could feed ourselves with low ongoing costs if we simply used endless and predictable resources such as the sun and the ocean.

Due to the high expense of desalination systems to produce irrigation water, and to the low salt tolerance of crops, alternative technologies have gradually emerged. Japanese start-up N-ARK has combined salt-tolerant technology with floating architecture to tackle the issues of sea-level rise and salt damage. In partnership with CULTIVERA agri-tech company, they aim to build a prototype of a floating marine farm "green ocean," conceived to float on the coast along urban areas. The facility makes use of a seawater agriculture technique based on moisculture, a humidity-controlled cultivation technology that reproduces the natural soil surface layer of about 15 cm using special fibers of 5 mm in diameter. Saline agriculture fertilizer is produced, thanks to a special circular process that absorbs water and nutrients in the air and mixes and neutralizes alkaline seawater and acidic rainwater. Moisculture requires only one tenth of the amount of water used in conventional irrigation farming.

The current challenge toward more resource-efficient cities is to shift cities metabolism from linear to circular, so that discarded material can become a resource for another process. Nutrients and carbon dioxide are two of the most common waste products generated by cities, and both are rarely reused or recycled before being discharged into the environment. A possible way to recycle nutrients and carbon dioxide is to use them as input for algae cultivation. Because of their ability to fix carbon via photosynthesis at up to 50 times the rate of terrestrial animals, algae are among the greatest organisms for CO_2 sequestration.

Cities are suitable locations for local recycling of waste due to their high concentration of nutrients and carbon dioxide. Unfortunately, dense urban areas often lack the space to implement large-scale algae cultivation. One alternative is to cultivate algae on the water, resulting in floating systems for biofuel and food production [34].

Another widespread practice is the integration of aquaculture within wider farming systems, contributing to the development of synergies between farming operators. Such systems are known as integrated agri-aquaculture systems (IAAS) and can help to improve water-nutrient balance through chemical or natural fertilization [35]. Agri-aquaculture systems generally comprise three major subsystems: aquaculture, agriculture, and household. Common positive interactions of agri-aquaculture systems include the use of animal manure as pond fertilizer, the use of crop by-products as supplementary feed for fish, the use of pond sediments as terrestrial crop fertilizers, and the use of aquaculture wastewater for crop irrigation.

Overall, producing, processing, and packaging food inside the city can significantly shorten the supply chain, add a certain social value and level of food security, contribute to new forms of urban circularity, and promote an efficient use of scarce space due to the lack of it. As a result, combining production facilities with the urban environment is expected to boost economic feasibility while also providing climate-proof expansion for a growing urban population.

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