AQUAPONICS: A POSITIVE IMPACT CIRCULAR ECONOMY APPROACH TO FEEDING CITIES

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Cradle to Cradle-certified architect and lecturer at the Free University of Brussels, Steven Beckers founded Lateral Thinking Factory, a consultancy that supports positive impact circular economy implementations in the real estate sector. He founded BIGH (Building Integrated GreenHouses), based on Berlin's ECF Farmsystems model, in 2015 after running several studies into the urban agriculture potential of Brussels and its surrounding region. The goal was to develop a commercial model for an urban farm based on building-integrated aquaponics, inspired by building-integrated photovoltaics. The first farm in the BIGH network, Abattoir Farm, opened in the Anderlecht district of Brussels in January 2018.

The Abattoir Farm, BIGH's first full-scale production site, was set up in 2015 on the roof of Foodmet, a food market in the Abattoir neighborhood in the Anderlecht district of Brussels. Designed to positive impact circular economy principles, the project leverages numerous synergies between the farm, the building housing it, the district and the wider city. The aquaponic production system, linking fish-farming tanks to greenhouses for growing plants, recreates a natural ecosystem in an artificial environment. It produces minimal waste, requires limited energy inputs and delivers positive impacts to the environment. It also provides city consumers with year-round access to quality, locally sourced products (tomatoes, fish, herbs and berries). With Abattoir Farm, BIGH is advocating for a productive urban agriculture with an economic model reliant primarily on the sale of produce. The aim is to duplicate the model elsewhere in Belgium and Europe.

INTRODUCTION

With high numbers of vacant spaces, on rooftops in particular, cities are reservoirs of under-exploited productive capacity. In 2015 Lateral Thinking Factory mapped 600 hectares of Brussels rooftops and estimated that 60 hectares could be used to site food-growing urban greenhouses. Integrated into buildings, the greenhouses would make it possible to produce food in the middle of the city, creating jobs, upgrading the urban environment and boosting biodiversity. They also offer ways to recover unused resources, such as using surplus energy, capturing carbon dioxide, harvesting rainwater, etc., while also cutting buildings' ecological footprints. In the same vein, the aquaponic urban farm – fish-rearing and plant-growing in a closed ecosystem — that BIGH has developed on the roof of the Brussels Foodmet market aims to provide high-quality products for distribution via short circuits, encouraging residents to consume local produce. It offers the people of Brussels fish, tomatoes and herbs grown and raised in the city center, in an approach guided by the positive impact circular economy approach.

APPLYING THE POSITIVE IMPACT CIRCULAR ECONOMY TO URBAN AGRICULTURE

FROM CUTTING NEGATIVE IMPACTS TO CREATING POSITIVE IMPACTS: WHAT CRADLE TO CRADLE BRINGS TO SUSTAINABILITY

Sustainable development, as defined by the 1992 Rio Earth Summit, is essentially predicated on setting goals for reducing the negative impact of human activities using indicators such as the volume of CO2 emissions, water consumed or kilowatt-hours per square meter. The risk with this highly quantified approach lies in overly focusing on targets that can fast become outdated. For example, a major architectural project will often follow a 10-year cycle whereas certifications change on average every five years.

To avoid this pitfall, designs that use *Cradle to Cradle* (C2C) start from a qualitative analysis to later set quantified goals. The process begins by setting out a vision, such as creating a clear-air district, which is subsequently translated into ideas for action. Goals, strategy, tactics and quantified indicators are determined at a later date (see Diagram 1). Developed in the early 1990s by German chemist Michael Braungart and American architect William McDonough, C2C seeks to manage fabrication processes that allow infinite recycling of materials. Materials are not intended for plain recycling (*downcycling*) but are also enhanced for use in the future (*upcycling*). The idea is not just to reduce negative impacts but more important still, to produce positive ones.

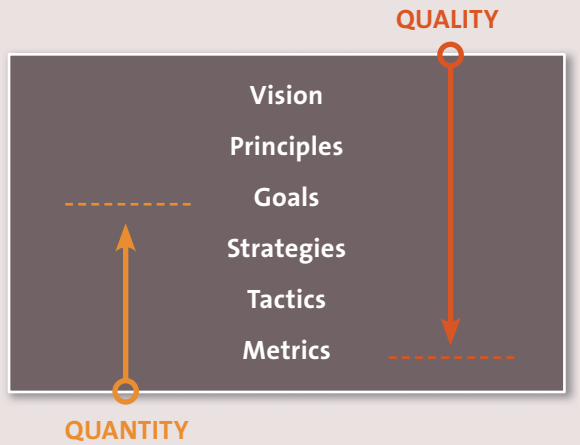
As applied to architecture, C2C's founders' vision of sustainability can be summed up as: "If buildings were like trees, cities would be like forests." Trees use photosynthesis to produce their own energy, they clean the air by capturing carbon dioxide, filter water while providing food and shelter for other species, and constitute a reserve of materials for the future. Inspired by these ideas it is possible to construct buildings that process their own water and filter their indoor air by employing non-toxic materials, probiotics and plants. These buildings are also adaptable to a range of uses, are flexibly designed and act as future materials banks (*BAMB – Building As Material Banks* European research project).

This positive impact circular economy approach is built on a progressive roadmap, not a brutal change of model. Turning off the tap on fossil fuels and switching to all-electric, or renouncing concrete in favor of building in wood alone, are radical ideas that risk triggering confrontations that will hamper rather than increase the speed of energy transition. Bringing about a comprehensive transformation in how cities are built and conceived requires a parallel drive to invent new ways of building and update long-standing techniques: for example, specifying wood while also working to create concretes with a positive carbon footprint, planning for electric vehicles as well as for using hydrogen and compressed air, and all the while working to limit the negative effects of fossil fuels.

IMAGINING URBAN AGRICULTURE ACCORDING TO THE PRINCIPLES OF A POSITIVE IMPACT CIRCULAR ECONOMY

Designing an urban farm as rooftop greenhouses that follow positive impact circular economy principles requires the creation of synergies between the farm, the building on which it is located and the farm's wider urban environment. It is important to take a holistic view of the urban environment by looking at the quality of the site, the air, water cycle, access to energy and raw materials, to mobility and food production networks and levels of biodiversity. The challenge is to incorporate these disparate dimensions while designing modular buildings and adopting a zero-waste approach, and without overlooking the project's social dimensions (see Figure 2).

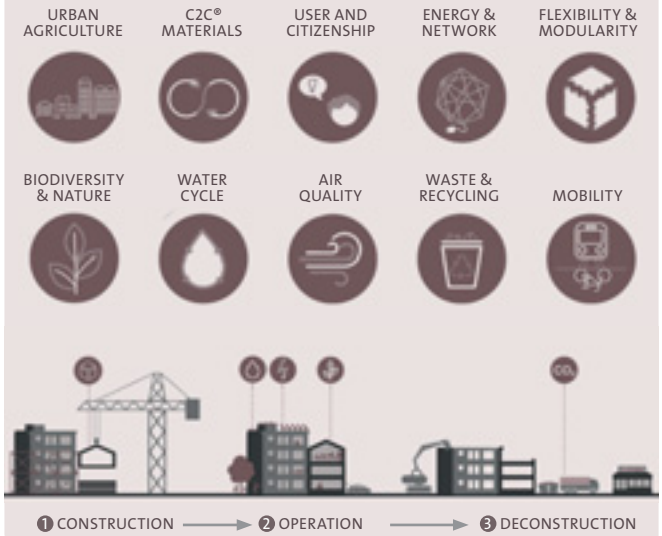
The C2C qualitative approach



Source: Lateral Thinking Factory

Figure 1

Designing a project with a holistic urban approach



Source: Lateral Thinking Factory

Figure 2

- **What the city and the building provide to the farm**: the city offers the farm access to its labor force, proximity to consumers and the microclimate afforded by city rooftops. Sheltered from the wind and protected by the thermal qualities of concrete, the rooftops are generally 2 to 3 degrees Celsius warmer than the surrounding countryside. There is also a higher concentration of CO_2: 500 to 600 ppm compared to an average in the countryside of 400 ppm. It should be remembered that, above and beyond being a greenhouse gas, CO_2 is the living world's most critical building-block. The farm is also able to recover stormwater thanks to a drainage system that stores it. Sunlight falling on the building can be captured using solar panels to produce renewable electricity. This means the building provides the farm with space, heat and even the CO_2 emitted by its users, as well as utility network connections and access for logistics.
- **What the farm provides to the building**: in return, the farm offers the building thermal protection and insulation, substituting roof maintenance costs for rental income. It helps boost the real estate value of the building by improving its image and reducing its ecological footprint. Research is under way into a range of different models that would allow building owners to invest in fitting out the greenhouses, the idea being that this would in turn boost the value of their building.

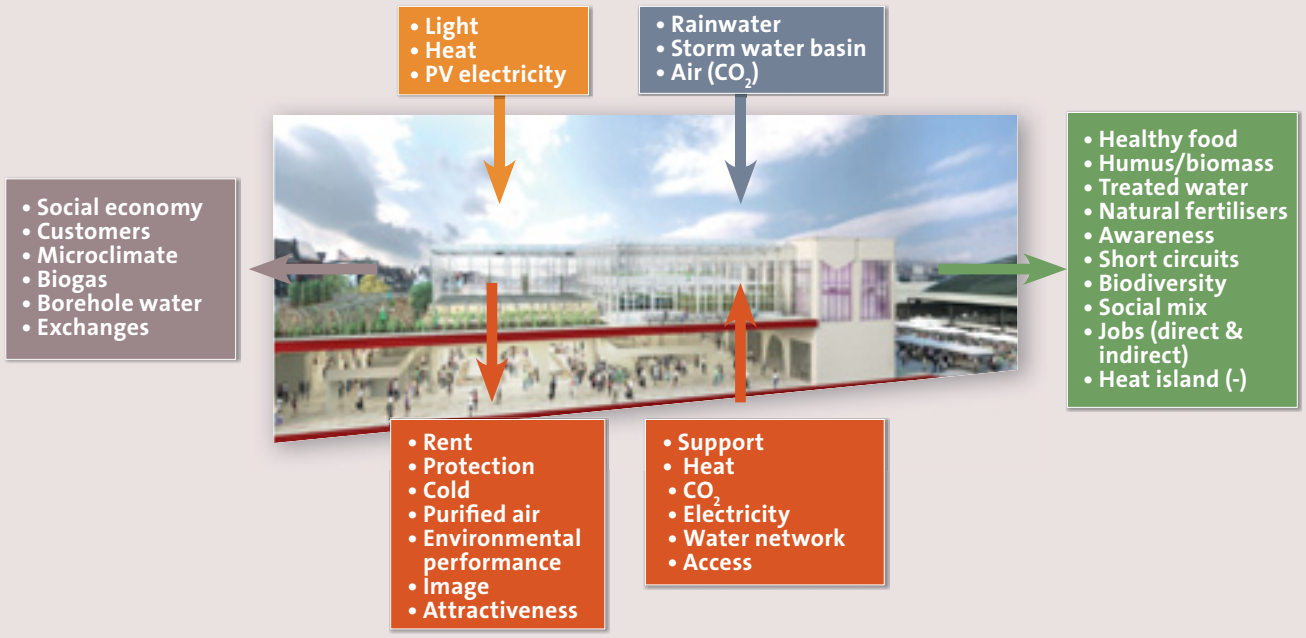
For the city, these positive interactions (*see Figure 3*) deliver year-round production of high-quality local produce that is free from artificial fertilizers, antibiotics and pesticides, as well as surplus humus and biomass that can be used for other non-farm purposes. They also provide the city with greater biodiversity and help to reduce heat islands because the greenhouse absorbs heat and the plants' humidity maintains the temperature below 26°C. This is a model that sees the urban farm become a center for innovation in the circular economy and for raising awareness about the importance of healthy eating. It also creates direct and indirect employment and, working with the social and solidarity economy, it can help to bring disadvantaged people back into paid work.

Abattoir Farm on the roof of Foodmet in Brussels - ©BIGH-isopix

BIGH'S ABATTOIR SITE IN BRUSSELS: AN INTEGRATED URBAN FARM MODEL

BIGH's first full-scale production site is Abattoir Farm on the roof of Foodmet, a food market that was restored in 2015 in the Abattoir neighborhood of Anderlecht in Brussels. The 4,000-square-meter surface is divided into 2,000 square

Positive interactions between the urban farm and its environment



Source: BIGH

Figure 3

meters of greenhouses and fish-farming installations, using the aquaponic method, and a further 2,000 square meters of outdoor kitchen gardens. The installation seeks to recreate a natural ecosystem in an artificial environment.

AQUAPONICS

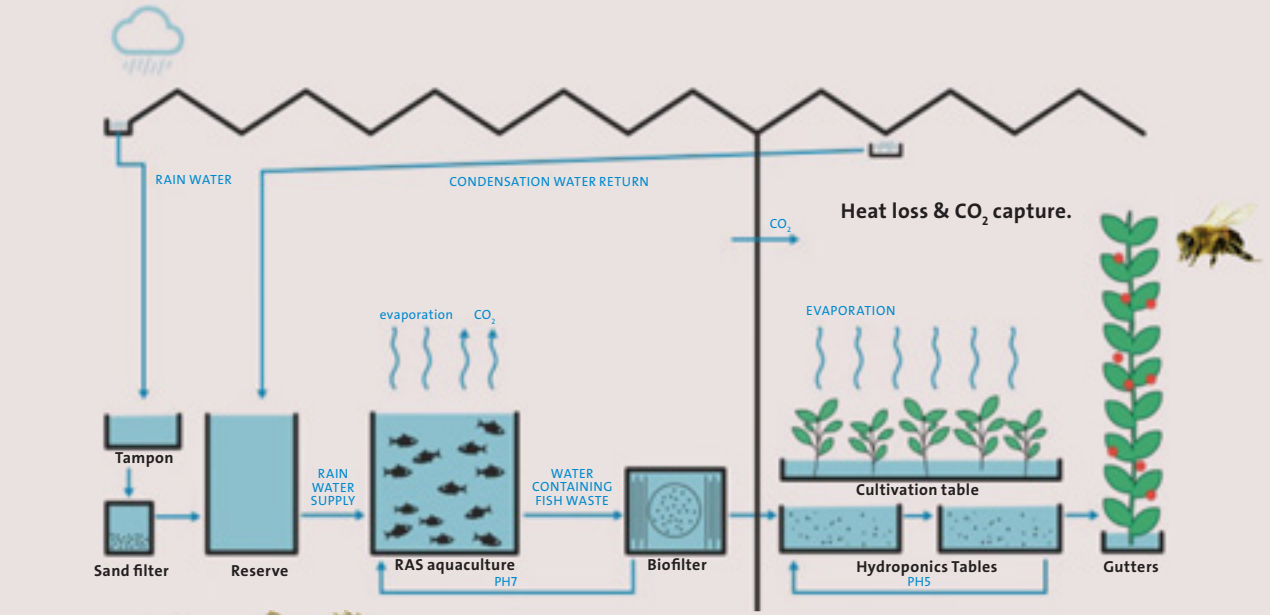
Well known to the Incas and used in Chinese rice paddies, aquaponics is a symbiotic combination of aquaculture (fish farming) and hydroponics (growing plants without soil). The system uses a bacterial process, with micro-organisms filtering and breaking down the ammonia in fish urine to create the nitrates that allow plants to use the nitrogen cycle to take nutrients from the water. For health reasons and to ensure the production of fish that are fit to eat, very little water from the plants is returned to the fish in the aquaponic system developed by BIGH. In fact, only condensed steam from the greenhouse is returned to the tanks. Fish and plants have indeed very different needs in terms of the pH value of water (pH7 for fish and pH5 for plants).

Water, an essential element in the circular economy, is the farm's primary resource, along with CO_2 and organic waste. The Recirculating Aquaculture System (RAS) uses a hundred times less water than conventional open systems. Even during a heatwave, the farm uses just 20 cubic meters of well water daily to supply its 200 cubic meters of tanks, cleaned every two hours by biofiltration, and the plants in the greenhouses and the outdoor kitchen gardens (4,000 square meters in all). Rainwater is harvested, filtered and used in the tanks too. Systems to filter and use water from fish tanks for growing plants hydroponically considerably reduce the amount of waste generated by the farm, unlike conventional fish-farming systems that discharge water into nature that is heavily contaminated with ammonia and antibiotics.

Designing an urban farm that follows positive impact circular economy principles requires the creation of synergies between the farm, the building on which it is located and the farm's wider urban environment

The seemingly burdensome task of constantly monitoring the parameters of the highly sensitive aquaponic ecosystem, with zero tolerance of antibiotics and chemicals, is in fact a guarantee of the healthiness and quality of the fish and plants produced at the farm. The use of bumblebees to pollinate plants in the greenhouse and mites and other insects to combat pests is proof of the lack of harmful chemical inputs in the system, which works on a closed loop. Lastly, the CO_2 emitted by the fish is also recovered and fed to the greenhouse to help the plants with photosynthesis.

The BIGH aquaponic farming model



Source: BIGH

Figure 4

Fish-rearing basins at the Abattoir site - ©BIGH-isopix

2,000 sq. m
of greenhouses and fish tanks

2,000 sq. m
of outdoor kitchen gardens

14
tanks

60,000
striped bass

35 metric tons
of fish raised each year

PRODUCING FISH AND MARKET GARDEN PRODUCE IN THE HEART OF THE CITY

The farm's 14 tanks contain 60,000 striped bass in various stages of development. The farm imports 9,000 fry monthly from a hatchery in Israel. The striped bass is a protected species that in the wild is found mainly in the salty waters of the St. Lawrence River. It was selected for its culinary qualities and ability to develop in freshwater over a 10-month cycle, compared to four years in the wild. Other species that are highly sensitive to water quality, such as Arctic char and different types of trout, can also be raised using the aquaponic system. The striped bass are reared without antibiotics in water kept at 23°C, a temperature they thrive in, with a constant current for them to swim against. Fed with certified GM-free food and kept in different tanks according to size, the fish are sold once they reach 350 to 600 grams. A total of 35 metric tons are produced each year and gutted fish retail for €18 to €22 per kilo, depending on size.

The market garden section of the farm produces three types of crop. One greenhouse grows two varieties of cherry tomato (red and yellow) on a coconut fiber substrate for 34 weeks a year. Tomatoes were chosen for biological as well as culinary reasons: they absorb a lot of nitrates as they grow, and their characteristic flavor makes it easy for consumers to judge the quality of the product. Some 15 metric tons of tomatoes are grown each year and are sold loose or on the vine for €15 to €25 per kilo, making them a high-end flagship product. Another 600-square-meter greenhouse is used year-round to grow organic plants in pots: 2,700 pots of kitchen herbs such as parsley, coriander, basil and thyme are produced weekly. Lastly, there is the more seasonal outdoor garden, where vegetables, fruits, salads and berries (blackberry, raspberry, bilberry and red currents) are produced from June to September for use in restaurants.

DIVERSIFIED ECONOMIC MODEL

A typology of the different types of urban agriculture projects makes it easier to understand BIGH's approach *(see Figure 5)*. A very large part of existing installations, in Brussels and elsewhere in Europe, are nonprofit projects that use urban agriculture to stimulate social bonds. Next come installations that focus on profile-raising and marketing, such as the greenhouse and garden on the roof of the Delhaize Boondael store in Brussels: aside from the marketing aspects, these projects are not economically viable but do influence consumers by spreading awareness about sustainable practices. Some companies have developed kitchen garden concepts as a consumer service: small private gardens are cared for on behalf of private individuals, sometimes even remotely managed via an app. Lastly, the fourth urban agriculture model involves truly producing food in the city, with an economic model that relies mainly on the sale of produce. These models each have purposes that are distinct yet complementary.

Abattoir Farm by BIGH belongs to the last category. Its economic model essentially relies on the sale of its produce, notably "local producer" sales in Carrefour supermarkets. The economic model also includes approximately €100,000 of earnings from corporate events and visits. Total revenue for the second trading year is estimated to be €1 million. The plan is to achieve profitability in the fall of 2019. Greater use of permaculture for the outdoor kitchen garden or, for future

Kitchen herbs grown in a greenhouse at the Abattoir site - ©BIGH-isopix

15 metric tons
of tomatoes and
170,000
pots of kitchen herbs produced each year

Typology of urban agriculture projects

Source: Lateral Thinking Factory

Figure 5

installations, setting aside more space for growing plants in tunnels and fish farming will achieve better economies of scale and greater diversity of production that will make it possible to accelerate break-even for this type of economic model. There are also plans for a third party to open a restaurant onsite, a move that will give a further boost to the image of the farm's produce.

The farm employs the equivalent of five full-time staff, including two specialists in hydroponics and fish farming and an agronomist in charge of managing the farm. From the financial standpoint, there are several private and public investors in BIGH Holding (Lateral Thinking Factory Development, Fidentia Green Buildings, Talence and Finance. Brussels SRIB) with financing completed via a loan from BNP Paribas Fortis. Although Abattoir Farm was not eligible for public subsidy, BIGH Holding has received public assistance by virtue of being a newly established Brussels business.

SOCIAL AND ENVIRONMENTAL SYNERGIES

Located in a priority development district, the Abattoir Farm site helps boost the image of the Anderlecht district, which is now home to an innovative activity that is an example of the circular economy in action. Apart from the outdoor-grown berries that serve the local restaurant trade, the remainder of the 2,000-square-meter outdoor kitchen garden is set aside for the benefit of the social and solidarity economy. Since it opened, a partnership with nonprofit Atelier Groot Eiland has delivered training at the farm to around 60 participants, either disabled people or people returning to the workforce. Produce from the gardens is served in the restaurant run by Atelier Groot Eiland.

Outdoor kitchen gardens at Abattoir Farm - ©BIGH-isopix

In terms of its environmental management, the farm is embedded in the Foodmet building in line with the circular economy principles set out above. It works in a way similar to a cooling tower: heat from refrigeration units on the floors below is recovered by a heat pump, providing 60% of the heat needed for the greenhouses and fish farm, and the greenhouses also supply cold that is used by the market's refrigeration units and cold rooms. Also, some of the farm's electricity is generated by Foodmet's solar PV panels.

Lastly, the farm is almost seamlessly integrated into its neighborhood. It produces no bad odors, and light pollution is reduced by using LED lighting in the greenhouses and a system of vertical and horizontal night-time blinds. All the farm's produce is subject to permanent sanitary quality checks.

CONCLUSION

In the years ahead BIGH hopes to roll out a network of European urban farms that work in synergy with the city buildings and industrial sites where they are located, each of them combining food production with the circular economy. The type of city site it is looking for will have a useable productive surface of 2,500 to 3,000 square meters, perhaps more. There are plans to develop two or three more aquaponic farms in Belgium and projects exist for three more, in the Paris region, in northern France and outside Milan. Larger installations than at Abattoir Farm could make it possible to diversify the range of indoor crops. For example, dividing greenhouses into different zones would allow tomatoes to be grown easily with zucchini. Recovering guano, fish excreta separated from the water using mechanical filters, would also provide the farm with additional resources. Also, further improvements to current photovoltaic technologies will bring the site closer to energy self-sufficiency by fitting PV panels inside greenhouses.

The idea is not to replace crop growing practices used in the countryside. However, urban agriculture can share the burden of growing certain crops and provide farmers with new ideas. Under certain circumstances, circular economy principles as applied in cities can help answer some of the wider challenges facing farming.

Peri-urban areas also offer outstanding potential growth opportunities thanks to lower land costs and easy access to water and energy resources. In addition, the aquaponic technology model, which has clearly shown the effectiveness of its water filtration techniques, may be a first step toward the application of circular economy principles to wastewater treatment.

Aquaponic tomato-growing at the Abattoir site - ©BIGH-isopix