Building Integrated Green Houses: Exploring feasibility, planning & policy responses for urban climate change in Brussels.

[Alice Berten]

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Prof. Ahmed Khan

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Building Integrated Green Houses: Exploring feasibility, planning & policy responses for urban climate change in Brussels.

ALICE BERTEN

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Abstract Nowadays, cities are home to more than half of the world's population and this number is constantly increasing. Food needs are growing, causing problems of pollution and natural resource management. The current agri-food system has separated rural farmers from urban dwellers, increasing transport and time from field to plate with all their consequences in terms of CO2 emissions. One way to solve this problem is to bring agriculture back to the city, and thus offer it more autonomy and therefore more resilience. To do this, the integrated greenhouse building (BIGH) system is studied, they are rooftop greenhouses whose metabolism is pooled with the one of the building. The flows of water, energy, CO2 and compost are connected to efficiently produce fruits and vegetables while improving the building's energy performance. The objective of this study is to verify the feasibility and potential of BIGHs in the city of Brussels, and to see the advantages and disadvantages that urban agriculture can offer to the inhabitants. The method consists of a literature review on urban agriculture in general, followed by a study of the flows common to greenhouses and buildings. Then, the city's urban planning laws are analysed to see the legal feasibility of integrating BIGHs, and proposals are made to facilitate it. Thanks to the Geographical Information System (GIS) program, it is then possible to identify all roofs that could be rehabilitated. In the end, the results show that BIGHs are a win-win facility for the building that houses them and for the production of food while optimizing the use of resources. There are a multitude of potential roofs, which can feed up to 30% of the population of Brussels. However, this figure should be revised downwards to reflect reality. Yet urban agriculture seems to be a solution to a large number of current problems ranging from prison reintegration to reducing the heat island effect of the city.

Keywords Urban agriculture, Building integrated greenhouse, food autonomy, resilient city, building metabolism

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List of Abbreviations:

UA: Urban Agriculture

BCR: Brussels-Capital Region

BIA: Building Integrated Agriculture

BIGH: Building Integrated Green Houses

FAO: Food and Agriculture Organization of the United Nations

GIS: Geographical Information System

RTF: Rooftop farming

RWH: Rainwater Harvesting

Introduction: Food in the city

« Pour les gens qui veulent bâtir un modèle de société en croissance infinie sur une planète déjà surexploitée, le mot utopie signifie l'illusion d'un rêve impossible à réaliser qui ne s'applique pas à leurs projets.
Pour nous qui cherchons à construire un nouveau modèle de société durable, dans une symbiose avec notre environnement naturel, le mot utopie veux dire simplement, un possible qui n'a pas encore été expérimenté. »

Luc Schuiten

Growing food has always had its place inside cities whether it is in Ancient Egypt or Greece (Janick 2002) and eating necessarily became a key challenge wherever men decided to live. Nevertheless, with the industrial revolution after the invention of the steam engine, the need for agricultural labour decreased considerably. There was then a significant rural exodus of landless farmers who left to seek work in urban industries. The mechanization of transport now makes it possible to transport food from fertile distant lands (America, India...) by train or boat. Europe's free trade policy at the time supported this movement. With the arrival of the engine, the exodus to the cities was confirmed, and by 1950 more than half of the inhabitants of the planet lived in cities. (Véron 2006) It is also the dawn of the era of agrochemicals simultaneously with that of the chemical, coal and oil industries. The new agricultural machines, together with weeding and fertilizing allow farmers to maintain larger surfaces with less manpower, with the result that monocultures bloom and production explodes. We are now able to feed many more people, and cities are becoming megalopolis. The globalization of the agricultural world aligns its prices with those of the major producers, without taking into account the productivity potential, which is actually very different from region to region. The rural exodus is intensifying, and while the number of farmers is decreasing more and more, the rate of global unemployment and poverty is increasing. In 2010 in Belgium, the agricultural sector employed only 81 000 farmers compared to 185 000 in 1980, while it remains the leading actor in the food chain. (Direction générale statistiques : Statistics Belgium 2017)

Nowadays, the Food and Agriculture Organization (FAO) of the United Nations says that by 2030, 60% of the world population will live in cities. In Europe this is already true for 75% of population (FAO s.d.). Land to grow enough food for all those people is currently mainly situated in rural areas, outside cities. Therefore, food must be processed, packed, transported and retailed to the urban population, using a considerable amount of fossil fuel. Today, we export food further than ever and most often by air. (Howe et Wheeler 1998) Simply by reducing the distance factor, Urban Farming has already had a major impact. Road freight traffic (trucks and vans) has been estimated to be responsible for 30% of urban greenhouse gas emissions linked to transport in Brussels by the regional centre of expertise for development strategy. (Région Bruxelles Capitale 2018)

Another concern is the reduction in the amount of arable land available to feed the urban population. For example, London needs the same productive area as the entire country to sustain itself; its ecological footprint is 125 times its surface. (Garnett 2000) Integrating agriculture would reduce the impact of agricultural lands in the rural area but would also increase the scarce green areas in the cities. This would also improve biodiversity (which is sometimes even richer in urban areas than it is in rural areas) by creating small plots with different cultures attracting various fauna, when in the countryside there are now mainly intensive monocultures.

It is now clear that the current food model does not meet the objective of feeding more people and limiting hunger. On the contrary, it increases the divide between social classes and the producers of the world. Moreover, the results of this intensive production method are only beginning to reveal the damage caused by ecosystem degradation. UA then presents itself as a solution to the food and environmental challenges ahead. It has already recently proven its value during the two greatest crises of the last century, i.e. the two world wars, in which the food models in place failed. We then saw the emergence of citizen movements, in Britain for example, the 'Dig for Victory' war effort for growing food which concluded after the second World War with the country producing half its needs in vegetables and fruits in urban areas (Howe et Wheeler 1998). In America, the same kind of patriotic gardens appeared. But after the wars, lands returned to their primary uses, and over time, with technology and globalization, we came back to this production model "out of sight out of mind".

To remedy this situation, it is necessary to relearn how to feed oneself, in a more sustainable and local way, to become as autonomous as possible so that people no longer depend on fossil fuels or other countries. In cities, the urban fabric becomes denser and soil permeability decreases, causing its share of problems. There is not much room left to integrate agriculture. Over the years, some studies have investigated the potential of the Brussels Capital Region to recover free and transformable surfaces into vegetable gardens. Currently the Regional Land Use Plan (PRAS) lists 645.6 hectares of arable land, the Terre en Vue association has 480 additional unrecognised hectares with a sufficient surface area of at least 0.5 hectares, allowing a semi-professional and sufficiently productive type of agriculture.(see Appendix : Farmland potential) Nevertheless, these lands represent only 6.9% of the total surface area of the region and will be cultivated with conventional or even permaculture techniques that allow a better yield. Nonetheless, it is still impossible for these 6.9% to feed the population of the Brussels-Capitale Region (BCR) in any significant way. We must therefore find other places.

In cities, surface recovery agriculture is a means of optimizing space and maximizing the implementation of nature and biodiversity in cities. Among these areas are fallow land, railway embankments, parks... Once again, it is possible to find a few more hectares, but the Brussels population is only increasing, unlike the land available. Today in 2018 there are 1,198,726 inhabitants, but the Brussels Institute of Statistics and Analysis (IBSA) forecasts a population of 1,274,713 by 2030. (IBSA 2018)

Since the city can no longer grow, and demographics are increasing, new cultivation areas must be found that can accommodate this growth. In the city, the most useless spaces are certainly the roofs. These spaces are neglected, their only function is to cover the building and protect it. However, viewing the urban landscape, it sometimes seems that the city is covered with flat roofs, simply raising the ground level above our heads.

As Le Corbusier proposed a few decades ago, it would be interesting to give back the surface taken to the ground by transforming the roofs into terraces. Here, the approach goes a step further, because the roof would not be offered as public space, or semi-private areas for the inhabitants, but to nature, which will gradually have the opportunity to regain its rights over the city.

It is already possible to glimpse the advantages that this would offer the city by integrating agriculture by imagining a green city where, instead of old grey roof waterproofing, gardens and vegetable greenhouses would flourish. Rehabilitating roofs is also a way to revive abandoned places, giving them a new function while minimizing their impact, without creating new buildings that draw on the Earth's resources. Producing intra muros would reduce freight transport and increase the city's autonomy. Of course, these gardens would have to be maintained and the distribution of the food produced would have to be taken care of, which would create many jobs.

In a less gloomy and dull city, men would learn to live differently. Indeed, for the inhabitants, cultivating a plot of land would be a godsend in the light of research on how contact with nature can improve their health. These spaces could also become new places for meeting and sharing.

For the metabolism of the city and its inhabitants, agriculture seems to be a worthwhile project. But is it worthwhile in terms of architecture and building metabolism? In the case of a garden roof, it is certain that the building will gain in insulation with a layer of soil on its existing roof, but it is the greenhouses that have the most to offer. According to some researchers and architects, the greenhouse would be a complementary element to the building. By integrating the ventilation system, the greenhouse could regulate the overall temperature of the building, simultaneously filter the air with its CO2 but also optimize water resources and reduce the amount of waste.

As a first step in this work, it will be necessary to examine the advantages and disadvantages of UA, for the inhabitants, but also for the city, identify their current problems and see if agricultural integration could solve them.

Then, in a second phase, the flows to be pooled between the building and the greenhouses, and the possible benefits will be analysed. Once the advantages have been listed and criticised, it is necessary to investigate whether this type of infrastructure can be set up in the Belgian capital. By studying the urban planning laws of the region, it will be possible to determine whether these laws are currently conducive to the integration of UA. Otherwise, new proposals will be submitted.

Once the challenges have been set, the potential of this agricultural technique for Brussels must be studied. To do this, the Geographical Information System (GIS) program will be used to find all roofs suitable for greenhouses. Once the areas have been selected, a quick calculation based on data from similar cases will give an indication of the quantity of food produced and the number of people who will be able to benefit from a complete autonomy in fruit and vegetables.

Then, to visualize the real issues and the possible scenarios where they can be transposed, three buildings with different functions will be chosen to house a greenhouse. It will be a matter of knowing the benefits that greenhouses will bring in each case study, but also of estimating the widespread feasibility for each function at the city level.

Once this information has been collected, it will be possible to assess the potential of the Brussels region to self-manage within a circular and local economic philosophy. It is a question here of discovering whether a smaller scale system, as in a city, will be able to hold economically, socially and environmentally.

To sceptical eyes, such a model seems utopian because it is in total contradiction with the industrial movement that has been going on for decades. Nonetheless, we must try to make our cities more resilient, in anticipation of the changes that are coming to challenge our system. If we do not find an answer, cities will not survive. As Pierre Rabhi, an imminent philosopher and agriculturist, said: "It is time for us to create together a civilization of ethics, beauty and moderation. It is only by putting more awareness into our daily actions that we and the planet will become healthier, physically and morally. It is not a question of turning back to the candle age, but of simply adjusting our needs to the reality of the resources the world has at its disposal. " Urban agriculture does not position itself here as a saviour of cities, because it is in global thinking that the changes will take place, but these words resonate as a solution to a myriad of current problems, and as an awakening of consciousness.

State of the art: Types of urban agriculture

Today, UA is being rediscovered all over the world, and different solutions are being put in place to better integrate it.

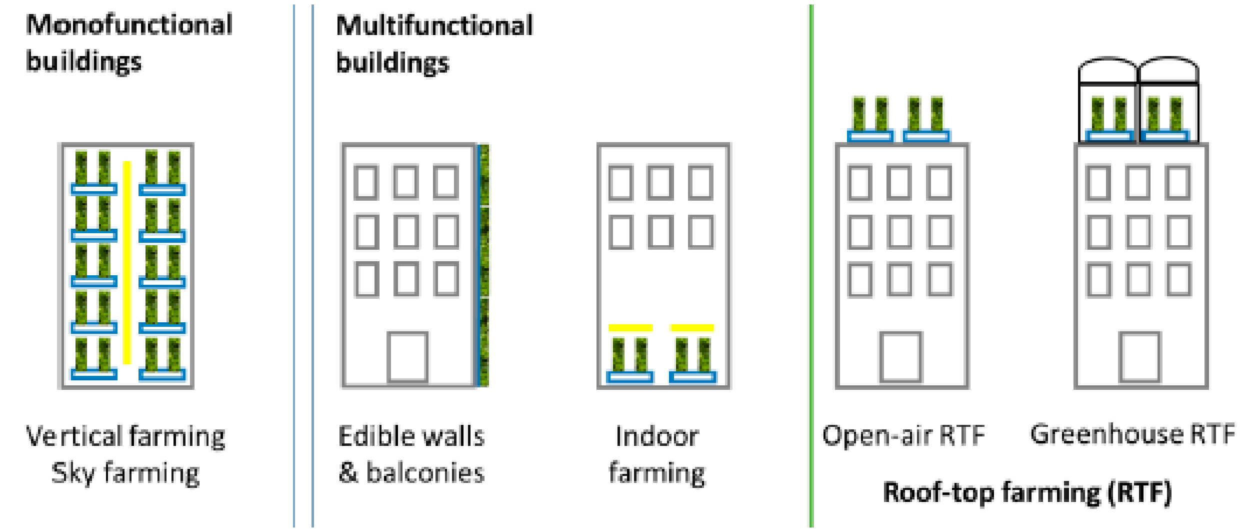


Figure 1: Nomenclature and typologies of Building Integrated Agriculture (Buelher et Junge 2016)

1. Soil-Grown

Under the city

There are a multitude of areas that can be recovered or reused for UA. The first category is often out of sight because it is in the basement. Protected from the sunlight, it is possible to grow plants that do not require light such as mushrooms, or chicory. For example, in Brussels and the surrounding area, there are already at least three start-ups that grow mushrooms on recycled substrates such as dry crumb bread, (SmartMush 2015) draff (waste from brewing beer) (Le Champignon de Bruxelles 2018) or even on coffee grounds in the underground tunnels of Tour et Taxi. (PermaFungi 2017) This type of system is interesting because it recovers unoccupied areas, recycles waste into substrates and produces food with relatively high growth and yield. In addition, it requires little energy to heat or light production areas. This schema is also easily reproducible given the little constraint it generates. (see Appendix: Under the city)

In the city

Culture in soil is the most common kind of agriculture, probably because it is adequate for small individual scale work as for large scale operations in the agroindustry business all around the world. In existing cities, there are many spaces that could be turned into vegetable gardens. For example, the embankments around railway tracks, or the highways, the piece of land under the trees…These kinds of spaces are most often neglected or forgotten but could easily and quickly become patch of earth that citizens could reclaim and cultivate freely. An association in Ixelles, “Aromatisez-vous” is working on such spaces, growing aromatic herbs and offering them to the public for free. (ASBL Aromatisez-vous 2015)

Another kind of space that could be dedicated to food are flowerbeds in public spaces and parks. Indeed, the transformation from flowers to vegetables would not need more infrastructure, though it would probably need more gardeners for maintenance. In the capital one already finds these kinds of “parterres” in parks such as Tournay-Solvay, Scheutbos or the King Baudoin park. (Bruxelles environnement 2018)

Figure 2: San Francisco City Hall : Slow Food Nation Victory Garden, 2008

Apart from these “mini spaces” that could be converted immediately, in Brussels there are also fields that have been fallow for years, and that could be turned into urban farms with the agreement of their owners. A few organisations are already in place like “Le chant des cailles”, or “La ferme de nos pilifs“ and are cultivating those fields as community gardens and welfare centres.

On an even larger scale, the association "Terre en vue" has identified unused land in the capital for professional exploitation. They looked for land larger than 0.5 hectares, which they said was the minimum size for intensive cultivation. These lands would not be specifically proposed to become community gardens but rather real small fields in the city, cultivated by real farmers.

Soil agriculture has the advantage of being able to grow a large variety of products, such as root vegetables, fruits, cereals. With a little help it can even produce eggs and honey which can attract other types of customers. (T. Caplow 2009) Putting your hands in the ground brings a multitude of benefits for body and mind. It also helps to replace the Earth's cycle in daily life, and to raise awareness among city dwellers about respect for the environment.

On the city

The previous scenarios concern field production, though this is not the only way to grow food in soil. Indeed, you can grow food in plant pots, or in bags inside and on the outside of buildings. As shown in Figure 1: Nomenclature and typologies of Building Integrated Agriculture , UA take many forms. Nevertheless, growing in soil has a few drawbacks. The major one is probably the weight of the earth that is quite significant, even when dry, but double its weight to 11kN/m^3 when the rain is pouring, and the soil is growing heavier, up to almost twice its original weight. (Ecores, Lateral thinking factory et Noemie Benoit consultant 2014) This has consequences for the use of UA, as it requires more restricting criteria in terms of structural capacity for the building.

Another drawback for soil-grown food on building is the soil erosion by the rain while exposed. Edible walls, and the vegetal walls in general suffer from earth settlement and depletion over the years and tend to fail to provide enough nutrients for plants if no flow of nutrients is put in place. (Manso et Castro-Gomes 2015) However, soil agriculture has other advantages that we can exploit, for example it can grow larger varieties of products, such as root vegetables, fruits, cereals.... (T. Caplow 2009)

Facade installations can help the building's energy performance. By being placed as a second skin around the building, it insulates it. Although considered as the future of urban agriculture for some, these techniques are still at the design stage. There is no prototype yet to be studied, but most are being considered with hydroculture techniques rather than in soil.

On the rooftops

Another place to integrate agriculture is on the many flat roofs in the city. Indeed, these underestimated spaces are currently most often empty. By ensuring their structural bearing capacity, they will be able to accommodate gardens or greenhouses. This surface recovery will make it possible to create new areas of high social and environmental value without occupying more land on the ground, which is becoming increasingly scarce due to urban population growth.

From the start, it seems difficult to install gardens on all existing roofs, where the transformation costs would be too high for a surface area too small, and therefore an insignificant yield. It is indeed necessary to ensure the bearing capacity of the roof as well as its access. Nevertheless, it is perhaps interesting to assess the potential of the current city including even its smallest roofs, to plan for a more resilient future city.

Open-air cultivation increases plant biodiversity in the city and thus attracts a multitude of animal species. Cultivating in the ground increases the city's permeable surface and allows water to percolate in the event of heavy rain, thus reducing the amount of water sent directly to the sewers. However, it is also more constraining to cultivate in the open air because all year round you have to work outside, in the rain or in the blazing sun. Plants are also directly affected by these changes in weather and temperature. It is therefore less easy to control their environment and growth.

Greenhouse crops means being able to control up to the access of air for the plants. But in the case of an integrated architecture, much more can be done. By coupling a greenhouse and a building, one can already recover the heat losses of this building, especially those by the roof which is often under insulated. The temperature delta between the two parts helps regulate humidity and temperature on both sides. The water can also be recovered, by the roofs of the greenhouse to water the plants, be sent to serve as water for the toilets, or even to be pre-heated by solar panels for domestic hot water. CO_2 from house occupants can also be sent into the greenhouse to increase plant yields and the plants in turn can purify the air before it is returned inside. One last flow can be pooled, it is compost. Making compost is a way to reduce the amount of household waste, and plants can benefit from natural, local fertilizer. These exchanges between greenhouses and buildings are summarized in the diagram below.

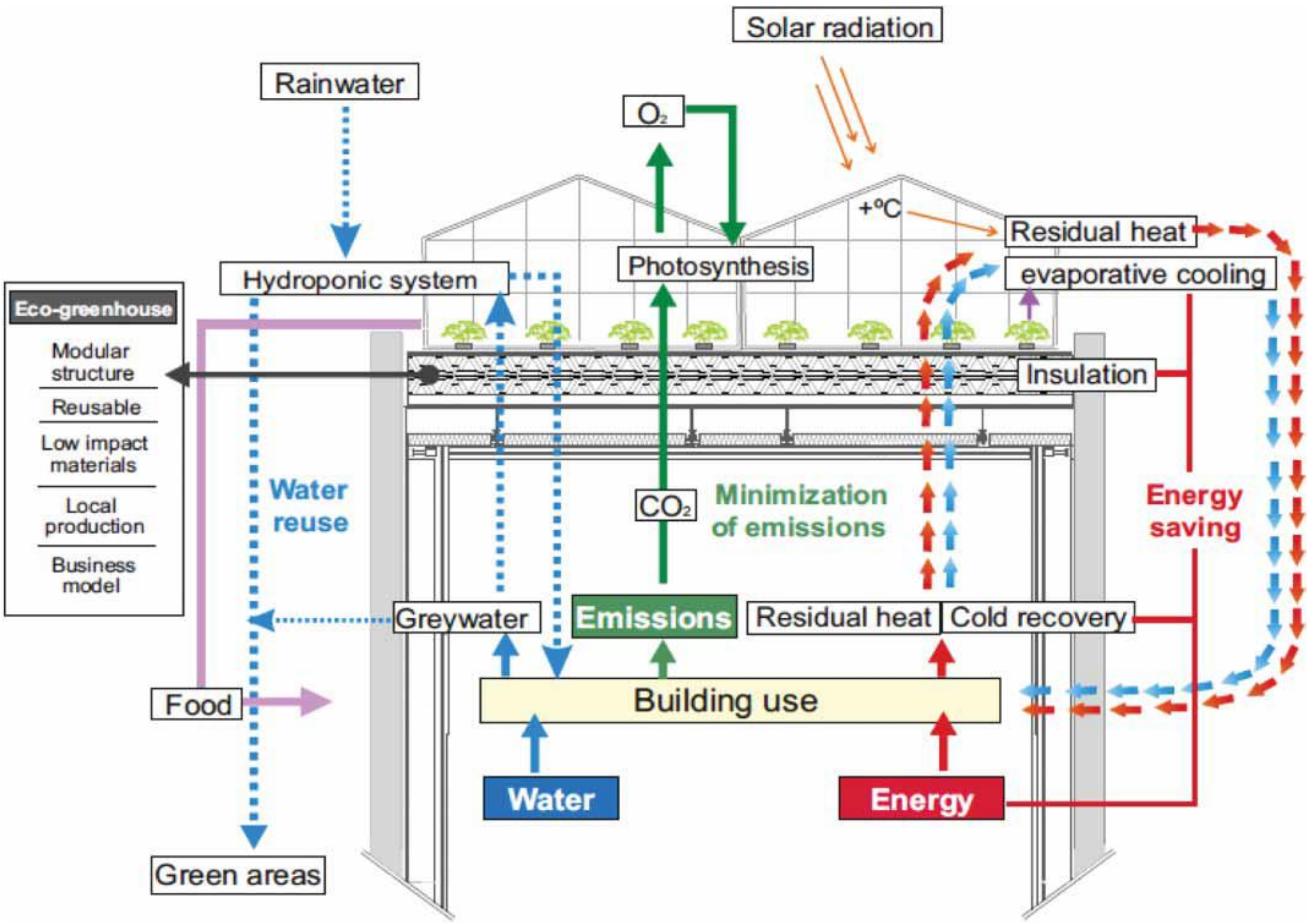


Figure 3: Building Integrated Greenhouse (Cerón-Palma, et al. 2012)

However, it should not be assumed that biodiversity does not exist under greenhouses. More control is indeed possible, but it is not an impermeable envelope. This has its advantages because it invites insects, but also its disadvantages because it does not filter the entry of pests.

Greenhouse agriculture, thanks to its controlled environment and coupled with hydroculture techniques, can have much higher yields than conventional agriculture. The objective of RTGs is therefore more intensive production. To be able to ensure high efficiency, qualified people must be in charge. Moreover, thanks to its above-ground position, access is restricted and allows more security against acts of vandalism. It would therefore be a question of transforming large flat roofs into new generation agricultural land that would not be a hobby for neo-bourgeois but a real productive activity.

2. Hydroculture

Although hydroculture is a relatively new word, growing plants in water has existed for centuries as in the case of the Babylon Hanging Gardens. (Resh 2012)The main advantage of hydroculture is that it uses less water than traditional earth cultivation. The quantities of water needed are less than the quantities of soil required for the same yield. It is therefore a water-saving system and as water weighs less than soil (and of course even less than saturated soil). It can therefore be installed in more places than cultivation in soil that is heavier and therefore requires stronger structures.

Aeroponics

Firstly, aeropony is certainly the most water and space-efficient crop*. (see Appendix* 3) It is a possible answer to the intense urbanization that awaits our cities. Plants placed in containers have their roots sprinkled with a mist filled with nutrients. In the case of indoor cultivation, it is then necessary to provide light to the plant with artificial LED lights. This energy-intensive mode is still more productive and economically advantageous because everything in the process is controlled and optimized. (Sarkar et Majumder 2018) For example, in New York we find the largest vertical farm, with 6500 m² and a production of 900 000 kg per year. That is 75% more efficient than an outdoor field of the same surface and using 95% less water. Organic supermarkets and starred restaurants are the main customers of this facility. (AeroFarms 2018)

Hydroponics

Hydroponics is similar to aeroponics, however, instead of spraying water, the roots are immersed in it. Water is enriched with nutrients by precisely measured addition. Again, the controlled environment plays in favour of the plants and offers a higher yield. The FarmBox company, which offers containers to be dropped off all over the city, *(see*

Figure 30: Urban Farm Unit*)* has developed a way of transforming compost into a nutrient to be mixed with water, thus opening the door to amateurs and making it possible to include the last piece of the food chain, waste. (Persico 2018)

Being able to reuse compost as fertilizer is one way to enter a more circular system. Because the defects that could be found in aeroponics and hydroponics techniques are that they are entirely artificial techniques, where farmers resemble chemists.

Aquaponics

This method of cultivation which has been used since antiquity, then long forgotten and yet still marginal today, consists in making in parallel a hydroponic culture and fish farming. These two cultures are connected in a closed circuit where plant nutrients are provided by fish droppings; and plants are used to purify the water that returns to the fish tanks. It is a win-win system where each culture benefits from what is brought by the other. (Ecores, Lateral thinking factory et Noemie Benoit consultant 2014) Unlike traditional agriculture, it uses 1/6 of the water to sustainably grow 8 times more food per acre, without the use of pesticides, herbicides or chemical fertilizers, year 'round, in any climate. *(see Appendix* 5*)*

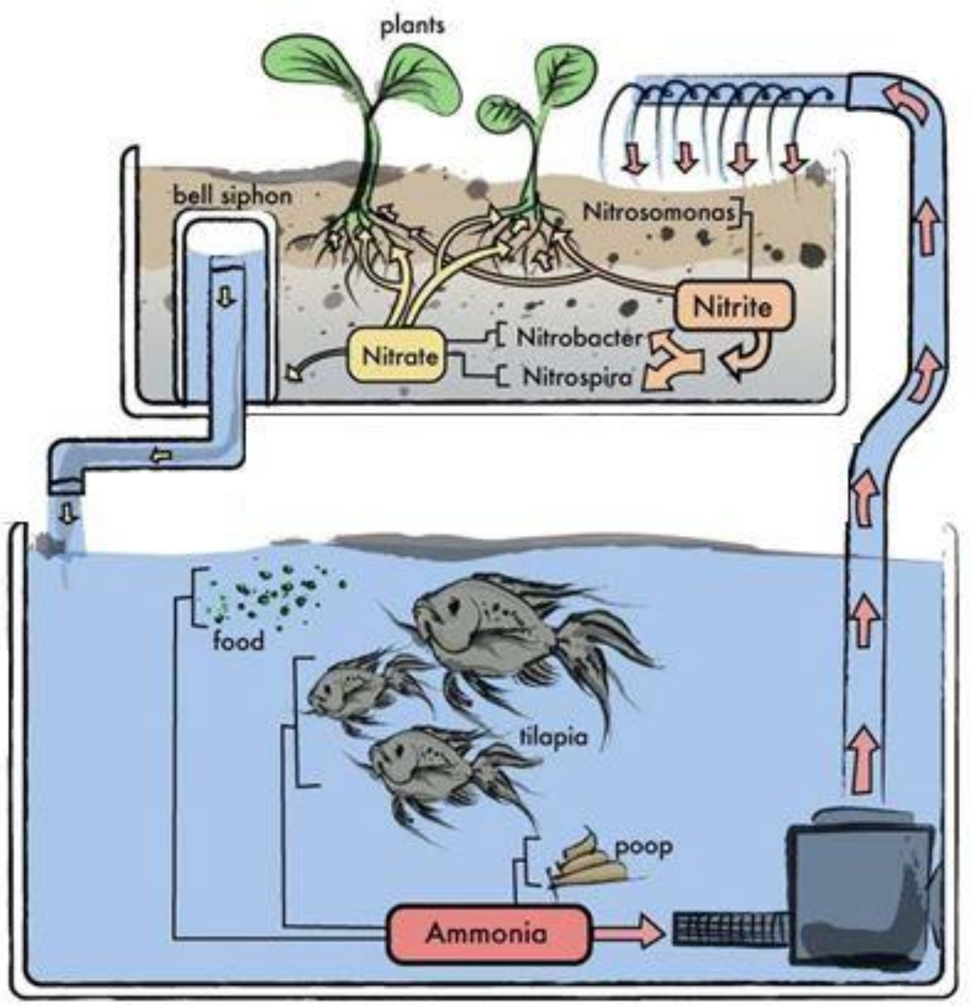


Figure 4: Bernstein, Aquaponic Gardening, Gabriola Island New Society Publishers, 2011.

It is indeed impossible to use harmful fertilizers or pesticides otherwise fish could get sick and in turn poison the plants. This system works with only a bio-filter composed of bacteria as the sole technique. There are two types, nitrosomonas (which convert ammonia released by fish into nitrite) and nitrobacter (which convert nitrite into nitrate). Thanks to the action of these two bacteria, fish waste is transformed into natural fertilizer. (Village Partenaire 2016)

Because its system offers total transparency, as well as the efficiency and weight advantages of hydroponics, aquaponics seems to be a very good candidate for UA. This is in fact the technique that was chosen for the first urban farm in Brussels at the FoodMet.

1. Stakes and potential of Urban Agriculture

Urban Agriculture: the answer to current problematics

1. Social

Urban Agriculture (UA) impacts on city life in various ways. The first one described here is the social impact. We can divide this category in two: the impact created by any kind of UA (for profit or community gardens), and the second concerning to what extent UA enhances the social situation of a neighbourhood or group of people.

First of all it is important to note that many social indicators are unsurprisingly linked to food, for example: support for food safety, support for nutritional education, life and health improvements, reuse of abandoned plot lands; (Pons, et al. 2015) not to mention that the "poverty index" is calculated on basis of the cost of food for a family. (Pothukuchi et Kaufman 1999)

Currently, as previously mentioned, mainly two kinds of UA take place in our cities, community supported agriculture (CSA) and commercial farming. In the first, it is often local volunteers who take care of the gardens, aspire to share farm food within their neighbourhood and communicate social and educational values without care for profit. By highlighting these principles, CSA creates united and self-sufficient communities while at the same time improving urban lifestyle. (Haberman, et al. 2014). Meanwhile, commercial farms focus on entrepreneurship and economic expansion than develop the civic aspect of UA. Sometimes, a tension also appears between those two concepts when a private enterprise controls a CSA, as the goal is also to create a relationship between the food producers and the local consumers. (De Lind 2002)

If, at first sight, Community Supported Gardens look more appealing due to its civic impact, there is nevertheless the other side of the coin. Indeed, studies by Kristin Reynolds show that social disparities are more present in CSA, and even in regard to farms situated in the middle of a low social index neighbourhood, the participants are from higher social status. (Reynolds 2014) Like many other social programs (social security for example) it is the middle and upper classes that benefit the most from it. On the contrary, with commercial farms, the gap is reduced, and we notice that employees come from local area, whatever its social index. (Hinrichs et Kremer 2002)

Another study from Cabannes and Raposo shows that periurban agriculture could help migrants to integrate into society, and also to expand biodiversity in the cities by cultivating fruits and vegetables from their homeland. In their paper, they compare two situations, one in Lisbon, the other in London, and the results, although specific to their city point out that the biodiversity resulting from those cultivated plots is not only environmental but also cultural and ethnic in nature. (Hinrichs et Kremer 2002)

The second type of UA, oriented from the beginning toward social impact, called Civic Agriculture or Social Farming has already taken place in the field of agriculture for a long time. In this case, it is usually an independent agricultural holding, which can also be a CSA or a commercial farm, where they receive people in difficulties for a few days a week. This practise is growing in all countries of Europe and can help a lot of marginalised people to reintegrate into society.

Client group	Number of clients	Percentage of total	Number of Care Farms	Number of clients on non-institutional Care Farms
Mentally challenged	3700	37	452	2953
Physically handicapped	398	3	138	321
Psychiatric demand	1322	13	221	1029
(Ex) addicts	262	3	80	220
Autistic persons	898	9	217	760
Children	388	4	43	364
Youths	587	6	87	370
Elderly	654	7	64	587
Elderly with dementia	220	2	50	106
Long-term unemployed	230	2	50	128
Burn-out	109	1	39	95
Persons with brain injury	102	1	53	79
Special education for people with learning difficulties	493	5	157	393
(Ex) prisoners	73	1	11	7
Other	472	5	64	442
Total	9908			7954

Table 1 Client groups of Social Farming in the Netherlands 2007 (Hassink, et al. 2007)

This table shows the diversity of people who could benefit from such program. Considering the number of possible installations and their small size manpower will be required massively. If policy were to investigate merging agriculture and social reinsertion a win-win solution could potentially be found. As in the case of rehabilitation of ex-convicts, as in Italy or the Czech Republic, in order to reduce the probability of reoffending (more than 50% in Belgium (Maes et Robert 2012)).

In 2012, the EESC (European Economic and Social Committee) acknowledged the positive impact of agriculture, as a productive activity that would not only contribute to the welfare of people in difficulty but also improve their health and their social inclusion by facilitating their learning and improving their self-confidence. They classified social agriculture in four main categories:

a) rehabilitation and therapeutic activities
b) work inclusion and social integration
c) education activities
d) personal support services.

All of them deliver without doubt high-value public services through sustainable development. Therefore, the EESC proposed to European countries that they should promote social agriculture and integrate it in numerous projects in order to receive combined funding. In 2012, despite the lack of data, social farming represented around 1% of all farm businesses. (EESC 2012) In Belgium for example, over 200 Social farms were active in Flanders in 2006. Mainly, those agricultural businesses are family farms where the owners welcome people in trouble for one or a few days a week in cooperation with care facilities. (Farming 2015)

2. Education

Over time, agriculture has moved out of Western cities due to industrialization, the availability of cheap public transport and improvement in food preservation. Nowadays farms are out of the sight of the urban consumers, causing them to lose contact with their food, and the reality of how it is processed. (Gorgolewski, Komisar et Nasr 2011) Bringing back agriculture within the city walls, at close proximity to homes and businesses would awaken consciousness and give people the opportunity to get involved or at least curious, leading to consumption of more accessible and better fruits and vegetables in terms of safety, taste, freshness and nutritional value.

Moreover, a substantial proportion of existing urban farms are built expressly to spread social and educational values, (Specht , et al. 2014) either by being attached to another function (like a school, a university, a restaurant, a market…) or by welcoming pupils or simply the public in the farm for didactic activities. Reconnecting children (and adults too) with the process of growing food will empower them to make responsible choices about their impact on the environment, (Specht, et al. 2014) and not only about food but also about energy and water economy. (Cerón-Palma, et al. 2012)

One step further toward education through agriculture would be to integrate it into school syllabi. A survey in 1998 in England showed that 70% of teachers believed that environmental education should be mandatory. (MORI 1998) And even though agricultural activities such as growing food and taking care of farm animals are rare, the schools that established such projects have noted significant benefits like the improvement of school morale, increased awareness of health and environmental issues, the involvement of the parents and guardians in school life. (Garnett, Urban agriculture in London: Rethinking our food economy 2000) Even the behaviour of the students seems to get better: in a pleasant environment, pupils tend to respect it more because their participation in a garden makes them feel responsible, as if it was their own. They learn social skills like sharing and cooperating which reduce vandalism and bullying. Moreover, incorporating vegetable gardens in the school could allow teachers to tackle cross-curricular subjects like maths (by planning the plot, measuring the area), science (by analysing soil structure, pollution, biodiversity), geography (learning the vegetables' origins, social and economic issues about food), history (with the food historical impact), physical education, not to mention experiencing and exploring the nature which is major factor in child development. (Garnett, Growing food in cities: A report to highlight and promote the benefits of urban agriculture in the UK 1996)

In Montreal in 2012, where UA is already quite developed, during a public consultation it was noticed that people wished UA to be tackled already in primary school for similar reasons to those in England. Another desire was to release funds to provide gardener training for adults too, beginners or experts to carry on with the maintenance of the existing (and the future) UA. (Etat de l'agriculture urbaine à Montréal 2012) Nevertheless, Montreal as previously said, is advanced in this area in comparison with many other countries, and in order to develop more horticultural training, jobs opportunities must be created. Indeed, without start-up or lands such investment would be certainly innovative and rewarding but unfortunately quite useless. (Garnett, Urban agriculture in London: Rethinking our food economy 2000)

3. Health

In 2016, the World Health Organisation (the WHO) published a report about the influence of green spaces in cities. According to this report, the presence alone of greenery can already promote mental health, reduce cardiovascular morbidity, obesity, diabetes and improve pregnancy outcomes thanks to a reduction in stress, noise and exposure to polluted air and psychological relaxation. (WHO 2016) This proximity invites people to question their food production resulting in a tendency to consume more local vegetables and fruits when they have a direct connection to them. (Frank 2011)

Today in Belgium the AFSCA has announced that 80% of fruit and 60% of vegetables contain pesticide residue. Now, because UA tends to establish itself in the interstitial spaces of the cities, those small areas do not need large quantities of pesticides or fertilizers like industrial agriculture, and even better, UA is mainly organic, using none at all. The reduction of chemicals on food and on soils is important to avoid the impoverishment of the soil and the absorption by humans or livestock leading to health problems or epidemics like the BSE (Bovine spongiform encephalopathy) crisis in the UK in the nineties. (Howe et Wheeler 1998) The drawback of the dense and small-scale aspect of UA is that food-borne diseases spread fast, therefore serious management and control should be put in place. (Specht, et al. 2014)

The major health concern about UA is the impact of the city pollution on the food produced. For soil-grown vegetables, there is a risk of lead and cadmium presence, therefore a minimum distance from the roads is recommended. (Säumel, et al. 2012) In Montreal, to remedy this problem, the city (la Direction de la santé publique) offers a service of soil contamination evaluation and takes action if necessary to clean or close the site. (Etat de l'agriculture urbaine à Montréal 2012) The influence of polluted air might also be a problem but to date, no study has proved their exact impact. One thing is for sure, the greenhouses where the air is controlled have nothing to fear. The last way of pollution transmission is through water irrigation. In Europe, using rainwater has low risks, but for developing countries where they use wastewater due to water scarcity, it is very important to establish strict controls. (IWMI 2006)

At first, even if the purpose of UA is not to feed the entire population of a city, it can contribute to greatly improve their diet. Food related health problems are the cause of many illnesses, whether due to unbalanced diet or excessive intake. While the World Health Organisation advocates a consumption of 400g of fruit and vegetables a day (for an adult), the reality is far from it. In Europe in 2016, Eurostast published that only 14.1% of the population were eating their quota, and 12.7% in Belgium, while more than a third of the EU do not eat any on a daily basis (even though on that point, Belgium is the leader with only 16.5%). (Eurostat 2016) Also, rich people eat better than poor people and the statistics of mortality due to their diet (obesity, heart disease, diabetes) is lower. (Bardsley et Morgan 1996) The richest 20% eat 20% more fresh green vegetables, 70% more fresh fruit, 72% more fish and over 400% more fruit juice than do the poorest 20%. (Garnett, Growing food in cities: A report to highlight and promote the benefits of urban agriculture in the UK 1996) The problem is even more serious for those housed in so called “food deserts” where no shops sell fresh food. Growing food in cities is an asset for all social classes, indeed in a study in the USA, we noticed that advantaged people (based on income, occupation or education) are eager to participate in UA for reasons of quality (fresh and organic food) in order to get food and health safety, while the lower classes emphasized food availability and affordability. (Hinrichs et Kremer 2002)

Table 2: Reasons for participation in CSA by componenets of class

	Food Quality Reasons	Support/Belief Reasons	Food Availability and Affordability Reasons
All Respondents (n = 41)	36.6	34.1	29.3
Household Income			
Less than $25,000 per year (n = 13)	23.1	23.1	53.8
$25,000 to $50,000 per year (n = 11)	36.4	45.4	18.2
More than $50,000 per year (n = 17)	47.1	35.3	17.6
Highest Household Occupation			
Not Employed/Retired (n = 6)	0.0	16.7	83.3
Employed Other than Managerial & Professional Occupations (n = 12)	33.3	33.3	33.3
Managerial & Professional Specialty Occupations (n = 23)	47.8	39.1	13.1
Highest Level of Household Education			
Up to an Associate Degree/Vocational Degree (n = 10)	30.0	10.0	60.0
Bachelor's Degree (n = 8)	12.5	75.0	12.5
Post-Graduate Degree (n = 23)	47.8	30.4	21.8

The last reason why UA can improve the health of the involved people is with physical exercise. Gardening is a way of practising gentle and regular exercise and while the widespread belief is that only vigorous physical activity is beneficial, health professionals argue that moderate exercise is as valuable and would probably be attractive to more people. Moreover, exercise activities require often time, money and motivation and they are not always available to all. To couple a productive hobby like growing food with physical activity would lead to a healthier society.

4. Economic

Urban agriculture even though globally promising for all the above reasons, is still risky for investors. Indeed, initial investment especially for technological installations like integrated greenhouses or soilless systems like hydroponics or aquaponics on a large scale require high infrastructures costs. (Cerón-Palma, et al. 2012) As nature takes its time, the repayment time is long. For example, in orchards, fruit trees will need a few years before coming into full production, but the food output is likely to increase considerably over time.

Nevertheless, there are ways of making UA investments profitable. In the case of an integrated infrastructures, savings can be made on energy and in resources (like water, waste and clean air) (Sanyé-Mengual, Llorach-Masana, et al. 2015) through metabolic flows. Moreover, by adding such installations in or on the building, its property value on the market is increased. (Frank 2011) A warning however should be made about the effect of gentrification. UA is potentially of great benefit to an underprivileged neighbourhood, but it is important to realise that the costs of construction involved could in fact detract from the proposed benefit which have such a major importance.

One way for the entrepreneurs to reduce their investment could be by teaming up with a business engaged in rooftop farming in order to be granted finance and later enjoy the benefits of free maintenance of the roof, stormwater management and energy savings, not to mention a better image for the company (Thomaier, et al. 2014) that is not negligible in this period of environmental conscious wakening. This is moreover interesting for commercial buildings in the food sector, like restaurants, supermarkets, or again for buildings which provide catering, like museums, sport centres, schools and universities that could optimize their build surface by retrofitting their rooftop.

Naturally the economic side of urban agriculture is not only about the profit made by the investors. By creating a new field of expertise, UA is also a boost for the local economy. By moving all those jobs and commercial infrastructure back into our cities, when for the moment they even are situated outside our country would create hundreds of jobs. Moreover, these jobs would not be relocatable, thus helping to reduce the unemployment rate of Brussels residents. It is also a training accessible to all and which has many advantages for those who practice it as explained above. (Verdonck, et al. 2012)

5. Environmental

Today, agriculture for alimentation is both a responsible activity and also a victim of climate change. In Belgium, agricultural production is responsible for 10% of greenhouse gas emissions and food represents 25% of a household's environmental impacts. (Ronsmans, Stratégie Good Food : Vers un système alimentaire durable en région de Bruxelles-Capitale 2015) Worldwide, deforestation (in order to create new agricultural land) and agriculture account for one third of greenhouse gas emissions, according to FAO. (Organisation des Nations Unies pour l'alimentation et l'agriculture (FAO) 2008) Since the Second World War agriculture has become more and more dependent on fossil fuels, not without reason. There are several crucial points to note:

- Mechanization of ploughing tools, where tractors replace plough animals. Then a generalization of this mechanization to work on ever larger fields, but of only one type of crop. Monoculture was born.
- An increase in synthetic pesticides needed to maintain monocultures, which are mostly from the petrochemical industry. For example, Belgium is one of the EU states that uses the most pesticides per unit area. (Bruxelles Environnement 2015)
- The replacement of high cost natural fertilizers, to the benefit of synthetic fertilizers, which are expensive in terms of natural gas.
- With the democratization of transport, the distances travelled by food at when it leaves the field have exploded.
- Product processing, packaging and waste treatment at the end of the cycle.

For all these reasons, the food industry is now complementary to the oil industry, as clearly shown on this graph of the FAO.

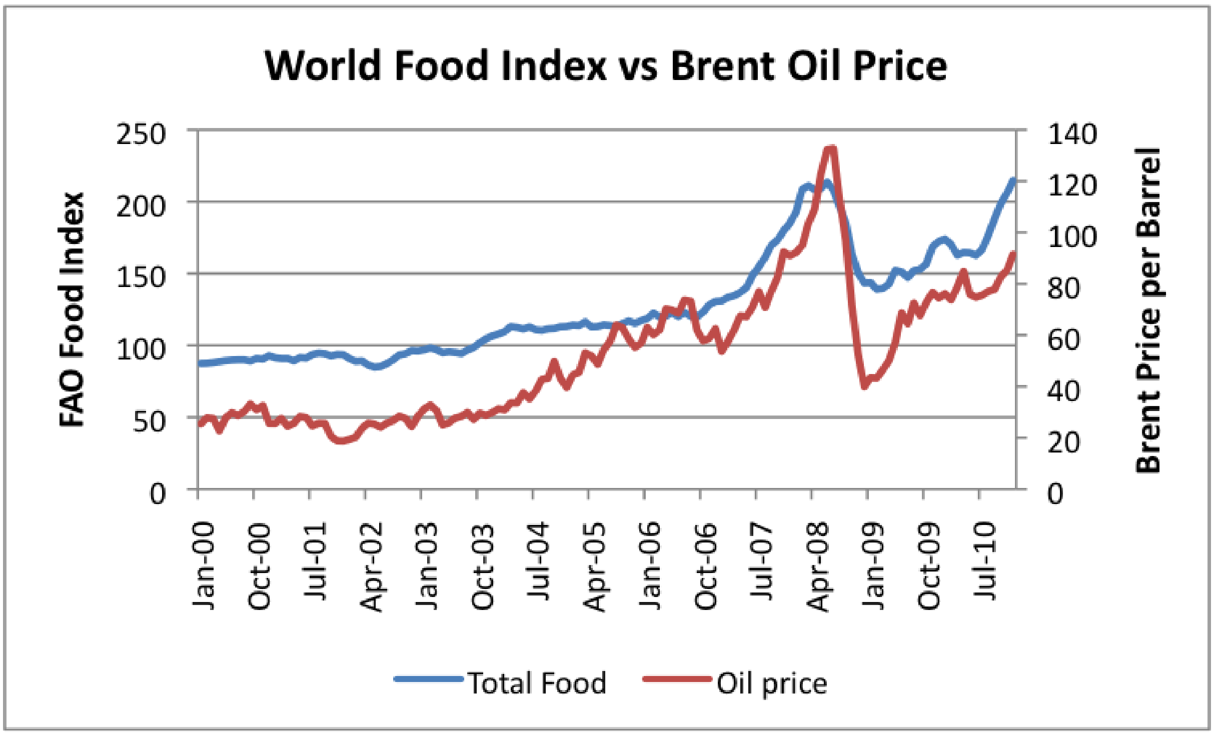


Figure 5: United Nations Food and Agriculture Organization (FAO), March 2011

Despite its success, monoculture has its downside. Indeed, the diversity of varieties is reduced, creating new areas unsuited to the ecosystems. These same ecosystems are being attacked by new generation pesticides. As for the increasing use of synthetic fertilizers, it reduces the carbon content of soils and promotes their erosion. (Verdonck, et al. 2012) In the end, the GIEC predicts that climate change will be responsible for increasingly violent and frequent droughts, floods, pest invasions and pathogens that will make farming more and more difficult. The IAASTD (International Assessment of Agricultural Knowledge, Science and Technology for Development) co-produced a report with the FAO stating that industrial agriculture could not adequately feed humanity in the long term, given its impact on climate, resource availability and dependence on fossil fuels.

In cities, the consequences of the relocation of crops to larger and further areas and the democratization of transport are reflected in the minimization of stocks. London, for example, imports 80% of its food from abroad, but the figure drops to 40% for the whole country. After a fuel carrier strike in 2000 that caused a food crisis, the government ordered studies to be launched. For Brussels, few studies have looked at the quantity and origin of imported food, but the few results available predict less than a week of autonomy. (Verdonck, et al. 2012)It is therefore complicated but essential to assess the resilience of the system in the face of possible obstacles to the transport or distribution of food.

Integrating a significant proportion of the city's food needs into the city could already relieve it of a significant percentage of heavy goods vehicles. Indeed, the reduction of food miles is an element on which the RBC, which has only a few industries, could reduce its CO_2 impact. Research on BIGHs in Barcelona by (Sanyé-Mengual, Oliver-Solà, et al. 2014)showed that 1kg of tomatoes produced intramuros could save 441g of CO_2 and 12MJ of energy, mainly due to the fact that these tomatoes saved the 900km journey usually covered. It has also proven that consuming seasonal fruits and vegetables can reduce greenhouse gas emissions along the food chain by 20%. (Bruxelles Environnement 2015)

Another problem is that of the Urban Island Heat Effect (UIHE) created by the use of dark colours on roads or buildings that absorb much more incident sun energy. These materials have a low albedo index. During scorching heat, the temperature in the city can be 3 to 7 degrees higher than in the outskirts, thereby increasing the mortality rate during heat waves. (Verdonck, et al. 2012) Replacing those flat roofs' waterproofing membrane by open air gardens or greenhouses would bring down the albedo index average of the city.

As for water, the UN and the Intergovernmental Panel on Climate Change (IPCC) forecasts are quite pessimistic. First of all, it is important to know that only 2.5% of the water on earth is fresh. In these 2.5%, 70% is used for agriculture. And by 2030, as climate change has done its job, access to fresh water will become more and more difficult, due to its scarcity, but also due to the planet's demographic growth. In short, if we keep the same agricultural system in place, water needs will be 40% higher than the possible supply in 2030. This situation will affect even more violently 30% of the population, mainly in developing countries where water shortages will reach up to 50%. (2030 Water Resources Group (2030 WRG) 2009) It is therefore urgent to find a new agricultural model that uses less water. Some answers can already be found in techniques such as permaculture or hydroponics and aquaponics. It is also important to value rainwater, and not to let it go down the drain, but to give it a use because it is free and for the moment, still abundant, so we must take advantage of it.

Concerning the BIGH, it is the energy savings made by saving resources and exploiting the building's metabolism that are of particular interest. The recovery of water and organic waste would cut the waste management cycle short, reducing the energy expended and benefiting UA. As for the recovery and use of heat and CO_2, these are flows that would simply be lost, and which will be beneficial both to plants and to the inhabitants of the buildings. However, although technology already has the tools to recover water, CO_2, waste heat or organic waste treatment, the implementation of these synergistic applications needs to be further studied. Overall, the case studies seem to lack technical details. This lack of precision seems to come from activists and researchers who seem to assume something inherent about the local scale. (Specht, et al. 2014)The second part of this paper focuses exclusively on the different flows and will look in more detail at their potential.

6. Stakes in Brussels

For a few years now in Brussels, an exodus of the middle and the affluent class to the outskirts has been identified. (Verdonck, et al. 2012) This tends to be problematic due to the reduction of the social mix and therefore of the contributory population. To reverse the trend, we must largely improve the quality of life inside the city. Around the year 2060, this exodus will make way for a demographic boom (35%), results of high natality rate and the continuous international immigration. Still nowadays, we already have consequence of this exodus. Indeed, the average income of the population is the lowest of the three Belgian regions creating problems regarding access to food supply, particularly for the very poor. The employment rate is also the lowest in Belgium, with reference mostly to young and lower skilled people. (Statbel 2018)

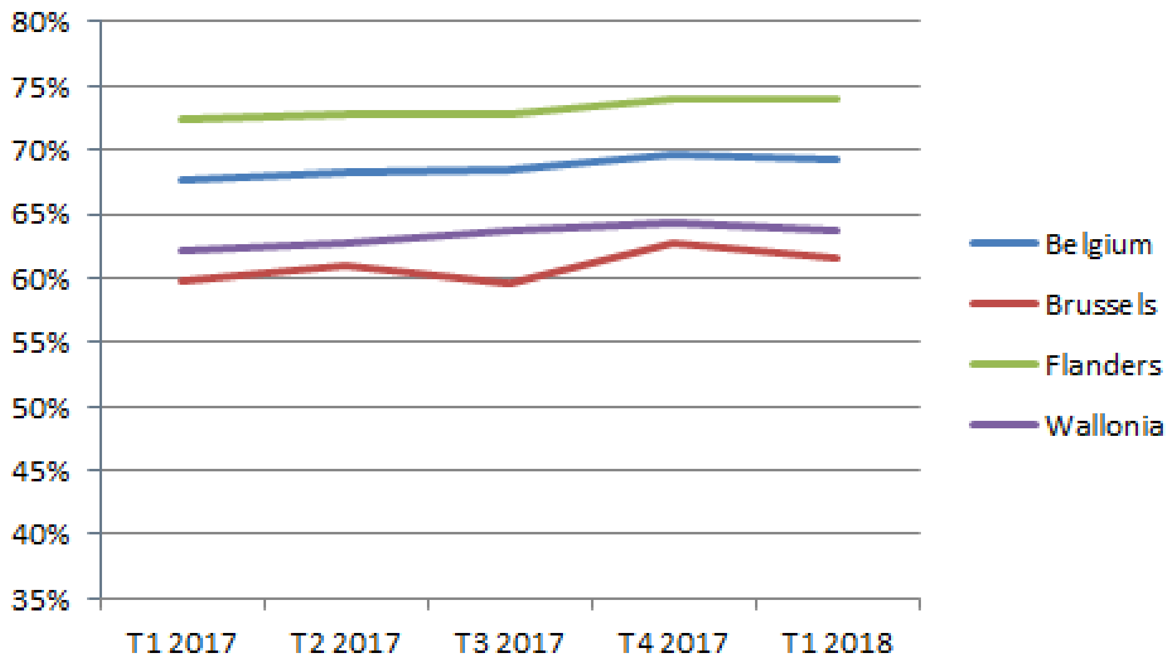


Figure 6: Employment rate in Belgium 2017-2018 (Statbel 2018)

Everyday in Brussels, there are 1 150 000 residents and 300 000 commuters that must be fed. (Radermaker et Degraeve 2017) As food is currently produced outside the city, hundreds of lorries enter the city daily, aggravating the traffic jams which are already dense and the pollution. (see Appendix: Traffic flow map and consequences in Brussels) Freight traffic by road (trucks and vans) is estimated to account for 14% of congestion and 30% of urban transport-related greenhouse gas emissions. (Région Bruxelles Capitale 2018) In addition, the food trucks that arrive are rarely full, and leave almost always empty. (Frijters, et al. 2017)

Brussels is a city of 161 km² with 49% of green spaces, but despite the parks, gardens, cemeteries, etc; it is easy to lose contact with nature. To remedy this problem, the region together with Brussels Environment propose campaigns to reconnect with mother nature (for example in 2017, the program “Nature in the city”). In 2016, among other issues, this regional group launched the program Goodfood aiming to reach **30% of food self-sufficiency for 2035**. More precisely, the objective is to produce 30% of fruit and vegetables in the city and within a 10km radius with the support of peri-urban agriculture. Beyond production itself, their goal is to enhance biodiversity, reduce traffic congestion, create jobs, advocate organic food and an improvement in the quality of life. This strategy is also to allow the population to get access to healthy food. Today, at the start of the exodus already more than 32 000 people depend on food aid while 11% of the Brussels population is obese. (Henrion, Mantell et Van Bambeke 2015) Still in the same direction, the goodfood strategy has already started to train 70 canteen staff to cook differently, in a more sustainable way; this represents 60 000 meals a day, or 15% of the 44% of the students who eat daily inschool canteens. (Ronsmans, Good Food à la cantine : Service, outils et accompagnements pour des repas plus durables à l'école et à la crèche 2017)

Another item on the Good Food agenda is the **reduction of food waste by 30% by 2020**. Among Brussels households, the white bin is composed of 12% of food waste, and half of it is food that has been started, a quarter is the leftovers from meals and the last quarter is discarded while untouched. Yet, this is a concrete issue as each year, waste represents over 660 000 tons of food and would account for a loss of 1.4 billion euro in Belgium.

Recently, orange bags for organic waste have been created and offered to residents (they are not yet mandatory). This waste is collected and sent to a biomethanisation plant. This seems at first sight to be an improvement, but when you look more closely, you discover that the waste is sent 123km from the capital, in trucks that then make their way back empty. It is therefore a small improvement but which hides an absurdity in this system where a step in the food chain is missing. (Hick et Maréchal 2018)

In 50 years, urbanization has spread in the capital. Even the natural overflow areas of rivers are covered with construction. At the same time, soil waterproofing - mainly due to road surfaces - throughout the Region has doubled from 18% to 37%... This causes two problems. First the overflow management in case of major rains. The sewer system hasn't been adapted since the massive waterproofing of the city. The result: frequent flooding during heavy thunderstorms. In most of the Brussels Region, there is neither room for new sewers nor for open ponds, so expensive storm basins are constructed all over the territory. (Vivaqua 2012) The second problem is the Urban Island Heat Effect (UIHE) created by the use of materials with a low albedo index. For example, 25% of summer warming observed in Uccle between 1960 and 1999 would be explained rather by the UIHE linked to the constant urbanisation than to the regional climate change. The installation of greenhouses on top of buildings could solve those problems linked to the waterproofing of the city surfaces. Indeed, simultaneously a rainwater harvesting system could be placed. When this practice is common, and a large area of roofs are occupied by greenhouses, rain falling on them will no longer be sent to the sewers but will be recovered to be injected into the metabolism of the house or into the greenhouse for watering. Concerning the UIHE, the replacement of the black surface of the sealing membrane by a reflective material like glass would reduce the heat captured by the inertia of the building.

Brussels Environment commissioned studies in 2016 on the desires of and opportunities offered to the inhabitants of Brussels to integrate agriculture at home, as well as studies on consumer choice. What comes out of it is that 17% already produce food, of which 10% cultivate vegetables. 40% of the people in the study justify their non-production as due to lack of space. Yet another study shows that 85% of the inhabitants of Bx have minimum space to grow plants. (Ronsmans, Stratégie Good Food : Vers un système alimentaire durable en région de Bruxelles-Capitale 2015) This difference between the studies may be due to people's underestimation of the space available to start UA, while the study took into account even the smallest balcony as they consider that 1m² could already give 10kg of vegetables a year.

Another objective of the GoodFood plan is that 30% of Brussels residents produce part of their food. Of the 17% who already produce, only the 10% who have fruits and vegetables are considered. However, production criteria (quantity or surface area) have not been defined. An employee of Brussels Environment was able to assure on the fact that it was more than just a jar of aromatic herbs, but nothing more. It is therefore complicated to estimate the challenges of this objective.

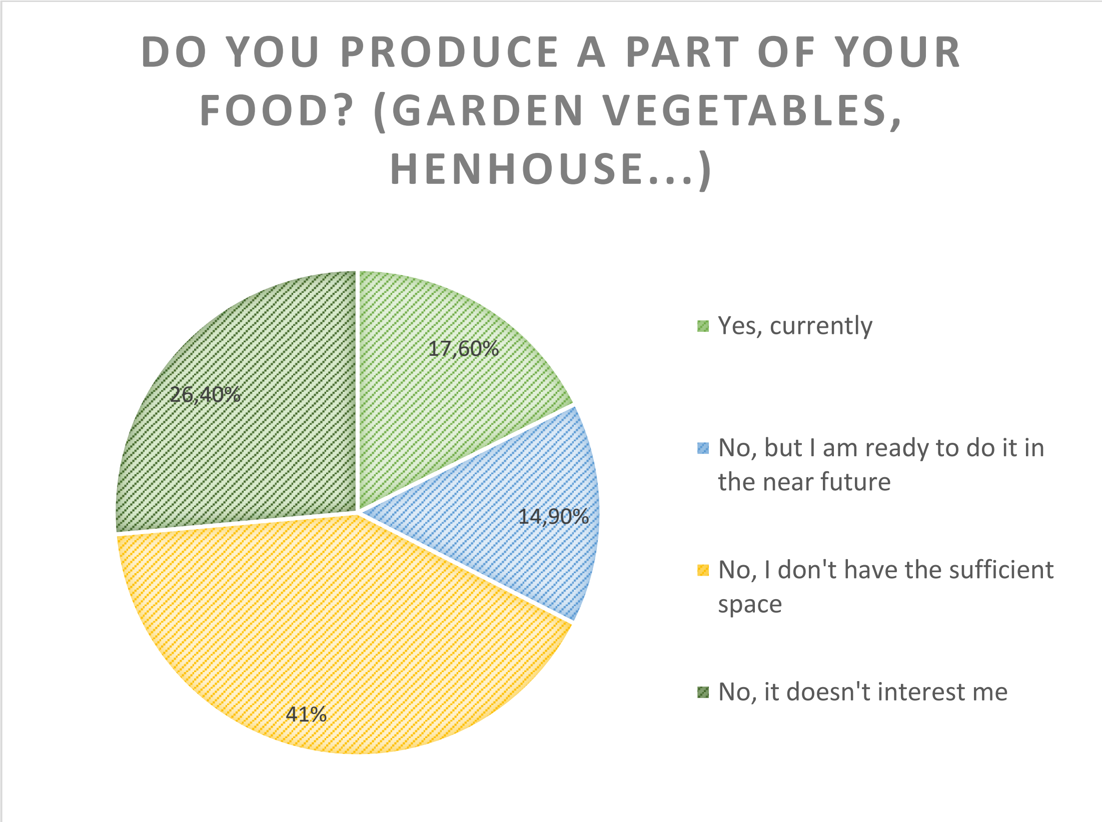


Figure 7 Citizen Production in Brussels (Radermaker et Degraeve 2017)

According to the FAO, organic farming generates an average of 30% more jobs that can't be relocated and at all levels of the sector (production, distribution, HoReCa, waste treatment or training). (Henrion, Mantell et Van Bambeke 2015)In terms of employment, the BCR has a lot to gain. Indeed, for the moment sustainable agriculture already creates more than 2500 jobs in the capital. Compared to other sectors, this industry continued to grow during crisis and also employs a large proportion of workers, workers under 25 and low-skilled workers. Research commissioned by the Brussels Institute of environment management (Institut Bruxellois pour la Gestion de l'Environnement) studied the potential of creating around 7700 new jobs in the capital in a context of UA development. No longer believing in the myth of industrial agriculture as a food source for humanity, the IAASTD (International Assessment of Agricultural Knowledge, Science and Technology for Development) in co-production with FAO is now rejecting it because of its impact on climate, resource availability and dependence on fossil fuels. According to this paper, the installation of a type of market gardening system that promotes manual labour, respectful of the environment could produce only 6000 jobs. This urban production could generate itself a thousand positions in the transformation, distribution and HoReCa sectors. Last but not least in the recycling chain, waste management could generate 200 jobs.

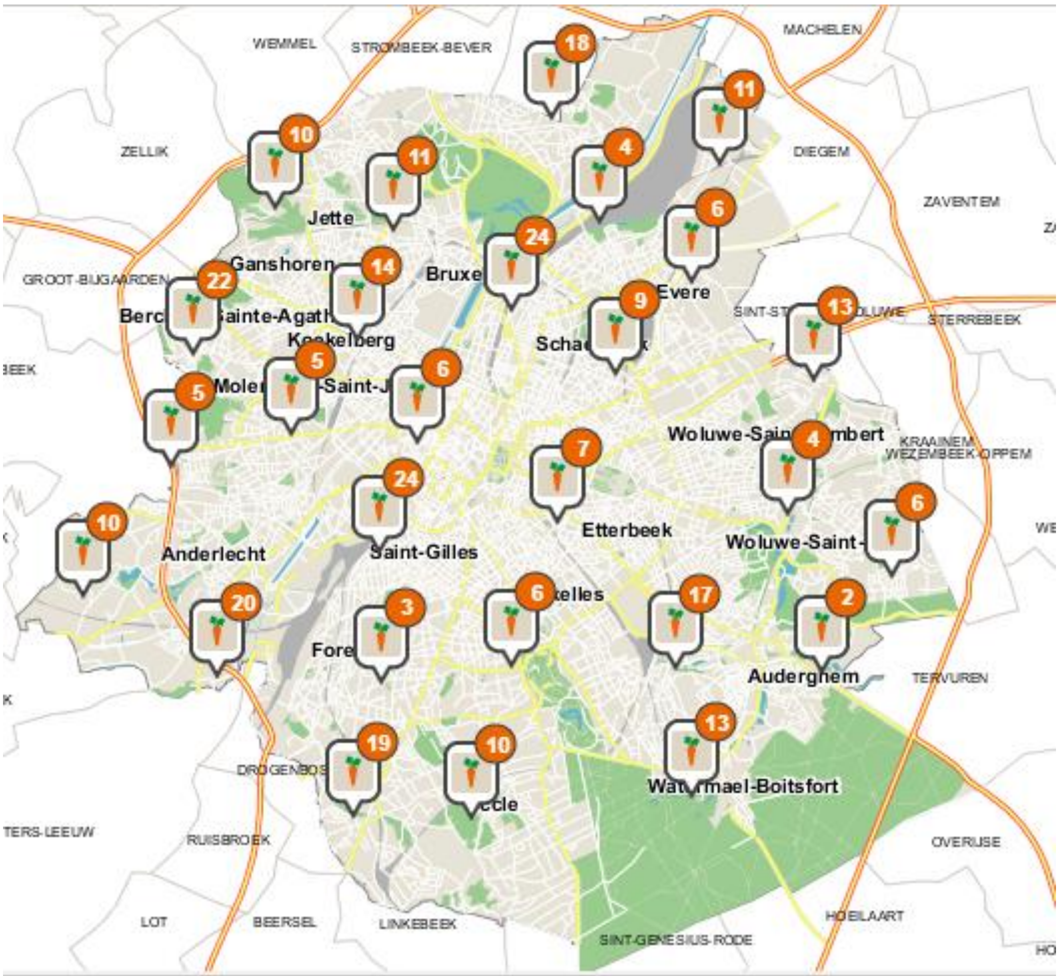


Figure 8:Brussels' 293 urban vegetable gardens (GoodFood 2018)

2. Potential of building integrated greenhouse

Building an integrated green house, means that the green house is fully integrated to the building, it is not considered as a supplementary annex to the building, but is totally a part of it. It is so because the flux of energy and resources are pooled.

1. Water

Safe water is probably the most precious resource for UA and will be the most precious resource on the planet in a couple of decades according to global warming experts. (Schewe, et al. 2013) This is the reason why Rainwater Harvesting (RWH) is crucial when installing an UA system. Moreover, studies clearly state that it is economically and environmentally beneficial to collect water. On a city scale RWH is of interest because any roof surface collecting rainwater represents litres of water that will not end up in sewers or storm ponds. In 1995, Verbanck estimated that number around 43% of rainwater. (see Figure 9: Bilan de l'eau en Région de Bruxelles-Capitale) With 11% of its population collecting water in 2001, Brussels is lagging behind two other regions (with 31% for Wallonia and 43% for Flanders) (Davesne, et al. 2015)

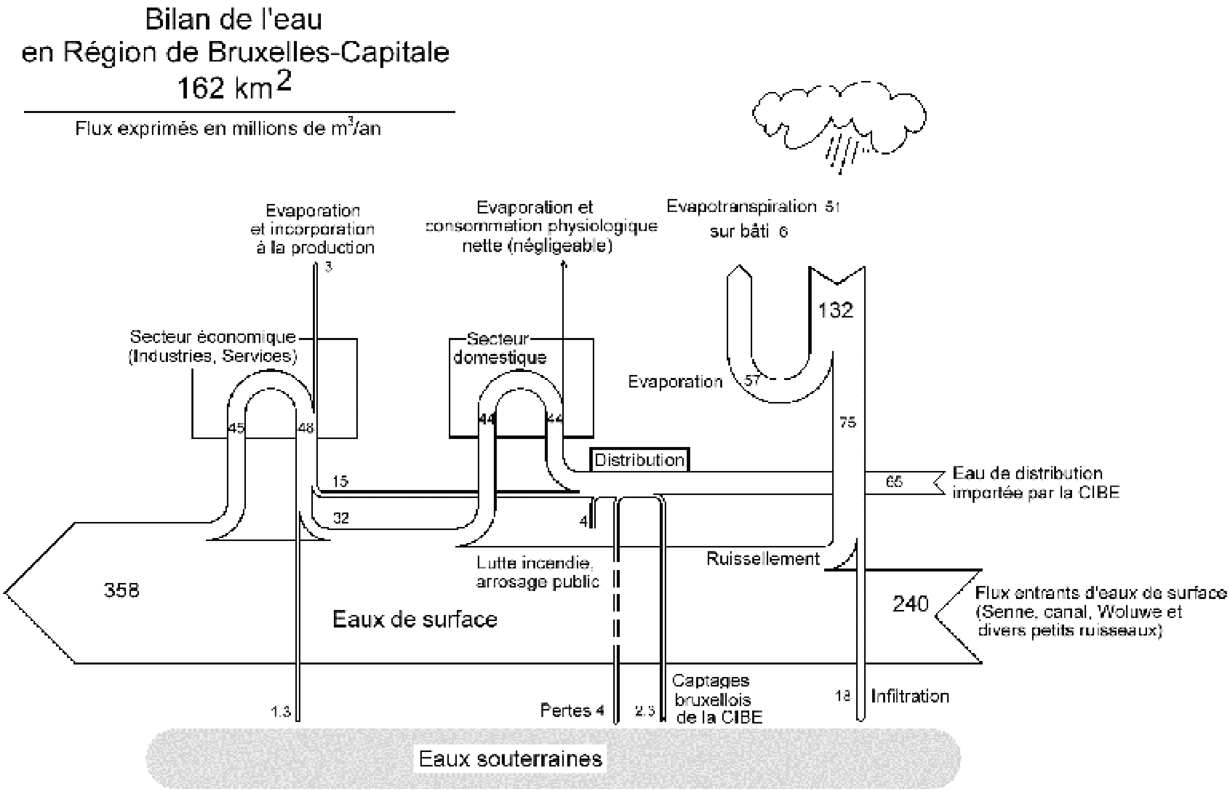


Figure 9: Bilan de l'eau en Région de Bruxelles-Capitale

Now at the scale of a house, RWH becomes attractive by offering a first step toward autonomy. With a mean precipitation of 800mm/year and an average of 200 days of rain a year in Belgium there is enough to find a new use for this water before ending up in the drains as dirty water. (Institut Royal Météorologique de Belgique, Brouyaux et Tricot 2006). This represents potentially 80000 litres of water accessible and collectable for a building with a roof surface of only 100m. According to a student's thesis report on water management in Brussels, for such a surface area, a 4 cubic metre cistern would have to be installed. (Segaert 2016)If rain water is so important for UA it is because watering the plant requires indeed a clean water, but also filled with nutrients. The water that runs in the system is like dead water, filtered and cleared with chlorine, therefore unusable for watering plants. (Beckers 2018) Moreover, RWH is the best simple way to assure the Cleanliness of the water against the use of improperly treated water or for example polluted sources for the irrigating system. (Specht, et al. 2014) In the case of a hydroponic or an aquaponic greenhouse, the amount of wather needed is 75% reduced. (Thomaier, et al. 2014) In the case of the RTG-Lab at the university of Barcelona, one of the first experimental integrated buildings, the rainwater could satisfy 450% of the crops needs. (Sanyé-Mengual, Oliver-Solà, et al. 2014) In this Spanish greenhouse, the different integrated fluxes are monodirectional, except for the water, that can flow from the building to the greenhouse, and also from the greenhouse to the building. With such a surplus of water, it makes sense to reinject the water in another function to optimize its use. The simplest way to do this is in the toilets, everyone has one, and it is not necessary to carry out heavy water quality tests, even if some smaller ones are still required. Moreover, flushing represents over a third of the daily water consumption that is evaluated at 96l/day/capita. (Vivaqua 2012)

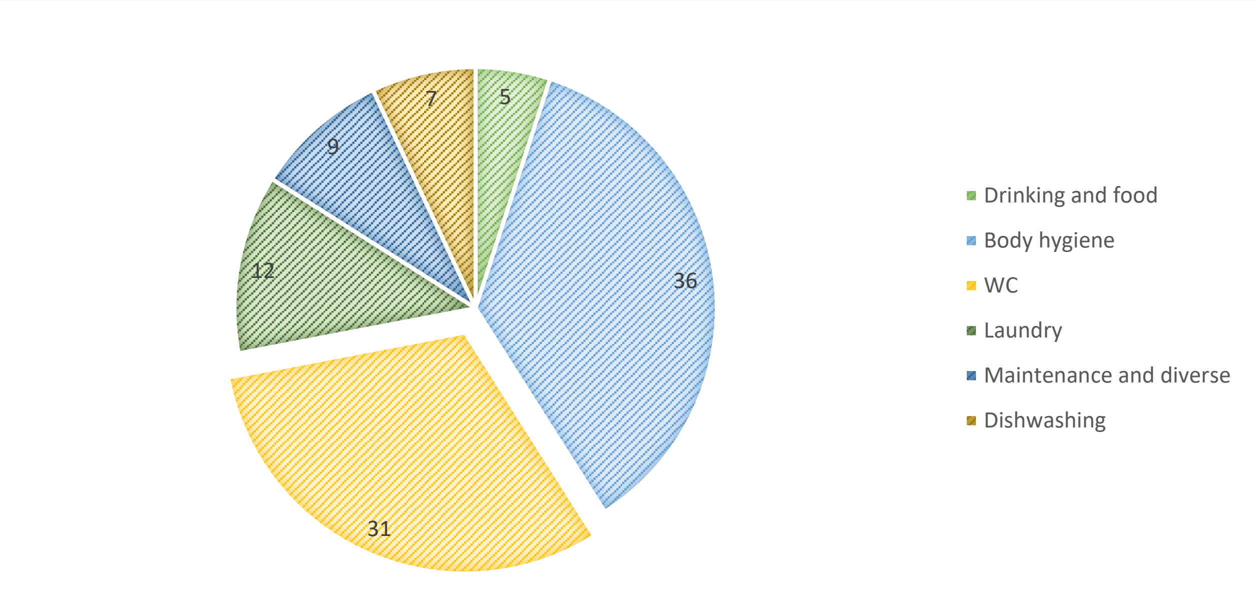


Figure 10: Domestic uses of distribution water in Belgium by households (2008) (Belgaqua 2008)

2. Heating, Ventilating and air conditioning

Sometimes an integrated building is called "energy integrated" due to the particularly interesting links created by the symbiosis of a building and a greenhouse. Indeed, the principle is to take advantages from the thermal difference of the two parts and to improve the thermal properties of both spaces. This procedure allows both to improve the climatic conditions in the greenhouse and thus to increase the crop yield, as well as the thermal comfort inside the building below. In the research-oriented RTF of Barcelona, the heat flux is monodirectional from the building to the greenhouse. (see Figure 11: Energy exchange between the greenhouse and the building of the RTG-Lab) The heat from offices and laboratories regulates the greenhouse temperature for cooling and heating to keep it between 15 and 30°C. If thermal conditions are optimized to increase yield, exceeding this range at the top or bottom can lead to large losses of plants.

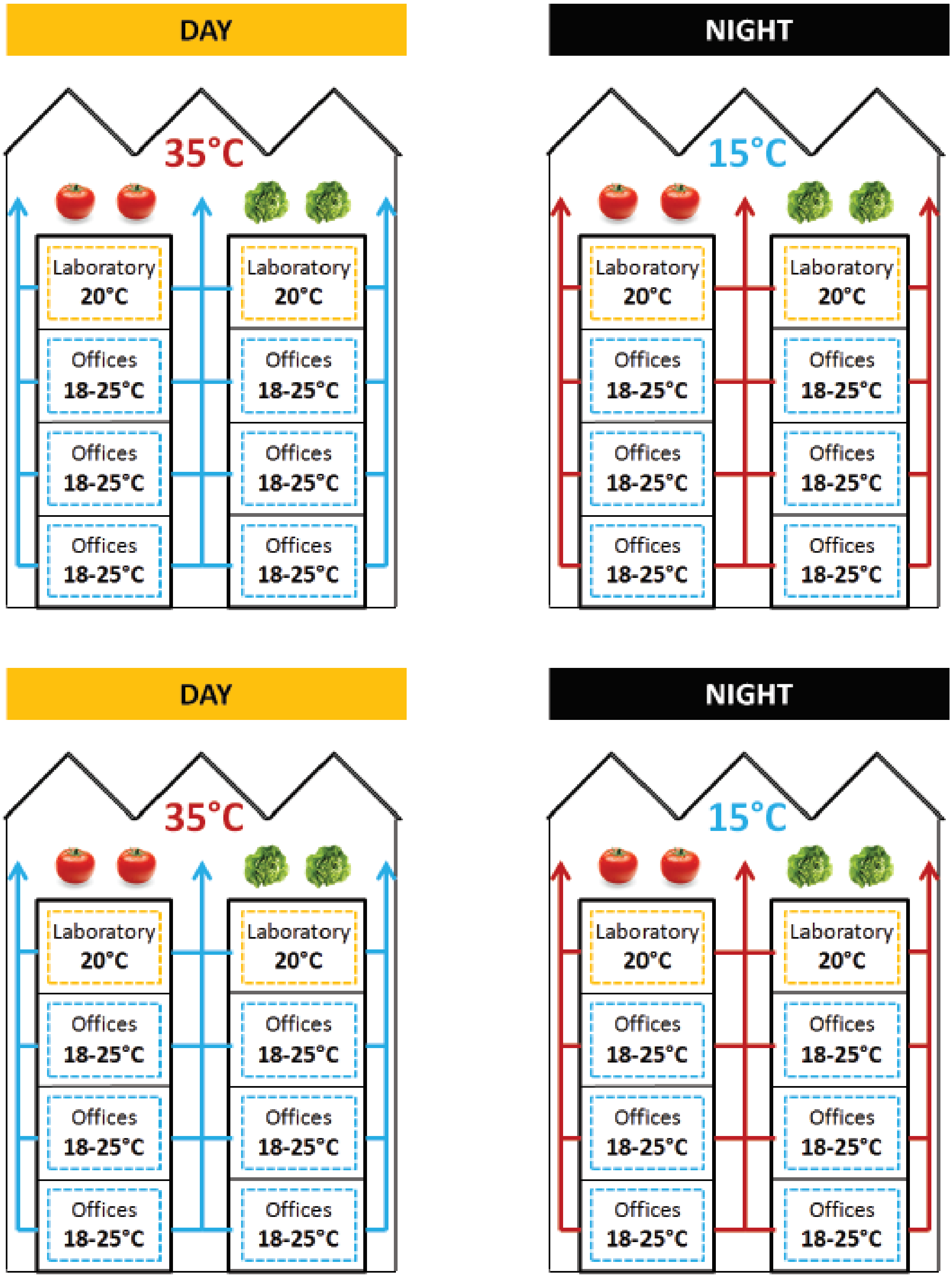


Figure 11: Energy exchange between the greenhouse and the building of the RTG-Lab (Sanyé-Mengual, Llorach-Masana, et al. 2015)

In the near future, Ceron says the BIGHs will be able to exchange air with the building below, providing it with warm air to reduce heating energy for example during sunny winter days. (Cerón-Palma, et al. 2012) According to Caplow and Nelkin, it would also be possible to cool down the greenhouse and the building thanks to the use of evaporative cooling. Evaporative cooling is a system composed of a cellulose pad, water supply pipe, a gutter to collect excess water, a sump tank, a pump, piping and a control box. During hot days, hot air will enter the greenhouse through the evaporative cooling pad, the energy carried will transform the humidity of the wet pad into water vapour, thus increasing the relative humidity (RH) of the greenhouse, which is very beneficial for the plants, and lowering the indoor temperature up to 10°C below the outside temperature. With the air moving throughout the greenhouse it will gradually warm up thanks to the sun, at the same time losing some of its moisture. Now the air is in a good condition to be sent into the occupied building through pumps that will replace the exhaust fans represented on Figure 13: Pad-fan evaporative cooling in greenhouse. .

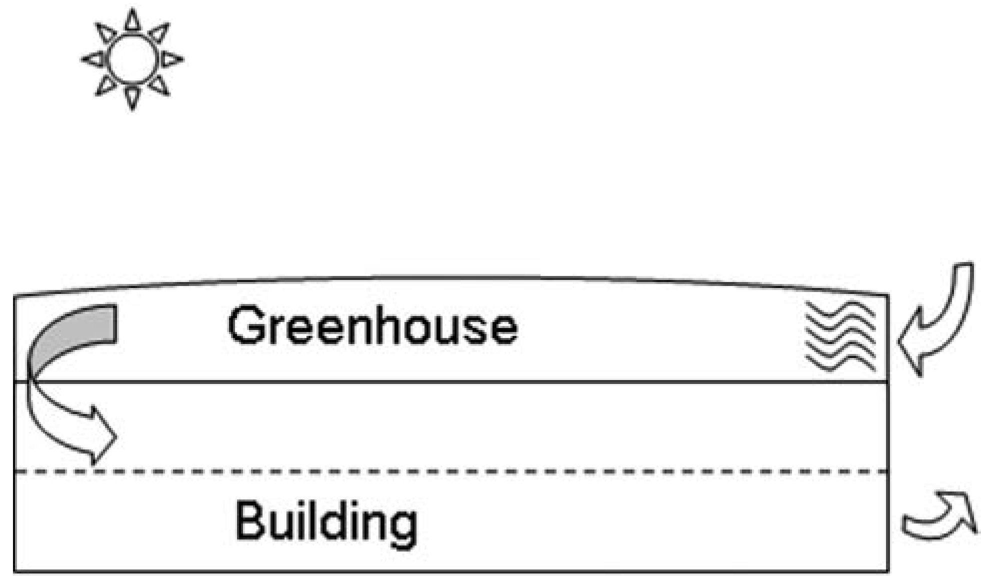


Figure 12: Schematic of greenhouse with evaporative cooling mounted on the roof of a two-story building. In typical summer operation, air: (1) enters the evaporative pad wall (top right) with high T and low RH; (2) becomes cool and saturated moving through the pad wall; (3) passes through the sunny greenhouse raising T and lowering RH to appropriate indoor levels; (4) moves into the building at a high flow rate; (5) is exhausted (Caplow et Nelkin 2007)

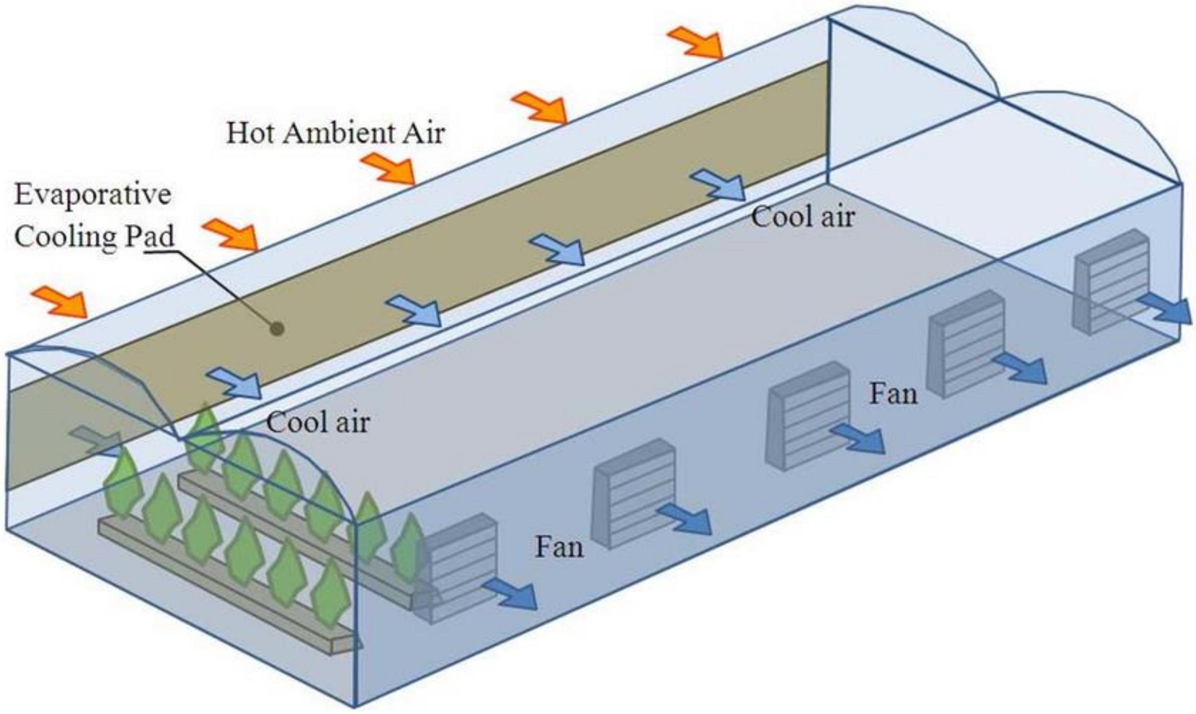


Figure 13: Pad-fan evaporative cooling in greenhouse. (Franco, Valera et Pena 2014)

Research funded by the UK Energy Research Council (UKERC) and conducted as part of the E-Futures DTC of the University of Sheffield, studied the energy needs to heat a building and a greenhouse when they are stand-alone structures (blue line) and when they are integrated (red line)? As you can see in the

Appendix: Comparison of heating needs for BIGH and stand-alone structures, the greatest savings in heating energy are made in the case of a house with little insulation, up to 41% against 13% for a well insulated building. This is due to the fact that most of the energy gained, is the one that escapes from the roofs. The greenhouse acts as a buffer between the inside and the outside, as an additional layer of insulation. The green roofs also offer insulation to the roof, even a little better than the greenhouse, nevertheless the advantage of BIGH is to be able to circulate the heat according to need. This information allows us to realize that surface recuperation, especially for old buildings with a lot of roof loss, is a definite advantage, even an outright solution. This reasoning should be taken a little further, by considering buildings whose function can sometimes generate a lot of waste heat.For example in New-York, Eli Zabar's Vinegar Factory's rooftop greenhouse uses the heat from a bakery. (Specht , et al. 2014) The idea here is to attach a greenhouse to improve the overall quality of construction,so it loses some of its interest when the building is already completely autonomous On the other hand, for more recent buildings, such as those built since 2015 in the Brussels region and which must be passive, the savings are reduced because the roof is already very well insulated and therefore does not allow much exchange.

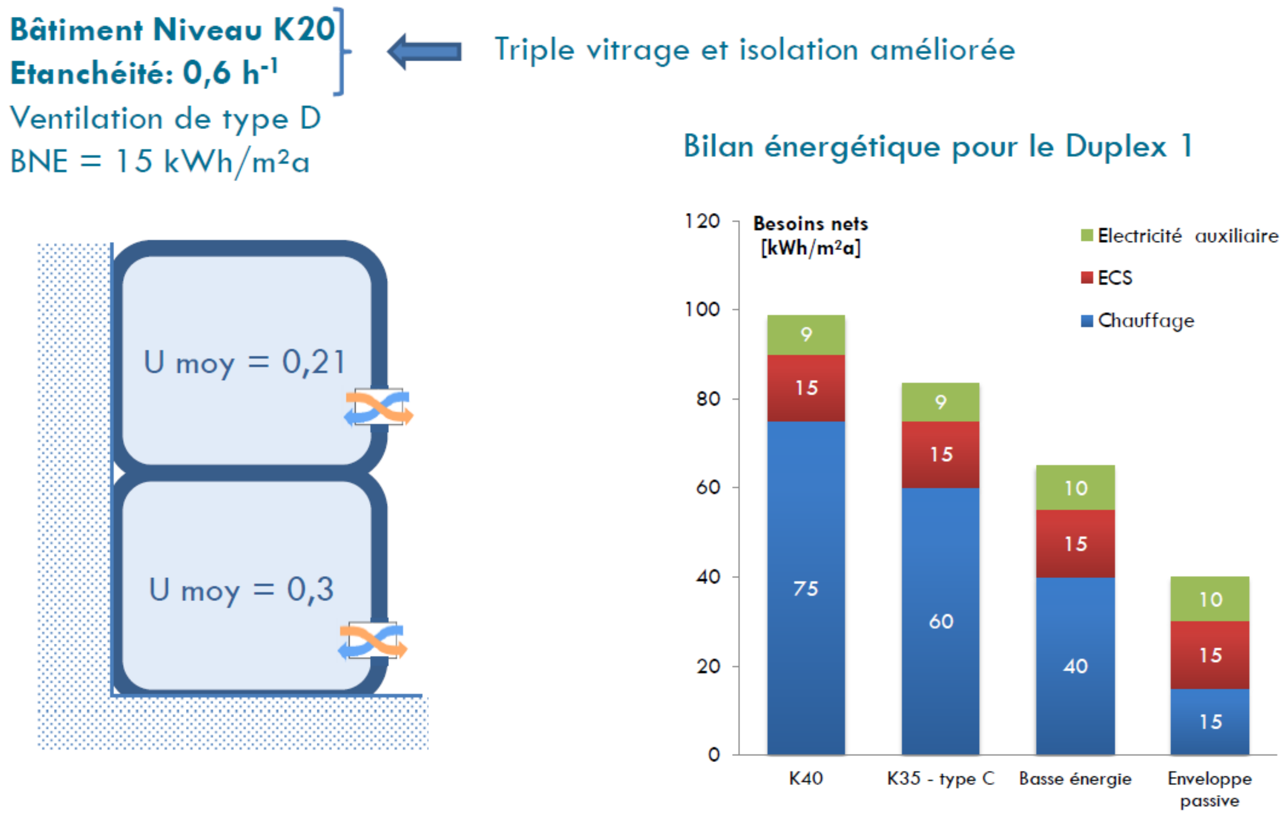


Figure 14: evolution of the energy standard up to the passive envelope (IBGE 2015)

Nevertheless, passive buildings have a certain advantage due to their ventilation system, in fact passive houses are equipped with a D system, where the supply and the evacuation are both mechanical, and not natural. This situation can allow, in the case of the addition of a greenhouse on the roof, to easily connect the air flows between them. (IBGE 2015) As can be seen, the demand for domestic hot water (Eau Chaude Sanitaire, ECS) remains constant, regardless of the energy class of the building. One way to reduce this energy consumption would be to take advantage of the natural greenhouse effect on the rooftop system to install thermal solar panels that could preheat the water without any help, apart from the sun. For a question of durability, thermal solar panels will have priority because they are made of simple and recyclable materials, compared to photovoltaic solar panels whose photovoltaic cells still pose problems for recycling. Moreover, being in an urban environment, housing can often be found nearby, where hot water will be a valuable resource.

3. CO_2

In order to make the most of the coupled ventilation system, the symbiotic exchange of CO2 and O2 can be used. The CO2 has the power to enhance crop production. (Toop, Silva et Botar 1988) According to Steven Beckers, with a sufficient supply of CO2, production can be boosted by up to 30% more. The airflow in the building has a much higher CO2 concentration than the greenhouse due the presence of humans. the area of education gives one of the best examples of this. Indeed, in schools or university where the flow of people is dense, moreover their presence is mainly concentrated during the daytime, which is advantageous since it is then that plants need it the most. The consumption of carbon dioxide by the crops helps in the photosynthesis process, the higher the CO2 concentration, the more efficient the photosynthesis process gets.

There are three ways to recover CO2. The first is linked to the function of the construction, in the case where it produces an excess of CO2, as for example in the case of the Rotterdam harbour, where industries send CO2 through large pipes to greenhouses at the exit of the city. (Stefanova 2011),or by recovering the ambient air containing the CO2 released by the breathing of the occupants of the building. The last way to collect CO2, is to send liquid CO2 bottles that would have been produced by industries elsewhere, in mass. (Beckers 2018) This last solution is still debatable since although the CO2 is reused, it is necessary to take account of transportation by truck. In the two first cases, with direct reinjection into the greenhouse, the quality of the CO2 must nonetheless be checked, and it must be ensured that CO has not mixed in.

Currently, RTG-Lab researchers only use CO2 from offices to send into greenhouses and help plants. But according to Steven Beckers, some of his projects already include the opposite path, i.e. fresh air that would have been injected from the building to the greenhouses, then filtered by plants and then returned clean to the living spaces. The advantages of this part of the building metabolism system are that by simply reintegrating the CO2 that we release back into the cycle, we get better production figures in terms of crops without fertilizer, clean air free of charge and all this without spending fossil energy, or money. Moreover, the CO2 flux is expected to remain constant throughout the year. (Sanyé-Mengual, Llorach-Masana, et al. 2015)

4. Waste

Waste management and valorisation is a crucial issue for cities. At a time when they are constantly growing, continuing to throw rubbish into landfills where it emits methane or burning it is no longer a viable solution. (Garnett, Growing food in cities: A report to highlight and promote the benefits of urban agriculture in the UK 1996) A Brussels resident wastes an average of 15kg of food per year, one third of which is half-eaten or expired vegetables or fruit (this does not include organic waste such as peelings or non-consumable greens). (Inter_environnement 2016) In terms of sorting of waste, Bx is not at the cutting edge, it is even behind the other two regions of Belgium. After analysing the mixed waste bins in the Region, it was discovered that they were half filled with bio-waste. This waste could easily be transformed into compost, either publicly by the region, or individually. (BATIr (ULB), Ecores sprl et ICEDD 2015)

Individual composting, worm composting, and collective composting are often considered the best ways to manage bio-waste. Ecologically speaking it is the simplest way because it does not require mechanized operation, nor transport. Economically, the citizen does not monetarize his work (which is furthermore rather light) and gains in purchasing power compared to the savings and the free fertilizer that he obtains. Socially, composting helps strengthen the social cohesion of a neighbourhood, raises awareness and responsibility about the environment. If nevertheless the management of this compost is taken in hand by the public authorities, the first phase will be the same as for the individual way. The second phase however a selective collection followed by the marketing of the compost. Nevertheless, compost is not a scarce resource, its economic value is rather low, so there is not much interest in transporting it more than 50km. It is therefore necessary to find a local utility to sell it.

So this is where the UA comes in. In a model where agriculture takes its place in the city and appropriates large areas, it becomes important to be able to feed the plants before they can do the same for us. For UA in open ground, it's easy to guess how the compost will be used, whether it's on the ground or on the roofs, it doesn't change anything. In the case of aquapony, the system is already in closed loop and will not need more compost. With regard to hydroponics, new techniques are being studied to transform compost fertilizer into nutrients that can be absorbed by plants when mixed with water, some of which are already functional. (Persico 2018)

3. Feasibility in Brussels

1. Urban planning law: Integration of urban farming

Current situation

To establish UA in the city, we must find space for it and allocate it. To this end, agricultural land must be included in zoning and urban planning regulations. Currently, in the Brussels Capital Region there are five mapping tools, the CoBAT (Code Bruxellois de l'Aménagement du Territoire) cites them as being: PRD, PRDD, PRAS, PCD and PPAS. In addition, there are two urban planning regulations: the RRU and the RCU. (see Table 3: Summary of Brussels' regulatory and strategic plans) Currently, 252 ha are used as agricultural land by professionals, representing 1.5% of the total area of the Brussels Capital Region. This area is officially recorded in the Integrated Management Information System control (SIGC) under the direct support of the Common Agricultural Policy (PAC) at European level. Out of 252 ha declared to the PAC, only 118 ha are registered in the PRAS as agricultural zones. Yet to recognize the function of agriculture is already to give it value but especially legitimacy. It is therefore necessary to consider modifying the PRAS to be able to dedicate more surface to UA.

To adapt a building, an urban planning permit is required, whether for simple interior or exterior transformations even when they do not modify the volume, with the exception of simple maintenance or conservation work. In the case of the addition of a greenhouse the volume is modified, worse it increases the building of a floor, when a priori the constructions are made as high as possible, to have the most surface, and thus earn more for selling or renting. The laws regarding the change of the building dimensions can be found in RRU Title 1. Today, the laws relating to green roofs and photovoltaic panels are newly integrated. However, as far as "eco-construction" is concerned and since these new techniques are constantly evolving, it is for the moment unthinkable to find a place for them in this urban planning regulation. (Gouvernement de la Région Bruxelles-Capitale 2006)

Acronym	Full name	Translation	Authority	Document Value	Scope
PRAS	Plan regional d'affectation des sols	Regional land use plan	Region	mandatory and regulatory value	Existing factual and legal situation, assignments and requirements, protection zones
PRD	Plan regional de développement	Regional development Plan	Region	indicative and committing	Development objectives, priorities, means and areas of intervention
PPAS	Plan particulier d'affectation des sols	Specific land use plan	Municipality	mandatory and regulatory value	Existing factual and legal situation, assignments and requirements, protection zones
PCD	Plan communal de développement	Municipal development plan	Municipality	indicative and committing	Development objectives, priorities, means and areas of intervention
RRU	Réglement d'urbanisme	Urban planning regulations	Region	regulatory value	Measures to ensure the salubrity, habitability, safety... of an area
RCU	Plan communal d'urbanisme	Municipal urban development plan	Region	regulatory value	Measures to ensure the salubrity, habitability, safety... of an area
PRDD	Plan Régional de Développement Durable	Regional Sustainable development Plan	Region	indicative and committing	development objectives and priorities, according to the medium and long term economic, social, environmental and mobility needs

Table 3: Summary of Brussels' regulatory and strategic plans

In recent years, the Brussels-Capital Region has launched plans to improve the city's environmental performance, among them the PRDD, which has been in preparation for several years and was signed on 12 July 2018. This plan seeks to localize urban metabolism flows in the country by increasing circular circuits and reducing production-distribution chains. The PRDD therefore goes beyond simple spatial planning and touches on the organization and functioning of the region to ensure it is well placed to progress towards sustainable development. Concerning food, its aim is to eradicate hunger, ensure food security, improve nutrition and promote sustainable agriculture. The Good Food strategy, which has already often been discussed in this thesis, is responsible for achieving these ambitions. The version that was signed in July is still very vague on the UA. Fortunately, revisions are still being considered at this time.

Propositions

In January 2018 the final report on the urban planning and legal study for the development of urban agriculture in the Brussels region has been published. This legal and urban planning study examined the possible adaptations that could be made to the PRDD proposal to promote the integration of the UA in the capital. It was written in collaboration with the administrations responsible for the decree. These amendments are still being considered pending acceptance or rejection in early 2019. (Detienne 2018)

- The PRAS and its glossary:

It is proposed to facilitate the implementation of installations and constructions for UA and specifically collective gardens by deleting preliminary town planning permits. Roofs and terraces will not be left behind as they would also be exempt from planning permission too. In this proposal, urban agriculture is redefined and vegetable gardens are legally recognized.

By implementing these proposed changes, various existing urban agriculture activities would be better defined, and project developers would therefore be better equipped to sustain their activities or launch new projects.

- The RRU:

Promoting green roofs and roof gardens and placing greenhouses on roofs could be possible thanks to shorter planning permit examination procedures as well as the absence of derogations. As an amendment to the RRU is currently under way, the proposed amendment, could quickly be approved and would therefore have an impact on the development of urban agriculture in the short term. These are specific projects related to buildings and in particular to their roofs. It is thus a good hope in regard to the interest that the authorities already have in the recovery of these surfaces, and even BIGH.

- The decree relating to town planning charges

Planning fees are taxes for planning permit applicants to finance the infrastructure needs generated by their project. They can be social facilities (nurseries, hospitals, etc.) or infrastructure such as roads, green spaces or an additional public transport line to manage the mobility of the new building's occupants. These infrastructures will be property of the region, without the region having to contribute financially to their creation. Of course, these fees only apply to large-scale projects and certain functions (offices, car parks, shops, hotels, and residential buildings).

The proposal of the January 2018 study is to add UA zones to the list of urban planning fees. This modification would allow the rapid integration of UA projects in the city thanks to real estate developments, because the authorities which grant urban planning permits could decide to impose the creation of an UA zone in the proposed projects.

- The farm lease and the suppression of the pre-emptive right

A farm lease allows a farmer in need to resell his land while allowing him to continue cultivating on his former land because that is the only function that the land can perform. He keeps part or all of his production under the terms of the lease.

The pre-emption right gives the farmer the priority to purchase the land in the event of a sale. The proposal here is to remove this right and offer it to RBC. Once the Region is in possession, it will be able to direct farmers towards certain production methods of its choice in accordance with the Good Food strategy via the appropriate occupancy contracts under the farm lease. For example, it could encourage the development of ecological market gardening projects. It's a way for them to keep control.

These are the four proposed amendments. However, there are some additional modifications that could be made to facilitate even more the integration of BIGH.

For example, in the RRU proposal, for the Article 8 on building heights, at the moment nothing concerns greenhouses but the legal study adds the underlined sentences:

> "ART. 8. § 1. THE HEIGHT OF THE CONSTRUCTIONS DOES NOT EXCEED THE AVERAGE HEIGHT OF THE BUILDINGS LOCATED ON THE LAND SURROUNDING THE LAND IN QUESTION, EVEN IF THE WHOLE COMPLEX OF LAND IS CROSSED BY ONE OR MORE ROADS.
>
> § 3 THE HEIGHT OF THE BUILDINGS REFERRED TO IN § 1 SHALL INCLUDE THE TECHNICAL FLOORS, THE FLOORS IN AND ELEVATOR CABINS; THESE ARE INTEGRATED INTO THE ROOF VOLUME.
>
> ONLY CHIMNEY OR VENTILATION STRAINS, ANTENNAS *AND GREENHOUSES* MAY BE USED. EXCEED THE ROOF TEMPLATE.
>
> FOR MOBILE TELEPHONE ANTENNAS, THE OVERRUN IS LIMITED TO 4 METRES, INCREASED IF IT FALLS WITHIN THE HEIGHT OF THE ACROTERION WALL.
>
> *FOR GREENHOUSES, THEIR SURFACE AREA, INCLUDING THE PROJECTION OF THEIR ROOF ON THE GROUND, SHALL NOT EXCEED 9 M2 AND THEIR TOTAL HEIGHT SHALL NOT EXCEED 3,00 M NOR EXCEED THE PLANE INCLINED AT 45° TO THE HORIZONTAL, STARTING AT THE TOP OF THE COMMON WALLS OR, IN THE ABSENCE OF A WALL, AT A HEIGHT OF 1,50 M IN LINE WITH THE COMMON BOUNDARY.*
>
> THE ADDITION OF THESE BUILT VOLUMES MAY ONLY BE AUTHORISED TO THE EXTENT THAT THEY ARE HARMONIOUSLY INTEGRATED INTO THE OVERALL COMPOSITION."

It is very beneficial to delete permit applications. This will really help promoters to integrate greenhouses. According to Steven Beckers, it is the administrative slowness that prevents the UA from developing despite its many assets. The maximum restriction of 9m² for a greenhouse is too small. At first sight, the most advantageous roofs will be the largest, but nine square meters of greenhouses is very little to allow for an UA which will impact on the city's food production.

Apart from reasons of uniformity, the height of a building is also calculated so that the sunlight can always reach the other side of the street, and thus not deprive the neighbours of the sun's rays. However, in a case where the additional floor is a greenhouse, and therefore composed of transparent materials the sunlight can continue to flow. We could therefore consider allowing an exception in RRU Title 1 to install greenhouses on roofs, even in the event that the height provided in the regulatory plans is exceeded.

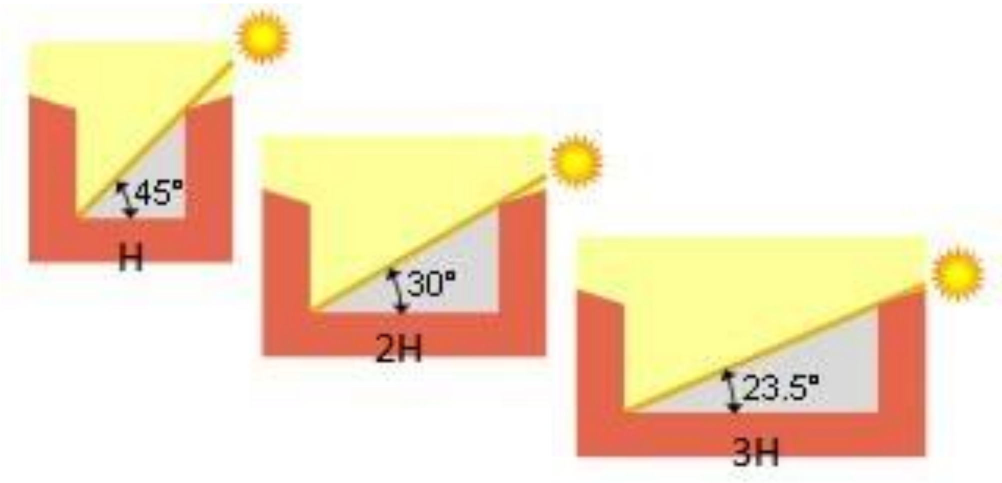


Figure 15: Scheme of the buildings' height in relation to the street width

Another element that seems important is to offer BIGH technology to those who will need it most. Indeed, the UA can allow families who are struggling to make ends meet to offer themselves a certain security by becoming more autonomous. At the moment, the first urban farm model, the FoodMet, has relatively high prices and, although rooted in a territory with a low social index, seems to attract only wealthy customers. Such results show that the UA could therefore have the opposite effect to the desired one, gentrification. To avoid such problems, urban planning charges can be of assistance. For example, by obliging developers to include part of agriculture in their social housing.

Roof surface access

It is also necessary to decide on the status under which the greenhouses will be built. Agriculture, even urban agriculture, requires recurrent work to maintain crops. It is therefore necessary to ensure almost continuous access to professionals. It is even better to leave access only to them, who can control it (for visits or whatever) and thus avoid any accident, or contamination. For vegetable gardens on the ground, it is also necessary to guard against acts of delinquency and degradation. Because they are not recognized by legislation, they are not protected by law either.

For the sustainability and image of these cultures, it is utopian to think that anyone can take care of them, yet the owners of the recovered buildings are not UA professionals. The purpose of roof recovery is to be able to offer it to a multitude of buildings, all functions combined. It cannot be expected that all interested persons will be trained for the correct maintenance. On the other hand, if access is fully privatized for professional horticulturists, this does not exclude the transfer of knowledge. Indeed, training for people from all walks of life can still take place there, but only provided by professionals, which in turn ensures the quality of knowledge and creates jobs.

To ensure proper maintenance, you must choose a production status. There are a multitude of possibilities to implement. This can be a rental or ownership contract. The production can be included in the contract or returned entirely to the producer.

1. Rental contract

A rental contract seems to be the easiest to implement. Nevertheless, the owner has the power to change his mind at any time (depending on the legal limits of the leases of course) and sell or rebuild. There is therefore no guarantee that the land will be leased on a long-term basis, which is necessary for an agricultural holding. Moreover, in the case of a relatively expensive installation, such as aquaponics or hydroponics, it is the owner who invests, and it would be strange if he did not get any paybacks.

2.Farm lease

In Belgium, for example, farmers often rent farm property by means of a "farm lease". Agricultural land cannot be used for any other purpose, so it is possible for a farmer in need to sell his land while continuing to cultivate it. According to the agreement, the farmer recovers part or all of the production.

3.Partnership

In the case of the FoodMet in Anderlecht, for example, it is a basic rental contract. However, there is also a partnership with slaughterhouses because there are many decisions to be taken jointly. Nevertheless Steven Beckers says that their future projects will be partnerships, that is, whoever owns the building has an interest in making it work well and therefore the architect has an interest in making his building work well too. According to him this is especially true with shops because there is a synergy in the sale of products but it can also be the case if it is an office building, because it enhances the image of the building, therefore also increases its value since it becomes more environmentally efficient and its image is boosted. (Beckers 2018)

This partnership system is also a way to ensure that competent and trained people for this type of exploitation are in charge of the greenhouse. It is important to guarantee the maintenance of the installation because these are often new and delicate techniques, which require specific knowledge. At the end, the idea of linking the professionals who build the extensions and the buyers in the long term therefore seems to be a solution with regard to crops.

2. Typologies of the existing urban fabric

Filters

In order to estimate the potential of refurbishment for Brussels in terms of BIGH, buildings must fulfil a series of condition to satisfy the adding of a greenhouse. Therefore, filters must be put in place to select the most appropriate constructions.

1. Spatial

First condition is, of course, to have a flat roof. The limit of service for inclined surface is between 0.5 and 4%. Then this roof must be of a sufficient area, indeed as seen previously, the green house must have a minimum size, that we fix at 3000m² for Brussels according to Steven Beckers (Beckers 2018), to be cost-effective and achieve a satisfactory yielding, in terms of vegetable production and therefore economics.

2. Functional

Naturally not all the buildings will be handled in the same way. Actually, they will all be different because of the logical thinking of creating a metabolism, an ecosystem working in the building. Indeed, the first phase is the analysis of the existing building in order to install the most suitable annex. Every building has its proper characteristics according to the roof area, the orientation, the height and the different flux exchanged with the exterior that BIGH could manage, as explained in the second part of this study. With the aim of creating a methodology to analyse Brussels City, the flux parameters will be contained within their functions. Four categories of functions have been selected:

- **Residential (RES)** ; containing *Zones d'Habitation à prédominance résidentielle (ZHPR), Zones d'habitation (ZH), Zones Mixtes (ZM), Zones de fortes mixité (ZFM*) and the *Points de variation de mixité*
- **Commercial (COMM)** ; containing *Zones d'équipements d'intérêt collectif ou de service public (ZE), Zones d'entreprises en milieu urbain (ZEMU*) and the *Lisière de noyau commercial*
- **Industrial (IND)** ; containing *Zones d'industries urbaines (ZIU)*
- **Parking (PARK);** containing the public parking buildings in Brussels

The residential function includes the dwelling zones and mixed zones, where buildings contain only dwelling (ZH), or mostly dwellings (ZHPR), then we have constructions that are allocated to dwelling but can be jointed, with a limited surface area, to equipment of collective interest, public service or offices. According to the size of the second function in the building they are referred as ZM or ZFM. (Bruxelles Urbanisme et Patrimoine 2018)

The residential function is chosen for the calculation of potential because first of all it is the most represented function in Brussels. It proposes of course the metabolism advantages as presented previously. Then, if a greenhouse can be proposed to a family, this offers the most direct connection to food for its owners. In addition to the benefits of a brand-new diet, thanks to the fresh vegetables and fruits, the family would benefit from all the other advantages linked to agriculture like the impact on their health whether it is mental or physical. Over all it is the consciousness of the energy, time and pleasure that growing food takes, that will be the most present and precious in the scenario of a family building integrated greenhouse.

Nevertheless the dimensions of a single-family house are too small. In order to produce enough to be economically viable, the surface should be over 3000m² according to Steven Becker. Of course, the probability of having such a big house is very low. It is then necessary to reduce the minimum surface area, and apart from the question of economic profitability (which will have a lower impact in residential) there is at least one spatial criterion that must always be met, it is the ratio between the horizontal and vertical surface. This is to allow the greenhouse to create thermal inertia with the air volume, the usual height for a greenhouse is around 5 meters high, therefore the minimum size to achieve the right ratio for the width is 20m. In the GIS filters, the minimum area for the residential function has therefore been modified to 400m² (20x20m) to expand the number of possibilities.

In second, **the commercial function** gathers the "business enterprise in urban zone" which is allocated to productive activities and services associated with companies. It also contains the "Collective interest equipment" that gathers the different buildings with a collective interest or a public service for example local government authorities, school, sports, social, health and religious establishments. (Bruxelles Urbanisme et Patrimoine 2018)

Refurbishing these kinds of establishments, has multiple advantages. In terms of metabolism, those buildings which are for public use use a lot of air, heat, water and sometimes produce organic waste. The HVAC system is a major factor in the realisation of those constructions. The most suited pooling is probably CO2 exchange. This aspect could be really profitable for the yield of vegetables and the purification of air.

The reason why this type of building is the most interesting is the fact that it could include an additional step in the production line. For commercial establishments like shops it could simply be the closure of the economic loop alongside the resources loop. Selling food directly, in the same building would reduce its price, by reducing intermediaries, transport time and therefore its (already small) footprint in terms of fuel and packing. For establishments like schools, universities, health or sports centres, a canteen or restaurant could be installed if not already present. It is interesting to have a product transformation as it increases significantly the economic value of the food produced. Moreover, the economic activity in place is offered a brand image, attracting people with fresh, healthy and local food. Concerning schools and universities, the educational aspect is significant. For universities, it could become a community service or an experimental greenhouse, while for schools and kindergarten it would be an asset for the teachers to introduce cross-curricular subjects. As for residential establishments, the very contact with the production system is crucial to understand the impact of food on our society, and respect for nature. For health centres, a rooftop installation could allow long term patients to reconnect with nature and enjoy all the benefits of agricultural therapy (as explained in the health section of this thesis) without even leaving the building. In this category we find also correctional establishments, where prisoners could benefit from a formation in agriculture that does not need any previous knowledge. In the same way as kitchens are sometimes maintained by prisoners, a greenhouse could provide at the same time an enriching experience and better food for everyone, given that the food served in prisons is often deplorable. (Pourveur 2015)

The third function analysed is **industrial facilities**, the urban zones of industries are affected to productive and logistic activities and also to facilities aiming at environmental improvement like waste reception/treatment centre or water-treatment plant. (Bruxelles Urbanisme et Patrimoine 2018)

Here the social and educational impact is less than for commercial and residential establishments, though the influence of UA is still there through its mere visual presence. But the association of urban agriculture and industries has a lot of potential in terms of energy optimisation. For this category, even more than for the others, each case will be unique. Depending on the nature of the production, industry creates waste energy, whether it is for cooling or heating. A factory coupled with an integrated green house would greatly benefit from the heat and air exchange by reducing this waste. On the other hand, the greenhouse would also profit from this, for example an industry wasting a lot of heat due to a melting process could reinject this heat into the greenhouse, turning it into a tropical ecosystem, and therefore producing exotic fruits and vegetables.

The last type of building studied here is **parking facilities**; they are chosen specifically due their initial structural resistance. Indeed, carparks are built to sustain the weight of many cars, therefore their structure, according to the year and process of construction, is sufficient to carry the weight of a greenhouse without or with a light structural reinforcement. For buildings with a roof only accessible for maintenance, it is the last floor that will be refurbished into a greenhouse, by tearing down the existing roof. If the roof is also composed of parking spaces, the greenhouse will be placed on it.

Charges d'exploitation pour les bâtiments

Note : Les effets dynamiques de résonance doivent être pris en compte au moyen d'une analyse dynamique particulière (v. ANB + EN §2.2(3)).
Les effets dynamiques des charges concentrées sont inclus dans la valeur de Q_k (ANB).

Catégorie d'utilisation			Charges verticales		Charges horizontales	
	Usage spécifique	Exemples	Charge répartie q_k [kN/m²] (1)	Charge concentrée **50 x 50 mm²** Q_k [kN]	Charge linéaire q_k [kN/m] (2)	Charge concentrée **100 x 100 mm²** Q_k [kN] (3)
F	Aires de circulation et de stationnement pour véhicules légers (PTAC ≤ 30 kN et nbr. places assises ≤ 9	Garages, parcs de stationnement, parkings à plusieurs étages,…	**2,5**	**20** (9)	Choc véhicule cfr. EN 1991-1-7	

Figure 16:Charges d'exploitation pour les parkings (CSTC 2015)

3. *Structural*

To be able to analyse the resistance of Brussels roofs, it is first necessary to determine the loads that a roof will have to support.

A. Operating loads

According to the Eurocodes, an accessible roof must bear the loads associated with its use. Depending on whether they are residential, commercial or public, the roofs must be able to take loads of respectively 2, 3 and 5 kN/m². When the roof is not accessible except for maintenance, its load-bearing capacity is between 0.2 and 0.8 kN/m².

If the RTF designed is accessible only for a few gardeners, for maintenance and cultivation, then the circulation areas (80cm wide) will have to be dimensioned to take a load of 1 to 2 kN. If the roof is entirely open to the public, in this case it will be necessary to apply the loads requirements given by the Eurocodes for public roofs.

B. Greenhouse loads

There are several types of greenhouses, however which are quite light structures per se. Their weight is mainly dependent on the type of transparent walls they have. They can be made of classic horticultural glass, toughened glass, laminated glass or polycarbonate. Toughened glass is much stronger than horticultural glass and shatters into small pieces when broken. In this case where the greenhouse is on the roof, for safety reasons toughened or laminated glass will be preferred. However, toughened glass is more expensive and heavier than polycarbonate. Polycarbonate is actually a plastic sheet with a honeycombed interior, which makes it a very good insulator. It is also more resistant and can support heavier weights than glass, which makes it a good element to take snow loads (0.4kN/m² in Brussels (CSTC 2015)). However, being lighter it will be less appropriate in strong winds.

There are few figures on the weight of greenhouses, the classic Mediterranean greenhouses on the ground are made of steel and plastic cover, whose weight is estimated at 8-12kg/m². (Sanyé-Mengual, Cerón-Palma, et al. 2015) The RTG-lab in Barcelona has built a greenhouse of the Mediterranean type, i.e. a light polycarbonate structure adapted to the mild climate. Its weight per square metre is estimated at 7.7kg. (Cerón-Palma, et al. 2012) According to the study made in Molenbeek, for a 4mm thick tempered single glazing structure with a steel structure, the weight would be between 35 and 50kg/m². Nevertheless, greenhouses on roofs, are subjected to the laws of classic town planning, as well as for safety and fire prevention. For example, in the case of glass greenhouses, the latter must be placed at least one metre from the edges of the roof, so that in the event of glass breakage, the risks of falling glass and accidents are limited. (Ecores, Lateral thinking factory et Noemie Benoit consultant 2014)

C. Loads for culture in containers

For an open ground culture, in containers, it is possible to overlook the exploitation loads in the places dedicated to the containers. Indeed, the design of the vegetable garden is planned from the start because its design has a major impact in load analysis. Once the design has been completed, the drawings will not be changed a priori. We can therefore zonify the roof to put more weight in one place than another

The weight of the pots depends on their depth, which in turn depends on the type of plants to be grown, in relation to their root depth. Soil load includes soil, potting soil and compost. It must understandably also consider the watering, in total the load is equal to 11kN/m^3. (Ecores, Lateral thinking factory et Noemie Benoit consultant 2014) If bins are stacked, their weight should of course also be taken into account.

D. Aquaponic and hydroponic loads

As with soil containers, the operating loads under the cultivation tanks can be ignored. For aquaponics and hydroponics, the weight will be smaller than for soil, it just depends on the height of water in the basins. According to Steven Beckers, aquaponics requires a load of 300kg/m², including the structure, furniture and plants in their water. (Beckers 2018) However, in fish farming areas, fish tanks require 1 metre depth, and will therefore weigh 10 kN/m² plus the proper weight of the pond structure.

The structural study of buildings can only be done on a case by case basis, each construction having its own unique structure. The age of the building can already give a significant clue. But the main material is also a good indicator to classify the structure. It is noted that reinforced concrete offers more stability and is often sufficient for the integration of a BIGH while roof structures made of metal (whether steel or aluminium) will have to be reinforced in a rehabilitation process. (Sanyé-Mengual, Cerón-Palma, et al. 2015) Now, according to a feasibility study carried out in Molenbeek by Noémie Benoit and the Lateral Thinking Factory, the load-bearing structure of the houses (i.e. the vertical elements such as walls, columns, etc.) is often sufficient to take on the burdens of urban agriculture. Nevertheless it is the horizontal structural elements (beams, slabs...) that pose problems. Indeed these are practically never dimensioned to be able to support such a weight.

These elements must then be reinforced, one solution is by a horizontal self-supporting structure resting on vertical supports. This solution is convenient because the changes are internal and therefore not visible from the outside. For buildings whose vertical and horizontal structure is insufficient and whose width is not too wide, it is possible to install a glazed metal exostructure that starts from the ground, wraps the building and ends in a greenhouse on the roof. For buildings with low insulation, this would mean killing two birds with one stone, insulating the building and the roof, while allowing the creation of a rooftop farm. (see Appendix : Exostructure for BIGH implementation)

4. Thermal performance

As the study of Delor explains, the worse the insulation, the better the connection to a greenhouse will benefit the building. (Delor 2011) Fortunately, a thermographic map of Brussels Environment lists the roofs through which the greatest heat loss occurs. The best candidates for the addition of an RTG are obviously those rated "very high" in the ranking and shown in red on the map.

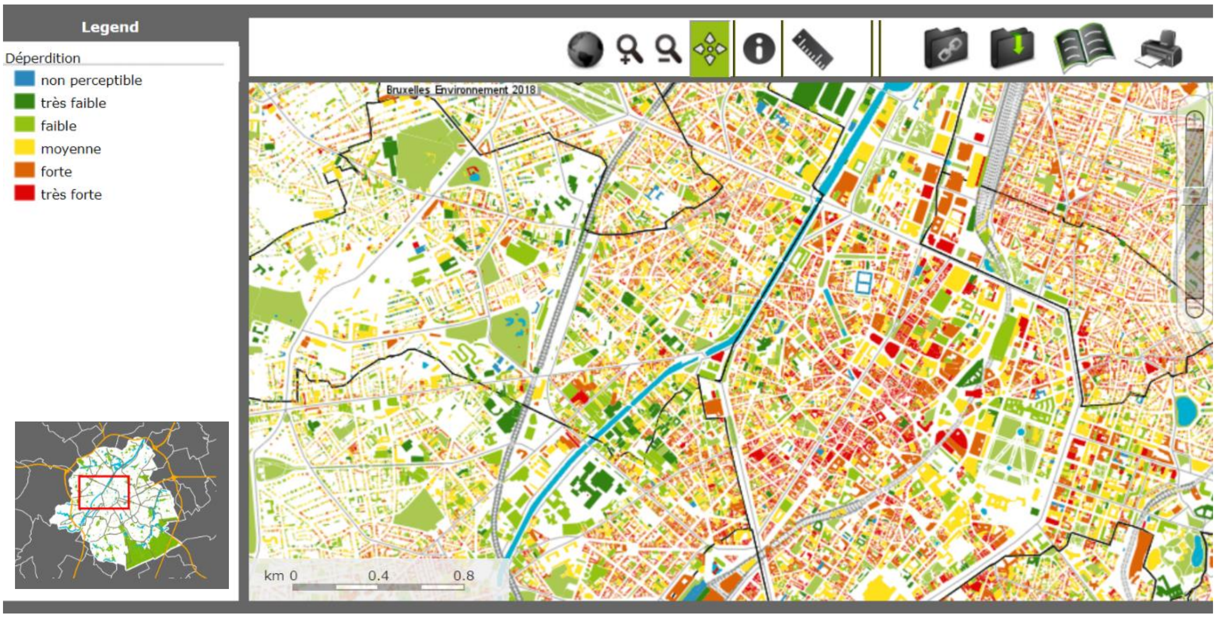


Figure 17: Brussels thermographic map (Bruxelles Environnement 2009)

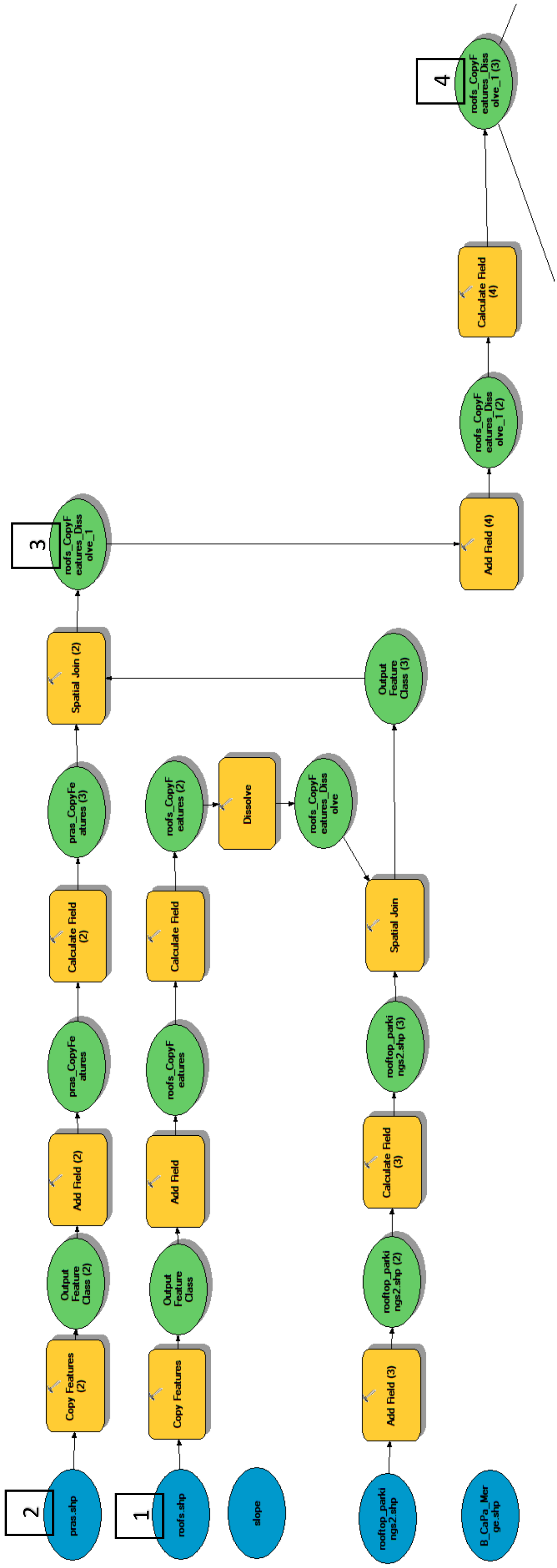
Roof competition

The absurdity of the size of unoccupied flat roofs has already been noticed by some. Valuation proposals were therefore found and presented. The most popular sector at the moment is the photovoltaic panels sector. The largest flat roofs and therefore with the best potential have often already been targeted by the solar panel market. On the Audi factory, for example, which would have made a very good candidate for the BIGH, the roof is already covered with panels. But that's not all, now the city of Brussels systematically installs photovoltaic panels on the roofs of schools and kindergartens (flat or not, though). (Carlot 2017) In Spain, for example, 54% of the photovoltaic installations in 2010 were made on the roofs of industries. (ASIF 2011) This shows the competition that this creates for BIGH.

Then there are the green roofs that have recently received support from the Region. Indeed, for almost a decade now, inaccessible flat roofs of more than 100m² have had to be converted into green roofs according to the RRU: Title I, Chapter 4, Article 13. (Gouvernement de la Région Bruxelles-Capitale 2006) Fortunately for the BIGH, it is specified here that only inaccessible roofs are targeted, and access is a major aspect of the greenhouses' design. However, financial assistance is available for those who wish to install green roofs. They offer a series of advantages such as thermal and acoustic insulation, fire prevention, slowing water runoff, improving air quality and biodiversity... (IBGE 2009) Moreover, they are cheaper to install than a greenhouse. Nevertheless, a greenhouse also offers many of these benefits, and also produces food. It is therefore necessary to ensure that the two installations do not shade each other, but rather that for each situation, the best option is chosen.

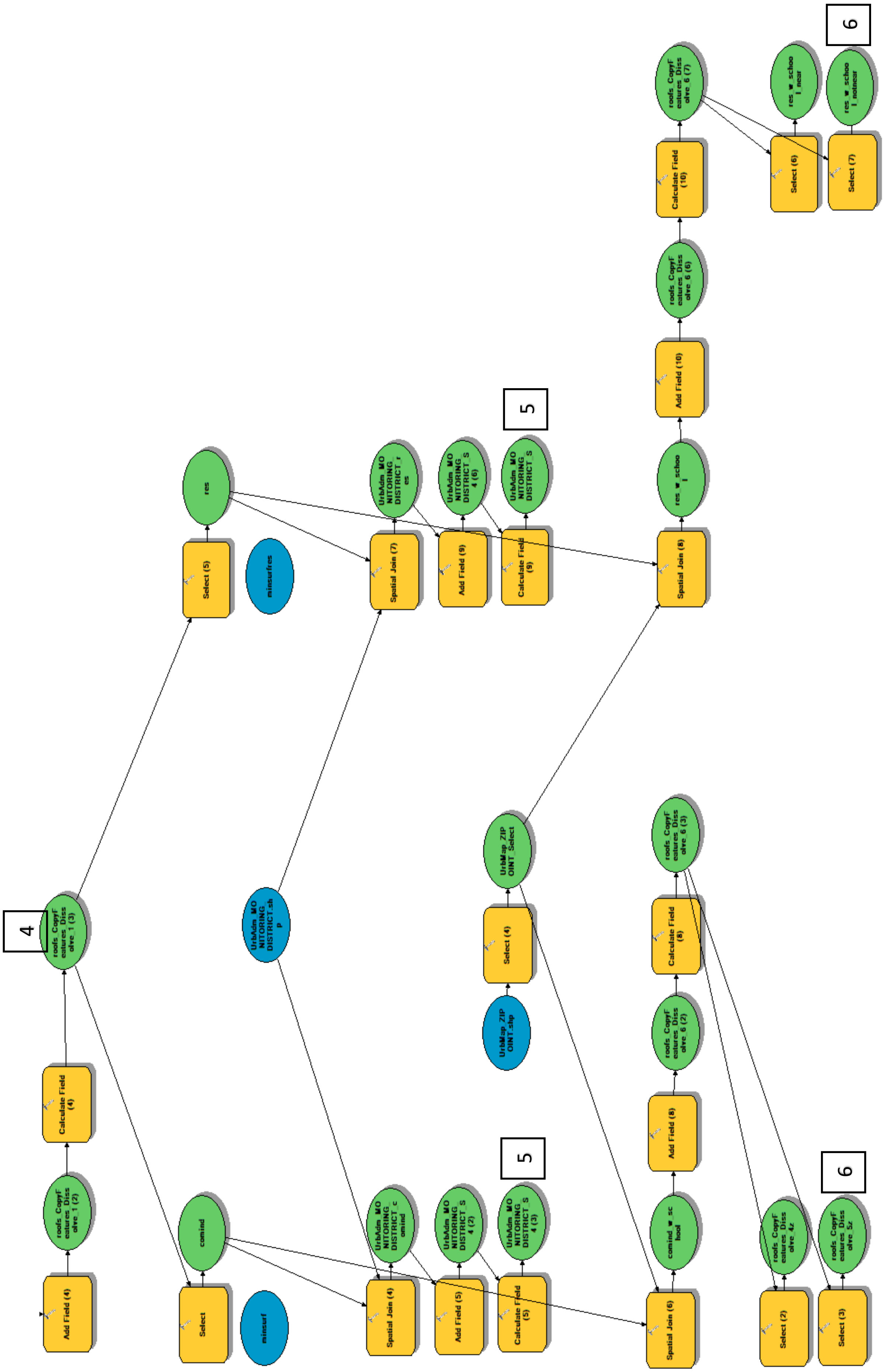
GIS methodology

These filters must be grouped together to determine which areas are suitable for UA integration. The Geographical Information System (GIS) program makes it possible to analyse the urban fabric according to parameters such as geometry, location, urban planning laws... By compilating data of large areas and applying the filters defined in the previous part, it is possible to find all buildings that meet all criteria simultaneously. The code also provides an idea of the areas with a high potential for UA integration.



At the beginning, the chosen background plan is a map showing the geometry of the roofs. **(1)** This map contains useful information such as the slope of the roof and its surface. To know the function of each building, a PRAS (see Table 3: Summary of Brussels' regulatory and strategic plans) background map is inserted. **(2)** In its parameters, only the zones listed in the filters paragraph will be selected. (see 2. Functional) Now, we have two maps that need to be combined into one, gathering all this information. The result of this merging is a map showing the buildings with flat roofs, their function**.** **(3)** Then it is necessary to reduce this number of choices by taking only the buildings with a minimum exploitable surface. Only sometimes the roofs are not completely flat everywhere, or are at different heights, creating kinds of platforms, which are nevertheless always possibly serviceable. It is thus necessary to be able to gather the juxtaposed flat surfaces and remove the parts in slope to have the exact exploitable flat surface. **(4)** Once this code is completed, it is possible to assign a minimum area to be reached by the selected building from **(3)**. After that, it is interesting to see on a city scale the areas of high potential. Indeed, by creating a dense zone of UA, certain services can be grouped together, and the synergy of the district can be increased. To analyse the areas in question, it is the division of the city into districts/neighbourhoods (the monitoring districts) which has been chosen instead of the division into communes because it allows a more precise analysis. To do this, the sum of all areas meeting the above criteria in zone A is divided by the area of zone A. This gives the density of UA per km^2. **(5)**

To help select the best roofs, buildings with educational functions (i.e. primary schools, secondary schools, international schools, university, higher education institutions, etc.) are added in a new layer. A filter determines if the roofs are within 350m of these establishments. **(6)** The value of 350m was chosen because 348m it is the distance that people agree to walk to find a green space. (Stessens, et al. 2016)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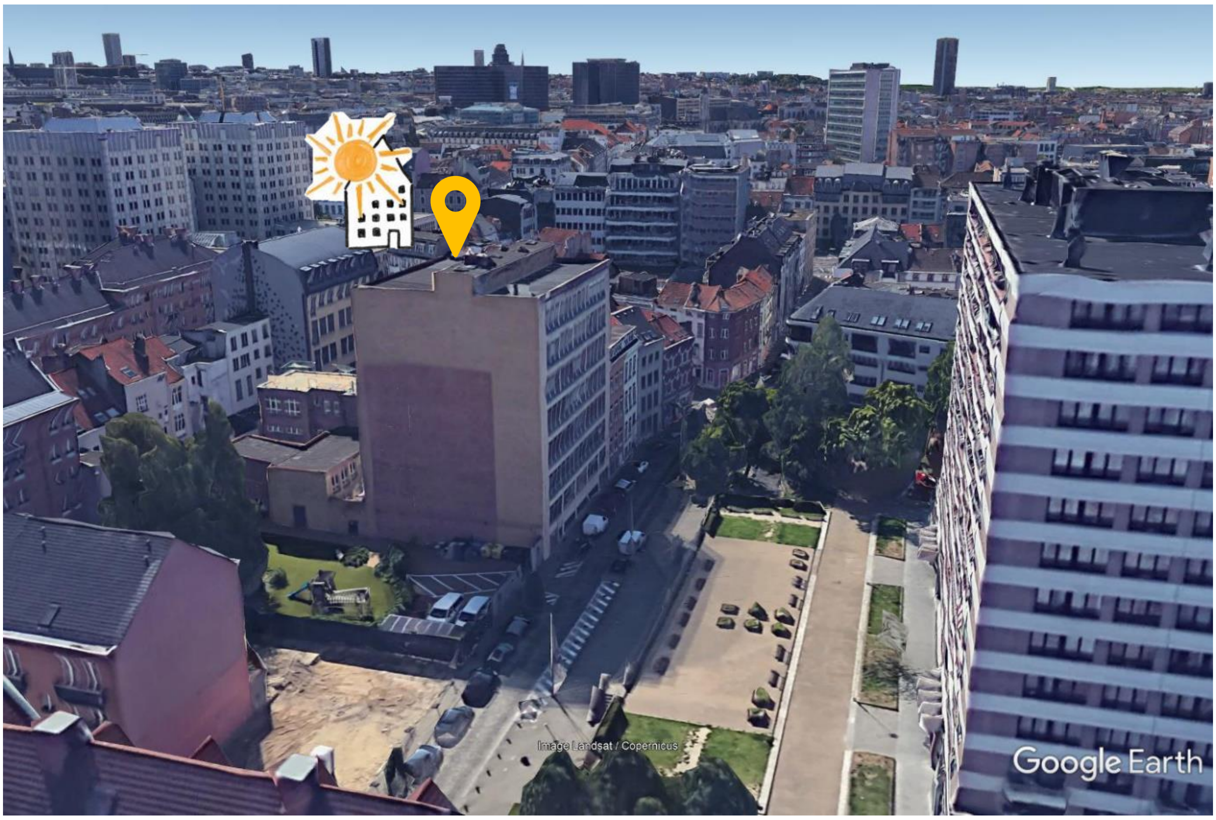
1. Case studies

See Appendix : Case study summary sheets

A. Residential



Maison d'enfants Reine Marie-Henriette. 14, rue de la flèche, Brussels.

Recovering space from residential roofs is difficult because the areas are generally too small. It is therefore necessary to turn to homes with several households. The advantage of doing this is that community garden maintenance increases social cohesion.

Description

The building

Among the 2209 residential buildings of more than 400m² selected by the GIS program, 14 rue de la Flèche has been chosen for this case study. This seven-storey building with 473m² of rooftop surface, is a shelter for children aged 0 to 14 from families in difficulty. It is located in the municipality of Brussels in an area of medium potential density according to the GIS code. The building at number 14 is composed of a crèche open to (almost) everyone, a reception centre for children from 0 to 14 years old (divided in more sections according to the children's age) and a support and assistance centre for families. In all, nearly 120 children spend their life, day and night, in this centre. A canteen is already in place to feed all these mouths. The presence of this kitchen within the building itself is a promise of food value, and the almost certainty that compost will be created.

The urban integration and the ground area

The building also has a relatively large plot of land of 536m², as well as the one around the building on the other side of the street, which is part of the same association and whose surface is about 2300m². It is interesting to combine roof and ground cultivation, already to increase the surface area available, but also the diversity of fruits and vegetables and market gardening techniques. Moreover, by opening the ground part to the neighbourhood, it would be possible to strengthen the ties of the neighbourhood, offering at the same time an intergenerational and multicultural contact for these young people in difficult circumstances.

Target audience

La Fleche was not chosen for its large available roof area but rather for its function and context. In this scenario, UA has the opportunity to assert its benefits in multiple areas. To begin with, from a social and educational point of view, this institution has much to gain from setting up cultivable plots. For the children in care, the opportunity to look after a garden will be a huge opportunity. Studies of schools with vegetable gardens show that students are more respectful of their environment because they feel partly responsible for it. Young people also learn new social skills by sharing and cooperating, thus reducing vandalism and harassment. (Garnett, Urban agriculture in London: Rethinking our food economy 2000) The creation of spaces to cultivate will also make it possible to create a few part-time jobs; we can imagine that these jobs will be offered to parents in difficulty to improve their situation, both financially and psychologically. However, the educational side of the greenhouse will not be reserved exclusively for the residents of the centre, it will also benefit at least two schools that are within walking distance, one of which is on the same block less than 58m away. It would therefore be possible to create a partnership with the students and a plot of land could even be offered to the nearest school, the Fraternité Saint-Vincent college.

By eating foods grown on site and therefore free of any pesticides or chemical fertilizers, the health of residents will already be improved. For young people who often come from urban poor backgrounds, access to fresh fruits and vegetables will probably be a novelty, (Bardsley et Morgan 1996) which will make them question the quality, access and production of food. For children already of age, it will also be possible for them to cultivate their own plot, offering them both a physical and productive activity.

Food distribution

From an economic point of view, it is clear that this scenario is not viable. The operating area on the roof is too small to ensure stable and continuous production. Nevertheless, if it is possible to access the land facing the building, and thus to recuperate the 2300m² and transform them into cultivable gardens by means of permaculture, it would be possible to reach much more interesting production figures. With all these lands, by cross-checking the figures from the various studies, we could feed between a quarter and a third of the residents. Of course the goal in this case is not so much to earn money, but rather to increase the autonomy of this foster home. However, energy savings will be noted for the building, and therefore financial savings.

If food production exceeds the needs of the children, or if some of the produce is reserved for sale to finance the rest of the vegetable garden, it is also possible to set up a collaboration with restaurants. The latter will have to commit to buy a certain amount regularly and to buy in advance, to offer some economic stability. For their part, this commitment will bring them high quality local, organic and tasty products. Less than 150m from the refuge there are already three restaurants. This scenario is a small-scale economic model that offers a win-win solution for both parties. (Ecores, Lateral thinking factory et Noemie Benoit consultant 2014)

Greenhouse integration

HVAC

The Queen Marie-Henriette shelter is a good candidate for the addition of a BIGH because its losses through the roof are ranked "very high" according to the 2009 thermographic map (no renovation of the roof since this date has been observed) As explained before, the greenhouse completes the construction using its weaknesses as its strength. As a result, poor roof insulation is an asset for plant growth under the greenhouse, and it is also in this case that the best energy improvements can be noted in the building. (Delor 2011)

Figure 18: rue de la Flèche, Thermographic map (Bruxelles Environnement 2009)

Currently the ventilation system in place is probably outdated and no record of renovation since the construction of the building has been found. Meanwhile the building 14 rue de la Fleche, is about to be renovated. An adjacent and smaller building will be built, and the existing part will be brought up to standard. This upgrade is an opportunity to install at the same time a new ventilation system that could be coupled with the greenhouse's one. Allowing the heating and cooling of both parts, not forgetting the connection of oxygen and CO2 produced by the occupants throughout the day.

Water

The limited roof surface is an obstacle to the installation of an aquaculture system. Indeed, the investment would be too high for its profitability compared to the surface of exploitation and to set up there a system of piping and pumps for such a small surface is not ideal. As a result, we will favour an open ground culture. The roof is already not strong enough to support the weight of aquaculture, so it needs to be reinforced whatever happens. However, when growing in the soil, the weight of the containers, the soil saturated with watering water and the plants must be taken into account when determining the loads.

Cultivation in open ground requires a certain amount of water to irrigate the crops, which will be collected directly from the roof by the greenhouse. A cistern of medium size adapted to the exploitable surface will be installed on the roof of the new adjacent building situated a few meters below and connected with a pump, while a second will recover the surplus for watering the parcels at ground level.

There is no shade on the roof of the building, so it is a favourable location to install thermal solar panels. This will primarily be able to heat sanitary water for the residents. It is possible to install between 6 and 8 rows of 5 solar panels between the two greenhouses. This means up to 80m² of panels, and therefore the possibility of heating enough water for 80 to 100 people from the 120 residents of the refuge. For each 20m² of panels, a 1000l tank is required which can be placed in the cellar. There is no need to check the load-bearing capacity of the roof between the greenhouses, if the panels are placed on a structure resting on the greenhouse, and the weight of the panels (19kg/m² see Appendix: Thermal solar panels) is included in the initial reinforcement calculation.

Compost

Composting has many advantages here. The first is again the educational side of production, the preparation of the last element of the food cycle loop. It also raises awareness about the food waste that is so important in Brussels. In the event that UA is not installed, it would still be appropriate to consider the creation of a compost that could be accessible to the neighbourhood, allowing residents to recycle their organic waste, and to lighten their garbage. The compost created can then be put into self-service and can certainly be used, at least by the two urban vegetable gardens already present within a radius of less than 300m. (see Appendix: Vegetable gardens near the Refuge Reine Marie-Henriette) The refuge itself is composed of at least one main kitchen, with cold and dry storage space, and several dining rooms. It is in these kitchens that the vegetables grown will be prepared. Any kitchen produces organic waste, but a canteen that will essentially cook vegetables will produce more, so it would be missing a quality resource not to set up a compost system

Installation

The greenhouse

Access is already present and is possible from the technical floor in the middle of the roof. However, a freight elevator may need to be installed, as both the arrival of the lift and the construction of the new construction annex may occur simultaneously. The technical storey with the ventilation system being nearby, its connection will be simplified.

To maximize the exploitable surface and avoid the constraint of having to build a glass greenhouse 1m from the edge, two polycarbonate greenhouses will be preferred. The 8 mm panels will be held by an aluminium structure. The total weight is estimated at 10 kg/m².

The type of farming

The soil-based farming system makes it easier to apply permaculture. This crop combination technique allows a wide variety of vegetables and herbs to be grown on a small area with a higher yield. To encourage these combinations, earth bins and mounds (in bins) will be installed with a height of 20 to 70cm of substrate. The wood for the bins can be recovered and the construction of the containers can be undertaken by the families of the association. In a mini ecosystem like this one, the compost, once ready, can be used directly on the vegetable rows.

Structural reinforcement

To allow such a load, but also the access to the public the roof will have to be resized to support 5kN/m², on minimum 80% of its surface. According to the architects responsible for the current renovation, it would clearly be possible to implement a roof garden. However, even if the vertical structure seems to be predisposed to take over the loads, the horizontal structure cannot. A self-supporting structure will then be placed under the current roof, and the loads will be redistributed on the columns or slabs.

Final Sketch

The project of La Fleche is above all a project with a social purpose. On this roof, children and employees will be able to grow a multitude of fruits and vegetables and improve their living environment. Few low socioeconomic class children have access to a garden. This vegetable garden will be like an oasis in the heart of the city for them. The goal here is not to make money, but to make food and create a bond. Nevertheless, between 25 and 30% of the fruit and vegetable needs will be covered by the gardens. The greenhouse alone will produce little, its advantages are more related to the building's metabolism, it will help with insulation and temperature regulation. It will also be able to easily produce up to 20% of the residents' domestic hot water needs. The compost produced by the kitchen will be very useful since the ground is cultivated and must therefore be fed. Compost ensures the quality of the soil, while respecting it. Most of the food will be produced on the ground, on the refuge site and across the street, where there is currently only a concrete square that has been abandoned despite its two or three public benches. This transformed space will offer increased productivity and high quality urban green space.

B. Retail space

Description

The building and its surroundings

The Fri-Agra building is a refrigerated warehouse for food. It is built with an all-steel structure. Its roof, spread over 7 different buildings, offers a usable surface area of 4718m², on the three largest roofs.

Fri-Agra is located in the municipality of Molenbeek-Saint-Jean, on the banks of the canal in an area of high industrialization combined with some housing. Within a radius of 350m, there are 2 primary and nursery schools. Further on, 650m away are the Anderlecht slaughterhouses on which the first urban farm in Brussels, the Foodmet, is located.

This area around the canal is expected to evolve in the coming years. All around are already being created a multitude of hotels, inns, museums... The "canal plan" intends for the next 20 years to solve certain problems related to housing, employment, mobility, quality of life and the economy in general. The establishment of a food source that will produce non-relocatable and affordable jobs therefore seems to be in line with the project's ambitions. In addition, the location of the building has a high visibility, located on the banks of the canal and therefore offers a restored image to this old hangar of low architectural value.

Economic viability

For such a large surface area, a professional installation is required, whether it is for the equipment but also for the recruitment of employees. Due to their proximity, it would be interesting to take advantage of Foodmet's infrastructure for product distribution. Why not even propose complete roof management to the Foodmet manager? As we will see later on, the conditions of this greenhouse will make it possible to grow a wider variety of species and thus expand the supply of the slaughterhouse market.

Greenhouse integration

HVAC

The interest of this scenario lies in the function of Fri-Agra. Refrigeration requires a lot of energy, which once transformed is lost in the form of heat. This heat can be recovered from the ventilation system and returned to the greenhouses, allowing the cultivation of more exotic plant types that usually require warmer climates than in Belgium, such as cucumbers or peppers. (Beckers 2018) The ventilation system in question is of system type D, the connections with the exhaust vents should be easy, being located on the roof.

The buildings to the north of the plot, in direct contact with the warehouses, are 8 dwellings housing at least one family each. The average household size in this neighbourhood is 2.5. (Statbel 2016) It can therefore be estimated that there are approximately 20 people living next door to Fri-Agra. To offer domestic hot water to these households, it will therefore be sufficient to use only 20m² of solar thermal panels and a single 1000l boiler. Depending on the exact number of inhabitants, it will be easy to find a few more free square metres on the roof to be able to best meet their needs.

Water

For the moment, the roof is not equipped with an RWH system. Recovering water is always interesting, even if it is only to slow down the flow of rainwater in evacuations during heavy rainfall. It is nevertheless best to find a use for it. However, the type of agriculture implemented here will be hydroculture for a cost-efficiency reason, so it will use little water. In addition, there is very little free floor space left on the plot. It is therefore difficult to store rainwater.

Compost and CO2

The Fri-Agra building does not house anyone, simply its twenty employees during the day. Food produced on the roof is not processed on site. These two factors therefore indicate that, a priori, no organic waste will be produced thanks to the implementation of the greenhouse. Moreover, with a hydroculture system, it could not be re-injected into the process.

As for CO2, it's the same story, there are not enough people in the building to be able to exploit the flow.

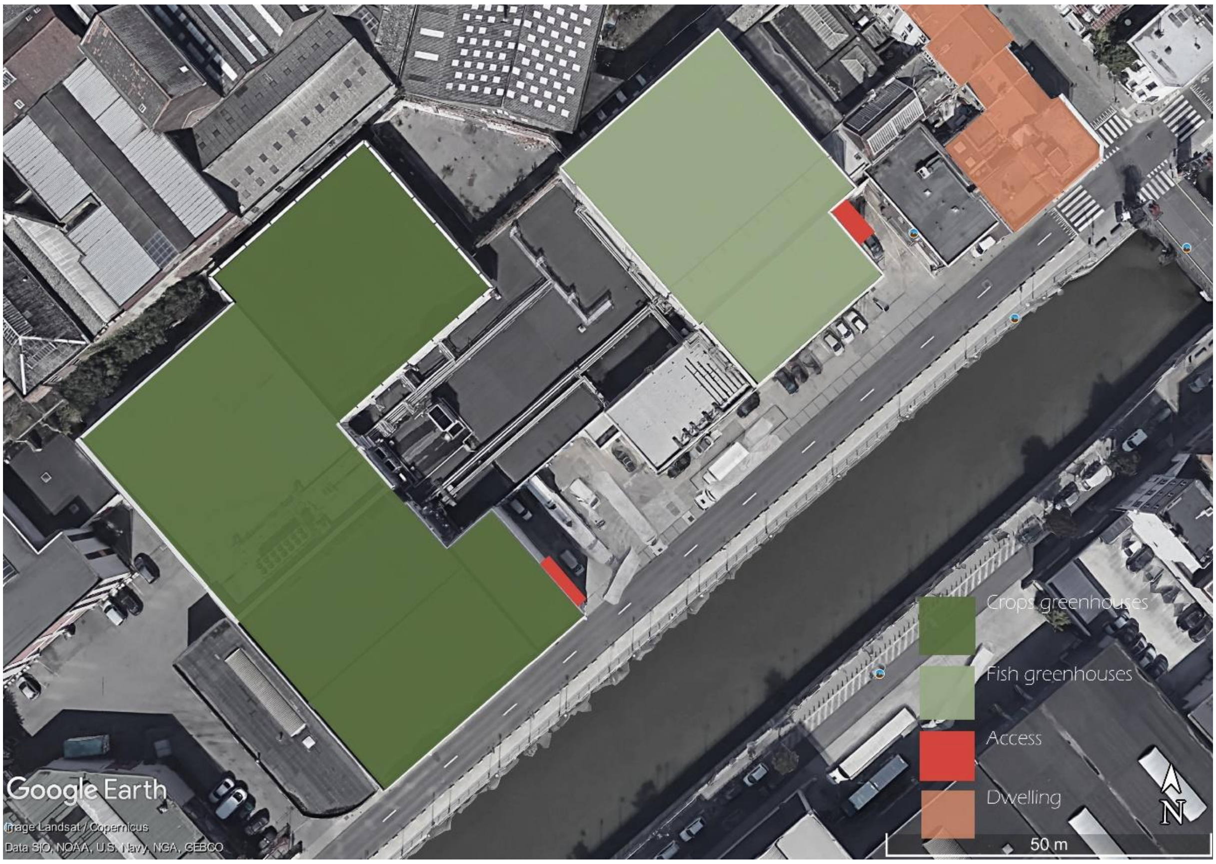


Figure 19: Fri-Agra plan

Installation

The greenhouse

To reduce the price, a polycarbonate greenhouse will be installed, with 8mm thick panels. Its distributed weight is 10kg/m², but it will be necessary to have an extra 19kg/m² for solar panels locally. (see Appendix: Thermal solar panels)

The roofs of the building are currently only accessible for maintenance and there is no proper access to allow employees to come to the roof on a daily basis. In addition, if the maintenance of the greenhouse is entrusted to the Foodmet managers, access must be outside the warehouse, in order not to mix the different jurisdictions. In front of the Fri-Agra headquarters, there is a small parking area that could easily be transformed into external stairs to reach the greenhouse on the northernmost building. As for the greenhouses to the south, access will also be via an outside staircase along the building. It is also necessary to provide for lifts for the products.

The type of farming

The Fri-Agra building is divided into several warehouses. Three of the five main warehouses have higher roofs at the same height between them, so this is where the greenhouses will be installed. For the sake of transparency in the system, aquaponics is chosen over hydroponics. Indeed, by installing this system, it is certain that vegetable cultivation will be carried out without chemical inputs to avoid killing fish, regardless of who will manage the greenhouses in the future. Therefore, a roof space must be reserved for fish tanks. The total usable surface area is 4718m², the fish farm must occupy about 30% of this surface area, i.e. 1415m². The roof on the northern part of the plot is almost the right size (1376m²), so this will be where the striped bass will be installed. This species of fish is chosen because it is the same species as on the Foodmet farms. They opted for this species because there is a market for it in Brussels. (Beckers 2018) Tilipia could also be used, but in order to simplify cultivation and distribution processes, the same striped bass as Foodmet will be preferred, again with the aim of bringing these two farms together.

The two greenhouses to the south will therefore be reserved for agriculture on 3400m². Thanks to the supply of heat from fridges, fruit and vegetable species usually grown in heated greenhouses or in regions milder than Belgium can be grown. They could be peppers, (Beckers 2018) or even bananas as in the Urbanana project on the Champs Elysées in Paris by the SOA office. (SOA 2012)

Structural reinforcement

Fri-Agra's roof, like the rest of its structure, is made of steel. This is a steel skeleton with a lightweight cover, classic for a warehouse. Its bearing capacity will not be sufficient to regain the weight of the farm even in the least-loaded areas. If the span had been smaller, an exostructure could have been put in place, such as wrapping the building in a second skin. Nevertheless, as vertical intermediate supports are necessary and possible to insert in the warehouses, it is preferable to opt for an overall reinforcement of the horizontal structure resting on the new columns. At planting locations, the load to be taken back will be 200 to 300 kg per m², including the load of plants, facilities, structure and staff.

For the greenhouse in the north which will house the fish farm, it is necessary to count 800kg/m² and up to 1000kg/m² locally for the basins including fish.

Final Sketch

The Fri-Agra case study is an example of a farm whose main, or even only, purpose will be to produce food. It offers a large recoverable area, in the heart of Brussels and close to the city's first urban farm. Its technical conditions are ideal for implementing an integrated greenhouse because refrigeration produces a lot of heat. The greenhouse then relies on the weaknesses of the system, and recovers the waste heat. With this free energy, the greenhouse will produce more tropical fruits and vegetables for a wider range of choices to offer. A partnership with Foodmet can start the creation of a hub of intense agricultural activity in the city, where the various infrastructures can be brought together, in a circular economy and resource saving scheme.

C. Public Space

Description

The building

Building U is the oldest building on the ULB campus, it was built from 1922 to 1924. During the research in the ULB archives to know the structure of the roof, it was discovered that originally it had 5 floors but during a laboratory fire in 1971, the top floor was destroyed. (see Appendix: Archives de l'ULB, Fire of 1971) This last floor was an aluminium superstructure and housed labs. During the fire it burned quickly, the underlying masonry structure resisted and did not spread the fire. (R. Rosbach 1971) Currently the roof is still accessible for maintenance, and multiple emergency exits connect it to the ground. On the southern part of the roof, a recently renovated annex is reserved for the architecture faculty. The southern part of the roof represents 4060m², of which more or less 4011m² are exploitable. The roof receives no shade from the surrounding buildings.

Inside the building, there are classrooms, auditoriums, student quarters, offices, workshops and laboratories. Most of these rooms do not require any special interior temperature, but laboratories or machine rooms must be kept at temperatures around 20°C. Currently the ventilation system only supports ventilation itself, and heating. On the Solbosch site, no building is air-conditioned, apart from the reserve of precious books and a machine room cooled by a cooling system with rainwater, installed by the ULB energy cell. Apart from these two places, air conditioning is non-existent. This sometimes causes problems as during this summer of 2018 when a heatwave plan had to be put in place by the university authorities, closing all the premises in the buildings at 3pm.

The urban integration

The building was chosen because it is located in the heart of the campus. A university campus is similar to a small town because of the diversity of its functions. That is to say, in a very small perimeter, a multitude of needs are gathered that BIGHs can meet in practically all the fields suggested earlier, among other things, housing with a need for hot water, and producing organic waste. But also right in front of the building are the university restaurants, with the necessary equipment for the transformation of the cultivated food, as well as their direct distribution. To transform food, by simply cooking it for immediate consumption for example is to give it extra value. Currently, the main restaurant already receives fresh vegetables, and has to transform them themselves, so it will not be necessary to provide new processing areas, as the kitchens are already equipped. The impact of the greenhouse on the health of academics is reflected in better nutrition in restaurants and an awakening of awareness about the importance of food and its means of production.

One of the strengths of this scenario is the visibility of the greenhouses, nearly 27,000 students cross the campus, not to mention the technicians, professors and employees of the university. The strong educational aspect does not need to be justified, given the geographical location of the project. However, we are not in a simple school, but in a university, so it is possible to keep a portion of the farm for experiments in agronomy, but also in building metabolism. Rare are the BIGH and it is necessary to take advantage of the opportunity to have, in one place, so many specialists in agronomy, architecture, energy etc to be able to study their feasibility.

Economic viability

From an economic strategy point of view, we find ourselves in a case where the main purpose of production is to be sent directly to restaurants to be processed and then sold. In short, enable the university to run on its own resources as far as possible. The surplus vegetables can however be sold, for example at the organic market which is held every Tuesday at the foot of the U building, on avenue Paul Héger.

Greenhouse integration

HVAC

Probably because it was not designed to remain bare, the roof loses a lot of heat. On the aerial map, the building is classified "high" in terms of leakage. (Bruxelles Environnement 2009) Its association with a greenhouse will thus enable it to make significant energy savings.

Figure 20: U building Thermographic map (Bruxelles Environnement 2009)

The connection of the ventilation system will make it possible to regulate the temperatures for the various rooms whose needs are particular, but also to have a pleasant temperature, throughout the seasons in the rest of the building. As explained above, the ventilation system does not make air conditioning, however it is composed of a fully mechanized system. Both air extraction and exhaust are controlled by pumps and fans, a so-called D-type system. It will therefore be easy to connect the air inlets and outlets to the greenhouse, and to start upgrading the metabolism of the construction. Each floor or large auditorium has its own independent ventilation system, all are computer controlled from a program grouping all ULB facilities in real time. (see Appendix: Ventilation system of the U building)

CO2

Hundreds of students roam the corridors and audiences of the U during the day, which is a good thing since it is during the same period that the plants photosynthesize. CO2 storage is not a simple process, so the simultaneity of plant and human cycles is essential. Especially since the CO2 released by the mass of students helps plants in the process of absorption and transformation of light.

Water

Currently there is no RWH system in place yet, such a surface could recover up a significant amount of rainwater per year. However, with the aquaponics system the need for water is much less important because it is in a closed cycle. Savings of up to 83% can be made compared to agriculture in the ground. The excess water could then be sent to the multiple toilets in the U building and save hundreds of litres of clean water per day wasted by the multitude of students running between two lectures. In another way of maximizing the use of greenhouses, a scenario involving solar thermal panels to heat water for the student housing will be considered further on.

Compost

As described above, the campus is similar to a small-scale city, where food is processed and consumed. To close the loop of this cycle, it is necessary to add the production link ensured by the greenhouses, and finally waste management. Once again, everything can be done on the ULB site itself, offering the mini composting centre both to the restaurants and cafés located on the site but also to students living on or in the immediate vicinity of the campus. The compost created can then be redistributed, for example at the ULB vegetable garden set up a few years ago, but also why not be at the disposal of students who would be lucky enough to have a garden, or simply a small planter on a window sill. Indeed, compost will not be useful for the BIGH, which runs in a closed cycle thanks to fish waste.

Installation

The greenhouse

To implement a structure that will last over time, we will choose single-glazed panels on a steel structure with a weight between 35 and 50kg/m of facade. Their facade height is 5m and 6m under the ridge to take advantage of the natural inertia effect. Since the walls will be brittle, the greenhouses are built 1m from the edge to avoid breakage falls on the people on the campus.

The accesses are already provided by the presence of emergency exits on the roof. Greenhouse entrances can then be made at these locations, while at the same time providing entrance airlocks to ensure the safety of plants, fishes and workers.

The type of farming

Building U has a usable area of 4011 m², so it is an interesting candidate for hydroculture. With such an area, the installation prices of the systems become more profitable and therefore conceivable. To ensure that the plantation is managed without herbicides or chemical fertilizers, aquaponics is chosen. This configuration offers 1200m² of fish farming and 2800m² of crops, which can have up to 60 000 fish and produce 84 000 kg of tomatoes per year (calculated on the Foodmet's yielding in Anderlecht). The pisciculture part will be implemented on the northernmost roof and will have the possibility of having its roof covered with solar thermal panels on the southern sloping part of the greenhouse on approximately 640m². Leaving the sides and half of the roof translucent, you can plan to grow climbing plants above the fish tanks. The weight of the plants would therefore be transmitted directly to the structure without adding any load on the horizontal structure, which would already have to take up the weight of the water. With the appropriate tanks, this could create hot water for all 212 students of the Willy Peers and Elisée Reclus kots (main housing located in the heart of the campus, facing the U) with less than the half of this area. With the remaining 360m², the water heated by the sun will be able to be distributed in all the buildings just around the U and the U building itself, knowing that these buildings require very little hot water.

Structural reinforcement

In plant cultivation areas, the weight can increase, including the greenhouse structure, bins, water, plants and people moving with the products (on pallets among others) up to between 200 and 300 kg per m². Knowing that the roof was previously occupied by a laboratory, the estimated bearing capacity is 300 to 400 kg/m²on the basis of the recent Eurocodes, however the building being old, it will still be preferable to make a more in-depth structural study. Furthermore, with an aquaponics system, most equipment can be suspended directly to the greenhouse, bringing the loads back to the edges of the roof, and therefore to the vertical structures, which are better able to withstand heavy loads.

In the fish farming area, the distributed weight is 800 kg/m² and goes up to 1000 kg/m² locally. In this case, it is very unlikely that the roof, even with its former floor status, can be strong enough. A study of the vertical structure will be required to see if the walls would be able to receive the additional load from the roof through self-supporting horizontal structures.

Final Sketch

The ULB's integrated greenhouse offers a comprehensive case study on how to optimize the performance of a BIGH. Its unique location in the heart of the campus provides it with an application case for many of its outputs. With a usable surface area of 4011m², the roof is divided into three parts. The northernmost part of 1065m²m² will be used as a fish farm greenhouse. On the steel structure, climbing plants will be suspended: for example, hops, for which students will certainly find an appropriate use, given that some cercles have already tried to brew their own artisanal beer. Its sloping roof facing south will be covered with solar thermal panels on 550m², to produce domestic hot water for all students living across from Building U during sunny days. The largest greenhouse in the west will be divided in two. On 525m², on the northern corner, will be the experimental aquaponics greenhouse for the various interested departments of the university. The remaining part of the roof, with its remaining 2420m² and including the area parallel to the fish farm greenhouse, will be the greenhouse that will produce vegetables for university restaurants and the market. With this configuration of the greenhouse on two distinct parts of the roof, it will be possible to create different climates, among other things thanks to the different orientations. And so, several varieties of vegetables can be grown simultaneously. To get an idea of the order of magnitude, on its 2420m² in total it will be able to produce up to 48 400kg of tomatoes from the very first year. Of course, it will be possible to grow many other things such as aromatic herbs, salads or microgreens. Microgreens are the results of germination of vegetable seed up to 7-8cm. They are then consumed at that time, they are foods with a high concentration of taste, nutrients and which naturally takes less time to grow.

The four building metabolism streams, HVAC, water, CO2 and compost, are all exploited. The greenhouse will considerably improve the overall metabolism of the building, allowing it to warm up but above all to cool down more easily. Solar thermal panels will also be able to heat domestic hot water for 212 students. And thanks to the RWH system, a small part of the rainwater can be sent to the greenhouse, but mostly in the grey water system for toilets. The CO2 emitted by the students will be filtered by the plants and the compost produced by the various restaurants and students living on or near the campus.

In addition to becoming more autonomous, the Université Libre de Bruxelles will benefit from a brand image and ecological progress that is unparalleled in the capital but also at national level, with significant potential for influence, as a university think tank on ecological issues and solutions.

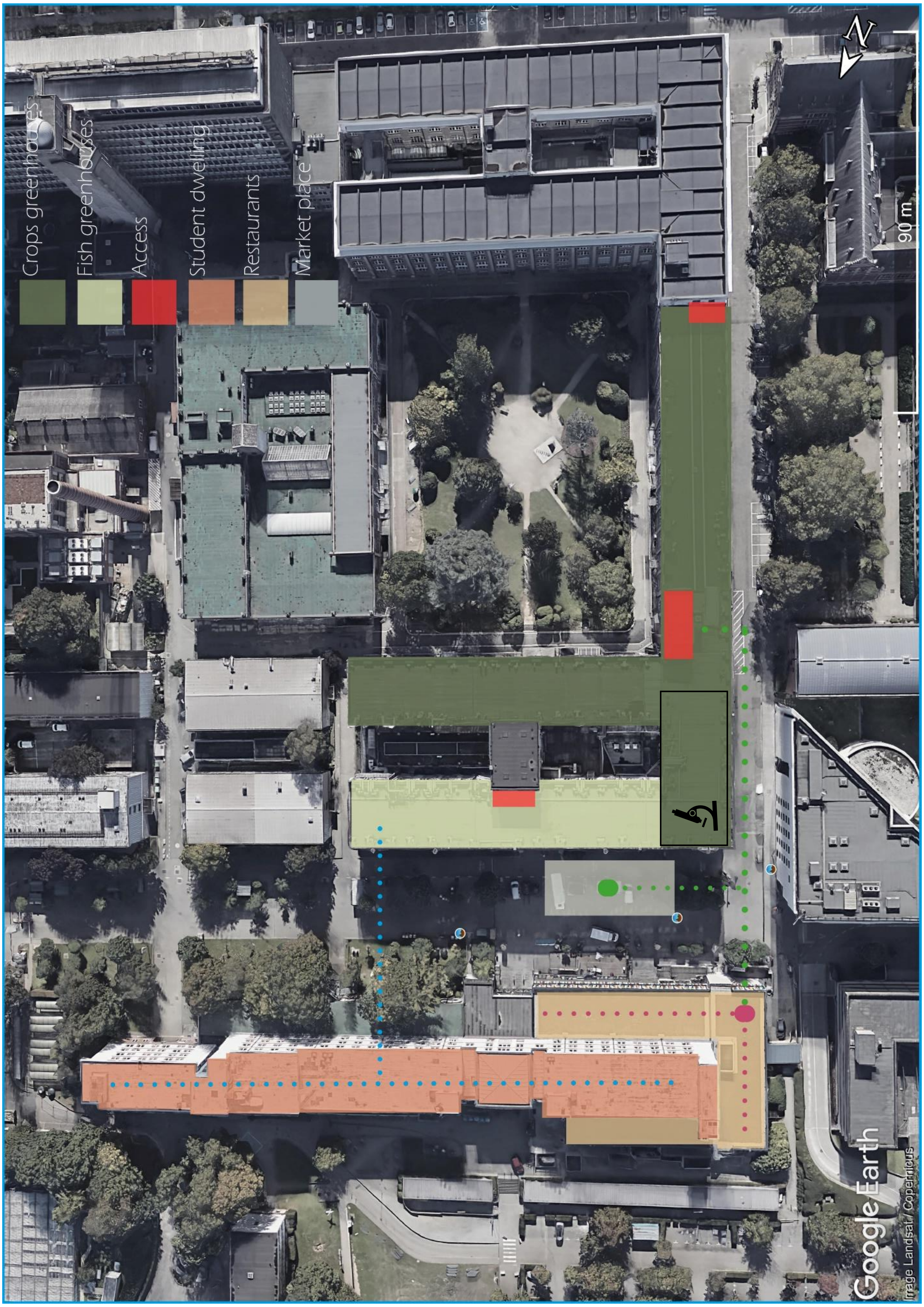


Figure 21: ULB plan

In green, the vegetables distribution; in pink, the distribution of processed food; in blue the solar heated water

Results and discussion

These case studies, which are very different in their function and purpose, allow us to visualize the different issues specific to each one. In the residential case, it is clear that the issue is more social than economic. It is to avoid excessive costs and professional maintenance that the technique of soil agriculture is preferred. In addition, such an installation allows the inhabitants of the building to take care of their own planting, offering them all the benefits for their health and an opportunity to strengthen social ties. Access to the roof is also simplified because it is not necessary to open it to the public and remains the prerogative of the inhabitants. It is particularly interesting to offer such a facility to social housing buildings, or at least in low social index neighbourhoods, because being able to produce part of one's food is a solution to food insecurity (Duchemin , Wegmuller et Legault 2008) which, as a reminder, forces 32,000 people each year to use food assistance in BCR. (Henrion, Mantell et Van Bambeke 2015) Nevertheless, it is necessary to ensure the maintenance of the greenhouse, because nature tends to quickly regain its rights, and a poorly maintained greenhouse will end up not yielding vegetables and would harm UA's image. Projects with only volunteers working, are often limited in time because there is no designated coordinator. A janitor-gardener position could be created for each facility. His or her role would be to supervise the maintenance of the vegetable garden throughout the year, and to plan the major works with the inhabitants. the gardener would also be there to train them and help them in their plantations. In this way, education in agriculture can be deployed and benefit everyone, while creating significant jobs if this pattern were to be repeated.

It should not be overlooked that soil cultivation requires a stronger load-bearing structure, and therefore reduces the likelihood that the roof will not be reinforced. There is therefore a relatively high cost to be expected for surface recovery on dwellings, a cost that will be difficult to offset through the production of vegetables since they will be intended for direct consumption and not for sale. Although soil cultivation is easier for amateurs to maintain, its yield is lower than that of hydroponics or aquaponics. Naturally, the inhabitants benefiting from a greenhouse will see their food expenses decrease, but the initial amount to be advanced remains a significant obstacle.

As for the energy performance of the housing building when a greenhouse is integrated, regardless of size, the benefits will be present. Indeed, heat recovery remains worthwhile to regulate the heat of the building, especially if the roof is poorly insulated. (Delor 2011) Collecting rainwater will be necessary, at least for watering plantations, but can be used to reduce household water consumption, by reinjecting rainwater for use in sanitation, for example. However, the CO2 flow is not particularly suitable for installation. Plants breathe during the day, but in the home, people emit more CO2 in the evening and at night. The cycle is therefore reversed, and since this air cannot be stored, it is difficult to recover CO2 from ventilation. (Beckers 2018) On the other hand, compost exchange is very worthwhile to set up, both for the household that reduces its waste, and for plant growth anywhere.

As far as the installation of these greenhouses at the urban level is concerned, there are two scenarios. If they are placed on an existing building,nowadays it a permit must still be applied for through the RRU. In the case of a new construction, it is certainly easier to plan all the connections for the different flows and the appropriate structure in advance. Nevertheless, the new buildings in Brussels must now be completely passive since 2015, so there is no longer really any energy inherently trapped to recover. (IBGE 2015) However, it would be possible to revise the definition of passive house in the case of a BIGH, where taking the building as a whole, could be considered passive, thanks to greenhouse regulations. By using the building's metabolism to regulate it, long-term savings of resources and means can be achieved.

In the end, the cost of installing a greenhouse and coupling the flows remains high. Paradoxically, it is the poorest, and therefore the least able to invest in such facilities, who would benefit most from them. It would therefore be appropriate to create support to promote BIGHs on residential buildings.

In fact, without financial assistance it will be difficult to make private greenhouses generally available. In addition, each of them, independently, is under the sole control of their respective owners. There is therefore no way of supervising the proper management of these greenhouses as a whole. The redistribution of surpluses will not be managed either. BIGHs on apartment buildings are therefore quite utopian, because they offer many benefits, but their installation seems complicated from an economic point of view.

Concerning the industrial function, we can find much larger areas and therefore the possibility of installing more technological agricultural techniques that can achieve higher yields.

In the case of this study, this is the main objective of the Fri-Agra greenhouse, the intensive production of food. Aquaponics that is employed here, indeed for large greenhouses, hydroculture seems to be essential for a matter of yield. Then you have to choose between hydroponics or aquaponics. However, aquaponics is a system that runs alone, without inputs and promises respect for plants (and fish), and is therefore a more sustainable approach. Had the roof not been able to take over the load of the fish tanks on the roof, and had no ground plot been available there either, then hydroponics could have been put back into the equation, because in hydroponics the load of the material remains constant on the whole roof and is light.

As far as the building metabolism is concerned, it is mainly the heat flows that are interesting here; the greenhouse can manage the wasted energy and transform it into an added value for the vegetables. Of course, here it is the heat that is recovered but it could be, in another establishment, a surplus of CO_2 that would have to be recovered. The concept is to focus on what the industry has to offer (or more precisely to lose) and what the greenhouse can recover and benefit from.

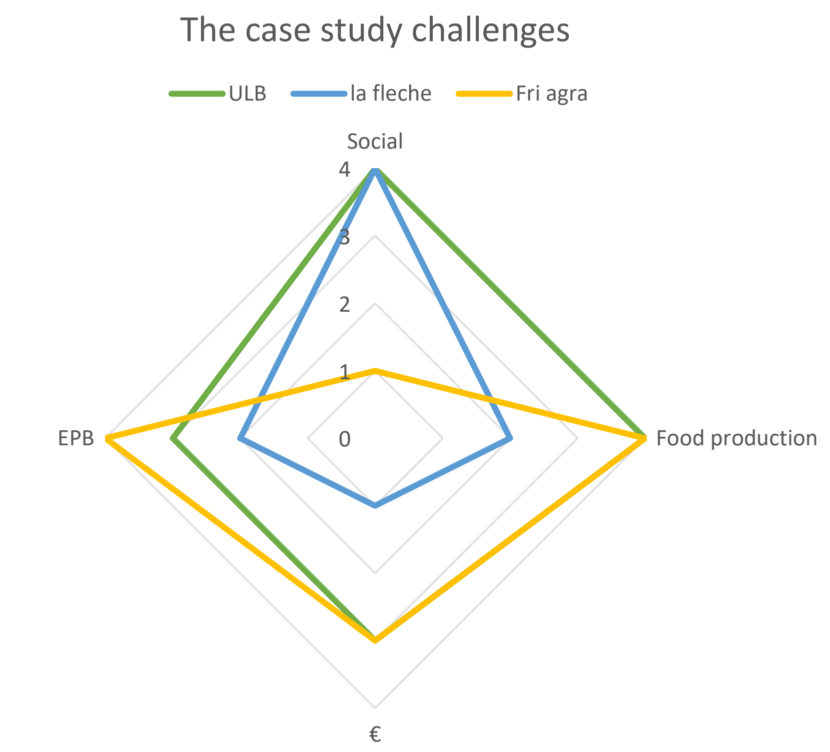
The maintenance of the greenhouse, given its size and cultivation system, is entrusted to professionals. Access to the greenhouse is completely restricted to employees for security purposes, and it is up to them to organize guided tours for educational purposes. Agricultural training can also be provided for people who are disabled, depressed, unemployed, former prisoners, in burnout... In order to help these people, but also to train as many people as possible in the ecological transition that is about to take place. Indeed, it would still be a shame to keep such a socially enriching space private. Education and training are therefore two key elements to make all aspects of UA profitable.

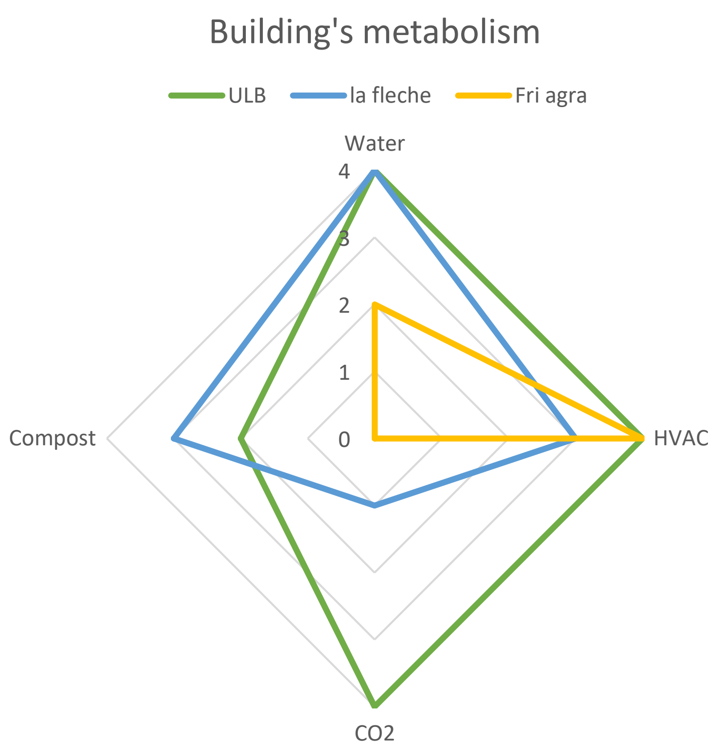
From an economic point of view, this scenario is much more viable than the previous one. On larger surfaces, it will be possible to ensure a constant production over the year, to build partnerships to distribute food and amortize the investment. As far as roof ownership is concerned, the proposal for a partnership between the building owner and the greenhouse manager seems to be the one that will ensure with the greatest certainty the proper maintenance of the installation. In this way, all actors are economically involved and have common interests in the proper functioning of the business.

In the case of ULB, the case study illustrates clearly how it is possible to optimize the ins and outs of a circular economy system. BIGH offers a diversification of campus services, and at the same time makes it more autonomous, while remaining within the confines of the university.

Roof arrangements for commercial functions are very similar to industrial functions. Indeed, given the size of the buildings, it is possible to find large ones that ensure a profitable investment. The activities that take place are sometimes sources of lost energy that the greenhouse could put to its advantage.

In terms of farming style, aquaponics is also the preferred option (unless there is a structural constraint).





The results of the GIS programme for the residential function show that there are 2209 buildings of more than 400m². In total more than 1 867 315 m² are gathered. If we only take into account buildings near schools, we have 1801 buildings with 1 539 862m² of usable space. Although the installation is not very profitable, the available surface area is not negligible. In the various studies, we find that with the yield of outdoor cultivation, it takes between 60 and 100m² to offer autonomy in fruit and vegetables for an adult (the area needed to meet the needs for cereals and meat is not considered here, as there is no space for such crops). In short, it would therefore be possible to feed 19 248 people, not counting the need for cereals or meat. At the city level, this represents 1,67% of the population.

The districts with the highest potential for integrating agriculture into the roofs of housing are Vieux Laeken Ouest, Kureghem Dauw, Hopital francais, Sheut and Woeste with a potential density ranging from 8.8% to 5.8% of their total area to be transformed. In total there are 109 districts out of 145 that offer at least one roof, and 73 of them have more than 1% of surface area to offer. The distribution is relatively random, there is no high concentration area although we can see a small core at the junction between Anderlecht, Molenbeek and Koekelberg.

One difference with industrial functions is that public establishments gather many people. This makes it more likely that CO_2 and compost flows can be exploited. The greenhouse can also create opportunities such as the creation of a restaurant, where food could be directly processed, or a store or market, where food could be distributed immediately, with or without prior processing. Knowing that each step added to the circuit creates jobs and adds value to the product, the local economy is strengthened.

Economically and in terms of the building's energy performance, it is the public service that is the most profitable

Given their common ground in terms of the feasibility, implementation, management and geometry of BIGH projects, public and industrial functions have been pooled in the GIS research programme.

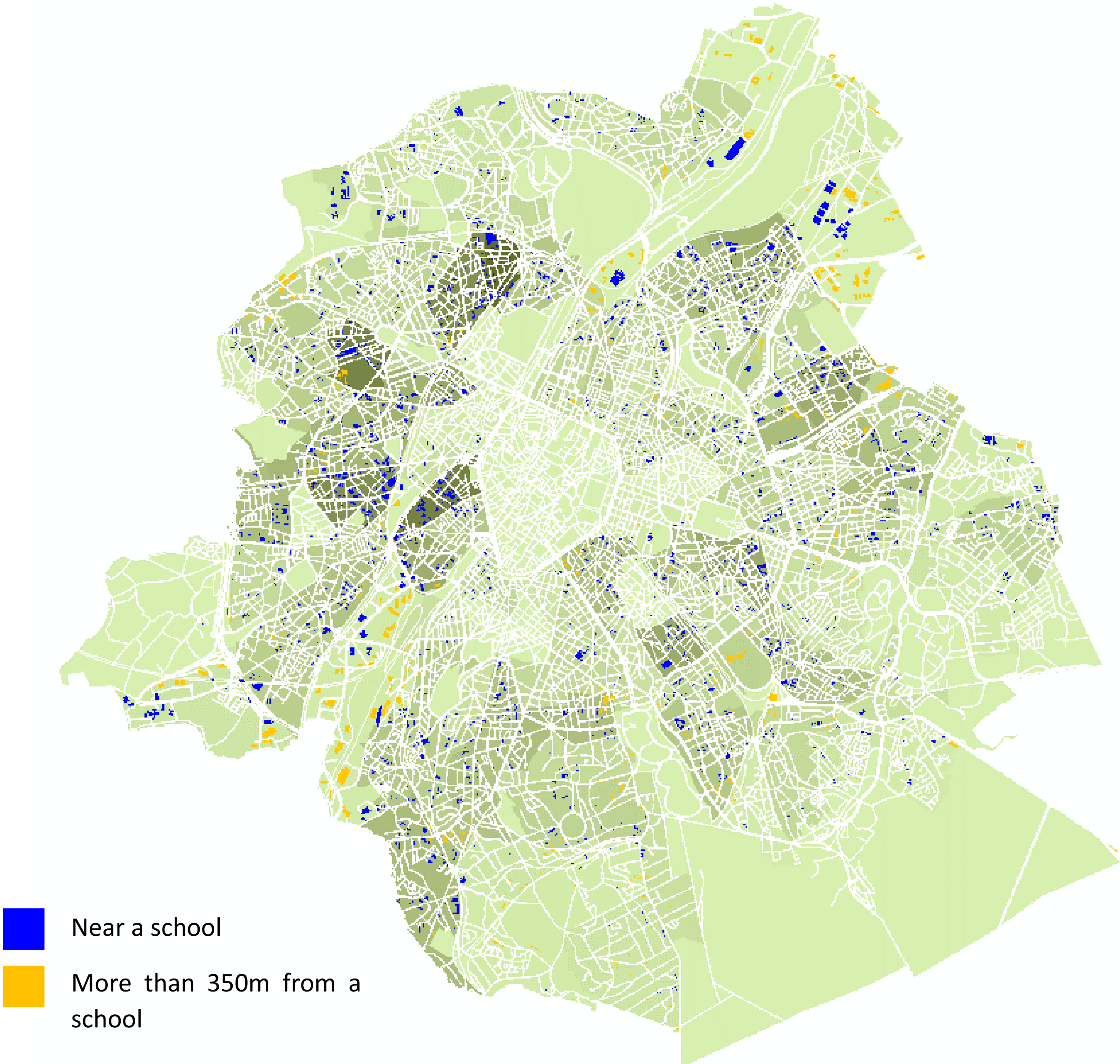


Figure 22: GIS results for residential buildings

Nevertheless, in this investigation, only buildings of more than 400m² were taken into account. This means that it is residential buildings rather than single-family homes. This does not mean that it is impossible to couple greenhouses with this type of housing, but for existing buildings, the investment (for strengthening, coupling flows and installing the agricultural system) is too high for a too low yield and to be replicated. However, for buildings under construction, one side of which is at least 20m long (for the inertia of the greenhouse heat, in proportion to the 5m height required) it would be possible to integrate the greenhouse from the beginning during the design stage. Therefore, with the adequate structure provided for in the initial plan, the addition of a plantation greenhouse should not be so expensive, since the very structure of the greenhouse is not very expensive, 60€/m² for an aluminium and polycarbonate greenhouse (Ecores, Lateral thinking factory et Noemie Benoit consultant 2014). Of course, agreement must be given that a greenhouse can be built above the top floor, and not in its place (see proposal for amendment of the RRU Art 8). For a house without a piece of land and where it is therefore impossible for its occupants to cultivate a garden, the benefits will be undeniable. Whether on their energy or water bills, their quality of life will also be improved by better nutrition, and a reduction in household waste through composting.

When entering the criteria for the industrial and public the first visible thing is the zoning, the darkest green areas are those with the largest potential roof area of more than 3000m² in relation to the size of the area (not in relation to the surface of the builded area). We already notice a green vein through the city, this vein runs along the canal. This is not surprising given the quantity of large industrial buildings on the banks. This observation is in line with one of the goals of this brief, because the Canal zone is a booming zone, with new buildings flourishing each year. However, it is also an area that is still quite poor at present. Integrating agriculture could help the population if the distribution is made in respect of their purchasing power, in order to avoid any gentrification. The most promising neighbourhoods are

- NATO (8,87%)
- Industrie Sud (7,27%)
- Delta(5,39%)
- Industrie Birmingham (4,46%)
- Parc Leopold (4,43%)

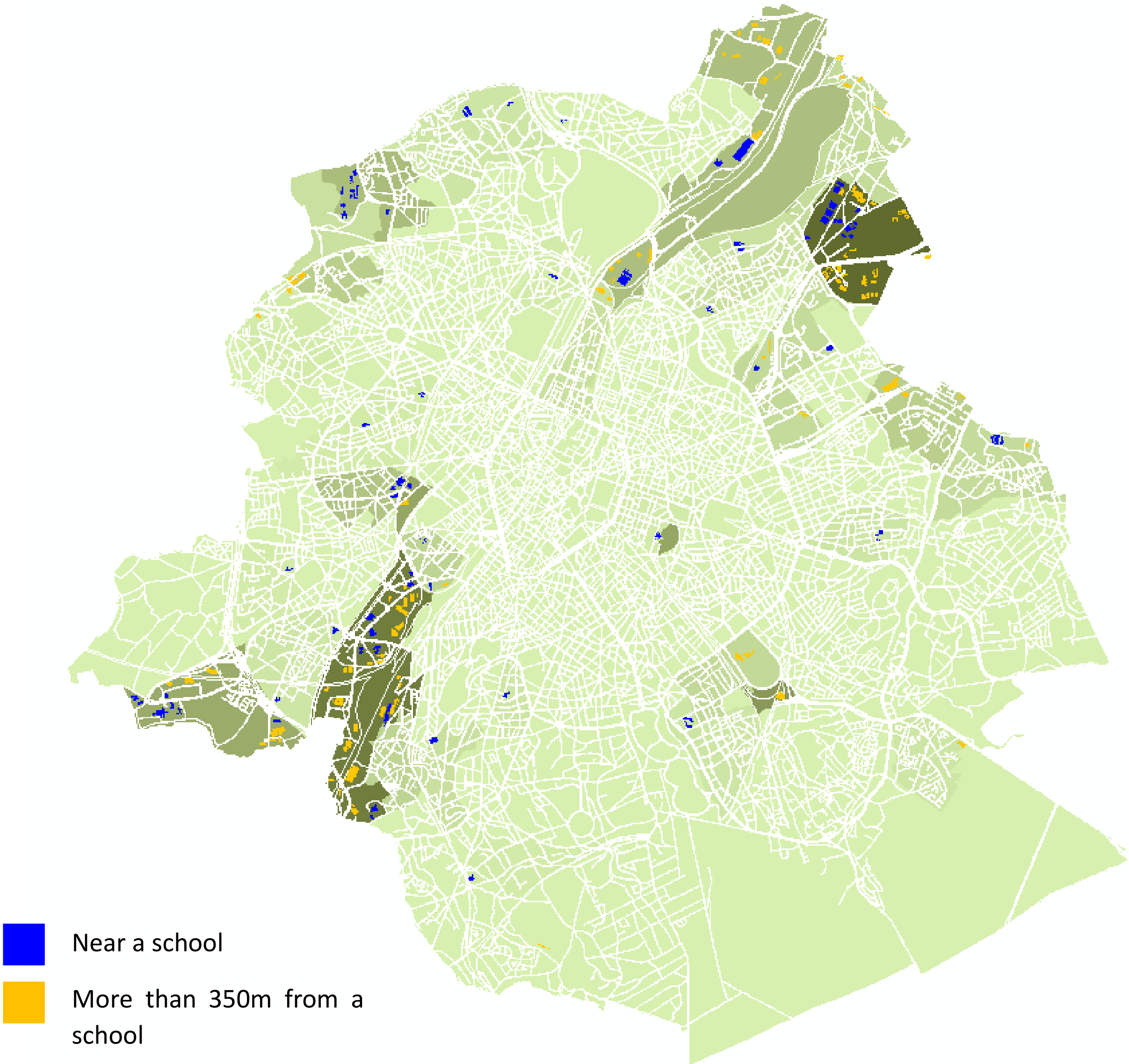


Figure 23: GIS results for Industrial and Public buildings

Compared to the map of high- potential residential areas, the areas are much more concentrated. Only 40 of the 145 districts have at least one building, and only 22 have more than 1% of their surface area to offer. This result is quite logical since industrial buildings are found in industrial zones that are more or less clustered.

The BCR has put in place a Canal plan for the next 20 years, its aim is to strengthen the residential function, but also employment and the economy as well as the quality of public spaces. (Région Bruxelles-Capitale 2014) Six pilot projects are already under study, at least one of which, in the Birmingham area (in which Fri-Agra is located), focuses on urban agriculture and highlights the different flows to be optimised with the presence of slaughterhouses and the Foodmet on its roof (see Appendix : Plan Canal – Fri-Agra zone) The advantage of having a high potential area is to be able to bring together certain transport or distribution services. It is appropriate to see that in Brussels, this could be the canal area since integrating as much urban agriculture as possible would represent a saving for the challenges of the Canal plan. Indeed, the new residents of the dwellings will have access to healthy food, improving their living conditions, but also by creating jobs that cannot be relocated, while offering a new and improved image of the area. It is also a place destined to be radically transformed, so it would be interesting to integrate UA projects into it, perhaps by means of urban planning charges.

In total, the programme lists 173 industrial or public buildings with a total of 1,187,943m². If we subtract those too far from schools, there are 76 left with 512,943m². This large decrease is explained by the fact that these buildings are located in highly industrialized areas, school facilities are more scarce than in other districts. However, it is expected that with the Canal Plan, the increase in the number of housing units will also increase the number of schools in the surrounding area.

The yields that can be expected from these greenhouses are much higher with hydroculture. Depending on the species, a yield of 10 to 50 kg/m² per year can be expected. At the Foodmet, after only one year, their tomatoes yield 20kg/m², but these figures can be improved. Knowing that an adult in the EU consumes 84kg of fresh fruit and vegetables per year, (Cerón-Palma, et al. 2012) and the Belgian is not far from this average with 85kg in 2017 (Vlaams Centrum voor Agro- en Visserijmarketing 2017). With an average yield of 30kg/m² (within the limits of the product's respect) with the surface of the 173 available buildings, 395,981 people could be fed, i.e. 33% of the total population. If aquaponics is installed, counting the basins on the roofs which would take up 30% of the surface area, 23.1% of the population will be self-sufficient in fruit and vegetables in BCR, not to mention the production of fish in addition.

With these numbers, we can see that it would be possible to achieve the objectives of the Goodfood plan, of 30% local autonomy in fruit and vegetables. And this by relying only on roofs, which represent 0.73% of the total surface area of the BCR. However, once again it would be preferable to use the benefits of nature by installing aquaponics systems that work almost in an autonomous way. Therefore, the Goodfood quota is not reached, but one can of course imagine that it is the community gardens on the ground that could take over to meet this goal.

GIS results

Table 4:GIS results summary table

	number of buildings	Roof space m²	% of total BCR surface	number of autonomous people *-Soil cultivation*	% population	number of autonomous people *-Hydroponics*	% population	number of autonomous people *-Aquaponics*	% population
Residential buildings - Total	2209	1867315	1,1567	23341	1,947	622438	51,925	435706	36,347
Residential buildings - Near School	1801	1539862	0,954	19248	1,605	513287	42,819	359301	29,973
Industrial and public buildings - Total	173	1187943	0,736	14849	1,239	395981	33,033	277186	23,123
Industrial and public buildings - Near School	76	512943	0,318	6411	0,535	170981	14,263	119686	9,984

Conclusion

City dwellers have lost contact with nature. The real value of things disappears behind the labels on supermarket packaging. Fruits and vegetables no longer follow the laws of the seasons because the sun is always shining bright enough somewhere in the world for tomatoes to turn red. Current alimentary systems have been turned upside down because industry and the development of transport have removed all constraints. But relying so heavily on fossil fuels for culture and distribution does not seem to have been designed to last. UA intends to help citizens regain control over their food. UA by its proximity offers inhabitants a reality that had fled the city a few decades ago, it enlightens, educates and improves the quality of life. By its interstitial typology it imposes an environmentally friendly style of agriculture without petrochemical inputs or ploughing machines. Fresh fruits and vegetables will be distributed directly without ever knowing any ship's holds or refrigerated containers. Of course, this type of agriculture requires more manpower, but it is also one of UA's challenges to create jobs that cannot be relocated.

Beyond the question of the benefits of the return of nature for people, there is the more global question of urban metabolism. Although intense, this relies heavily on external resources. The city of Brussels, like many of its European neighbours, would not be able to feed its inhabitants on its own for more than a week. A blockade of the city or a shortage of oil stock would make food security very difficult. Through its secondary sectors, UA can also solve flooding problems in the event of a storm by collecting rainwater. It also offers a reevaluation of household waste by recovering organic waste, but above all it includes it in a loop. Indeed, it is not useful to collect waste and transform it if it is not used. However, this is where the best facet of agriculture lies, it is that nothing is lost or created, the whole thing works in a cycle. By integrating it into the city, each output finds a purpose. Current urban planning plans tend towards the most mixed functions, and it is in this kind of microcosm that UA is best integrated, as it is the missing piece in the cycle of circular urban economy.

According to the PRAS, there is 4% of the total BCR land area allocated to agriculture, in other words 6,456km². The association Terre en Vue, lists 4.8km² that can be used in addition. By really assigning an agrarian function to each of these areas, we could produce enough food for about 12% of the population. So we have to find other places to cultivate. Flat roofs are spaces that are too often neglected, and which could certainly benefit from more than just a new function. Indeed, thanks to BIGH, buildings can now produce food while improving energy performance. The integrated greenhouses are complementary to the buildings. The BIGH relies on the weaknesses of the building (heat loss, overproduction of CO_2, absence of RWH system, production of organic waste) to increase the efficiency of food production. Thus the metabolism of the building including the greenhouse tends towards an autonomy of regulation, in a win-win system.

In the end, in which case is it most appropriate to integrate greenhouses into the building's metabolism? We observe that placing BIGH on existing residential properties will often be too complicated, too expensive and unprofitable. If even if all the houses of more than 400m² found by the programme received a greenhouse on their roof, this would only feed 2% of the total population (with an open ground agricultural system). Furthermore, with the number of private buildings, it will be impossible for the region to put in place a strategic plan for their overall management. Good maintenance would therefore be left in the hands of the tenants or owners without any obligation to perpetuate the stewardship of the greenhouse. It is better to offer families opportunities to cultivate community gardens. In this way, they will be able to enjoy the psycho-social benefits of culture and reduce food insecurity in their households. Moreover, it is by bringing people into contact with the earth that they will learn to eat better.

For new residential constructions, if BIGH is immediately included in the project, it drastically reduces the costs of reinforcement and coupling. However, the laws allowing the construction of an additional floor must be passed. Hiring expert gardeners to supervise the maintenance of the greenhouse is a guarantee of sustainability, regardless of the number of inhabitants who may follow one another. In terms of energy, as housing must be passive, the gains will not be incredible. Unless it is the entire building, including the greenhouse and its facilities, that must have a zero footprint overall, only then will it be possible to reduce a significant amount of cooling and heating systems as well as the water autonomy that can be increased.

The residential buildings on which it would be most favourable to install a farm are social housing. Social housing is under the jurisdiction of the region, so it is possible to envisage a global supervised management of greenhouses and the creation of private horticulturalists' positions. Moreover, it is for the less wealthy households that the maintenance of a vegetable garden helps the most. First of all, because it can offer them a measure of autonomy, not related to their income, but also a healthy and educational hobby that can end up in a future formation, in view of the future societal upheaval due to global warming, not to mention all the benefits that have a direct impact on their health. A garden is also a timeless place where all generations can meet and grow together.

On the other hand, public or industrial buildings afford a great opportunity to integrate agriculture in the city. Using these unproductive roofs as a food source could be a major asset for BCR. By recovering all the roofs of industries along the canal and public or recreational buildings, Brussels could feed between 23% and 33% of its population and change its face.

For industries, the biggest advantage is the energy and CO_2 that can be recovered from activities and re-injected into the greenhouse for yields that beat all competition thanks to hydroculture. The disadvantage is that industries are mostly built with very light structures, so it is almost always necessary to strengthen them. The second concern is that industries are the least integrated functions in the urban fabric. In the past, it has been preferable to gather them in one place, which works both in favour and against UA. The negative side is that it will be surrounded by a majority of other industries. It is therefore difficult to set up domestic hot water flows, whether for toilets and or indeed for compost. At best, it could still be produced nearby by a neighbourhood community, but it will not be exploitable on hydroculture farms. Schools are also quite far from these buildings. However, the positive point of this proximity is the reduction of distribution or transformation sites. The services necessary for the food circuit can be gathered and used in a philosophy of resource sharing. At the same time, the area of high potential corresponds to the area of the Canal Plan, so it is very appropriate to combine the projects of the Plan with the development of a new UA centre. The Canal plan aims to bring back what is currently missing, i.e. more housing, schools, etc. In short, a greater diversity in which greenhouses can easily thrive.

For public buildings, it is this same diversity of functions that is the major asset. Indeed, we can once again manage the different metabolic flows, but it is the very functioning of the building as a whole that makes the difference here. First of all, it is the function for which the CO_2 flow is most useful, a building that houses people that produce this natural fertilizer for plants. The undesirable CO_2 on the lower level then becomes a source of wealth for the greenhouse. In return, the occupants receive oxygen-rich air. Then it is in these establishments, such as schools, shops, museums, sports halls, where links can be inserted into the circuit by transforming the products, distributing them, and recycling them in one place only. We can thus find a real ecosystem that is partly autonomous and creates long-term jobs. Another benefit is the improved image that the establishment has of itself, and in fact in these situations it is often possible or even necessary to create a canteen or a restaurant. Cutting all deliveries short, greenhouse products can be directly processed to enhance the restaurant's menu with fresh, high quality fruit and vegetables. The organic waste from this kitchen will also find an market, by being transformed into compost.

However, a paradox exists, as it is the old constructions with a lot of energy loss that would have the most to gain from installing a BIGH. Therefore, it may be necessary to target renovation projects. Indeed, the construction industry is already one of the most polluting in the world, so in order to save resources, we must start promoting repair and renovation rather than reconstruction. Nevertheless, in the studies that have been done, very few roofs can currently handle the loads (even the lightest) of UA. Vertical structures are often able to regain weight, but it is the horizontal structures (beams, slabs...) of the roof that pose a problem... Naturally there are several technical solutions to remedy this, but they have a cost.

It is still interesting, depending on this cost of roof transformation, to consider the installation of a greenhouse. Indeed, because in order to solve the problems that the greenhouse could make profitable, it would be necessary to install cooling systems that are sometimes very polluting and energy consuming. While the greenhouse, thanks to inertia and a simple ventilation system, can regulate the temperature of the unit for life. No longer is there any need to reinsulate the roof.

But the GIS estimate remains very rough, there are many roofs that will be tricky to transform. Either because of lack of access, or because it is impossible to reinforce the roof from a technical or economic point of view. It may also be that the geometry is too complex (see Figure 24: Complex geometry roof, GIS and maps), or that the exploitable areas are too small, although contiguous. Because GIS lists flat roofs here, not especially at the same height, in some cases, such as Fri-Agra, this does not pose a problem but sometimes the differences in levels are too pronounced, or too numerous to be able to install greenhouses on them. It is also necessary, when the roof is an option, that it must not already be occupied. The largest roofs are often already covered with solar panels because the aberration of such a large unused area has already been detected. According to Steven Beckers, there are not many roofs that could be recovered as they are at present, his personal research on the capital's territory has found only half a dozen in and around Brussels.

Figure 24: Complex geometry roof, GIS and maps

By comparing the results of this research with Mr Beckers' study, we can see that the available 118 hectares is to be revised downwards. However, the potential for roof recovery exists more than one might think. And their performance is such that their impact would be significant.

The two biggest obstacles at the moment are the horizontal load-bearing capacity of roofs, which is too often insufficient, and the minimum roof size of 3000 m² to be able to make the installation costs profitable. To extend the possibilities of integration, and to widen the movement, it is therefore necessary to reduce the costs and weight of the greenhouses. It was noted that for industrial buildings, the current BIGHs already have a field of application that will occupy builders for the next few years. On the other hand, the residential sector has a lot to offer, and few means to deliver it. To this point, only those options that were economically viable have been considered. To be of interest to leaders, it is necessary to propose projects that can be managed on a large scale and replicated. However, gardens can offer more than money to those who cultivate them. For the individual users, it would still be good to offer them a new function for their flat roof, if only for their personal enrichment.

In order to be able to offer it at low cost to the inhabitants of Brussels, and therefore find a solution to integrate it into homes, it is necessary to reduce the weight of the installation. The basic requirement is to have a roof that can support the gardeners because this load cannot be reduced. For the growing system itself, a low-cost and easy-to-maintain system is needed. There are already small aquaponics greenhouses connected to a $1m^3$ basin that produce good results. Aquaponics runs almost alone, so a family can maintain it without too much difficulty if they are properly informed. For the installation it only takes a few items of equipment, many of which can be made or recuperated. There must be plant containers, an aquarium, a pipe system to connect the two and a pump. (Village Partenaire 2016)The fish tank can be located elsewhere than on the roof, which removes the main load-bearing constraint of this installation. The last element to be optimized is the greenhouse itself, currently available in glass or polycarbonate. However, there are even lighter materials with excellent translucency qualities, such as ETFE (ethylene tetrafluoroethylene). This material is a very light and resistant transparent polymer membrane that allows more light to pass through than glass, it is cheaper and can be recycled. This material is increasingly used for all the reasons mentioned above, and could offer a multitude of possibilities for greenhouses on large or small roofs.

Making the city fully autonomous seems utopian, because the population density is too high. The city will always have to depend on its rural surroundings to provide for its needs. Peri-urban agriculture is a major component of the food sector. First of all, because it is not possible to make cereal fields in the city, nor to raise herds of cattle. There is therefore no question of displacing conventional farmers.

However, by combining traditional soil-based agriculture with rooftop hydroculture techniques, the challenges of the Goodfood plan now seem attainable. The 30% autonomy can be achieved if the laws allowing the integration of the UA are accepted in the Regional Sustainable Development Plan (PRDD) still under discussion. Among these laws it is crucial to simplify access to land and roofs, to make them officially dedicated to agriculture. Because in order to make a difference in the climate, we must act quickly. Except that building permits and legal procedures are currently heavy and slow, it is therefore necessary to reduce permit conditions to encourage initiatives.

It is high time to make our cities more resilient. The consequences of climate change are at our doorstep, and it is time to prepare. We must re-learn to live in symbiosis with nature. Build a more autonomous city and become ourselves more autonomous. UA has a role beyond that of nourisher, it is an awakening of conscience for all generations of urban dwellers. It gives people back power over their food and opens their eyes to the system in place.

Admittedly, agriculture is not an easy thing, you have to be able to roll up your sleeves and get dirty, summer and winter, under the rain and the sun. But in return, it brings much more than food. Imagine a city where everyone participates in their own food production, freeing themselves from the current system. Taking control of your life certainly requires time and work, two things that today's economic model monopolizes in the name of productivity. However, it may be time to ask more fundamental questions again, such as the place of work in a life. On a planet that must slow down, perhaps we must start ourselves, in a philosophy of degrowth where the goal will be to live with less but more. Where we will no longer be dependent on distant greedy companies but where we will learn to cultivate harmony with our Earth.

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Appendix

1. Appendix : Farmland potential

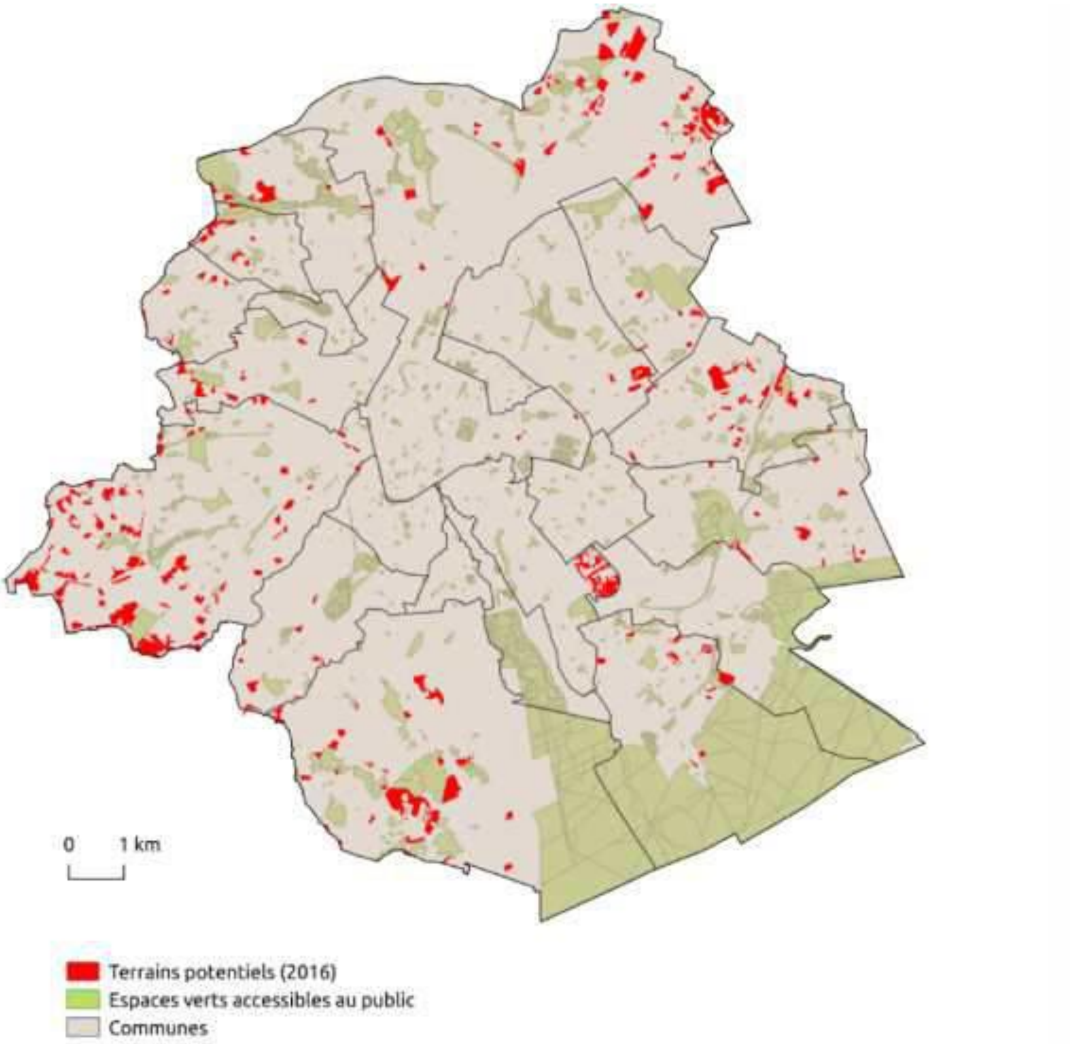


Figure 25 : Farmland potential (IBGE 2013, SPF finance 2015 Terre en vue)

2. Appendix: Under the city

Figure 26: Cellars of Le Champignon de Bruxelles. Cultivation on draff substrate,

Figure 27: Cultivation on coffee ground substrate at Permafungi

(Bergé 2017)

3. Appendix: Aeroponic system

Figure 28: Aeroponic system

Figure 29: AeroFarm, New-York, 2016

(AeroFarms 2018)

4. Appendix: Hydroponic system

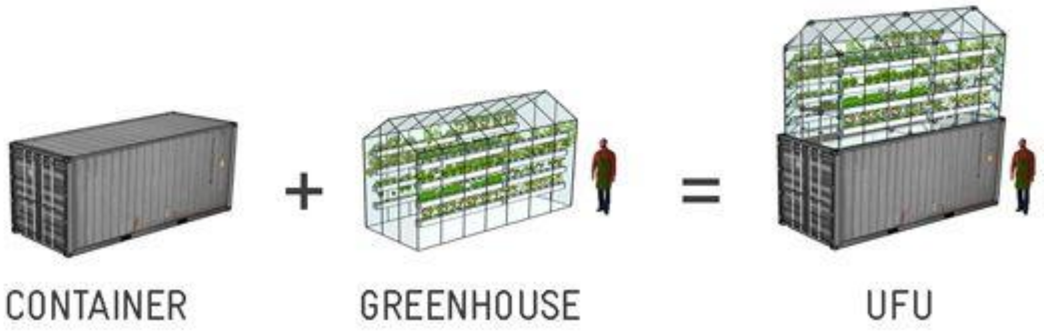


Figure 30: Urban Farm Unit (Persico 2018)

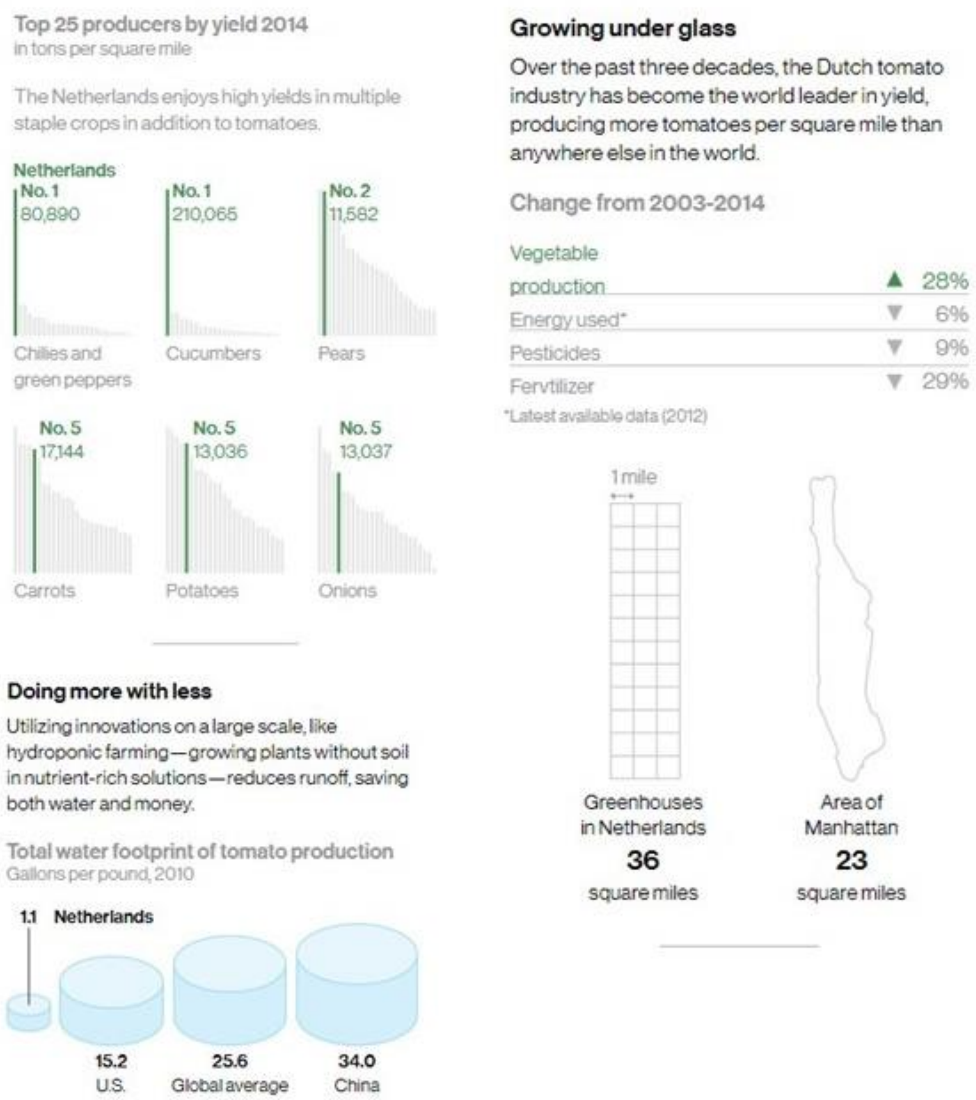


Figure 31: The Netherlands investing in hydroponics (Viviano 2017)

5. Appendix: Aquaponic system

Figure 32:Aquaponic farm, Lufa farm, Montréal, 2016

6. Appendix: Traffic flow map and consequences in Brussels

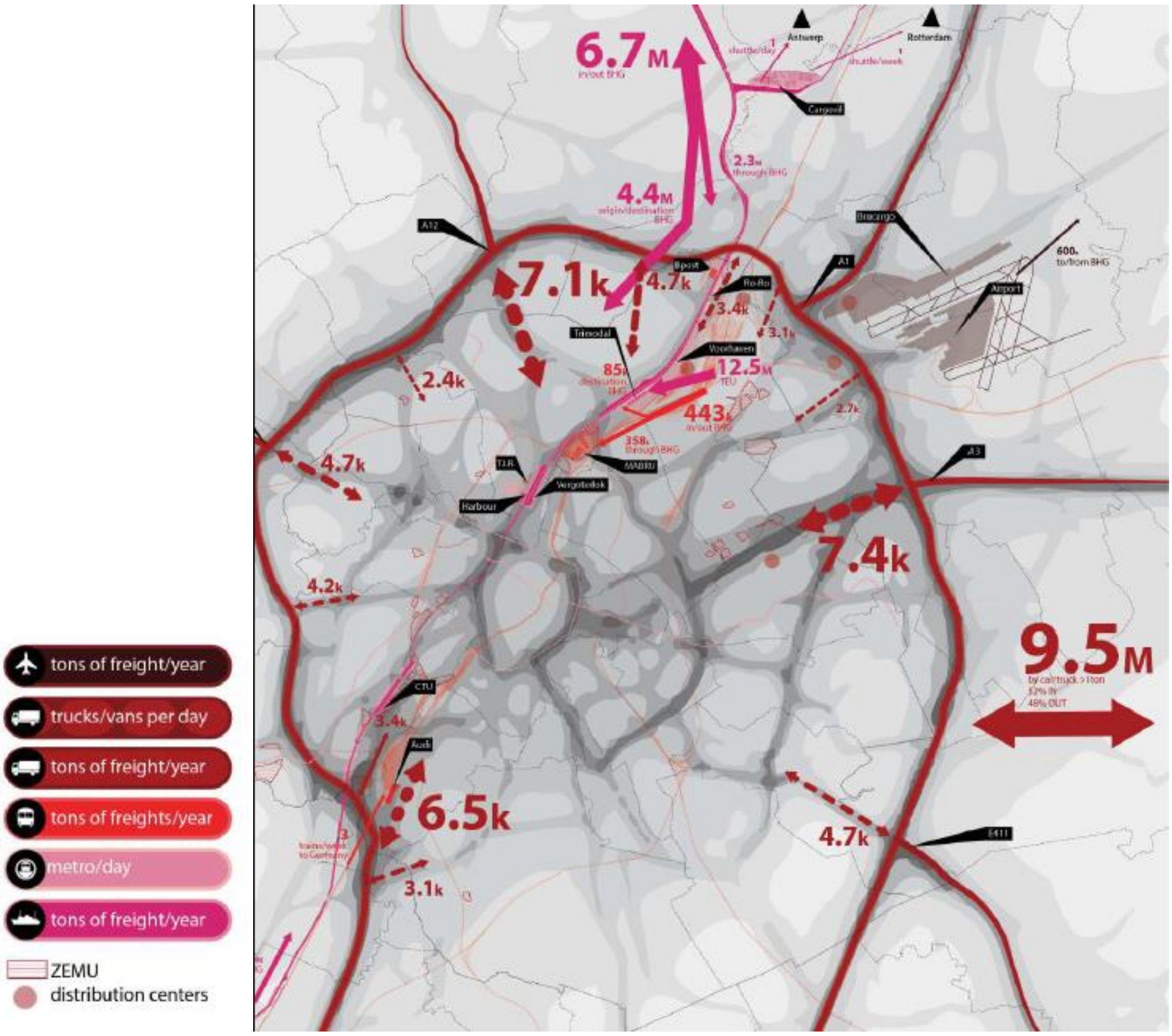


Figure 33: Freight flow map

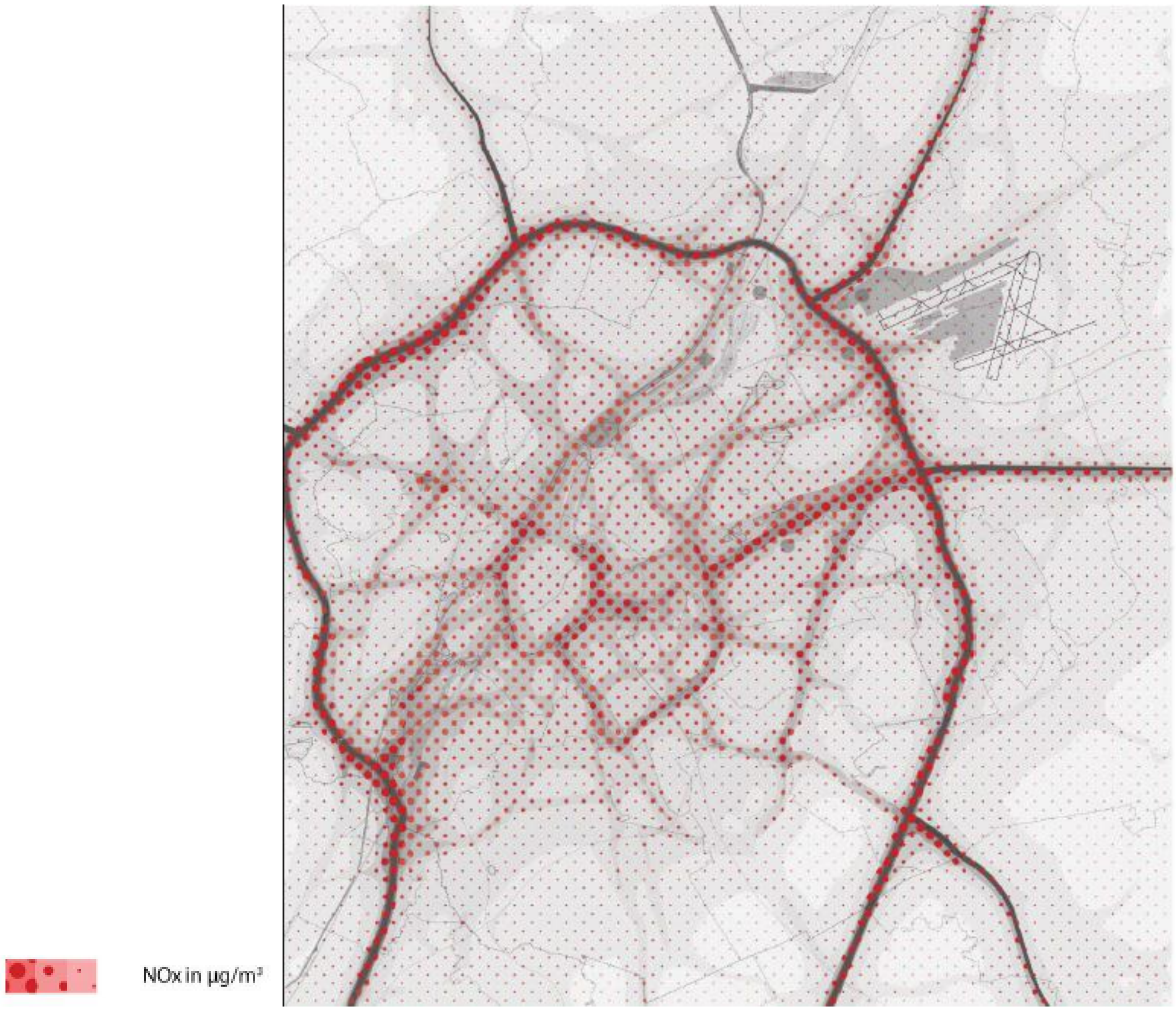


Figure 34: NOx Air Pollution

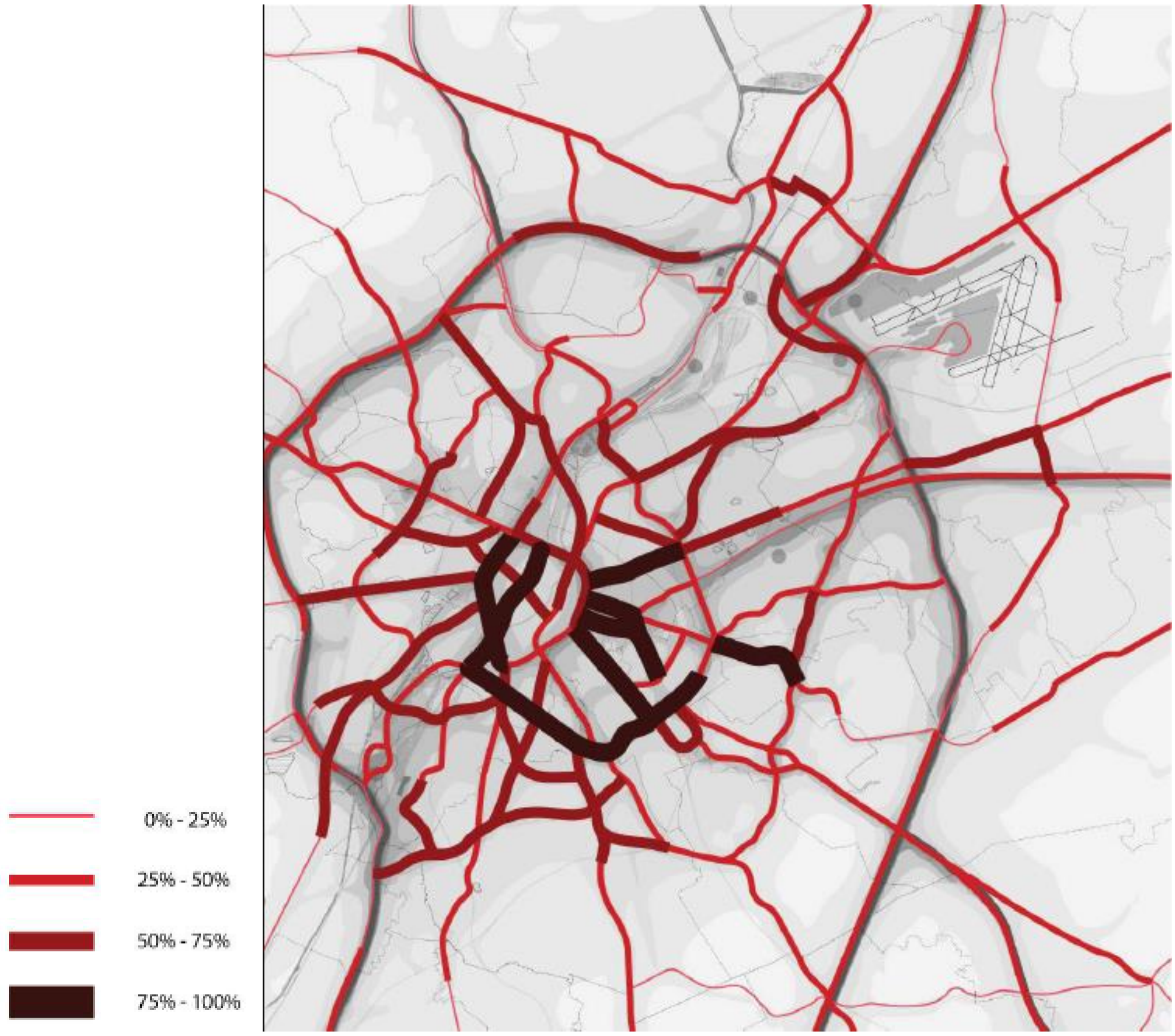
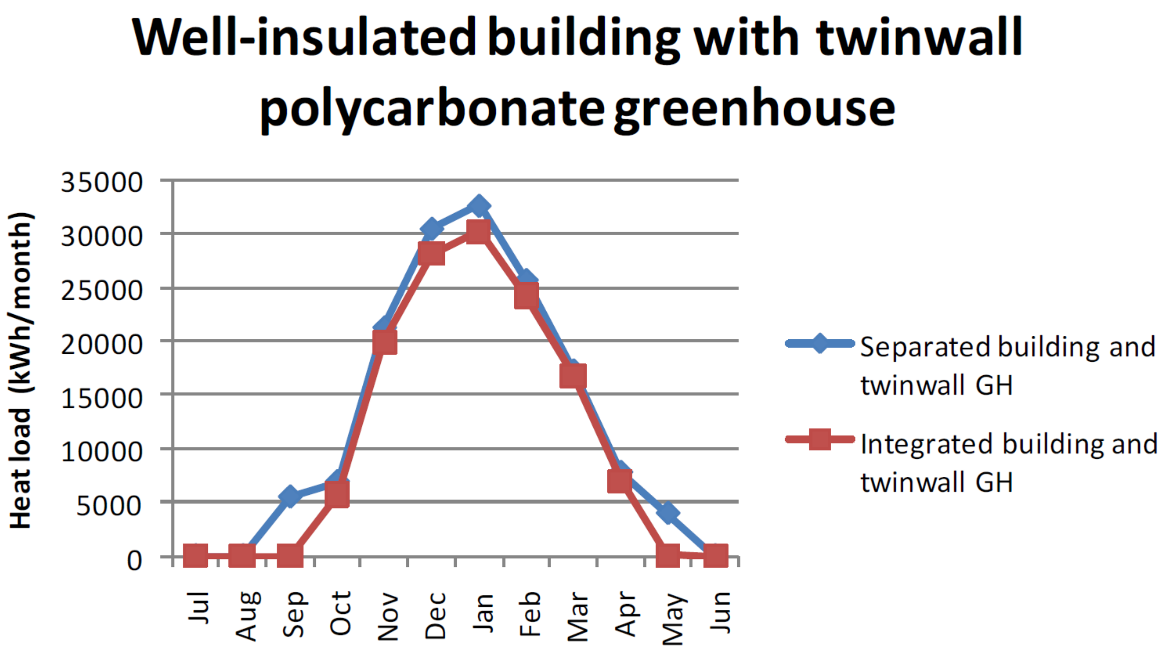


Figure 35: Traffic congestion

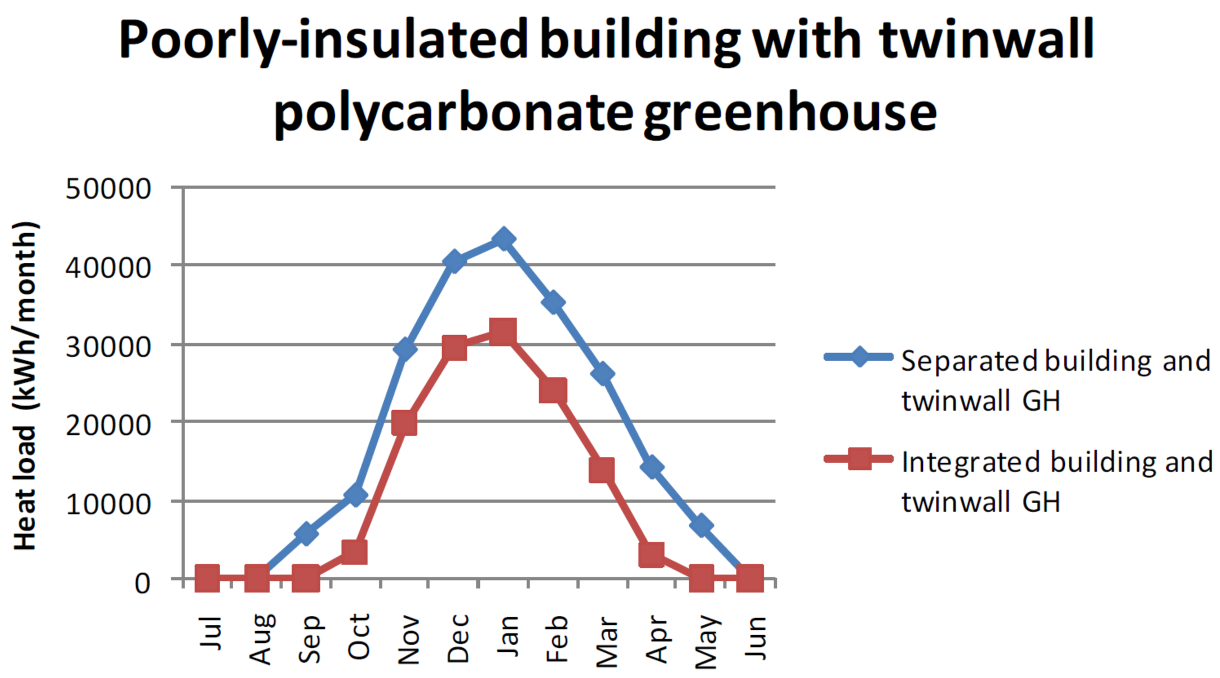
(Frijters, et al. 2017)

7. Appendix: Comparison of heating needs for BIGH and stand-alone structures

Well insulated building (U-values: roof = 0.4 $Wm_{-2}K_{-1}$, walls = 0.8 $Wm_{-2}K_{-1}$) and 10mm twinwall polycarbonate greenhouse (U-value = 3.2, transmissivity = 72%):



Poorly insulated building (U-values: roof = 8 Wm-2K-1, walls = 2 Wm-2K-1) and 10mm twinwall polycarbonate greenhouse (U-value = 3.2, transmissivity = 72%) :



(Delor 2011)

8. Appendix : Exostructure for BIGH implementation

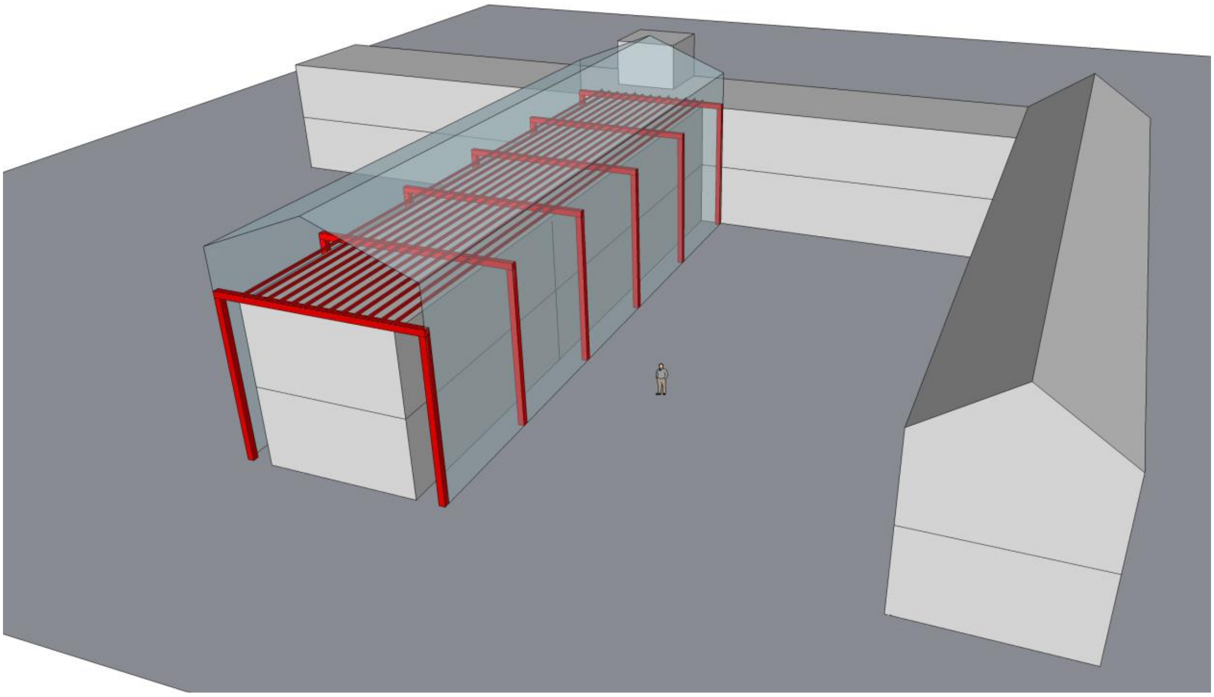


Figure 36: Example of exostructure (Ecores, Lateral thinking factory et Noemie Benoit consultant 2014)

9. Appendix: Vegetable gardens near the Refuge Reine Marie-Henriette

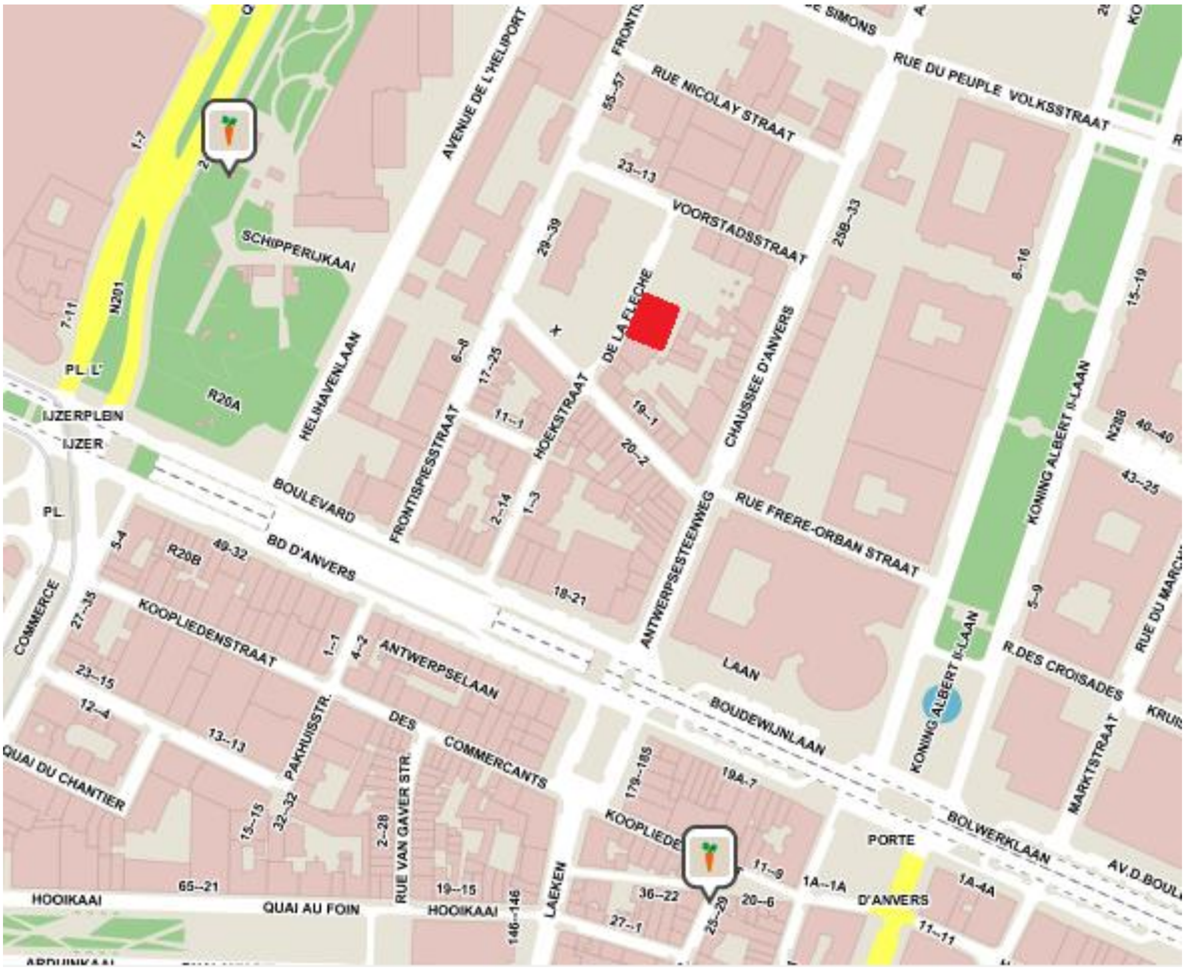


Figure 37: Community vegetables gardens nearby

10. Appendix: Thermal solar panels

Table 5:Fact sheet Unical Panels (Unical 2011)

✦ Kit de production d'ECS avec ballon BISER et panneaux TITANIUM (2 m²)

Nombre de personnes			2/4	4/6	7/9	9/13	14/18	16/20	20/25
Désignation		REF	Nombre	Nombre	Nombre	Nombre	Nombre	Nombre	Nombre
Panneaux TITANIUM		07481	2	3	4	5	6	8	10
BISER 300		07486	1	1	-	-	-	-	-
BISER 500		07487	-	-	1	1	-	-	-
BISER 800		07488	-	-	-	-	1	-	-
BISER 1000		07489	-	-	-	-	-	1	1
Groupe de circulation complet bicolonne		07505	1	1	1	1	1	1	1
Régulation HELIOS EASY		08011	1	1	1	1	1	1	1
Kit de raccords pour 2 panneaux	non intégrés	07507	1	1	1	1	1	2	2
	intégrés	07508							
Kit raccords supplémentaires (par panneau)		07509	1	2	3	4	5	6	8
Vase d'expansion de 18 litres		07516	1	1	-	-	2	2	-
de 25 litres		07517	-	-	1	1	-	-	-
de 50 litres		07518	-	-	-	-	-	-	1
Bidon de liquide antigel de 5 litres		07519	1	2	2	3	3	4	5
Installation non intégrée sur toiture inclinée									
Support pour 2 panneaux		07511	1	-	2	1	-	4	2
Support pour 3 panneaux		07512	-	1	-	1	2	-	2
KIT REFERENCE		B T	2/4 TI	4/6 TI	7/9 TI	9/13 TI	14/18 TI	16/20 TI	20/25 TI
Installation sur terrasse et surface plane									
Support pour 1 panneau		07515	2	3	4	5	6	8	10
KIT REFERENCE		B T	2/4 TSP	4/6 TSP	7/9 TSP	9/13 TSP	14/18 TSP	16/20 TSP	20/25 TSP
Installation intégrée en toiture inclinée									
Support pour 2 panneaux		07513	1	1	1	1	1	2	2
Support par panneau supplémentaire		07514	-	1	2	3	4	4	6
KIT REFERENCE		B T	2/4 ITI	4/6 ITI	7/9 ITI	9/13 ITI	14/18 ITI	16/20 ITI	20/25 ITI

11. Appendix: Archives de l'ULB, Fire of 1971

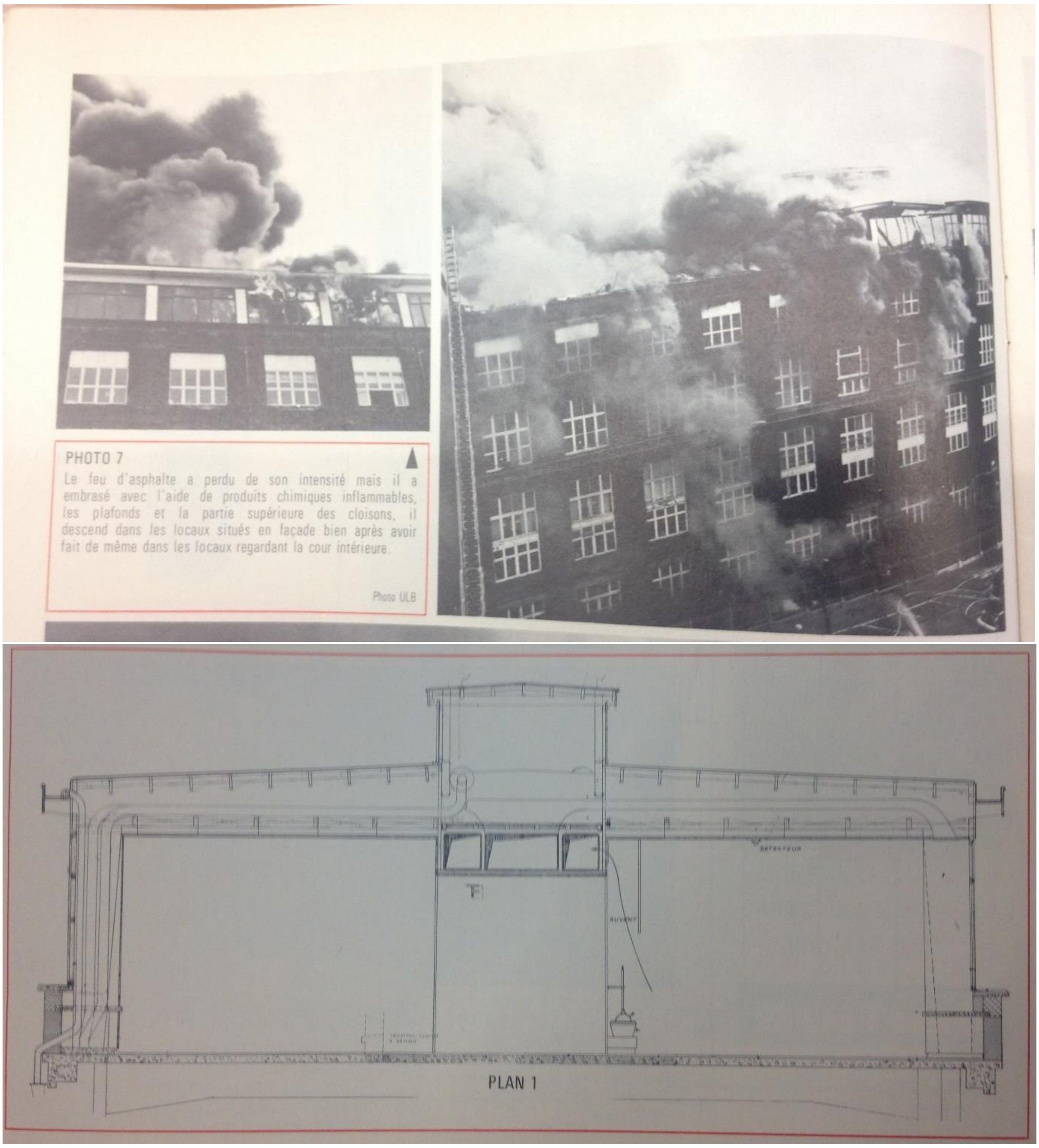
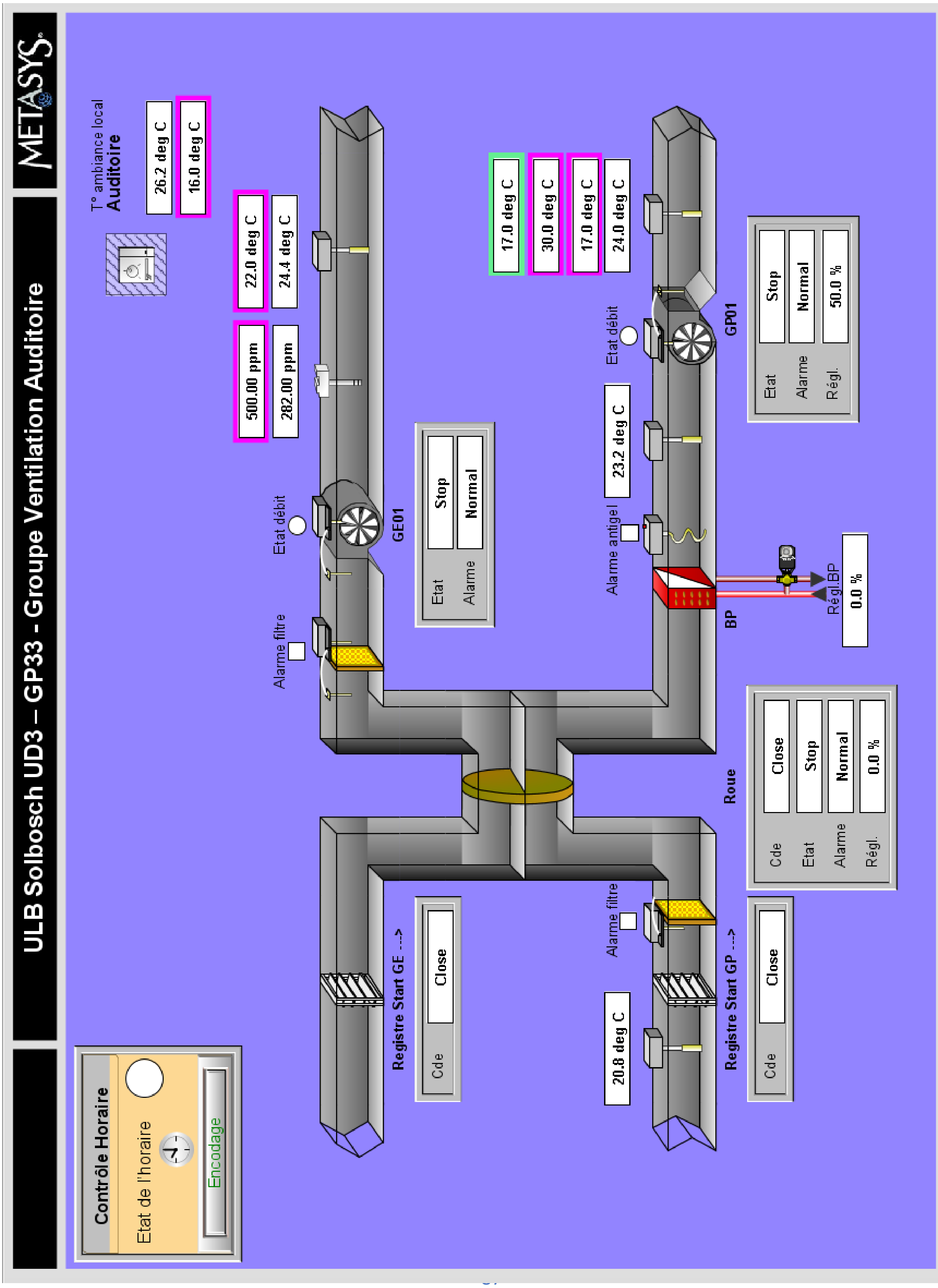
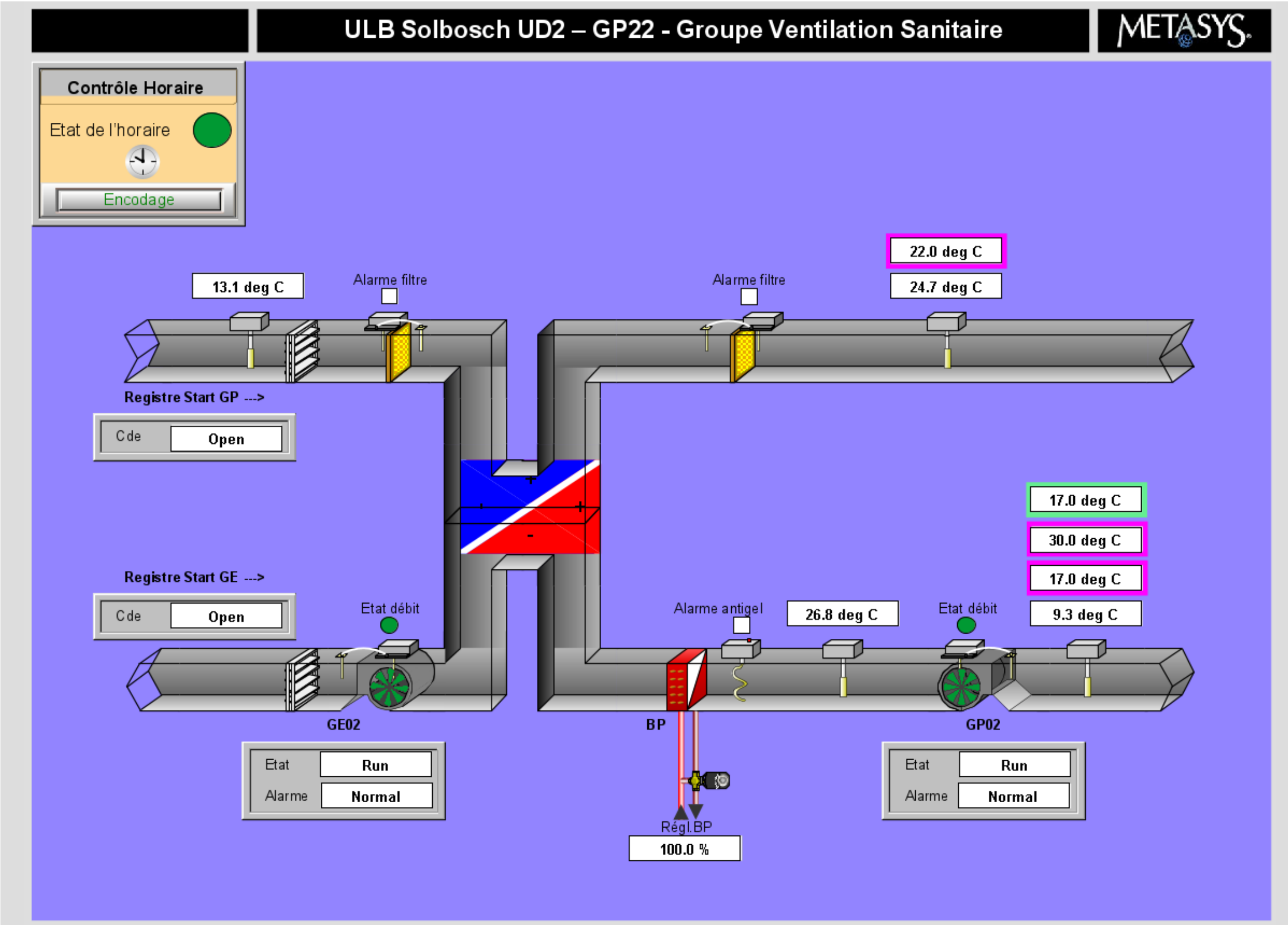


Figure 38:Photos of the fire and section of the existing floor (R. Rosbach 1971)

12. Appendix: Ventilation system of the U building




ULB Solbosch UD2 – GP22 - Groupe Ventilation Sanitaire
METASYS
Contrôle Horaire
Etat de l'horaire
Encodage
13.1 deg C
Alarme filtre
Alarme filtre
22.0 deg C
24.7 deg C
Registre Start GP --->
Cde
Open
17.0 deg C
30.0 deg C
17.0 deg C
Registre Start GE --->
Cde
Open
Etat débit
Alarme antigel
26.8 deg C
Etat débit
9.3 deg C
GE02
BP
GP02
Etat
Run
Alarme
Normal
Etat
Run
Alarme
Normal
Régl.BP
100.0 %

13. Appendix : Plan Canal – Fri-Agra zone

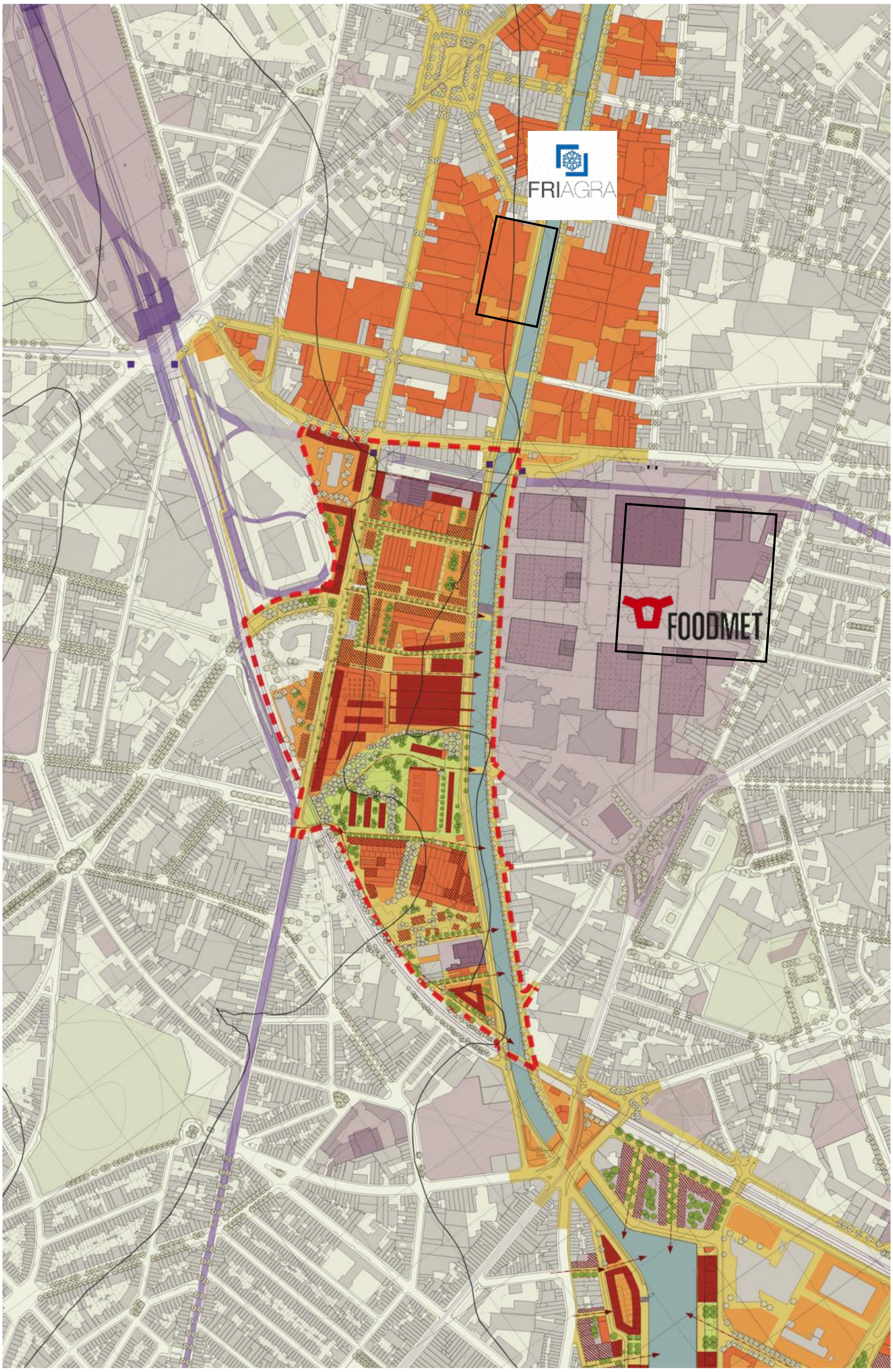


Figure 39: Birmingham redesign plan

In colour, the area of regional interest. In red the modified buildings.

14. Appendix: Interview with Steven Beckers

AB: Cela m'intéresserait déjà de savoir sur quel genre de projet vous travaillez, combien vous en avez en ce moment, je suppose que vous travaillez déjà dans quelques pays.

Steven Beckers : OK. Bon donc la ferme d'Anderlecht est ouverte, elle démarre, elle tourne plutôt bien, donc on est content ! Là on est sur le toit d'un marché couvert. Il y a un toit qui avait été construit pour pouvoir recevoir le poids d'une ferme urbaine. Il a été construit sans savoir ce qu'ils allaient faire comme ferme urbaine par contre. Ils avaient prévu en certains endroits plus de 1 200 kg par m2 et de surcharge possible et en d'autres endroits 600, 800, ce genre de choses. Donc on s'est adapté à cela. C'est assez rare de trouver des toitures qui ont des portances pareilles. Très souvent on est dans les limites. Vous parliez de tout ce qui est commerces, centres sportifs, etc, en général cela a été calculé juste pour le poids de la neige, même parfois pour le photovoltaïque ce n'est pas évident ! Donc pour dire que ce n'est pas évident de trouver de bons sites. J'ai sur Bruxelles 3 ou 4 autres projets qui sont des projets basés sur soit des parkings, parkings de supermarché ou parkings de centres commerciaux ou alors sur des nouvelles dalles, de nouvelles dalles sous lesquelles il va y avoir soit de la logistique soit autre chose mais je ne peux pas vous dire exactement lesquelles car c'est un peu délicat. Mais voilà on a plusieurs projets qui sont sur de nouvelles extensions ou des parkings existants. Il faut savoir que des parkings des années 60, 70 qui ont été construits de manière assez faible à l'époque permettant en général avec un peu d'astuce de reprendre même la partie pisciculture qui est la partie la plus lourde pour laquelle il faut compter plus ou moins 800 kg/m2 et localement 1000 kilos. La partie serre il faut compter entre 200 et 300 kilos par m2. De toute façon il y a des zones où il faut avoir 300 kg/m2 les zones où il faut circuler avec les produits, etc, avec les équipements, les élévateurs, et autres avec des palettes, il faut pouvoir gérer cela. Il faut savoir que la plupart des choses en culture sous serre sont effectivement suspendues à la serre, donc le poids est repris par la structure de la serre, principalement et pas tellement au sol. C'est un avantage de la culture sous serre.

Alors d'autres projets en Flandre, en Wallonie et à l'étranger : en général, il s'agit de plusieurs projets sur des centres commerciaux. J'en ai un en Italie qui est sur l'extension d'un centre commercial à côté de Milan. Il fait à peu près 4000 m2 et là on va dessiner l'extension pour pouvoir supporter le poids de la ferme. Il y aura un lien direct avec toute la partie restauration, food court du centre commercial en question. C'est autrement intéressant parce que ça permettrait de vendre directement aux magasins qui sont en-dessous et à la restauration etc. en plus de distribuer dans tout Milan, donc on peut distribuer dans tout Milan en restant en circuit relativement court.

L'objectif quand on cherche des sites c'est de faire en sorte que cela soit dans un endroit assez accessible et visible, visible ce sera de moins en moins le cas : au début par exemple la serre d'Anderlecht elle n'est pas très visible depuis le rue, il faut chercher un petit peu ! Mais bon on en fait un tel ramdam que tout le monde sait que c'est une serre. Et tout le site d'Anderlecht est en train de changer, d'être modifié pour devenir de plus en plus accessible au grand public.

AB: J'ai été me promener sur le site et j'ai vu des photos d'avant-projet. Il me semble que c'était beaucoup plus étendu que ce n'est maintenant, ou bien c'est parce que ce n'est pas visible ou bien que ce n'est pas encore fini.

SB : Si, elle est finie, il y a une partie des jardins qui n'est pas encore terminée, qui n'est pas encore aménagée, mais la serre elle-même, elle est terminée. Du sol on ne voit pas grand-chose. Donc l'idée de la visibilité, c'est pour que les gens puissent comprendre l'aquaponie, les poissons avec le biofiltre entre les deux, voire tous les bénéfices de la transparence finalement dans le système qui permet de prouver que ce sont des produits sans pesticide, sans antibiotique etc…Cet après-midi je vais à un marché bio à Uccle, il y a un poissonnier ambulant qui me disait : « Oui mais les poissons d'élevage je ne veux jamais en entendre parler mais je ne lui ai pas dit ce que je faisais, et il y avait une dame qui demandait si son poisson était un poisson sauvage. Il a dit : « Mais bien sûr, Madame. On ne fait que ça et le reste c'est de la merde. » Voilà, il va falloir modifier les choses parce que tout d'abord, le poisson sauvage, il y en a de moins en moins, il est de moins en moins sûr parce que la mer est de plus en plus polluée, donc ce n'est plus forcément un critère.

Pour revenir aux différents lieux : -le logement c'est très difficile parce qu'en général ce n'est pas assez large : il faut au moins 20 m de large pour faire une serre, car une serre va faire au moins au minimum 5 m de haut, en général parce qu'elle a besoin d'inertie thermique qui doit être créée par le volume d'air parce que la serre elle-même n'en a pas. Donc à partir du moment où une serre fait 5 m de haut, si elle fait moins de 20 m de large, vous commencez à avoir beaucoup trop de surface verticale par rapport aux surfaces horizontales au niveau des déperditions et puis rien qu'au niveau de l'exploitation il faut suffisamment de largeur pour pouvoir travailler. Il faut savoir que dès qu'on s'approche des bords, c'est dangereux pour les plantes qui sont dedans. Plus on a de zones intérieures, on va dire, idéalement dans un carré, ou dans un rectangle pas trop allongé, car s'il est comme les logements c'est entre 12 et 15 m d'épaisseur, ce n'est pas très intéressant. Il y a autre chose qui n'est pas intéressante avec le logement c'est que la ventilation, on peut extraire normalement le CO_2 pour alimenter les plantes, pour aider la photosynthèse, mais les gens respirent la nuit, les plantes respirent le jour, donc le cycle est inversé, donc comme on ne peut pas stocker cet air, on peut difficilement récupérer du CO_2 sur la ventilation. En plus de cela, les logements deviennent de plus en plus efficaces au niveau énergétique, donc c'est difficile de trouver de l'énergie fatale dans les logements. C'est plus facile à trouver là où il y a des processus industriels ou bien alors il faut refroidir comme des commerces alimentaires comme des bureaux où il y a un minimum de rafraichissement qui fait que l'on a quand même de la chaleur qui se perd.

D'autres projets sont au sol tout simplement, mais à côté d'usines ou de processus industriels qui gaspillent normalement beaucoup de chaleur. On a en plusieurs là on peut faire des fermes plus grandes, c'est plus simple et moins cher au m2. Le tout c'est d'être quand même en zone péri- urbaine. La notion de « local » pour produire ou de circuit court, on a beaucoup de discussions là-dessus. J'ai un site dans le Brabant wallon où on a trois ou quatre villes d'importance moyenne à une vingtaine de kilomètres du site de production. Si c'est du circuit court ? Je pense que oui. Cela dépend comment on fait les livraisons aussi, si on utilise des véhicules électriques, il y a tout cet aspect-là aussi. Et il faut savoir que faire 20 kilomètres dans le Brabant wallon coûte moins d'énergie que d'en faire trois à Bruxelles : le transport, la circulation, etc. Ce sont des choix à faire à certains moments dans l'objectif que l'on se fixe. On va avoir un projet près d'une source assez importante de chaleur à Bruxelles. On est en train de négocier un projet de 6000 m2 pour commencer et puis éventuellement doubler sa superficie. Cela permettra de faire baisser les prix de production, parce que à Anderlecht on est dans les prix du bio, c'est quand même dans le haut du marché, même si on est dans les prix du marché, on est dans les prix hauts du marché et j'aimerais bien démocratiser cela un petit peu aussi pour que l'agriculture urbaine ne soit pas juste de l'alimentation pour « bobos » !

AB: Je voulais d'ailleurs vous poser la question de la gentrification que cela pouvait entrainer et qui a déjà été pointée du doigt. Du coup les fruits ça coûte assez cher de les produire.

SB: Forcément ça coûte plus cher que les produits de basse qualité produits sur des centaines d'hectares avec des pesticides. Il y a autre choses aussi, c'est que les fruits, les légumes et poissons de qualité ça dure plus longtemps aussi quand on les achète. Donc il y a moins de gaspillage ! Il faut arriver à ne cueillir qu'au moment où l'on vend et arriver à avoir un minimum d'incertitude, c'est évidemment la grosse difficulté des produits, parce que, évidemment, les tomates n'attendent pas, quand elles sont mûres, elles sont mûres ! Il faut essayer d'éviter de les mettre en frigo ; on peut les garder au frais simplement pour qu'elles ne s'abîment pas, mais cela représente deux, trois jours question de transport. Ce n'est pas vraiment dans des frigos comme on fait d'habitude parce que là on a une perte de qualité au niveau des vitamines, au niveau du goût, an niveau de l'odeur de la tomate. C'est clair que quand on la cueille et que l'on vend tout de suite, c'est totalement différent ! Donc quand on arrive avec des quantités assez grande ;, ce que le marché demande aujourd'hui, c'est d'avoir notamment dans les grands magasins, style Carrefour, Delhaize ils veulent tous faire du produit local de qualité, éventuellement bio, mais le bio a de moins en moins d'importance, c'est plus le côté local qualitatif et transparent parce que le bio est un peu surfait, c'est parfois un peu difficile de prouver ce qui est bien bio et ce qui ne l'est pas. Les réglementations ne sont pas très claires là-dessus.

AB: Ce n'est pas transparent, il y a énormément de labels et on ne sait pas toujours ce qu'ils représentent

SB : Non ! Cela varie d'une région à l'autre et pour donner un exemple, nos herbes en pot, si on les vend en pot, elles sont bio, mais si on les coupe et qu'on les met dans un petit sachet en plastique elles ne le sont plus. D'après la réglementation c'est une plante en pot et on est censé la vendre pour qu'elle soit plantée dans votre jardin ce que personne ne fait ou pas grand monde ! C'est le côté un peu illogique des réglementations bio qui ont leur protectionnisme, je le comprends, mais aux USA l'aquaponie est déjà passée dans le label bio. Moi je ne cherche pas tellement ça, j'aimerais bien que l'aquaponie devienne un label en soi.

AB: Je voudrais savoir ce que vous trouvez le plus optimal à placer sur un toit à Bruxelles, aussi comment choisir entre aquaponie ou terre pleine ?

SB: Moi je suis plus branché aquaponie puisque c'est ce qu'on fait. Pourquoi on a fait l'aquaponie, c'est pour qu'il y ait une meilleure rentabilité. Je n'ai pas encore trouvé d'autres systèmes qui soient rentables en agriculture urbaine, qui soient rentables par la vente des produits, j'insiste c'est parce que moi je veux transformer l'alimentation circulaire pour qu'on soit vraiment dans un modèle qui fonctionne. Tous les modèles comme « peas and love » qui sont très chouettes, sont des modèles qui ne fonctionnent pas par la vente des produits, mais par le concept et la location d'espace et de services etc . Pour moi ce n'est plus vraiment de l'agriculture, on est plus dans l'animation ; c'est une réponse à un besoin et qui va durer, je crois, mais pour moi ce n'est pas ça qui va changer l'alimentation. L'objectif que je pense qu'il faut poursuivre à Bruxelles et ailleurs c'est de trouver des solutions qui soient viables, pérennes et qui permettent de fonctionner toute l'année. Parce que si on produit des fruits et des légumes six mois par an, que se passe-t-il pendant les autres six mois, l'autre moitié de l'année ? Si on veut qu'il y ait des circuits qui se mettent en place et que les magasins et la grande distribution elle-même commencent à travailler en circuit court etc… il lui faut quelque chose de régulier. Autrement cela ne marchera pas. Et si ça ne rapporte pas à celui qui cultive, ça ne marchera pas. Il y a des moments où il faut essayer de trouver le juste milieu et pour cela il y a une question de taille. A partir du moment où l'on a une ferme qui est rentable et moi que je définis comme étant de 3000 m2 .

AB : D'accord, donc c'est un peu un minimum?

SB: C'est un peu un minimum. A Anderlecht on a 4000 m2, mais dont seulement 2000 en intérieur et la partie 2000 en extérieur elle n'est pas rentable. C'est seulement la partie 2000 en intérieur qui est rentable. Donc l'un plus l'autre c'est un peu juste. Il y en a un qui perd un peu d'argent et l'autre qui en gagne. L'idée c'est de trouver une solution qui soit un peu plus sûre au niveau surface et donc au-delà de 3000 m2 là on commence à être à l'aise. Mais 3000 m2 cela ne se trouve pas sur n'importe quel bâtiment, moi je cherche un peu en permanence. Aujourd'hui j'ai cinq, six ou sept possibilités dans et autour de Bruxelles. Il y en a déjà trois qui sont tombées parce que c'est trop compliqué : il faut de l'accessibilité, il faut que le centre commercial puisse être fermé pendant que la ferme est ouverte et vice-versa, donc il y a un tas de choses qui font qu'il y a un peu de résistance parce que c'est nouveau, parce que c'est compliqué et aussi parce que les structures sont « limites ». Donc si il faut commencer à renforcer les structures d'un centre commercial sur toute la hauteur, j'ai essayé sur City 2 par exemple, on a été très loin dans les discussions et puis même au niveau structures ça allait, mais en fait il y avait des zones qu'ils croyaient être libérables et qui ne l'étaient pas. Cela a tout fichu par terre mais c'était très limite partout aussi. C'est très difficile ! Par contre là il y aurait moyen de faire deux ou trois potagers mais qui vont coûter et qui ne vont jamais rien rapporter réellement, sauf par une animation, ce genre de chose, ce qui est bien aussi. J'ai une vision plus économie circulaire et globale du principe. Sinon il y a pas mal d'infrastructures type hôpitaux qui sont idéales parce qu'un hôpital ça génère toujours énormément de chaleur, ça a besoin de nourriture, ça a besoin d'apprendre aux gens à manger convenablement, ça a besoin de faire preuve de produits de qualité … D'un autre côté le problème des hôpitaux c'est que cela prend des années et des années à bouger, donc il y a énormément de questions. Il y a tout ce qui est logistique qui part de hangars, quelque chose comme cela, parce que les hangars existants en général c'est, je parle de la toiture, c'est très difficile, on peut imaginer transformer un hangar existant à l'intérieur s'il n'est pas utilisé pour autre chose, pour faire des cultures sous LED ou d'autres types de cultures. Je suis un peu mitigé moi personnellement sur la technique de culture qui est uniquement sous LED, je crois que cela devient un peu extrême dans l'autre sens, je crois qu'il y a beaucoup de potentiel, mais d'où vient l'énergie ? Et je crois qu'à partir du moment où on peut, nous on a du LED pour les arbres, mais c'est seulement en complément au soleil quand il n'y en a plus, ou pour allonger un peu la journée pour pouvoir produire de herbes toute l'année. Produire de herbes toute l'année que avec du LED, je pense que cela n'a pas beaucoup de sens.

AL : Pourquoi votre choix s'est-il porté sur l'aquaponie ? Si j'ai bien compris, c'est plus rentable, mais je me questionnais sur l'hydroponie. Est-ce que l'on peut considérer que l'aquaponie est plus naturel parce qu'en circuit fermé où on n'ajoute rien ? Alors que concernant l'hydroponie je me pose des questions sur la valeur nutritionnelle des légumes. Car si j'ai bien compris on ajoute des nutriments dans l'eau qu'on fait couler dans les racines et du coup je me posais la question du produit au final. Est-ce qu'il est aussi riche qu'un autre, est-ce que l'aquaponie balance un peu dans ce côté chimique ?

SB: Tout dépend de ce que l'on met dans l'eau ! L'hydroponie, il y en a des milliers d'hectares en Hollande et en Espagne et qui sont bourrés de chimie de synthèse et voilà ! Avec beaucoup de produits, malheureusement, qui n'ont pas de goût et qui ont très peu de valeur nutritive parce qu'ils produisent de la quantité et pas de la qualité. Il y en a qui le font, mais ils sont rares et chers parce que justement ils retombent de nouveau dans des produits soupe bio, des choses vraiment qualitatives où on fait moins de kilos. Il faut savoir par exemple, pour les tomates en Hollande, vous avez des serres qui produisent 100 kilos de tomates par m2 ; nous on est à 20 par an. Si on faisait de plus grosses tomates on pourrait peut-être à 40 ; mais jamais à 100 parce que à 100 il faut booster les tomates comme des fous. Là par exemple il a fait très beau alors on a produit plus que prévu. Je pense que du coup les plans vont produire moins plus tard aussi ; il y a toute une balance naturelle pour ces produits et qu'il faut faire attention ; et ici l'aquaponie fait en sorte que alors oui c'est le même problème. L'hydroponie a mauvaise réputation parce que dans beaucoup d'endroits on fait n'importe quoi. Non seulement c'est plein de chimie, mais c'est aussi plein de pesticides. Finalement ce sont des produits qui sont pleins d'eau, qui n'ont pas beaucoup de corps et puis il y a l'aquaculture, donc la pisciculture qui a aussi mauvaise réputation aussi parce qu'on les bourre d'antibiotiques. En mettant les deux ensemble, on améliore et l'aquaculture et l'hydroponie puisqu'elles fonctionnent ensemble avec un bio-filtre entre les deux et si je mets des pesticides et des antibiotiques dans le système, cela tue le système. Toute la transparence, elle est là. Ca élève un peu des deux des deux côtés. Il y a très bien moyen de faire de l'hydroponie toute seule, avec de soupe bio c'est ce qu'on fait au démarrage. On n'a pas encore assez de poissons pour nourrir les tomates. On a déjà presque 30 000 poissons, mais ils sont tout petits, donc ils ne produisent pas encore assez d'excréments, d'urine pour que le bio-filtre transforme aussi assez pour les tomates ou les herbes, mais on a la soupe bio, donc c'est pour moi la qualité qui sort déjà. A partir de cet été, dans un mois et demi environ on aura vraiment les nutriments qui viennent uniquement du bio-filtre et on rajoute simplement quelques minéraux parce que les plants de tomates ont besoin de minéraux, on est aussi proche que possible d'un système, d'un écosystème naturel et avec des nutriments de qualité pour les plantes. Il y a des gens qui ne jurent que par la pleine terre, moi j'en ai déjà converti pas mal qui sont venus voir, qui ont goûté, qui ont dit « oui, pas mal ». Dans les discussions même au niveau théorique, je ne sais pas si tu sais qui est Jean-Pierre Coffe, malheureusement décédé. Il était tout d'abord cuisinier, mais surtout défendeur de la pleine terre en France, il était très près du terroir etc. J'avais fait une interview en duplex avec lui à la RTBF et c'était assez sympa parce qu'à la fin il m'a dit : « D'habitude je n'y crois pas à ce genre de chose, mais là si vous nous dites que votre système est aussi transparent qu'il ne l'est. Il n'y a pas de raison que ça ne marche pas ! Enfin des gens comme ça qui sont un peu extrémistes sont prêts à voir. Bien sûr ils ont en tête la mauvaise réputation de beaucoup d'exploitations. Ici on pourrait aussi le faire mal mais si on le faisait mal on ne produirait pas, mais on tiendrait pas parce que cela tuerait le système, ça tuerait le biofiltre, les antibiotiques tueraient les microorganismes du biofiltre qui transforment l'ammoniaque qui nourrit les poissons en nitrites et puis en nitrates, mais tout ça j'imagine que tu as déjà des informations.

AB: Pourrait-on imaginer des combinaisons de cultures un peu comme dans la permaculture mais toujours sous le système d'aquaponie en serres ?

SB: Oui, oui ! C'est ce qu'on va faire avec les jardins extérieurs. On est en train de préparer pour 2019 de nourrir les jardins extérieurs avec l'aquaponie aussi donc avec l'eau qui vient des poissons également, mais aussi travailler en permaculture sur substrat en toiture. On est même en discussion avec des gens comme la Ferme du Bec Hellouin et d'autres spécialistes en France qui sont les références de la permaculture et qui au début c'est la même réaction car c'est en toiture et puis ils se rendent compte que le substrat qu'on a formé commence à bien donner, à bien marcher : il va y avoir des vers de terre dedans, ça commence à être vivant, donc finalement ils ne demandent qu'à voir. Moi je voudrais arriver à faire de la permaculture en toiture parce que la permaculture peut amener une certaine forme de rentabilité par les produits parce que cela densifie et surtout ça fonctionne toute l'année, aussi avec les saisons etc. Donc c'est un chouette complément à l'aquaponie. De nouveau je garde l'aquaponie comme un point central pour pouvoir nourrir et irriguer avec de l'eau chargée en aliments naturels.

AB: Est-ce que les serres sont toujours fermées ou bien est-ce qu'elles sont ouvertes vers l'extérieur pour de la ventilation naturelle?

AR: Elles s'ouvrent pour les ventiler. On est protégé quand même d'une bonne partie de la pollution – la pollution en ville : tout est relatif, il y en a autant à la campagne. C'est même pire à la campagne avec les pesticides. En fait la pollution en ville, les métaux lourds, il faut s'éloigner des grands axes et de quelques mètres en hauteur et de quelques mètres en recul et en général cela suffit. Le reste, le vent trimbale tout et cela veut dire que les plantes en gros peuvent être simplement rincées et cette pollution elle s'en va, elle n'est pas trop dans les plantes elles-mêmes. On a regardé pas mal d'études dans ce domaine-là : il n'y a rien qui prouve qu'il y a plus de pollution dans une plante qui pousse sur un toit et il n’y a rien qui prouve le contraire non plus. La comparaison est souvent : il faut voir avec quoi on compare.

AB: Pour le coup je posais plutôt la question par rapport à la biodiversité que l’on pourrait amener en ville. Si je ne me trompe pas en hydroponie il faut avoir une serre fermée pour bien réguler tout ce qui est contrôle et donc on perd un peu le côté qu’on apporte de la nature en ville.

SB: Oui en biodiversité c’ est limité, mais un potager aussi ; franchement parce qu’on doit déjà enlever toutes les mauvaises herbes , alors je crois que ce qu’il vaut mieux faire par rapport à cela, c’est de réserver quand on a des jardins potagers et des serres, c’est de réserver des surfaces autour avec des plantes mellifères et des choses comme ça. Il faut savoir que les abeilles ce n’est pas idéal pour les serres parce que les abeilles détruisent les fleurs en prenant le pollen. Elles les pollinisent mais elles les détruisent aussi par rapport à des bourdons, nous on travaille avec des bourdons parce qu’ils ne font pas de miel, en fait ils frottent les fleurs, ils les pollinisent mais sans prendre tout le pollen et sans abimer la fleur et donc beaucoup de fleurs qui sont touchées par les abeilles ne vont pas faire de fruit. Donc pour les tomates, c’est gênant. Mais les abeilles peuvent être à l’extérieur. Nous on a décidé de ne pas mettre de moustiquaires ni de filets fins sur les serres parce que l’on pense que ce n’est pas nécessaire parce qu’aux abattoirs on est en toiture. On protège par contre les jardins extérieurs contre les oiseaux, on est près du canal et il y a les mouettes et les corneilles à la fin du marché, c’est une invasion ; donc au début on a eu quelques laitues qui sont parties avec les corneilles. De manière générale je pense que la biodiversité il faut la traiter en même temps. Pour faire de l’agriculture urbaine, si on veut qu’elle soit productive, il faut quand même qu’elle soit contrôlée. C’est quelque chose de sérieux que de nourrir les gens ! Moi c’est une des choses qui m’inquiète un peu dans l’agriculture urbaine, c’est qu’il y a peu tout le monde et n’importe quoi fait quelque chose. Moi-même si je le faisais seul je ferais des catastrophes. Quand je vois les spécialistes avec qui on travaille pour être sûr qu’on n’ait pas telle et telle maladie, c’est pas que pour la production, c’est pour la sécurité des gens. Quand on voit les normes de l’AFSCA, qui gère tout ce qui est hygiène dans la production alimentaire, et qui sont quand même très poussées et auxquelles on doit être tenu, parce que nous on le fait de manière professionnelle, un peu industrielle, on fait de l’industrie urbaine si vous voulez. Les gens qui ne font pas ça, qui mélangent des déchets avec des trucs etc enfin… ils y quand même des risques sanitaires auxquels il faut faire attention. Il faut en être conscient. On travaille avec des partenaires hollandais qui nous donnent pas mal de conseils notamment pour les micro-pousses. Je ne sais pas si tu vois ce que sont les micro-pousses ? Tu as les graines germées qui sont des petits germes qui se nourrissent que de la graine ; si tu continues et tu les mets dans un petit substrat avec de l’eau et tu les laisses pousser jusqu’à 7, 8 cm et tu obtiens les micro-pouces. Il y a une cinquantaine de plantes que l’on peut faire en micro-pousses : vous pouvez faire des micro-pousses de brocoli, de moutarde… et cela a énormément de goût, toute la plante adulte se trouve dans la micro-pousse.

AB: Et l’avantage c’est que le rendement est plus grand puisqu’il faut attendre moins longtemps ?

SB: Le rendement est plus grand, mais surtout c’est une autre alimentation car dans une plante très petite, tu concentres toutes les vitamines, le goût et cela est bon pour donner de la saveur dans les salades et c’est de plus en plus vu comme une plante très bonne pour la santé, comme c’est rempli de vitamines. Pour pouvoir faire cela il faut cultiver cela dans un milieu assez contrôlé, chaud et humide. On pourrait imaginer qu’il y ait n’importe quoi comme bactérie nocive pour l’humain qui se développe dedans. Et quand eux nous ont proposé de nous aider on leur a demandé pourquoi ils étaient d’accord de nous aider alors que tout le monde nous avait dit qu’il n’y avait pas moyen de visiter leurs serres en Hollande, parce qu’ils sont des leaders mondiaux, la réponse a été « vous le faites de manière professionnelle, on veut prouver que ça marche et si vous faites des conneries, cela va nous retomber dessus. Parce que si quelqu’un décède ou est malade à cause de vous on va dire les microgreens c’est pas bon. » Donc c'est pour cela qu'ils résistent par rapport aux autres, ils disent aux autres « ne le faites pas ! » Nous on a des spécialistes et tout ce qu'ils font ils nous expliquent comment on fait, comment on vérifie qu'il n'y ait pas de maladies qui se développent et pas de parasites qui pourraient rendre les gens malades. Tout cela fait que l'agriculture urbaine est en train d'évoluer. Il y a une partie sociale qui doit toujours être présente, qui est le lien social ,etc il y a la formation, créer de l' emploi également, il y a le côté local, le circuit court, …

AB: Vous avez combien de personnes par hectare ?

SB: En hectare cela n'a pas beaucoup de sens ; par ferme pour la partie pisciculture et horticulture intérieure, on va dire que cela va faire entre 5 et 10 personnes temps plein, selon la taille des fermes. Elles vont faire différentes tâches ; ils se relayent aussi par exemple ; pour les poissons il faut une permanence, on ne peut pas laisser les poissons tout seul. La pisciculture elle-même c'est 600 m2, la serre autour fait 1400 m2, on a ainsi 2000 m2 de surface intérieure de production. Et 2000 extérieur et dans le jardin extérieur on travaille avec deux, enfin surtout avec une société d'économie sociale qui emploie des personnes soit déprimées, soit légèrement handicapées, soit en insertion, et là en deux ans on a formé une soixantaine de personnes. Ce sont des gens vraiment locaux, c'est vraiment un aspect important qu'on veut maintenir. Et cela est vrai pour tous les types d'agriculture urbaine, mais c'est surtout vrai quand il y a un professionnel qui s'en occupe. Le problème des projets où il n'y a que du bénévolat c'est que ça ne tient qu'un temps. Pour un bénévole qui fait tout et que les autres ne l'aident pas, il en vite marre et puis s'il n'est pas payé on ne peut pas l'engueuler non plus. Il y a ainsi beaucoup de projets qui se cassent la figure ou qui deviennent des chancres ; plusieurs fois de la part des autorités communales qui disent : « oh encore de l'agriculture urbaine, on va encore avoir des problèmes ! » Ils le veulent tous mais ils disent « et si ce n'est pas bien géré ? » Pour que cela soit bien géré il faut qu'il y ait un minimum de rentabilité quelque part.

AB: Et vous dans vos projets vous êtes partenaire avec les gens qui vous offrent les toitures ?

SB: Oui, l'objectif ici à l'Abattoir, on loue simplement la toiture et cela fait quand même une forme de partenariat parce qu'il y a beaucoup de choses à décider ensemble concernant le bâtiment. Mais à l'avenir, les autres projets qu'on monte, on est partenaire, c'est-à-dire que celui à qui appartient le bâtiment a intérêt à ce que cela fonctionne bien et donc on a intérêt à ce que son bâtiment fonctionne bien. C'est vrai surtout avec les commerces bien sûr parce que là il y a une synergie de vente de produits etc mais cela peut être aussi le cas si c'est un immeuble de bureaux, cela fait partie de l'image du bâtiment, cela augmente aussi la valeur du bâtiment puisqu'il devient plus performant au niveau environnemental et donne une plus chouette image. Il y a plus de gens qui vont vouloir venir louer un bâtiment dans lesquels on fait ce genre d'agriculture. Et puis il y a une rentabilité financière puisqu'on paie un loyer. Pour une toiture qui normalement ne lui rapporte rien et lui coûte quelque chose : notre plus grand concurrent c'est le photovoltaïque.

AB: Donc vous louez les toitures et vous gérez le personnel, les ventes, …

SB: On est l'opérateur. Nous ce qu'on fait c'est louer la toiture et puis louer la serre qui est dessus, c'est-à-dire que le propriétaire du bâtiment investit dans la serre et nous on la loue pendant trente ans. Donc lui il a un retour sur son investissement, cela améliore son bâtiment et nous cela nous évite de devoir sortir pour chaque projet une somme importante d'argent, om met seulement la moitié pour à peu près tout l'équipement qui va dans la serre et puis on gère l'exploitation.

AB: Etes-vous en contact toujours avec tous les projets que vous avez faits ?

SB: Oui, c'est l'objectif !

AB: Ce n'est pas pour un moment céder l'exploitation à la personne qui en est propriétaire, enfin si c'est un supermarché qui va revendre des fruits et des légumes ?

SB: Ah cela peut se faire sous forme de franchise alors. L'important c'est que ce soit toujours notre équipe technique avec nos spécialistes qui va contrôler ce qui se passe. C'est comme avec les hamburgers, il y a quelqu'un qui passe tous les jours chez Mc Donald pour voir s'ils peuvent garder leur licence et s'ils ne font pas de bêtises. Je n'aime pas me comparer avec Mc Do, mais c'est le principe de la franchise, c'est-à-dire qu'il faut vérifier que s'ils font des fermes BIG (ils l'appellent comme ils veulent !) avec notre application, il faut que ce soit fait convenablement.

AB: Et en terme d'économie d'énergie ? Y a-t-il des études qui sont faites là-dessus ou bien suivant chaque cas, on étudie ce qu'il serait possible de récupérer ?

SB: Chaque cas est différent, malheureusement il a fallu chaque fois étudier. A l'abattoir je pense qu'on a entre 55 à 65 % de l'énergie qui vient de pompes à chaleur qui prennent l'énergie qui vient des frigos. En fait nous on donne du froid et eux nous donnent du chaud, ce qui est un avantage pour les bâtiments en-dessous, parce que cela coûte plus cher du froid que de faire du chaud. Cela consomme deux fois plus d'énergie. Donc nous on prend du chaud et on leur donne du froid. On peut faire éventuellement le contraire, c'est-à-dire que quand on a trop de chaleur c'est très souvent le cas dans une serre exposée au soleil, donc au lieu de la laisser aux petits oiseaux en ouvrant la toiture, on pourrait récupérer avec une pompe à chaleur sur air-eau, on pourrait aussi faire de l'eau chaude et l'utiliser. Prenons le cas de l'abattoir il n'y a pas vraiment de besoin parce qu'ils ont déjà leurs chaudières pour faire de l'eau chaude, mais on pourrait seulement leur faire de l'eau chaude, là les installations existaient. Par exemple, s'il y avait du logement à proximité ou un hôtel pour leur faire de l'eau chaude. Ou alors on la stocke dans le sol pour nous-mêmes et on récupère la chaleur quand on en a besoin. Mais ce sont des installations assez coûteuses.

AB: Dans mes recherches, j'ai essayé de trouver un peu des chiffres pour voir les flux, pour voir les différents cas.

SB: C'est impossible ! Moi j'ai cherché partout, j'ai demandé à tous les fabricants de serres en Hollande, soit ils ne veulent pas le dire, soit ce n'est pas vraiment des recherches qui ont été faites, il faudrait voir, c'est assez récent scientifique que les agriculteurs essaient vraiment d'économiser de l'énergie. Ce n'est pas pour des raisons écologiques, c'est purement pour des raisons économiques. Dans certains cas, il y en a qui veulent que ce soit une marque aussi par rapport au bio etc, mais la plupart du temps ce n'est pas comme ça. Il y a en Hollande des projets qui font de la géothermie par exemple très profonde etc qui sont difficiles à financer sauf pour des exploitations de plusieurs hectares. Quand je dis plusieurs hectares, c'est des dizaines d'hectares.

AB: Est-ce qu'il y a en Belgique des subsides ou des aides qui sont données pour financer ?

SB: A Bruxelles, pas ! On s'est battus comme des fous. Parce que tout le monde pousse l'agriculture urbaine, mais la région Bruxelles capitale a oublié de demander à l'Europe de l'argent pour l'agriculture et ce qui fait qu'il n'y en avait pas ! On nous a promis mais ce n'était pas possible, par contre en Flandre comme en Wallonie et dans la plupart des régions en France, il y en a, Bruxelles a raté le coche. Cela devrait arriver, mais je n'ai pas encore entendu parce que comme on a d'autres projets en cours, je me pose la question régulièrement.

AB: Et ça concerne quels domaines ? Est-ce que ça se joue un peu sur l'économie d'énergie ou plutot sur la création de multifonctionnalités, de mixité ?

SB: Un peu de tout. En fait, normalement on est éligible pour au moins dix choses. Surtout à Anderlecht, on est dans le plan Canal, on est créateur d'emplois, de formations on est dans l'économie circulaire. On est vraiment dans ce concept-là. Et aussi zéro déchet, on est dans l'amélioration d'énergie, la recherche des performances des bâtiments etc. Autant de subventions que je pourrais avoir, mais je ne peux pas parce que c'est de l'agriculture et quand ça tombe dans de la politique agricole commune de l'Europe, en fait les régions ne peuvent pas aider ou les communes, mais surtout les régions ne peuvent pas aider l'agriculture sans que ce soit accepté par la politique agricole commune et voilà ils ont oublié de regarder cela. Nous on a un projet qui est rentable en soi, mais clairement les subventions permettraient d'avancer plus vite pour d'autres projets.

AB: Par rapport à la diversité des légumes, avez-vous un peu de tout ? Vous parlez beaucoup de tomate et dans les recherches que j'ai trouvées il est beaucoup question de la tomate. Est-ce parce que c'est beaucoup plus rentable ?

SB: Les tomates, c'est presqu'un passage obligé quand on démarre ce genre de choses parce que c'est un produit pour lequel les gens ont une affinité. Ils aiment ou ils n'aiment pas telle et telles tomates. C'est plus difficile avec un concombre ou une courge. Les gens vous leur demandez s'ils veulent une courge, oui elle a l'air plus fraîche mais les tomates ça a des goûts différents selon la variété, même chose avec les herbes : le basilic qu'on produit ça n'a rien à voir avec le basilic de chez Delhaize, c'est évident. Même chez Carrefour on a fait des tests et les gens qui prennent le pot habituel et ensuite s'ils sentent l'odeur de notre basilic à proximité, ils remettent le pot et prennent le nôtre. En plus il est plus gros, plus beau et la différence c'est que le nôtre il est encore vivant. Les autres, on a l'impression qu'ils sont vivants, mais en fait ils ont changé de température tellement de fois que lorsqu'on rentre à la maison, ils se cassent la figure. Il y a plein de sortes différentes : nos partenaires en Allemagne ont fait des tests avec beaucoup de légumes, toutes sortes de laitues, et il y a des choses que je n'avais jamais vues de ma vie qui sont magnifiques. C'est une question de quantité, c'est-à-dire que dans une petite ferme il est difficile de faire dix produits différents parce que c'est des zones de climats différents, ce sont des taux de croissance différents, il faut protéger contre la lumière de façons différentes, cela coûte donc assez cher de subdiviser une petite ferme en petits zones. C'est clair que si j'ai une ferme de 10 000 m2 je ferai beaucoup plus de sortes différentes que dans une ferme de 2000, c'est d'ailleurs ce que l'on vise. En Allemagne, par exemple, maintenant ils ont des fermes qui font du tilapia et du basilic, point ! Voilà, je trouve cela un peu dommage. Nous on a déjà cinq produits différents, cinq ou six même plus avec les différents herbes etc Donc on a quatre sortes de tomates c'est déjà une chose, on a du basilic, du coriandre, de pistou, du persil plat, plus des micro-pousses : cela fait quand même une quinzaine de produits différents que nous pouvons mettre sur le marché, malgré que ce soit une serre de 2000 m2. Les laitues par exemple cela prend moins de chaleur que les tomates, et moins d'énergie. Si par exemple on est sur un bâtiment ou à proximité d'un bâtiment qui peut fournir un peu d'énergie mais à basse température on ne va pas forcément faire des tomates et si on a « beaucoup d'énergie », on va faire des concombres ou des poivrons. Quand je parle de beaucoup d'énergie gratuite entre guillemets ou de l'énergie fatale que l'on puisse récupérer.

AB: Donc c'est vraiment selon les conditions que l'on a et la surface ?

SB: C'est pourquoi je disais malheureusement tout à l'heure, chaque projet est vraiment différent. Cela demande vraiment une étude approfondie, bon, c'est intéressant en même temps. Voilà parce qu'il faut étudier le marché aussi et il y a des pays où notamment en France où ils n'aiment pas du tout les poissons d'eau douce. Nous on a la truite. Vous allez dans les pays de l'Est, ils ne mangent que cela, parce qu'ils ne sont près de la mer. Donc il faut choisir. Les tilapias marchent bien en Allemagne, pourraient marcher chez nous en Belgique, mais jamais en France ! Question de nom de et de type de poissons. Le bar rayé qu'on fait, on pense qu'ils peuvent fonctionner à peu près partout mais c'est un marché relativement limité. On va faire 36 tonnes par an, il faut les vendre ! On va faire cinq fermes avec du bar rayé donc.

AB: Dans l'interview que vous avez donnée pour le mémoire que vous m'avez envoyé, vous parliez des études de faisabilité qui étaient extrêmement chères. Comment cela se fait-il que cela soit aussi cher ?

SB: Mais parce que dans le modèle que nous avons développé à partir du moment où il faut convaincre des banquiers, des financiers, des partenaires etc, il faut aller assez loin dans les études. Quand les gens mettent de l'argent, ils veulent toujours avoir un maximum de garanties pour être certains que ça va marcher et par exemple rien que l'étude de marché dans une zone définie, pour savoir quel fruit, quel légume, quel poisson on va faire etc ça doit se commander à des pros. Pas simplement aller se renseigner à gauche ou à droite.

AB: C'est des études sur l'économie pour savoir quoi importer ?

SB: Ce qui va se vendre et à quel prix, à quel moment ?

AB: Les études structurelles et d'énergie, c'est autre chose que cela encore ou bien ?

SB: Cela fait partie des études aussi, mais ce n'est pas le plus lourd. Cela dépend des projets : si on est sur un bâtiment existant, c'est peut-être un peu plus compliqué parce qu'il faut aller faire des analyses etc. Mais de manière générale, moi je parle en tant qu'architecte, pour moi cela me paraît assez évident à faire, mais cela représente quand même des heures de travail. Il faut quand même prouver, il faut déposer un permis, il faut être sûr qu'au niveau énergétique, ça fonctionne et qu'au niveau structurel ça fonctionne aussi, la résistance au vent, tout ce qui est pompier …Dans ce cas il y a pas mal de travail. Pour tout ce qui est nouveau, tout est en dérogation. Quand on va voir les autorités, ils vont chaque fois dire « c'est quoi ce truc ? C'est du commerce ? C'est de l'industrie ? C'est de l'agriculture ? C'est quoi ? »

AB: Et donc, cette étude de faisabilité, son prix vient surtout de l'étude de marché ?

SB: C'est une grosse partie du coût, oui. Si vous voulez en fonction de la quantité de soleil, c'est l'endroit auquel on se trouve, en fonction de la quantité de chaleur gratuite, fatale que l'on puisse avoir en fonction de la qualité de l'eau, c'est très important, c'est d'ailleurs quelque chose que j'ai totalement découverte, moi en tant qu'architecte. De l'eau, c'est de l'eau, elle est propre, elle est grise, elle est noire, on la traite, on ne la traite pas et quand on parle avec un pisciculteur, il y a 1000 critères qui s'ajoutent. Quand on parle à un horticulteur et à un pisciculteur il y a 2000 critères qui s'ajoutent et qui vont dire « oui, mais l'eau il faut la filtrer comme ça, en gros on va toujours finir par la filtrer à un moment et y rajouter de la manière la plus naturelle possible ce qu'il faut. Cela peut se faire par des mélanges entre de l'eau de source et de l'eau de pluie, ça peut être, si possible éviter l'eau de la distribution, parce qu'elle est de toute façon morte et chlorée, donc il faut l'éliminer et enfin l'eau du sous-sol elle peut être polluée aussi, donc il y a par exemple trop de chlorure dans l'eau à 70 mètres de profondeur, il y a trop de chlorure, c'est apparemment général à Bruxelles. Personne ne peut me dire si c'est l'industrie ou la nature du sol ou autre chose, ce n'est jamais que du sel, ce n'est pas grave, mais il faut le filtrer. C'est en fonction de tous ces critères là qu'il faut mettre ensemble dans un document et dire OK, investissez X millions d'€ dans le projet.

AB: Et quels sont les plus gros obstacles à l'heure actuelle à Bruxelles pour construire ?

SB: La lenteur de l'immobilier. C'est le gros obstacle déjà pour les promoteurs immobiliers, alors en plus de ça moi c'est à Bruxelles, à Paris ou ailleurs, j'ai plusieurs projets qui pourront sortir et qui vont sortir en 2021, 2022, 2023, 2024 et 2025 et pour réaliser cela en 2018, 2019 ou 2020 c'est difficile parce que cela prend énormément de temps. Et du coup plusieurs des projets sur lesquels on travaille sont des projets qui sont à côté de bâtiments pour pouvoir les faire rapidement car quand c'est sur un bâtiment, il faut attendre le permis du bâtiment lui-même et puis la construction, alors pour arriver à sortir quelque chose … Sur l'abattoir on a été relativement vite, les permis ont été obtenus vite, parce que le bâtiment existait et avait été fait pour et finalement le permis on l'a eu en trois ou quatre mois, ce n'était pas un problème. On a dû montrer patte blanche aux pompiers et ceux-ci m'ont même demandé quelle était la charge au feu d'un poisson dans l'eau ! Je ne suis pas certain que ce n'était pas de l'humour au départ. « Quand l'eau s'évapore, quand il n'y a plus d'eau, il n'y a pas de poissons. – Ah oui, c'est vrai, vous avez raison ! – De toute façon il est cuit, s'il ne s'est pas évaporé ? » Tout cela pour dire que c'est quelque chose de nouveau et que c'est très difficile d'anticiper le genre de questions que l'on va avoir lors de chaque demande.

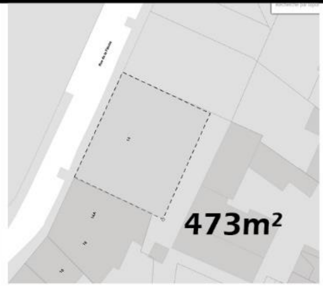
AB: Est-ce que ce ne sont pas plutôt les lois d'urbanisme qui font entrave ou bien les normes de sécurité ou …

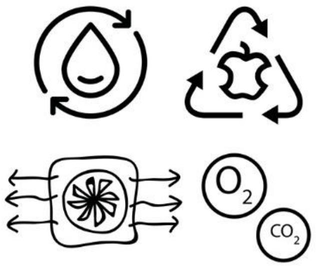
SB: Non, c'est le temps que cela prend.

AB: C'est aussi un gros investissement ?

SB: Oui, oui, aussi, mais … par rapport à un projet de cent millions d'Euros en rajouter deux millions pour une ferme urbaine, ça ne fait jamais que deux pourcents. Par contre sur un projet de deux millions c'est différent. J'ai le cas pour le moment, j'ai quelqu'un qui va transformer un bâtiment et qui met deux millions d'Euros et si je vais lui demander de mettre deux millions dans une ferme urbaine, alors je sais que cela ne va pas marcher. C'est aussi important que son projet lui-même, donc on va trouver une façon de faire autrement mais parce que les deux millions d'Euros qu'il investit, c'est dans la transformation d'un bâtiment existant et la ferme urbaine à mettre dessus, elle va coûter entre trois et quatre millions ; donc lui il devrait mettre environ la moitié, ou la moitié de la moitié on va dire, il va mettre 1,5 million, les banques peuvent mettre le reste, mais c'est quand même une fameuse prise de responsabilité.

15. Appendix : Case study summary sheets





Structure

The rooftop will need horizontal reinforcement. A self-supporting structure is to be set up to sustain the load of the earthen containers.

Flows

The rooftop is currently loosing a large amount of heat that a greenhouse will be able to recover. The water excess of the UA is to be pooled with the sanitaries'system.

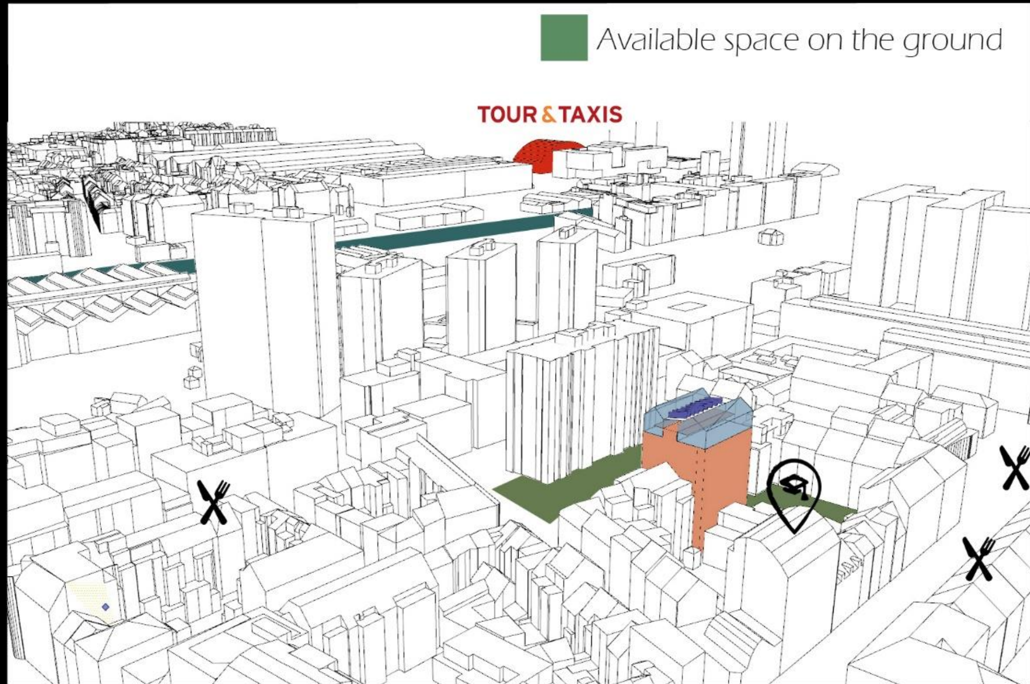
Contexte

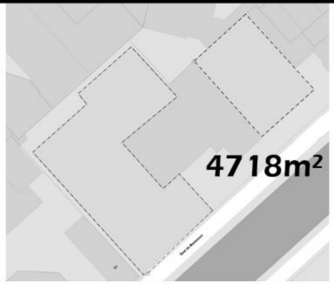
Close to the canal, this building's property is also composed of a plot of land that could be cultivated by the residents of the house. The food would immediatly be processed for the building's canteen.

SOIL CULTURE

Brief description

This building is a shelter for about 120 young people in foster care, from infants to 14 years old. The building was built during the second half of the 20th century and is very inefficient from an energy point of view. Renovation work is planned in 2019, an opportunity to integrate the greenhouses. The facility is not there to make a profit, but rather to offer the benefits of agriculture to these young people. At the same time, offer them future-oriented training and healthier food. It is a project with a social rather than an economic scope.





Structure

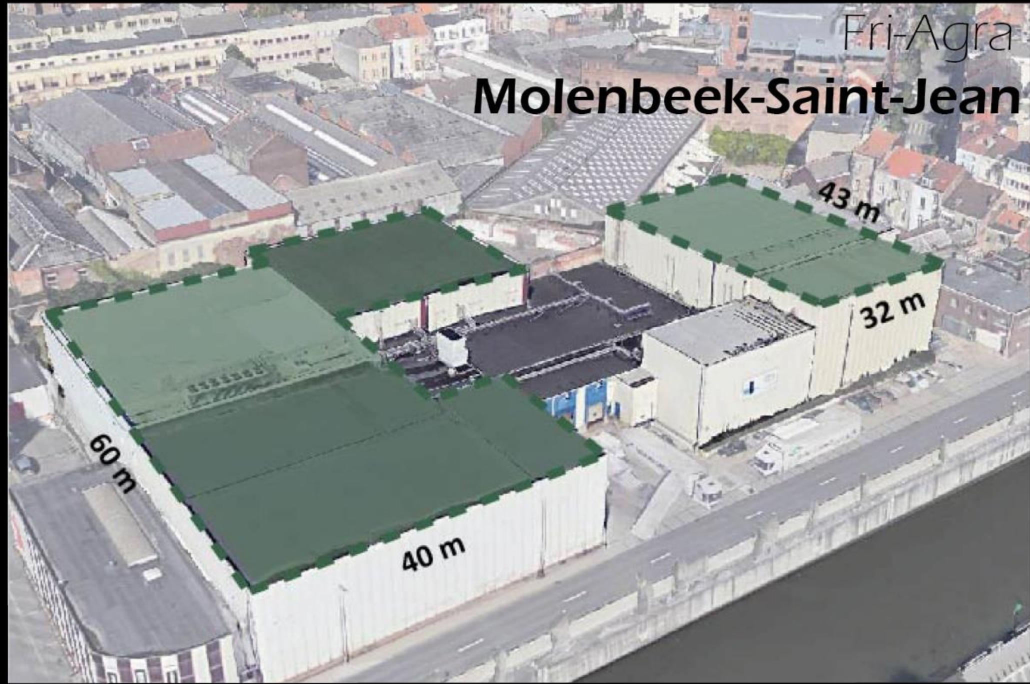
The structure made of steel is totally unsufficient to sustain agricultural loads. The spans are too large to consider an exostructure. A complete reinforcement is planned.

Flows

Fri-agra is a refrigeration company. The excess heat produced by the cooling system is recovered by the greenhouse.

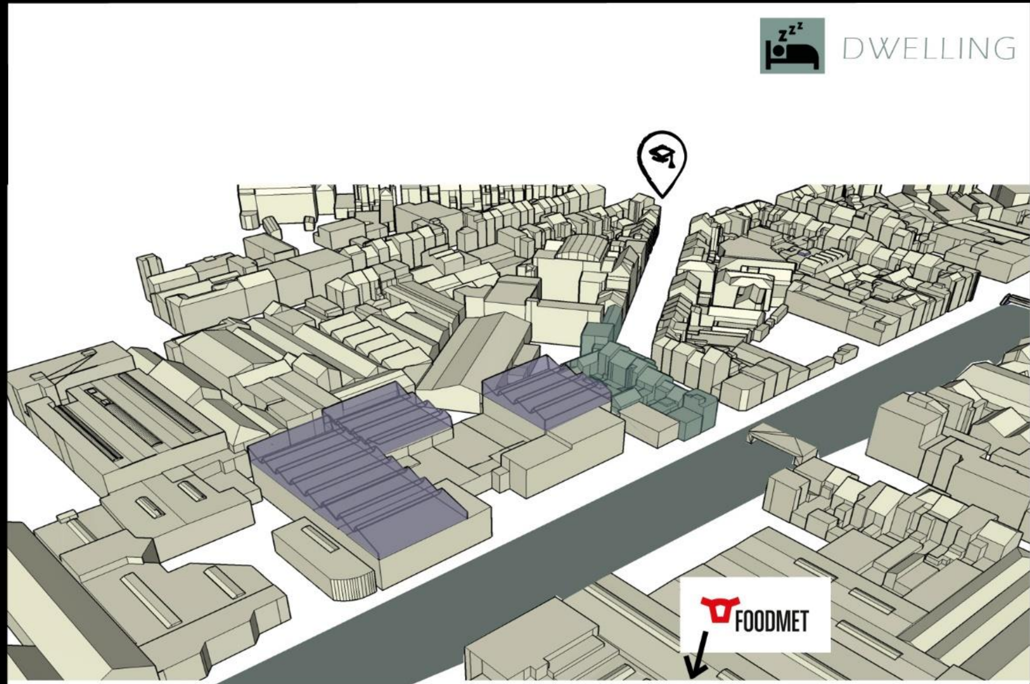
Contexte

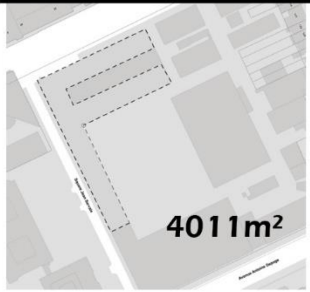
Fri-Agra is located on the banks of the canal in the Birmingham district of Molenbeek. This neighborhood is about to be refurbished over the next 20 years.

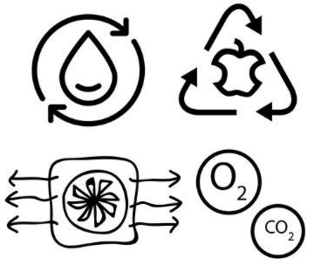


Brief description

Located near the Foodmet, but with a very different metabolism, the greenhouse will be able to grow other varieties of fruits and vegetables. The industry occupies most of the floor space, impossible to distribute the products on site, but why not take advantage of Foodmet's infrastructure to join the services and create a hub of intense urban agriculture.







Structure

Build from 1922 to 1924, its structure is in concrete. The roof used to bear another storie, its bearing capacity is therefore analysed at 300 to 400kN/m².

Flows

The building has the adequate system to connect the air flow. Its function requires a large quantity of water for sanitaries, the RWH system is currently non existing.

Contexte

First building of the ULB, the U building is a central piece of the campus, facing the university's restaurants. Opportunity to expand the little market. Educative potential

Building U - ULB

Ixelles

AQUAPONICS

Brief description

Originally a sixth story stood on that part, but was demolished after a fire in 1971. It is therefore easy to recover this roof to integrate aquaponics greenhouses. The food can be directly processed on site and consumed by the students. By installing solar panels on the aquaculture greenhouse, it will be possible to heat the domestic hot water of all students living on campus.