EL **BARRI** DE
LOCAVORE

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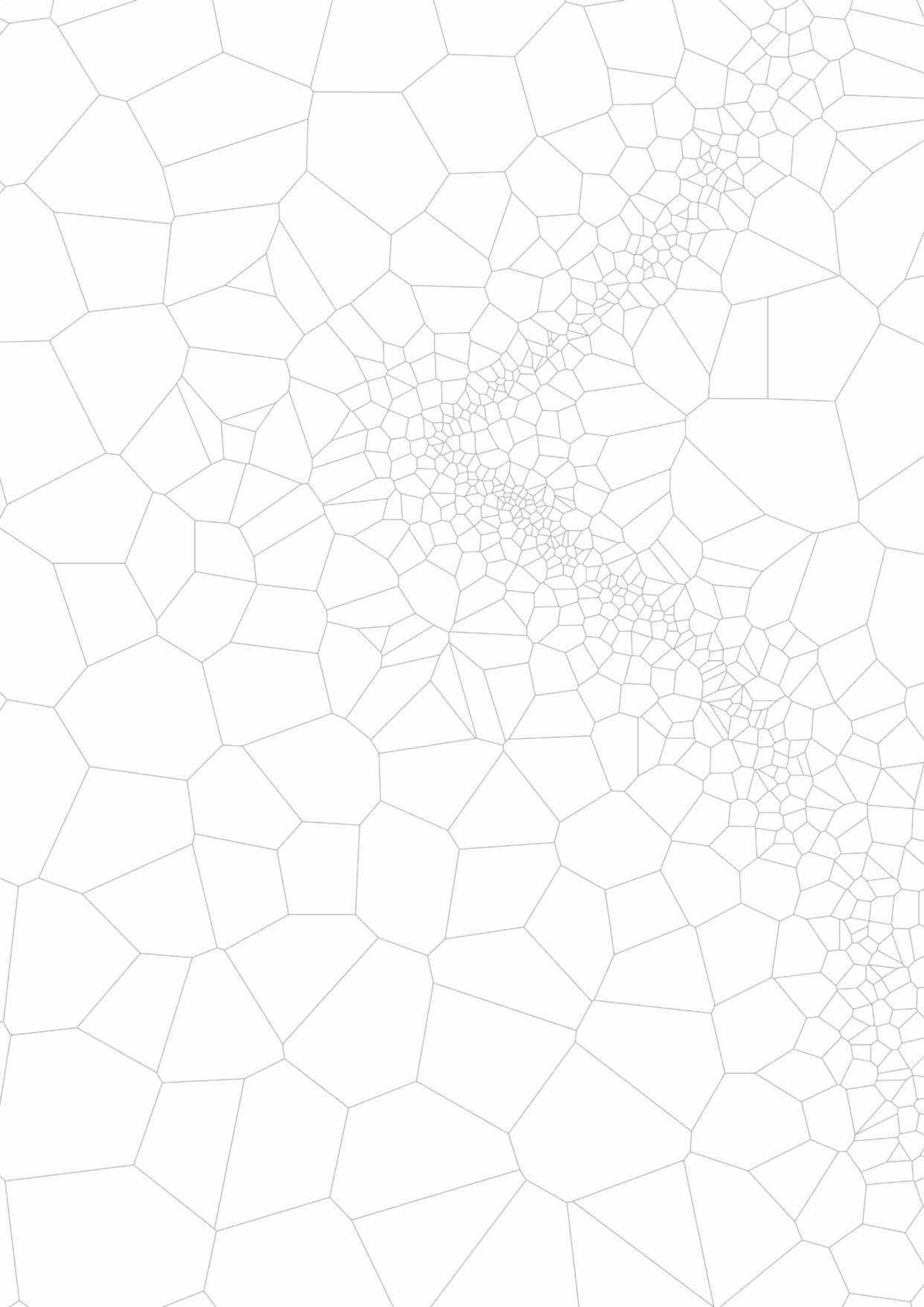
Integrating Urban Agriculture In Canyelles Neighbourhood, Barcelona



POLITECNICO DI MILANO
BUILDING AND ARCHITECTURAL
ENGINEERING

EL **BARRI** DE **LOCAVORE**

Integrating Urban Agriculture In Canyelles Neighbourhood, Barcelona

Thesis submitted in partial fulfillment of the requirements for the degree of master of science

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2017-2018

ACKNOWLEDGEMENT

We express our gratitude and appreciation to the efforts of the teaching staff that guided us during this project and we would mention:

Our Tutor, Professor Massimo Tadi
Professor Gabriele Masera
Professor Paolo Martinelli
Professor Angela Colucci
Professor Matteo Brasca

and all the professors, assistant professors, tutors, and members who contributed to our knowledge during our study at Politecnico Di Milano.

We would like to thank in particular:

Elena: simone, parents,

Zeynab
I dedicate this work to my family that was always a support to me during my academic pursuit.

Adel,

To my parents, the first architects that inspired me.
To my sisters, my backbone
To my friend, Mahmood Islam for his resourceful support
To

ABSTRACT

Food security is becoming more of a global concern even for nations associated with food abundance. The future of food is present on contemporary agendas as a key for assuring a sustainable development for societies. However, the reality is that the future is foretelling numerous threats that call for unprecedented global collaboration. And as we have seen portions of the world suffering from hunger, we didn't envision that this threat will be the concern for everyone in the coming years. The challenge encompasses many aspects: food production, food transport, food demand, and food safety. This gave more importance in the past years particularly to food production in cities through urban agriculture, as a means to face future production shortages. Although the concept is not new, new methods are investigated to meet the current cities' needs and demands. However, the practice we can say is relatively limited. The idea is that we need to be aware of a hidden threat, and work to spread the practice of urban agriculture everywhere, starting from our everyday life encounters, to the design of our cities and buildings. Around the world we can see many examples of cities integrating urban agriculture policies in their plans. Many associations and research bodies have elaborated their efforts in methodologies and applications. Urban designers and architects are not far from this, as the integration of urban agriculture in city morphology and particularly in building fabric will be a huge contributor to the enhancement of food production in cities.

Based on this fact, we will investigate the neighbourhood of Canyelles, in northern district of Nou Barris, Barcelona, as a case study of the integration of urban agriculture in an urban and architectural context. The project elaborates on the study of a social housing complex in the designed masterplan area. The goal is to arrive to a feasible integration of the practice in the proposed area on the threshold between Barcelona and the mountain Collserola, not only in a spatial way, but also in a social one, by encouraging the current residents to become:' Locavores', or people eating their locally grown food. The project analyses this approach and tries to highlight possible implementation on the level of the neighbourhood and on the level of the building, moving from the urban scale of the neighbourhood to the level of the building detail.

ABSTRACT

La sicurezza alimentare sta diventando sempre di più un tema di interesse globale, anche per le nazioni associate all'abbondanza di cibo. Il futuro dell'alimentazione è presente nelle agende contemporanee come chiave per assicurare uno sviluppo sostenibile alle società. Tuttavia, la realtà è che il futuro prevede numerose minacce che richiedono una collaborazione globale senza precedenti. E anche se sono state viste parti del mondo che soffrivano la fame, non si immaginava che questa minaccia sarebbe stata la preoccupazione per tutti nei prossimi anni. La sfida comprende molti aspetti: produzione alimentare, trasporto alimentare, domanda alimentare e sicurezza alimentare. Questo ha dato, a partire dagli anni passati, maggiore importanza in particolare alla produzione di cibo nelle città attraverso l'agricoltura urbana, come mezzo per far fronte alle future carenze di produzione. Sebbene il concetto non sia nuovo, vengono studiati nuovi metodi per soddisfare le esigenze e le richieste delle città attuali. Tuttavia, si può dire che la parte pratica sia relativamente limitata. L'idea è che dobbiamo essere consapevoli di una minaccia nascosta e lavorare per diffondere la pratica dell'agricoltura urbana ovunque, a partire dai nostri incontri quotidiani, fino alla progettazione delle nostre città e dei nostri edifici. In tutto il mondo possiamo vedere molti esempi di città che integrano le politiche di agricoltura urbana nei loro piani di sviluppo.
Molte associazioni e organismi di ricerca hanno messo a frutto i loro sforzi elaborando metodologie e applicazioni. Progettisti e architetti non sono lontani da questo, poiché l'integrazione dell'agricoltura urbana nella morfologia delle città e in particolare nel tessuto edilizio contribuirà enormemente alla valorizzazione della produzione alimentare nelle città.

Sulla base di questo, studieremo il quartiere di Canyelles, nel distretto settentrionale di Nou Barris, a Barcellona, come caso di studio dell'integrazione dell'agricoltura urbana in un contesto urbano e architettonico. Il progetto elabora lo studio di un complesso abitativo sociale all'interno dell'area coperta dal masterplan di progettato. L'obiettivo è arrivare ad una possibile integrazione della pratica nell'area proposta sulla soglia tra Barcellona e la montagna di Collserola, non solo in modo spaziale, ma anche sociale, incoraggiando gli attuali residenti a diventare: "Locavores", ovvero persone che mangiano il loro cibo coltivato localmente. Il progetto analizza questo approccio e cerca di evidenziare la possibile implementazione a livello del quartiere e del livello dell'edificio.

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INTRODUCTION

Europan 14/ Y. 2017

The project is based on the Europan 14 international competition 2017 with the theme 'productive cities'. This version 14 of Europan aims at implementing ways to create productive activities in cities around Europe in 35 sites.

The ideology of the mixed-city is now shared. But how mixed is actually the mixed-city? In many urban development projects housing is the main program. We add some offices and public amenities, bars and shops to create a "genuine vibrant urban neighbourhood". But one program has been excluded: the productive economy. It has left the city to go to the periphery. There is now in many European cities a spatial and social mismatch between living and working conditions. The city provides high-skilled professionals with many working possibilities while a large part of low-skilled workers live in the city with no work opportunity. This mismatch generates many problems with regard to economy, mobility and sociality.

Figure 0.1
Europan 14 (2017) entitled: 'The Productive city'-participating cities

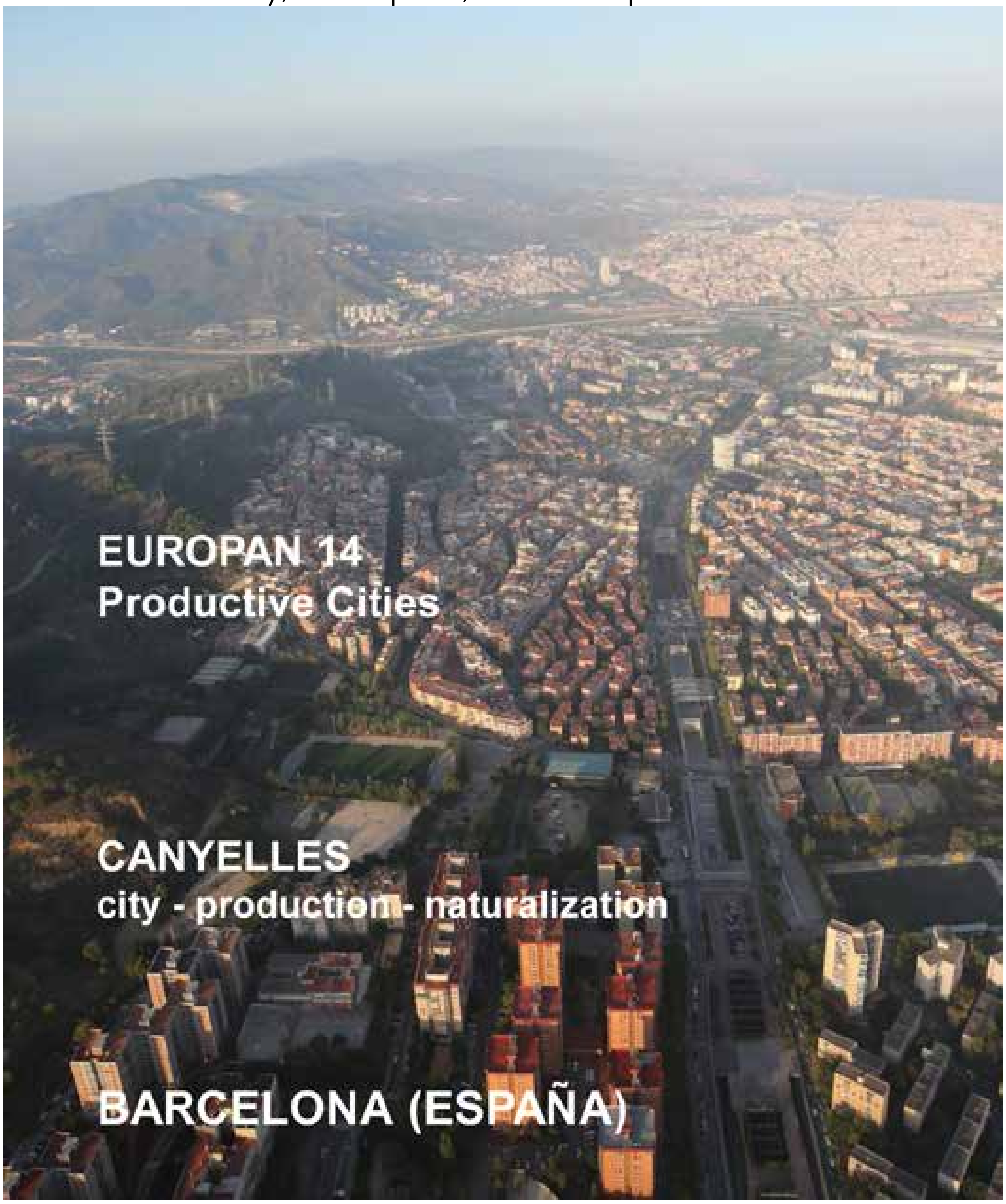
Proposed site: Canyelles, Barcelona

The site proposed by the Barcelona City Council's Urban Ecology Area is in an urban situation that is currently under renewal. Some of the city's new urban planning principles included in the programme details must be implemented, and sustainability criteria must be included. This proposal is expected to be a framework for dialogue with local residents, with a view to generating positive synergies.

Figure 0.2
The site under study in Canyelles, Barcelona

The site is in a northern Barcelona suburb, between Canyelles, the last residential district built in the city, and Roquetas, a clear example of owner-built districts.

Figure 0.3
Project site: Canyelles neighborhoud in Barcelona, Spain



PROBLEMATIC

What are we facing on a global scale?

Currently, the world is faced with an unprecedented call for action at a momen- which four countries have been identified as at risk of famine, and demand for humanitarian and resilience assistance is escalating. Against this background, informing the global and national food security community on the risk of food crises and on the severity of such crises is of fundamental importance. In recent years, stakeholders have made major investments to improve food security analysis and related early warning systems in order to prevent and tackle food crises more efficiently. Although significant improvements have been made over time in the methods and technologies used to improve the quality and timeliness of food security assessments and monitoring systems, a comprehensive global pictures of food crises is still often missing. Partial geographical coverage and a lack of comparable data within a standardised system make it difficult to get a full global picture of food crises at any given time

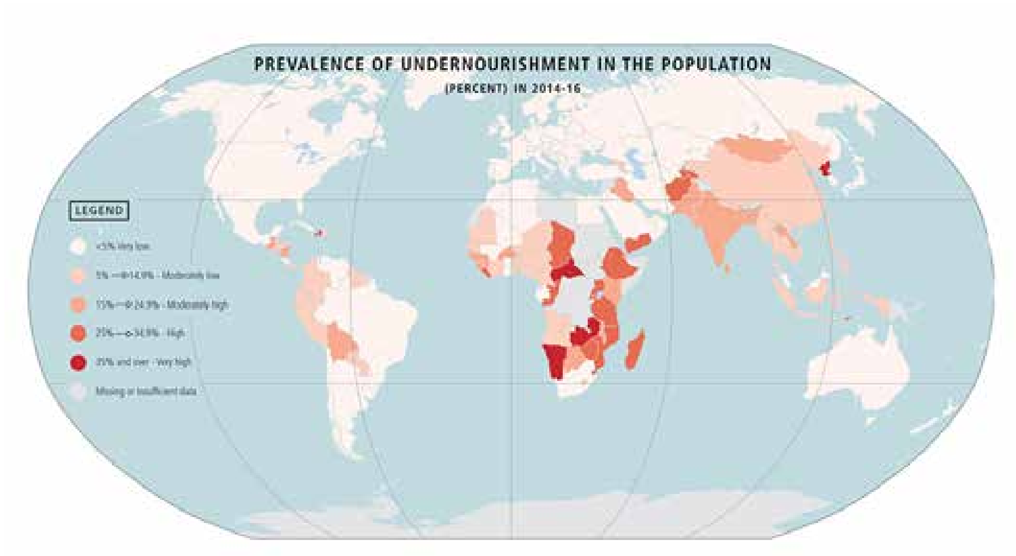
Figure 0.4
We are facing drought, hunger, and water scarcity of ascending threat

Globally, 108 million people in 2016 were reported to be facing Crisis level food insecurity or worse (IPC Phase 3 and above). This represents a 35 percent increase compared to 2015 when the figure was almost 80 million. The acute and wide-reaching effects of conflicts left significant numbers of food insecure people in need of urgent assistance in Yemen (17 million); Syria (7.0 million); South Sudan (4.9 million); Somalia (2.9 million); northeast Nigeria (4.7 million), Burundi (2.3 million) and Central African Republic (2 million). The immediate outlook points to worsening conditions in some locations, with risk of famine in isolated areas of northeast Nigeria, South Sudan, Somalia and Yemen.

Conflict causes widespread displacement (internal and external), protracting food insecurity and placing a burden on host communities. The populations worst affected are those of Syria (6.3 million Internally Displaced People) and Syrian refugees in neighbouring countries (4.8 million); Iraq (3.1 million); Yemen (3.2 million), South Sudan (3 million), Somalia (2.1 million) and northeast Nigeria (2.1 million). In some countries, food security has been undermined by El Niño, which largely manifested in drought conditions that damaged agricultural livelihoods. The countries most affected are in eastern and southern Africa and include Somalia, Ethiopia (9.7 million), Madagascar (0.8 million in the Grand Sud), Malawi (6.7 million), Mozambique (1.9 million) and Zimbabwe (4.1 million). Projections for early 2017 indicate an increase in the severity of food insecurity in these regions. This is particularly the case in southern and south-eastern Ethiopia, Kenya and Somalia

What were the actions so far?

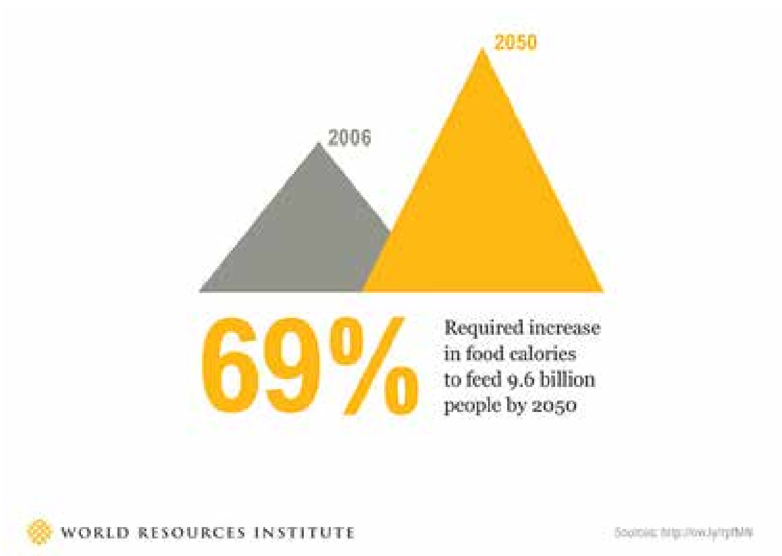
Figure 0.5
Prevailance of under-nourishment in the population(%) 2014-16



The European Union, WFP and FAO have joined forces to coordinate the compilation of analyses to increase the impact of humanitarian and resilience responses through the preparation of the “Global report on Food Crises”.

The World Humanitarian Summit has prompted a major rethink of the way response financing is delivered in crisis settings. Since 2013 , the European Commission has worked to develop ways to compare and clarify the results of food security analyses across partners and geographical areas. In 2015, the Joint Research Centre of the European Commission (ECJRC) produced an annual report on food insecurity hot-spots to inform decisions on food crisis allocations at the global level. In 2016, the European Commission invited FAO and WFP to contribute by providing additional food security data and analysis. Following the successful experience of the 2016 analysis, the three organizations agreed to move forward, with the aim of producing a consensus based yearly report from early 2017.

Figure 0.6
The expected food demand casts serious need for current action



What is needed to combat increasing scarcity?

Figure 0.7
Food scarcity in conflict areas is just more evident currently

It is clear that the problem is extremely complex since so many factors play a part in the determination of rising food prices. However, that is not to say that there are not equally clear ways in which we can prevent food prices reaching unaffordable prices for most people around the world, with the devastating consequences this would have.

Firstly, investment in improved food production via higher yields is vital. As already stated, it is estimated that food production must increase by 70% by 2050 to meet the growing demand, and most of this increase must come from higher yields since arable land is scarce. This must be done in a responsible and sustainable manner: land grabs to benefit powerful countries must end. Legislation is required to prohibit the acquisition of land for purely profitable reasons; the deals must be overseen over a long period to ensure that land acquired by foreign investors is put to productive use. Investment in alternative renewable energy must be made to combat the food insecurity problem. Biofuels are not the answer since there is only a marginal reduction in pollution, more land is used, and often the positives results are counteracted by the damaging effects on soil and water quality.

Figure 0.8
The future of food production is to start from now

CHAPTER 1 – GLOBAL FOOD SECURITY

"Imagine all the food mankind has produced over the past 8,000 years. Now consider that we need to produce that same amount again – but in just the next 40 years if we are to feed our growing and hungry world."

Paul Polman, CEO of Unilever, and Daniel Servitje, CEO of Grupo Bimbo

1.1 Food security- general view

Figure 1.1
What can we think of when considering food security?

(source: https://i.ytimg.com/vi/Xv2OQF7iCMI/maxresdefault.jpg)

The negative impact of conflict on food security, nutrition and agriculture is an uncontested and globally recognized phenomenon. Conflict is a leading cause of food insecurity and hunger in several parts of the world, undermining food security in multiple ways and creating access problems for governments and humanitarian agencies who often struggle to reach those most in need. The causes of food insecurity are diverse but often coupled to disruptions in food production and food systems, plundering of crops and livestock, loss of assets and incomes or population displacement which all directly or indirectly impact availability, access and utilisation of food. In general, in conflict affected areas, the lack of adequate access to food, combined with poor access to medical facilities – in some cases even a lack of access to clean water, has an immediate detrimental effect on malnutrition, especially for vulnerable groups such as children under five, and pregnant or breastfeeding women.

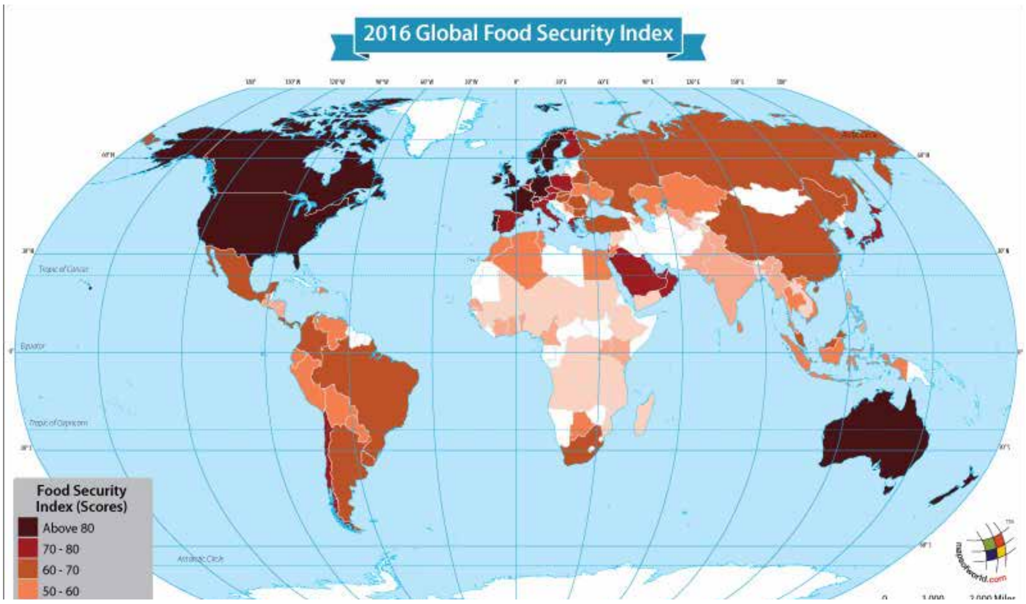


Figure 1.2
2016 Global Food Security Index

(source: https://www.mapsofworld.com/headlinesworld/miscellaneous/least-food-secure-nations-world/attachment/world-map-2016-global-food-security-index/)

The immediate outlook points to a further deterioration of food security in certain hotspots, particularly in areas that have been severely affected by droughts and conflict. In southern Africa, the poor 2016 harvests have greatly reduced household food supplies. This is expected to result in a harsher lean season in early 2017. Further ahead, the early 2017 production outlook points to an expected recovery based on favourable rainfall forecasts, with the main harvest expected to start in April. However, there are forecasts of worsening food security, particularly for Malawi, Zimbabwe and Mozambique. The current drought in East Africa is expected to increase food insecurity in early 2017, with major concerns in southern Somalia, south and south-eastern Ethiopia and south eastern and coastal parts of Kenya. According to the latest figures, the number of food-insecure people in Kenya increased from 1.3 million to 2.2 million in February 2017, leading the government to declare the current drought a national disaster. Conflict and civil insecurity remain the primary drivers of acute food insecurity in many countries, severely constraining food access and eroding the resilience of households and governments. Some areas will be particularly hard hit and there is a risk of famine in places such as northeast Nigeria, South Sudan, Yemen and Somalia, particularly if humanitarian assistance cannot reach the population in need. The latest analysis in South Sudan reported confirmed famine, or high risk of famine, in conflict-affected areas of Unity State between February and July. In 2017, widespread food insecurity still persists in Iraq and Syria (including among refugees in neighboring countries). Other countries are currently facing more localized or less acute food insecurity but are at risk of worsening food security and nutrition in 2017. These are Afghanistan, Bangladesh, Burundi, Central African Republic, Madagascar, Uganda and the United Republic of Tanzania.

Figure 1.3
Food security

(source: https://www.bigpicnic.net/media/images/Food_security_diagram.width-800.jpg)

Early warning sources also point to Libya, Myanmar, Sri Lanka and Ukraine, as countries that could be falling under this category. Finally, the worsening economic situation in Venezuela might also cause severe shortages of consumer goods, including food and medicine. Hence, food security here will need to be monitored.

1.2 FOOD DEMAND V/S SUPPLY

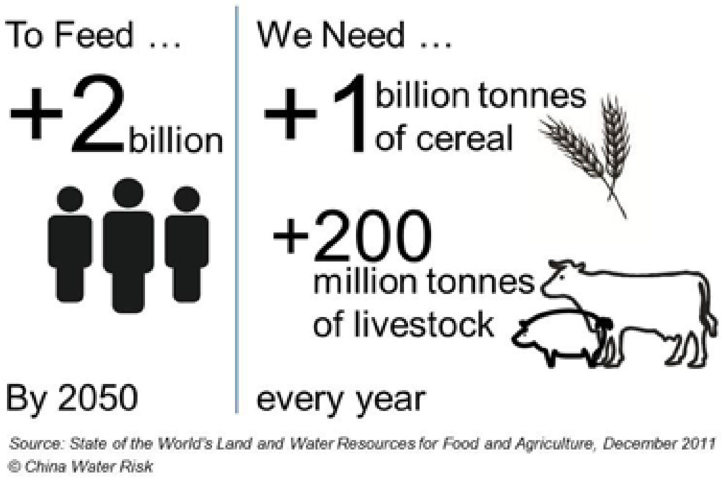


Figure 1.4 Expected food demand in 2050

(source: http://chinawaterrisk.org/wp-content/uploads/2012/02/More-population-more-food.jpg)

It is expected that global demand for food will grow significantly in the coming years. The increase in population and living standards will be determining factors for this increase. At the same time, it provides a strong growth of agricultural land for the production of biofuels, which will come into direct competition with food production. Moreover, it is likely that food production resulting influenced by the consequences of climate change that have been modified cultivation techniques for reasons of adaptation to climate variations and changes in the distribution and behavior of animal and plant pests and diseases. The incorporation of sustainability throughout the food chain must be a key element to ensure a safe and eco-efficient economy based on efficiency in resource consumption and minimizing impacts on the environment and health.

Demand Shocks Change in Diets

A huge factor in the growing demand for food goods is the changes in diets we are seeing around the world. The following table, published in a 2003 report from the FAO on Global and Regional Food Consumptions and Trends, shows us the pattern of the daily average calorie intake for each person in each area of the world and the world for in total.

Global and regional per capita food consumption (kcal per capita per day)

Region	1964–1966	1974–1976	1984–1986	1997–1999	2015	2030
World	2358	2435	2655	2803	2940	3050
Developing countries	2054	2152	2450	2681	2850	2980
Near East and North Africa	2290	2591	2953	3006	3090	3170
Sub-Saharan Africa[a]	2058	2079	2057	2195	2360	2540
Latin America and the Caribbean	2393	2546	2689	2824	2980	3140
East Asia	1957	2105	2559	2921	3060	3190
South Asia	2017	1986	2205	2403	2700	2900
Industrialized countries	2947	3065	3206	3380	3440	3500
Transition countries	3222	3385	3379	2906	3060	3180

[a] Excludes South Africa.

Table 1.1 The rise in food demand from 1964-2030

(source: http://http://www.who.int/dietphysicalactivity/publications/trs916/en/gsfao_global.pdf?ua=1)

We can clearly see that there has been a general trend of greater food consumption around the world for the past 50 years and this is predicted to continue in the future 20 years. This is particularly true of developing countries as they get richer and make the transition from basic to more luxurious diets, just as developed countries around the world have already. Transitional countries have actually decreased their intake of calories, however from an already high level. Sub-Sahara Africa on the other hand has the slowest growth of calorie intake, and it actually decreased in the 1980s and 1990s. However, overall, this table paints a picture of a growing demand for food in the past and in the future.

Table 1.2
Demand of calories according to country classification

(source: http://www.who.int/dietphysicalactivity/publications/trs916/en/gsfao_global.pdf?ua=1)

Vegetable and animal sources of energy in the diet (kcal per capita per day)

Region	1967–1969			1977–1979			1987–1989			1997–1999		
	T	V	A	T	V	A	T	V	A	T	V	A
Developing countries	2059	1898	161	2254	2070	184	2490	2248	242	2681	2344	337
Transition countries	3287	2507	780	3400	2507	893	3396	2455	941	2906	2235	671
Industrialized countries	3003	2132	871	3112	2206	906	3283	2333	950	3380	2437	943

The above table tells us that developing countries have continued to increase their demand for calories, most of which has come from an increase in the demand of calories from animal origin. Industrialized countries have also continued to increase their overall calorie intake, mostly from a large increase in animal products since the 1960s, although there was a slight decrease in this as a source of energy in the late 1990s. In contrast to this, transition countries have decreased their meat, fish and dairy intake since the 1980s, as well as their overall total calorie intake. However, when calculating the total difference in demand for calories from animal origin, there is an overall growth of 139 calories per capita, in the time period studied.

We have seen that demand for calories differ greatly around the world and increases over time as countries develop and become richer. This is not to say that this demand is met, or at least for some people. Huge inequalities around the world mean that generally the richest nations get what they want; which is generally speaking more than necessary, whereas many in poorer nations go without the adequate amount. Furthermore, shocks in the supply of the global food market causes prices to rise, which increases the difficulties for poorer countries in acquiring the sufficient calories necessary to survive.

(source: https://allroundthetable.files.wordpress.com/2014/04/colourbox3408099.jpg)

1.3 Food production

1.3.1 Production with sustainability

Improving productivity with sustainability is a key element to give adequate response to all these social and environmental challenges, which requires the application of production methods of high performance as well as profound changes in the way we produce and distribute food. These changes can affect directly, both positive and negative, product safety, biodiversity, the environment and the perception of citizens. Also, the scientific risk assessment and improved analytical techniques are causing agents that a few years ago were impossible to detect unknown or switch to expand the list of issues to be managed.

Figure 1.5 Sustainable Food Production Cyle

(source: <https://cdn.patchcdn.com/users/102377/2012/05/T800x600/a8b56548e0dfbf-757cae82dc75e4c23b.jpg)

1.3.2 Impact of Food Production on the environment

The food production has become a serious environmental concern. Rapidly growing world's population requires increased food production which is of the greatest causes of environmental degradation throughout the world. Of particular concern is meat production as modern practices of animal raising directly contribute to water and air pollution and increase carbon dioxide emissions, while crop production for animal feed and the use of land for grazing threaten biodiversity and wildlife species.

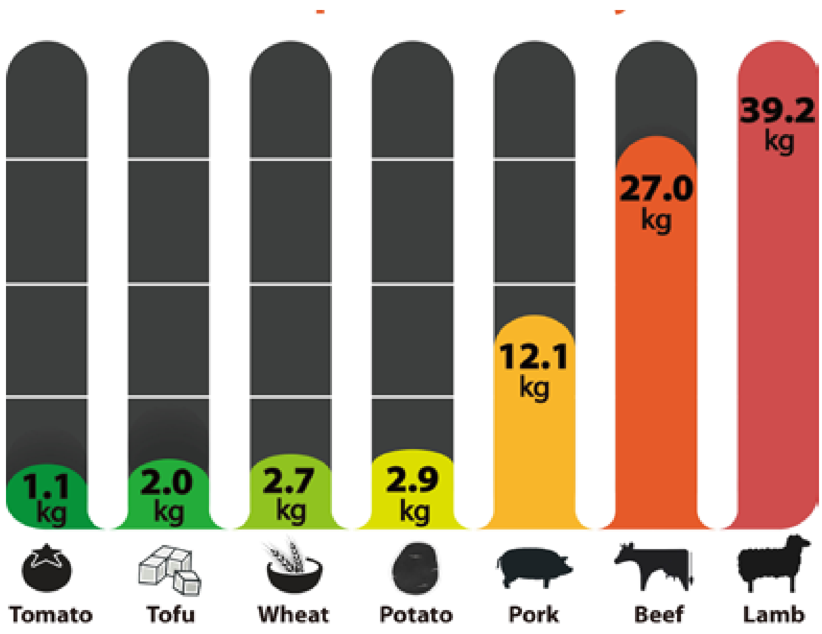


Figure 1.6
Carbon Footprint of the food we eat

(source: http://green-monday.org/wp-content/uploads/-21.jpg)

Mass meat production has also been shown to be one of the main contributors to carbon dioxide emissions which in turn are the main cause of the climate change. The meat industry is estimated to be responsible for about 9 percent of total carbon dioxide emissions which are a result of emissions of various gases from the farms as well as from the microbial activities after application of animal waste as fertilizers.

Lastly, animal husbandry poses a serious threat to the local ecosystems and biodiversity due to the use of the land for grazing and animal feed production. As much as one quarter of the Earth's surface is used for grazing and about one third of arable land is used to produce animal feed. As a result, the wildlife species struggle with lack of habitat, while some are even threatened with extinction.

1.3.3 Effects of climate change

Unpredictable Weather and Climate Change

As seasons are becoming more extreme due to climate change, pressure over the years has mounted on farmers to continue producing despite harsher environments. It is predicted that for every 1 degree Celsius increase in the dry growing season, there could be up to a 10% decline in rice yields. In Sub-Saharan countries such as Sudan and Senegal, rising temperatures could cause up to a 50% reduction in yields (Oxfam 2011). Climate change is similarly bringing about a greater number of weather related natural disasters such as floods and droughts. The current drought in the Horn of Africa is a clear example of a worsening of weather conditions that is having an irreversible effect on harvests and thus millions of people's food supply. Climate change is therefore having a damaging effect on the productivity of farms. However, in turn, the rising demand for greater levels of agricultural production is undoubtedly increasing vulnerability to climate change. Therefore food and climate change is a complex and interlinking problem that ultimately needs to be addressed from the demand side.

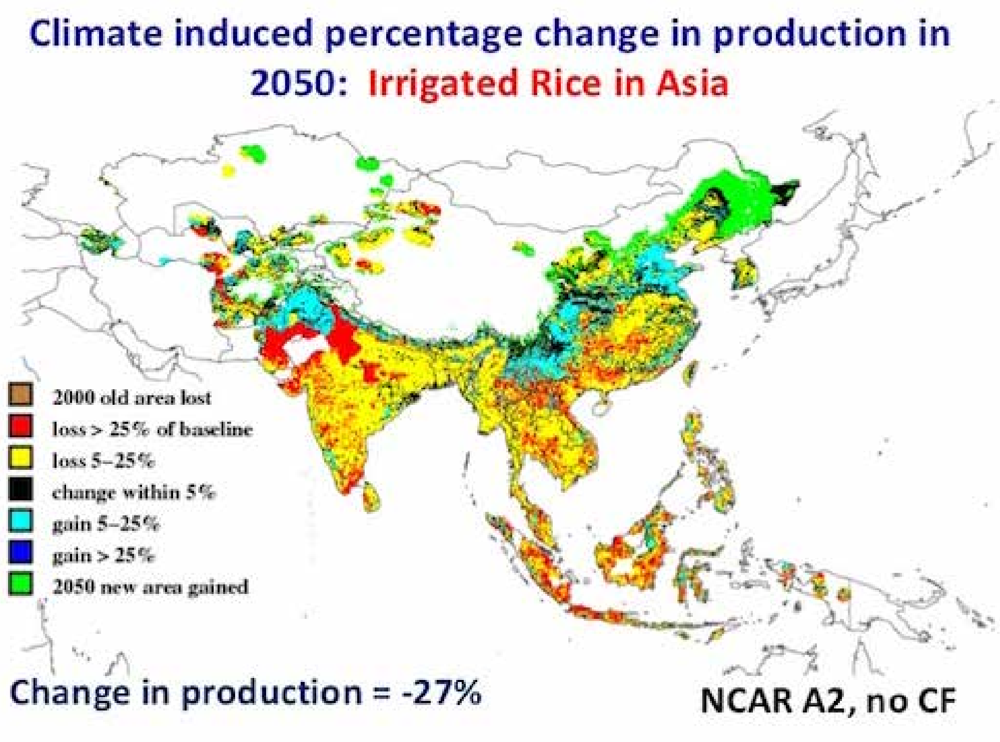


Figure 1.7
Effect of Climate Change in food production

(source: http://warmheartworldwide.org/wp-content/uploads/2016/06/climate-change-and-food-security-in-south-east-asia-issues-and-policy-options-13-728.jpeg)

1-Horn of Africa Drought - 2011

Undoubtedly one of the most severe humanitarian crisis for many years sees over 12 million people now requiring emergency assistance in areas of Kenya, Uganda, Somalia, Ethiopia and Djibouti, with part of Somalia being identified as famine struck. This is a result of two years of almost no rainfall and thus the driest season for over 60 years, combined with higher global food prices – resulting in the inability for millions to grow or buy food. (FAO 2011).

2-Russia Wildfires – 2010

The summer of 2010 saw Russia's record hottest summer, with temperatures on average well over 35 degree Celsius, resulting not only in drought which causes crop failures but also the outbreak of wildfires in the west of the country, that quickly spread across many regions and their farms. The effect on the year's crops was the loss of a third of the previous years harvest, which caused the government to put a temporary ban on all grain exports so that domestic prices would not be sacrificed. This in turn caused global food priced to surge since Russia is one of the worlds biggest producers of wheat, barley and rye. (BBC 2010)

3-Pakistan Floods – 2010

Severe flooding hit one fifth of Pakistan land area in 2010 and affected the lives of around 20 million people. Furthermore it cost the country vast amounts in terms of livestock and crops such as cotton, sugar cane, rice, pulses and tobacco, which the country relies on for economical stability. This huge reduction in the supply of these crops pushed global prices up and caused a strain of the availability of the crops (FAO 2011).

1.4 Linking food security to production

Investments in agriculture are important to increase food security. The channels are complex and multiple. Rising productivity increases rural incomes and lowers food prices, making food more accessible to the poor. Other investments—such as improved irrigation and drought-tolerant crops—reduce price and income variability by mitigating the impact of a drought. Productivity gains are key to food security in countries with foreign exchange shortage or limited infrastructure to import food. The same applies to households with poor access to food markets. Nutritionally improved crops give access to better diets. The contributions that agriculture makes to food security need to be complemented by medium-term programs to raise incomes of the poor, as well as insurance and safety nets, including food aid, to protect the chronic and transitory poor.

Figure 1.8
The link of food security to production

(source: https://pcdnetwork.org/wp-content/uploads/2016/07/Food-Security-Resources.jpg)

1.4.1 Need for sustainable production

Thus, food production is an important part of food security, but not the only part. Progress towards improved food security does depend on making agriculture more productive. This presents us with a paradox. Food security largely depends on access and entitlements to food, which depend on improved incomes for many.

Furthermore, although recent analyses of food security have highlighted the differences between food production and food availability and access, most have failed to address fully the need for social, economic and environmental sustainability in food production. The emphasis on increasing yields has led policy makers to disregard or misunderstand how these approaches may hinder, rather than help, food security in the developing world. Sustainable agriculture offers opportunities to deal with these issues in an integrated way.

The links between sustainable agriculture and food security shows how achieving food security depends on ensuring that three key conditions are fulfilled:

- Sustainable food production through the use of regenerative technologies, the full participation of farmers in the processes of planning, research and

extension;
- A conserved natural resource base through approaches, practices and technologies that build upon and enhance the health and diversity of available natural resources without depleting them;
- Entitlements or access to food through approaches which strengthen local capacity and build strong and diversified rural economies source.

1.4.2 Challenges for sustainable food production

Challenges for Agricultural Development

As this century draws to a close, agricultural development faces some unprecedented challenges. By the year 2020, the world will have to support some 8.4 billion people. Even though enough food is produced in aggregate to feed everyone, some 800 million people still do not have access to sufficient food. This includes 180 million children who are underweight and suffering from malnutrition. Recent approaches to agricultural development, including food production and food security, have largely failed to reduce the absolute numbers of the food insecure or to ensure environmental sustainability. Whilst global achievements in food production have been impressive in the last 50 years, the global inequalities in food entitlements (i.e.., people's ability to acquire food and gain access to and control of productive resources) remain one of the biggest obstacles to achieving food security for all.

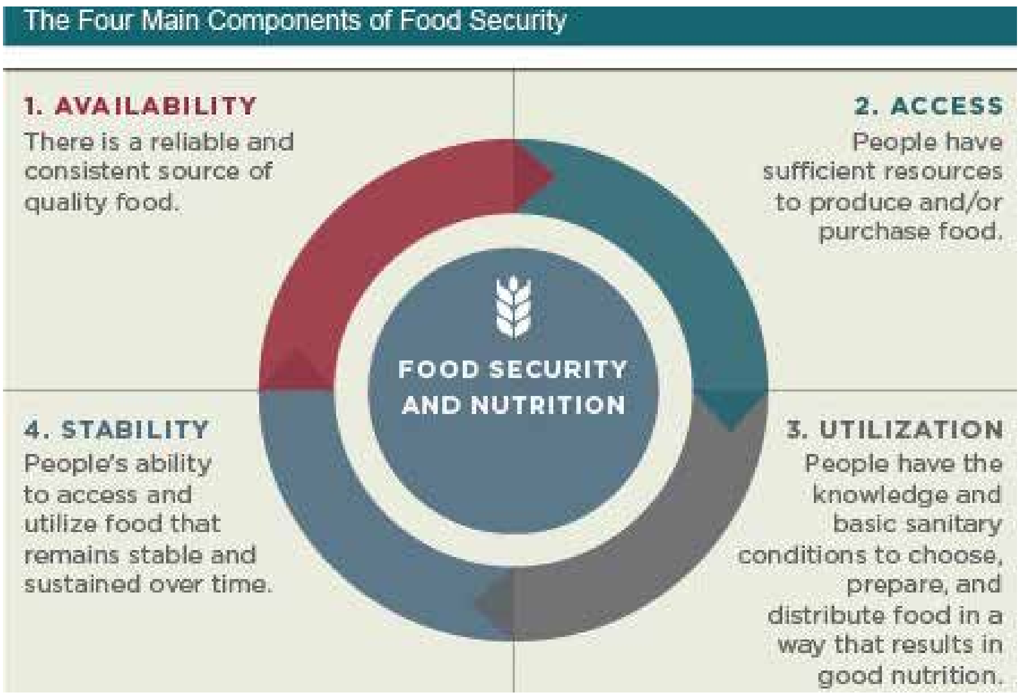


Figure 1.9 Components of Food Security

(source: https://i.pinimg.com/736x->/59/06/85/590685fe638083b9f8fb661ea61ff236--food-engineering-food-technology.jpg)

There are five contrasting schools of thought on how we should approach these challenges. (see McCalla, 1994; Hazell, 1995; Pretty, 1995a; Thompson 1995a; Pretty and Thompson, 1996, for summaries). Many assume that increasing food production is the only necessary condition for improving food security. It is clearly important, especially in the complex, diverse, risk-prone agriculture which characterizes some of the most food insecure regions of the world. However, there is more to food security than producing more food. However, sustainable agriculture in its widest sense can also help to enhance rural people's entitlements and access to food.

A shift to sustainable agriculture will require many different investments, if productivity and environmental sustainability are to be enhanced and if they are to be linked to food security (Hinchcliffe et al., 1996).

The Rise of Bio-fuels

Developing alternative energy sources has been at the forefront of scientists' research for years as fears increase over the world's finite supply of oil. The use of biofuels as an alternative to oil is seen as useful and sustainable since it emits less greenhouse gas to the atmosphere when burned and is renewable. However, there are major drawbacks to the use of biofuels. Firstly, it requires vast amounts of land and already a huge area of rainforests and farmland have been turned into biofuel farms, causing destruction to ecosystems, people's livelihoods and biodiversity. Secondly, the heavy use of pesticides in the farming of biofuel crops counteracts the reduced greenhouse gas emitted from burning biofuels, since the pesticides themselves emit a vast amount of greenhouse gas as well as contaminating nearby water areas, destroying these waters' biodiversity. Thirdly, in order for the crop yield to be high, a large amount of water is required, limiting water supply for other requirements. The problem of biofuels is worsened by government promotion of targets to be met on the usage of biofuels for environmental reasons. An example is the current EU target that 10% of all energy used in their member states comes from a renewable source.

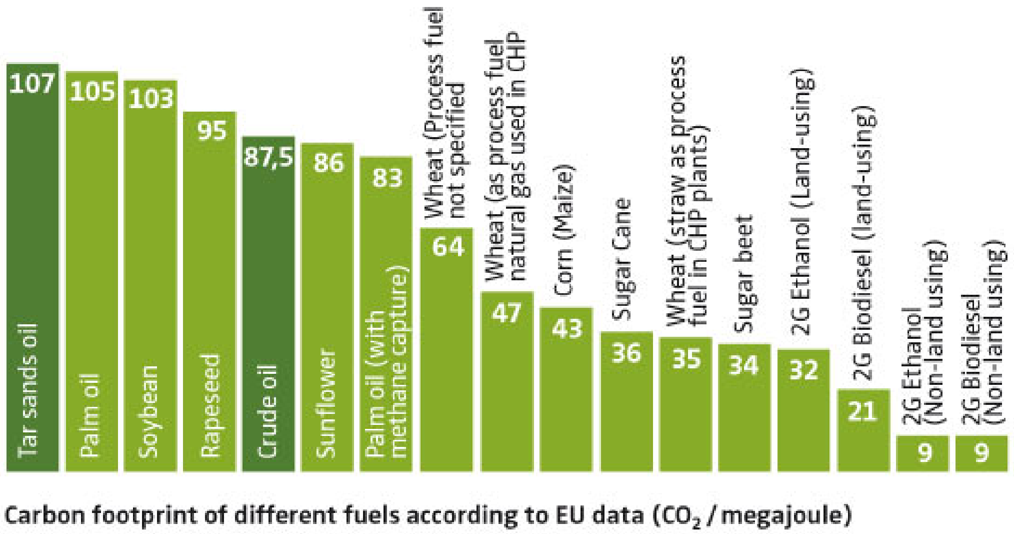


Figure 1.10
What does the demand for biofuel production cost ?
(source: https://www.rainforest-rescue.org/uploads/photos/eu-carbon-footprint-fuels.jpg)

The Population Problem

An underlying factor that intensifies the concerns over the future of food production is the rate at which global population in growing. With more and more mouths to feed and a finite space to grow the food in, it is clear that there are and will be problems in catering to the growing demand. Global population has grown by seven times over the last two centuries. Medical, scientific and technological development in the recent centuries has meant that mortality rates have reduced and people are living for longer, but has also meant that the earth is rapidly reaching the limits of resources such as water, food and energy. Population growth is concentrated in developing nations where access to contraception is poor and woman's rights are often weak. Education for women ends early, promoting an early start to family formation. To combat population growth before it becomes an irreversible problem, developing countries must enforce responsible policy surrounding fertility. For example, birth control must be taken seriously and access to contraception needs to be widely enforced in all communities. Keeping children in education until a later age will undoubtedly prevent teenage pregnancy and thus reduce the likelihood of having larger families. Similarly, education specifically on the subject of overpopulation and the environment will give children the all important information about the social benefits of responsible family planning. Furthermore, developing countries where woman's rights are restricted must make a move towards strengthening their rights to education and their choice over timing in starting a family.

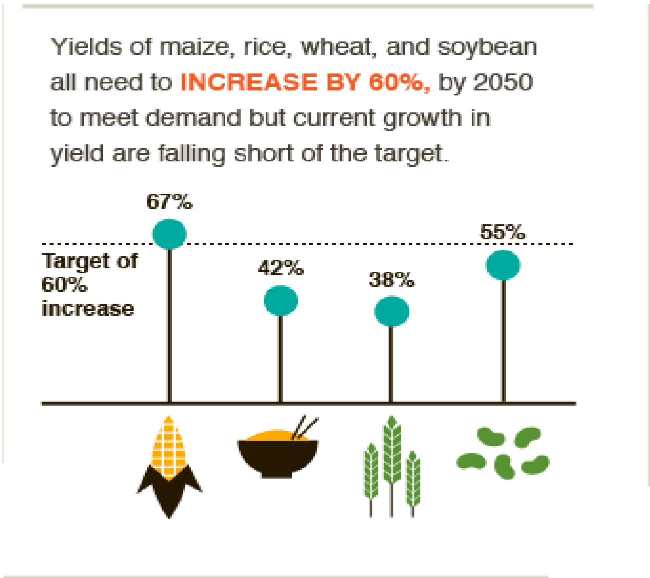


Figure 1.11
What is the challenge of population growth we are facing?

(source: https://ccafs.cgiar.org/bigfacts/img/themes/food-security/Food-Security7.png)

"Land Grabs"

As land becomes a scarcer resource, it becomes more expensive – and the 2008 food price hike sparked speculation in the price of land causing a buying frenzy – particularly in developing countries where land is cheap. Since 2000 it is estimated that there has been 1,200 land deals either completed or under negotiation. Although investment is generally seen as a positive, particularly in developing nations, it is not always the case that, once bought, the land is put to productive and sustainable use. It can be that the land is just held for speculative gain rather than productive agricultural purposes. This has damaging effects on the food supply and prices. This in turn increases greenhouse gas emissions and pushes food prices up (Guardian 2011)

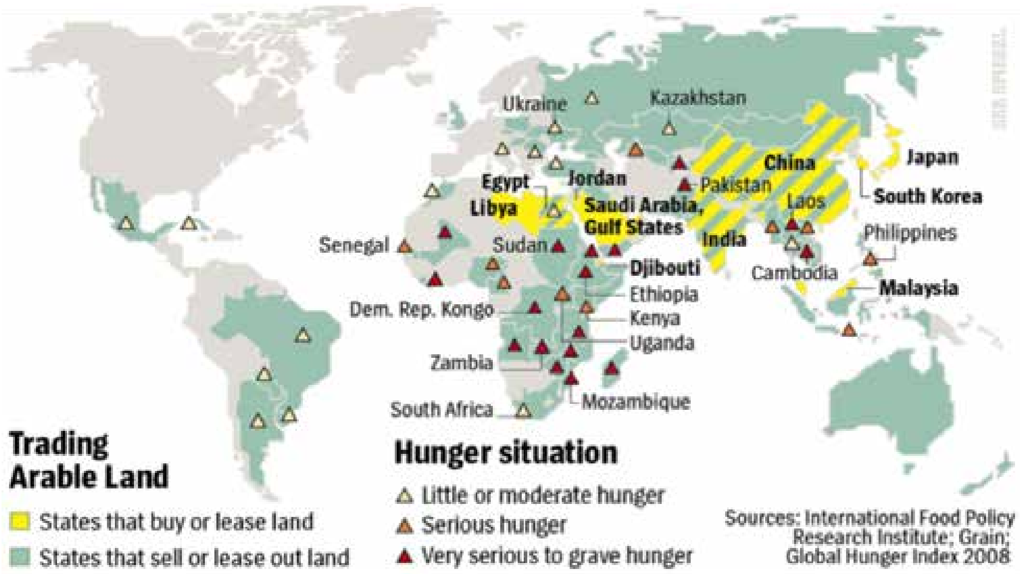


Figure 1.12
Land Grabs versus hunger situation

(source: https://www.globalresearch.ca/wp-content/uploads/2015/06/terre-4.png)

The Future Food Price Forecasts

Between 1961 and 2000, demand for agricultural production doubled, and with nearly all arable land currently available for agricultural production being utilized, it has meant that technology has had to progress in order to meet these demands. This will also be true in coming years since demand for agricultural products is expected to double again by 2050. Technology has always played a vital role in helping to feed a growing population. Advancement in areas such as biotechnology, water efficiency, mechanization and land management has meant that food production has dramatically increased without a proportionate increase in land use.

By 2050 it is estimated that food production must increase by 70% in order to reach the demand of a growing population, rising incomes and the urbanization that is occurring around the world, particularly in developing countries (FAO 2009). Since land has a finite capacity, much of the increase in production must come from dramatically higher yields, since it is estimated that an extra 200 million tones of meat and 900 million tones of cereal annually will be required by 2050 (FAO 2009). Thus investment in agriculture is vital to the future of food production; without it, we will see famines occur more regularly and food prices reach unaffordable levels for many.

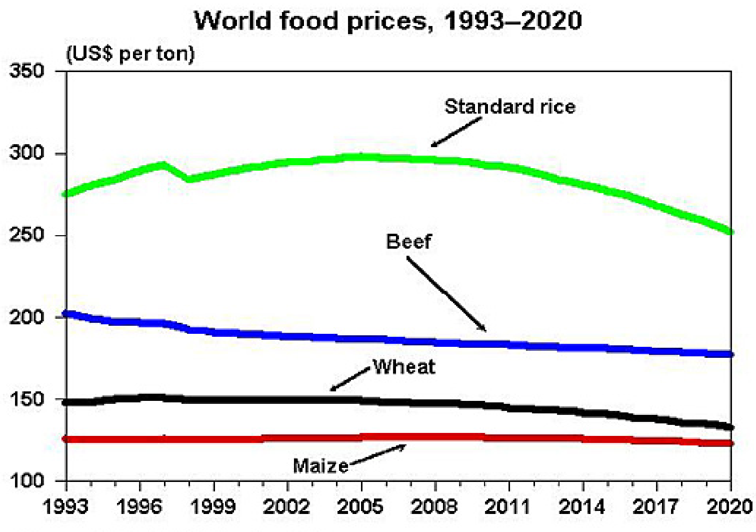


Figure 1.13 Forecast of food prices in 2020

(source: http://www.apsnet.org/publications/apsnetfeatures/Article%20Images/FoodSecurityFig13.JPG)

1.5 Food transport and distribution

Food transport and distribution can be grouped in two subsystems:

- The "food supply to cities" subsystem includes all the activities that are required to produce food and bring it to cities: production (including urban food production), imports as well as rural- and periurban-urban linkages (processing, storage, assembly, handling, packaging, transport, etc.);
- The "urban food distribution" subsystem includes all the formal, informal, traditional and modern activities that are required to distribute food within the urban area: wholesale, intra-urban transport, retailing, street food, restaurants, etc.

1.5.1 "Food supply to cities" subsystem:

More food will have to be produced in areas presently under cultivation (if higher yields are possible), from new lands (which are likely to be more distant and less productive) and/or imported. This requires increasing private investments and efforts which producers often lacking suitable land, safe water, fertilizers, pesticides, machinery, skills, manpower as well as credit may not be able to undertake. In addition, markets may not be accessible. Private investments in food production are limited also by lack of rural roads to potential production areas and rural markets, required to assemble marketable production.

Country		Land used for food and agricultural products
Bangkok (Thailand)		60% of the land in the metropolitan area is in agriculture.
Beijing (China)		28% of the city area is used for agriculture.
Beira (Mozambique)		88% of the green spaces in the city are used for family agriculture.
Madrid (Spain)		60% of the land in the metropolitan area is used for agriculture.
San Jose (Costa Rica)		60% of the metropolitan area is used for agriculture
(Dominican Republic)		15% of the urban area contributes to less than 5 percent of the city's food need.
Zaria (Nigeria)		66% of the city area is cultivated.

Table 1.3 Extent of Urban and Periurban Land Used for Food and Agricultural Products in Selected Cities

(source: http://www.apsnet.org/publications/apsnetfeatures/Article%20Images/FoodSecurityFig13.JPG)

1.5.2 "Urban food distribution" subsystem

The urban food distribution subsystem is composed of the following elements: wholesale, intra-urban linkages (e.g.: packaging, transport, market information and credit), formal-informal and traditional-modern retailing (markets, shops and supermarkets), street food and restaurants.

Wholesale markets

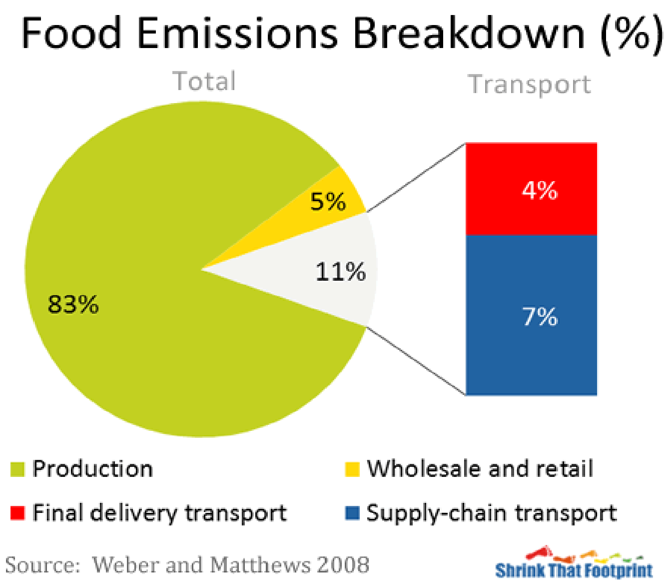
Many wholesale markets have not adapted to the increase in food quantities consumed by cities. Most of them were constructed twenty or thirty years ago and are now positioned in areas which urban expansion has transformed in central, high-density spots. This increases traffic congestion and there is no space for market expansion. On-market storage facilities, and particularly cold storage, are insufficient and/or badly managed. Difficulties faced by traders operating in such markets are thus responsible for additional costs and losses as well as increased food contamination. Examples of these problems can be found in cities throughout the world: Accra, Abidjan, Lahore and Santo Domingo.

1.5.3 Rural- and periurban-urban linkages

Once produced, food products need to be assembled, prepared, packaged, stored, processed and transported to urban areas. These functions require skills; assembly markets in rural and periurban areas; handling, packaging, storage, processing and transport facilities; credit to transporters and traders; market information and extension for production and marketing decisions; appropriately enforced legislation and regulations. All such infrastructure, facilities and services need to be efficiently provided and managed. Otherwise, the various costs relating to each of the above elements will be higher than necessary. Post-harvest food losses can be as high as 35 percent in perishable food products.

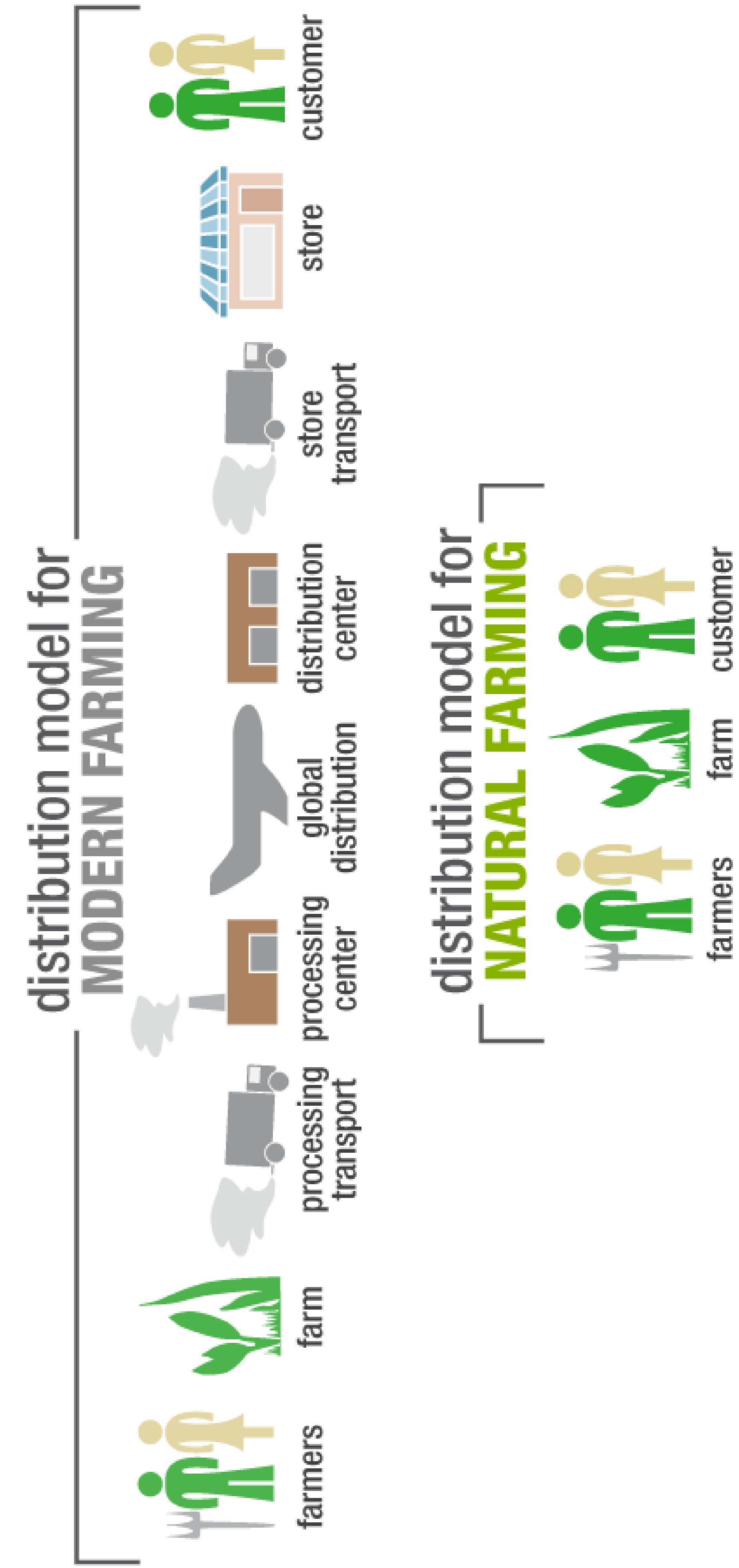
Figure 1.14
What is the impact of food transport?

(source: http://shrinkthatfootprint.com/wp-content/uploads/2013/02/food-emissions.gif)



1.5.4 Imports

Cities depend to a varying extent on imported food. Imports require infrastructure, facilities and services, an administrative system and regulations. Issues of relevance to the analysis of FSDSs are: the enforcement of import control regulations for health and environmental purposes, the efficiency of the administrative system for clearing imported goods, dockside storage conditions, the control of imports by importers, etc.



(Source: http://www.pmlydon.com/2013/the-maddening-simplicity-of-good-food/)

1.6 Food production in cities

Figure 1.15 Vegetable Plantation in urban gardens

(source: https://www.alternet.org/food/urban-farming-revolutionizing-our-cities-and-food-system)

Urban and periurban agriculture can be an important source of food for some cities, especially when the national food marketing and transportation system is not well developed. Food production in urban and periurban areas has being receiving increasing attention because it can contribute to:

- local supply of fresh, nutritious food such as poultry, small ruminant meat, fruits, vegetables and dairy products;
- alleviating poverty and improving food security through consumption of self-grown products, employment and income generation;
- cost-effective environmental management through productive use of organic waste for fertilizer;
- productive use of suitable and unused open space, contributing to bio-diversity and watershed management.

1.6.1 Challenges

Urban food production helps cities feed their growing population. There are a number of problems connected with urban and periurban food production which stem from its close proximity to densely populated areas sharing the same air, water and soil resources. Food production in the polluted environment of cities may cause food contamination. The inadequate use of chemicals, solid and liquid waste in farming can contaminate food, soil as well as water resources used for drinking and food processing. The practice of livestock raising inland close to urban areas may generate health problems to residents. While many of the problems could be solved by information and extension assistance, CLAs have responded by destroying food crops and evicting food producers from public lands under cultivation.

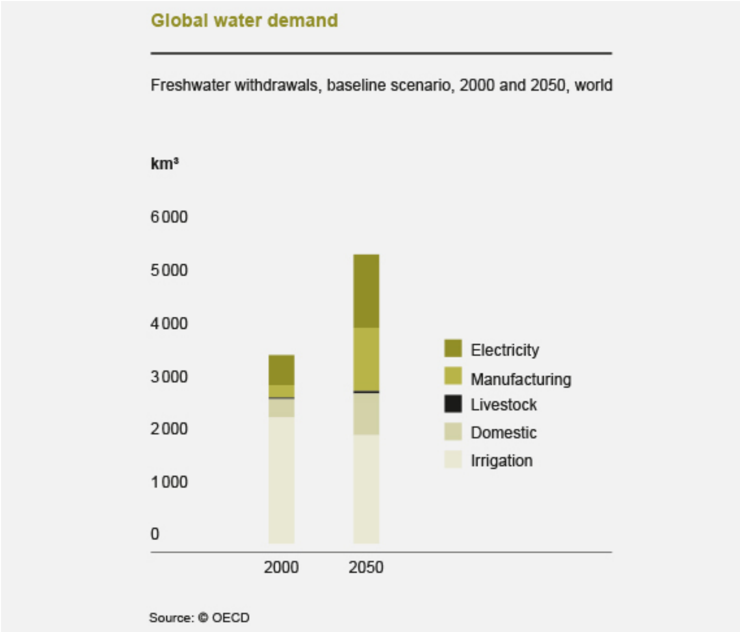


Figure 1.16 Water demand is a major challenge for urban food production

(source: http://www.sulzer.com/en-US/-/media/Media/Images/Corporate/Investors/ar_2015/graphs/story_water_graph.jpg?la=en)

Increasing quantities and varieties of fresh and processed food are required to meet the needs of urban dwellers. Other requirements are:

- land-use management to keep suitable land in urban and periurban areas for efficient and sustainable food production;
- measures to protect human health and environment from contamination;
- water supply commensurate in quantity and quality for food production, processing and drinking;
- sufficient supply of fuel-wood for food processing and cooking;
- enough parking, loading and unloading facilities for a growing number of food trucks;
- additional wholesale markets and slaughterhouses with plenty of facilities and professional management, away from city centres;
- retail outlets easily accessible, adequately equipped and well managed, particularly in low-income areas;
- facilities for spontaneous markets;
- food producer markets, itinerant traders and retailer associations in low-income districts;
- private investment in food shops, market improvement, transport facilities, etc.;
- appropriate arrangements to manage escalating quantities of waste from markets and slaughterhouses;
- market information for better production and marketing decisions;
- better packaging and handling methods to reduce food losses;
- simple, coherent and well understood food production, processing and marketing regulations.

1.6.2 Food Movements Involved

In response to the practice of urban agriculture, different views arose. The supporters believed in the value of the practice and its contribution to alleviating future food crisis. However, there were also opposition. The opposition party believed that the spread of the urban agriculture practice will not aid in significant ways to resolve the threat and that we should look in other ways. So the movements involved were: “Locavores” (eating local) versus “Globavore” (eat global)So what is the “Locavore”?

Locavores are people committed to eating only foods that have been grown and produced locally. They are at the forefront of the local food and Slow Food movements, and they restrict their diets for environmental, economical and gustatory reasons. Some like the challenge of cooking with seasonal foods, others say food that goes from field to plate in one day just tastes better.

The definition of locavore, however, isn't as strict as it sounds. Locavores set their own radius for what they consider "local." That can limit them to 100 miles from home or be as broad as the entire state. Some locavores also make exceptions for mainstays that aren't local to most places such as sugar, salt, coffee and olive oil. (Although in the Santa Ynez Valley we now have a thriving olive oil production.)

The movement sounds expensive but its actually in keeping with slow economic times—locavores sometimes supplement their food with produce from their own garden. After all, it doesn't get any more local than your own backyard or balcony garden.

1.6.3 Prospects

Urban agriculture won't resolve all food production and distribution problems, but it could take pressure off rural land while providing other advantages. As writer and former Vancouver city councillor Peter Ladner (also a David Suzuki Foundation board member) writes in The Urban Food Revolution: Changing the Way We Feed Cities, "When urban agriculture flourishes, our children are healthier and smarter about what they eat, fewer people are hungry, more local jobs are created, local economies are stronger, our neighbourhoods are greener and safer, and our communities are more inclusive."

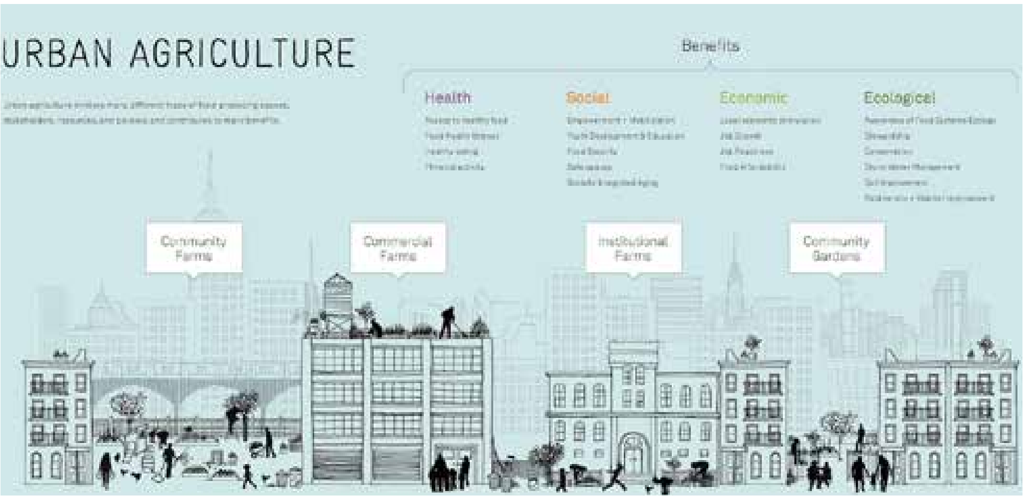


Figure 1.17 Urban Agriculture implementation forms in cities

(source: http://designtrust.org/media/images/5BF-umbrella_1.png.490x490_q85.png)

Local and urban agriculture can also help reduce greenhouse gas emissions and recycle nutrient-rich food scraps, plant debris and other "wastes." Because maintaining lawns for little more than aesthetic value requires lots of water, energy for upkeep and often pesticides and fertilizers, converting them to food gardens makes sense.

A 2016 study from the U.S. Johns Hopkins Center for a Liveable Future found that urban agriculture could "increase social capital, community well-being and civic engagement with the food system," as well as enhance food security, provide ecosystem services, improve health and build residents' skills. Gardening is also therapeutic.

The study found many climate benefits, including reduced emissions from transporting food; carbon sequestration by vegetation and crops; possible reduced energy, resource inputs and waste outputs; and enhanced public interest in protecting green spaces. It also noted some limitations: possible increases in greenhouse gas emissions and water use "if plants are grown in energy-or resource-intensive locations"; less efficiency than conventional agriculture in terms of resource use and transportation emissions; and, depending on practices, pollution from pesticide and fertilizer use. The study found urban agriculture to be positive overall, but concluded support from all levels of government is required to make it viable.

Figure 1.18 AECOM designfor conceptual city where aquaponics is used

(source: https://inhabitat.com/urban-food-jungle-concept-incorporates-aquaponics-in-amazing-futuristic-design/urban-food-jungle-690/)

Urban agriculture isn't new. During the First and Second World Wars, Canada, the U.S., the U.K., Australia and Germany encouraged "victory gardens" to aid the war effort by reducing pressure on food systems and farms. Gardens and chicken coops appeared in yards, parks, school fields, golf courses, railway edges and vacant lots. Sheep grazed on sports fields and kept grass in check. Peter Ladner notes that, during the Second World War, the U.K. had 1.5 million allotment plots producing 10 percent of the country's food, including half its fruit and vegetables; and by war's end, more than 20 million home gardens supplied 40 percent of U.S. domestically consumed produce.

CHAPTER 2 – FARMING IN BARCELONA. WORK FOR FOOD

"Our twenty-first century economy may focus on agriculture, not information."

James Howard Kunstler

2.1 Food security in Spain

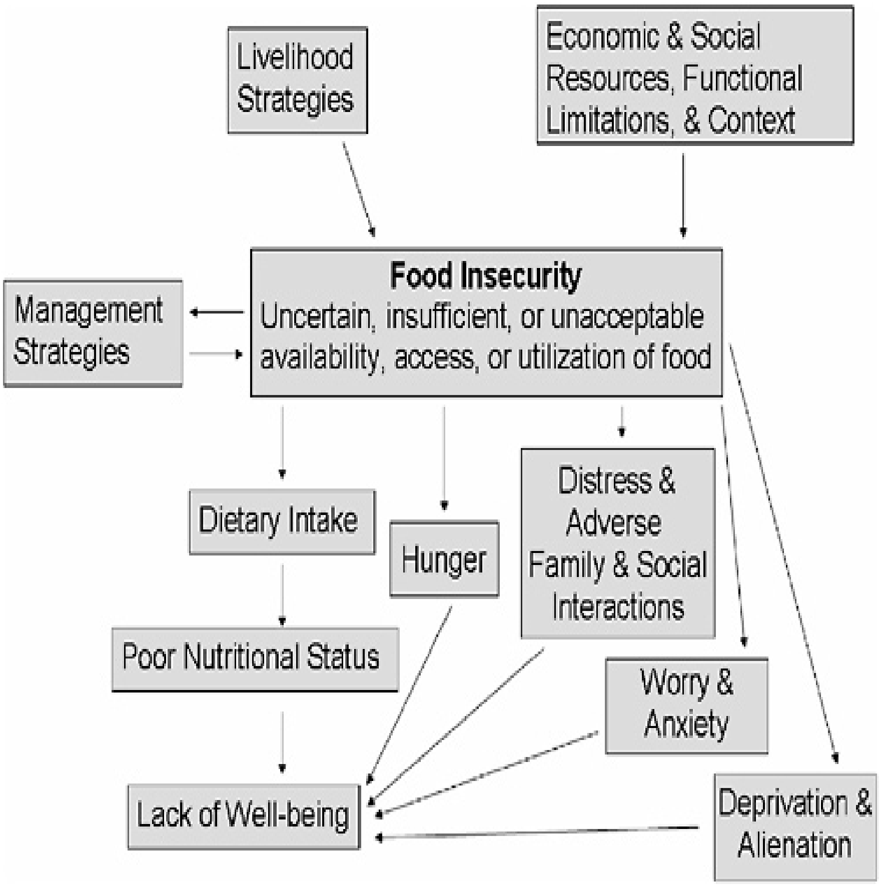


Figure 2.1 Food security agents

(source: https://www.nap.edu/read/11578/chapter/5)

Food security will go beyond physical availability linked to production as it was the old criterion - placing the emphasis on the social and political framework that regulates the relationships that social aggregates acquire their food in a globally organized economy (wages, Prices, taxes), producing them (property rights) or entering welfare programs (spending Social public).

The five conditions associated with food security (Chateneuf, 1995) are:

- Sufficiency: food in sufficient quantity to supply the entire population,
- Stability: seasonal variations do not compromise the provision,
- Autonomy: as long as it does not depend on external supply,
- Sustainability: because the type of exploitation of the resources makes possible its reproduction in the future.

In the last two decades, Spain has worked closely with FAO, primarily focusing on the fisheries sector and the promotion of policies that guarantee the right to food, protect plant genetic resources and food security. Cooperation also includes support in the form of human resources contributed by the Ministry of Agriculture, Food and Environment (MAGRAMA) and the Spanish Agency for International Development Cooperation (AECID) under FAO's Associate Professional Officers Programme.

The food price crisis of 2008 evidenced the vulnerability to hunger and food shortages of many countries throughout the world. In poor countries the effects of this price spike on staple food put at risk sufficient food access, exacerbating the hunger

Figure 2.2 Spain ranking in food security agents

(source: http://food-securityindex.eiu.com/Country/Details#Spain)

1) AFFORDABILITY

Rank		Score / 100	Δ
1	Qatar	93.3	-0.3
2	Singapore	91.3	+0.1
3	United States	85.9	+0.1
4	United Arab Emirates	84.9	-0.1
5	Ireland	84.4	+1.1
6	Australia	83.8	0.0
7	Kuwait	83.1	-1.1
8	Austria	82.7	+0.3
9	Germany	82.2	+0.2
10	United Kingdom	82.1	+0.4
=11	Denmark	82.0	+0.2
=11	Netherlands	82.0	+0.2
13	Sweden	81.3	+0.1
=14	Canada	80.9	-0.3
=14	New Zealand	80.9	+0.5
=16	Belgium	80.7	0.0
=16	Switzerland	80.7	-0.1
18	Finland	80.2	0.0
19	France	80.1	0.0
20	Japan	79.2	+0.1
21	Spain	79.1	+0.1
22	Italy	79.0	+0.1
23	Norway	78.2	+1.3
24	Bahrain	77.9	-1.0
25	Israel	77.8	-0.3

2) AVAILABILITY

Rank		Score / 100	Δ
1	United Kingdom	87.2	+0.1
2	Ireland	86.5	-1.6
3	Germany	83.1	-2.1
4	Norway	83.0	-1.0
=5	Switzerland	82.7	-1.8
=5	United States	82.7	-1.4
7	Canada	82.6	-1.2
8	Netherlands	82.3	-2.0
9	France	81.9	-2.1
10	Australia	81.6	-0.5
11	New Zealand	81.0	-1.6
12	Sweden	80.8	-0.7
13	Austria	80.1	-1.9
14	Finland	80.0	+2.1
15	Israel	79.7	-2.1
16	Singapore	79.5	-1.3
17	Japan	79.1	+0.7
18	Belgium	77.9	-1.1
19	Denmark	77.7	-0.7
20	Portugal	77.3	-3.1
21	Oman	75.3	+0.7
22	South Korea	75.2	-1.0
23	Chile	74.4	-0.1
24	Spain	74.2	-2.1
25	Czech Republic	74.1	+1.7

3) QUALITY AND SAFETY

Rank		Score / 100	Δ
1	Portugal	89.7	0.0
2	France	88.7	0.0
3	United States	86.6	0.0
4	Australia	86.4	0.0
5	Greece	86.3	0.0
6	Spain	86.2	0.0
7	Netherlands	86.1	0.0
8	Finland	86.0	0.0
9	Ireland	85.8	0.0
10	Sweden	85.4	0.0
11	Norway	85.1	0.0
12	Canada	84.4	0.0
13	Denmark	83.4	0.0
14	Italy	83.3	0.0
15	Belgium	82.9	0.0
16	Austria	82.8	0.0
17	South Korea	81.9	-0.3
18	Japan	81.8	0.0
=19	Germany	81.3	0.0
=19	New Zealand	81.3	0.0
21	United Kingdom	81.0	0.0
22	Israel	80.9	0.0
23	Switzerland	80.6	0.0
24	Singapore	78.3	0.0
25	Czech Republic	75.9	0.0

problem. In developed countries the price spike did not compromise food access of households for the most part, although it impacted on consumer's food purchasing power.

For example, the average food consumer price index in Spain increased by about 7% compared to only 3% before (CEC, 2008). This differentiated set of consequences from price changes and volatility supports the idea that challenges to increase food security worldwide will vary depending on the socio-political context of countries. Yet the food security debate at the global level is very much focused on the quantitative side, although more recently the FAO is turning increased attention to the importance and potential for quicker progress by considering the qualitative aspect of "safe and nutritious food" and "food preferences for an active and healthy life".

In countries like Spain, production and access are largely guaranteed, and food security is linked to the idea of guaranteeing food safety and food nutrition. Figure 2.3 offers a conceptual diagram to consider all the different qualitative aspects of food security definition applied to Spain.

Despite the efforts, Spain is confronting a nutritional problem, as 12.9% of the Spanish population is now obese, compared to e.g. 20% in the USA and 5% in countries like China or Japan (Aranceta-Bartrina et al., 2005). As in other European countries, there has been a substantial shift in the dietary habits of Spanish consumers in the last decades (see Figure 4). Today Spanish consumers:

- eat 30% more animal proteins
- and 60% more processed food (sugar, bakery, fast food) and alcohol compared to the gold standard Mediterranean diet (a diet officially recognized

by the World Health Organization for its health benefits and its equilibrated nutritional balance (Padilla et al., 2006; 2010)).

Meanwhile, the intake of cereals, legumes, fruits and vegetables has dropped by half. This has been possible to a large extent because of Spain's animal product imports from third countries.

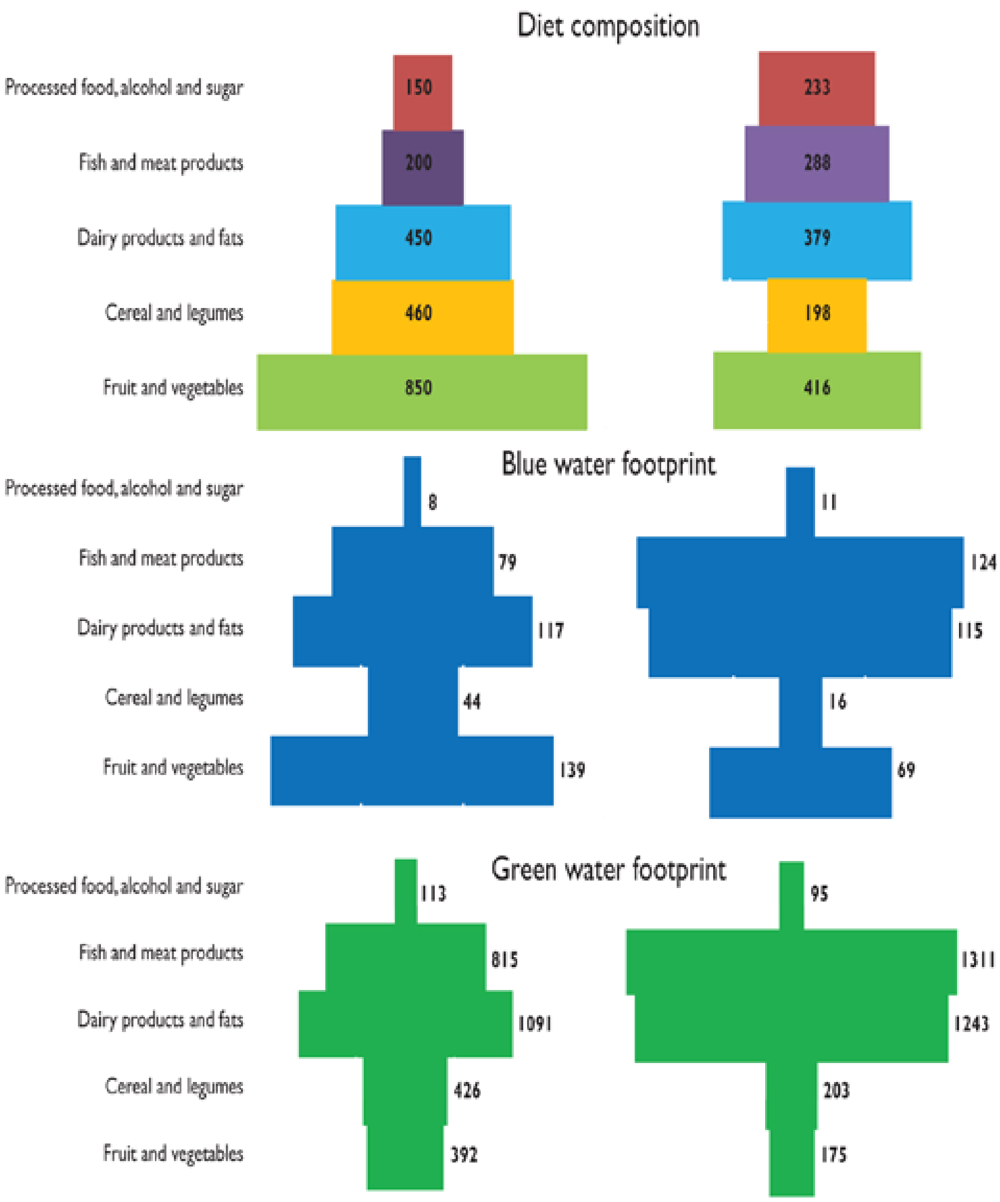


Figure 2.3 Composition (gr/person/day), blue and green water footprint (L/day) of the recommended Mediterranean diet (left) and the current average diet (right) of a Spanish adult consumer

(source: https://www.researchgate.net/publication/258109898_The_Concept_of_Water_and_Food_Security_in_Spain tion/258109898_The_Concept_of_Water_and_Food_Security_in_Spain)

2.2 Food security in Catalunya

Food systems in Catalunya

The globalization of food trade makes food consumed in Catalonia come from anywhere in the world and have access to the European market through border inspection points in any Member State. The food and the associated risks are no longer limited by borders. What once could be subject to regional management measures must now be understood as a global problem. This forces us to be aware of all available sources of information and any incident that may occur in any part of the world may seem distant at first.

All these factors undoubtedly pose challenges regarding assessment, management and communication of risk in food safety and forced to adapt quickly. The organizational framework, institutional and political should be able to adapt to meet these requirements. Catalonia already has a network of highly specialized organizations with extensive experience and ability to adapt to meet the challenges that may appear on food safety.

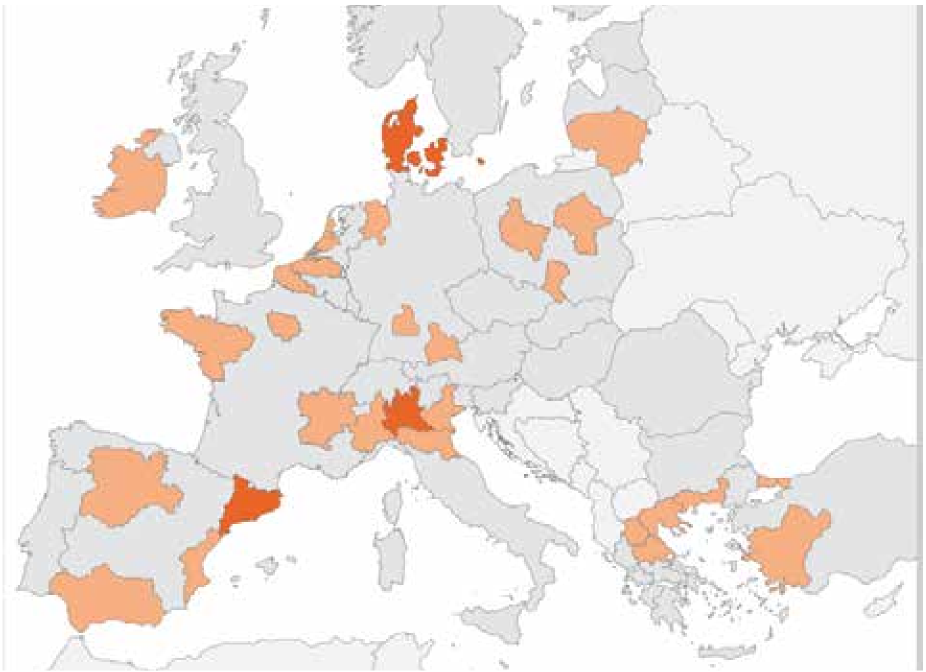


Figure 2.4 Regions of europe with highest agri-industry status

(source: l'Observatori Europeu de Clústers (CSV) de l'Escola Econòmica d'Estocolm (2006))

Agricultural sector and food industry

The agricultural sector, together with the food processing industry represents around 4% of gross domestic product (GDP) of Catalonia and a proportion of 2.4% of the employed population. If we add the food trade and catering, the proportion in terms of GDP is 5.9% (data 2007). Note that this occurs in a context where the global service sector has two third of the total GDP. With net sales in 2010 of 18,842 million euros, the food industry is vital to the Catalan industrial complex (20.1%).

The transformation of food and drink has become the leading industrial sector in terms of net sales, followed closely by the chemical industry and the manufacture of transport equipment. The food industry is equally important as a generator of jobs, with a workforce of 75,593 people (first position in all industrial sectors) distributed throughout the country in nearly 3,000 establishments with employees (third place). But the importance of the sector beyond Catalan territory. In the whole of Spain, Catalonia agri-food sales also occupy a dominant position, as head of the classification regions, both in terms of sales, with 22.9% of global, as compared to the number of workers (20.8% of total).

Table 2.1 Ranking of agricultural and food industries of top regions in europe 2016

(source: Pla de seguretat alimentària de Catalunya 2012-2016)

	Agri- industry	Food Industry	Total industry
• **Catalunya (Barcelona)**	**26.434**	**103.066**	**129.500**
• Llombardia (Milà), Itàlia	15.293	107.806	123.099
• Dinamarca, Dinamarca	10.740	76.203	86.943
• Andalusia (Sevilla), Espanya	28.247	51.801	80.048
• Emília-Romanya (Bolonya), Itàlia	9.438	63.745	73.183
• Vlaams Gewest (Anvers), Bèlgica	6.562	64.903	71.465
• Bretanya (Rennes), França	2.840	67.830	70.670
• Vèneto (Venècia), Itàlia	8.488	62.162	70.650
• Holanda Septentrional (Amsterdam), Països Baixos	20.973	45.787	66.760
• País del Loira (Nantes), França	2.944	61.321	64.265

Looking at the table above, it can be seen that the three most competitive regions according to the size of the food processing industries are Catalonia, Lombardy and Denmark.

The sum of the two industries, the first processing agricultural and food processing, consolidate Catalonia as prominently food first region in Europe. It is very closely followed by Lombardia.

(source: https://catalanwine365.wordpress.com/tag/d-o-catalunya/)

2.3 Food security in Barcelona

2.3.1 Why to work for food security in Barcelona

The benefits are numerous. We can start by increasing biodiversity and reducing water consumption, energy and land, as well as global warming. Think the current situation of food travel is responsible for between a quarter and a third of global emissions of greenhouse gases. Also an improved health for more people and jobs as it is shown that replacing products food that are of own production create thousands of jobs, especially if they are distributed via short marketing channels (CCC) and adopting agro-ecological agriculture, that demands more and more qualified human labour.

Then, before the agribusiness model, globalized and wasteful, what can public policy do to promote farming, the transition to agro-ecological one, relocation of production and responsibility to healthy food consumption?

In the production phase:

- It would be to encourage the agro-ecological production and local one, and between urban and peri-urban where it should be possible to create a municipal agricultural park.

- Barcelona has stepped up community gardens, academic and social ones in parks and gardens town, giving them municipal infrastructure, adapting regulations when necessary and giving management to neighbourhood groups.

In the phase distribution circuits:

- there should be promoted short sales (field plate), promoting direct selling markets and fairs farmers,

- and helping agroecological consumer groups proliferate neighbourhoods of the city, which must be provided meeting spaces and resources to help them regularize their situation, adapting the existing regulations (Employment, public spaces, taxation ...).

In the phase of consumption :

- It would be to improve access citizenship to food items. The proximity to agro-ecological and fair trade everywhere, to local markets and school canteens.

- Changing the management model of school restaurants is another step to promote strategic food planning because, in addition to promoting healthy eating habits and generating market for agro-ecological production and proximity, it sensitizes people. Consumers will be future producers.

- Last but not least, we must continue watching food safety as the highest level requirement.

Given that currently half the world's population lives in cities, studying the way to feed urban areas is crucial to set food systems. Production systems and using access to food will impact cities against such serious problems as hunger, rural poverty and climate change.

Figure 2.5 Food Smart Cities For Development : Barcelona, GRAIN and Soberania alimentaria logo

(source: https://www.milanurbanfoodpolicypact.org/barcelona/)

Aware of this, in October 2015, more than hundred cities around the world signed the Milan Urban Food Policy, which was joined by Barcelona. The Agreement, which has the support of FAO and the United Nations, involves a commitment by governments that these cities "develop food systems that are sustainable, inclusive, resilient, secure and diversified to ensure healthy and accessible. A framework for action based on the human right to health and food, in order to reduce waste food and preserve biodiversity, at the same time reduce and adapt to the effects climate change. "

Hence arises the new Barcelona challenges in managing food policy, inspirational and instigator, the Charter for food sovereignty from the municipality is a proposal for social movements made in Zaragoza 2014, in the framework of the International Congress Social Economy and Solidarity, which has served both to stress the need to develop municipal policies and shaping first steps councils which, like California, have begun to consider the need to impact decisively food circuits.

2.3.2 Steps Taken for Food Security in Barcelona

Figure 2.6 Mural Soberanía Alimentaria (alimentary sovereignity)

(source: https://revistasoberaniaalimentaria.files.wordpress.com/2013/04/mural-soberanc3a-da-alimentaria-movimiento-aragc3b3n-libre-de-transgc3a9nicos.jpg)

Formal steps have started to materialize in Barcelona with the participation of the project European Smart Cities Food for Development through a joint between City Hall Magazine organizations and Food sovereignty, Biodiversity and Cultures Foundation and GRAIN.

The bulk of this project consisted of conducting a series of conferences and meetings over the years 2015 and 2016, under the Plowing Barcelona process, which has enabled consulting and discussion of the situation of the food system as an important part of metropolitan local agro-ecological movement (producers, distributors, traders, consumers, activists, etc.) This document contains a set of actions within which are articulated the food policy council Barcelona, which shares objectives with commitments letter Zaragoza Charter for Food sovereignty of municipalities (Signed in 2014) and Milan Pact (signed in 2015).

Many actions included here are being carried out; others can be promoted by different areas, and it is desirable that way. In this phase, it is important that the City Council is resolutely oriented towards the development of a comprehensive local agro-ecological approach and stand as socioeconomic active agent, materializing the concept of the good life in their policies and giving support for the initiatives of local agro-ecological existing or pregnancy.

Many departments and city institution are involved in the implementation of the Milan Urban Food Policy Pact. Two departments are directly involved in the Food Smart Cities for Development project : the Global Justice and International Cooperation Department and the Department of Consumer Affairs.

Figure 2.7 Alimentary Sovereighnity/; a series of meetings to discuss the topc conducted by the joint between the BCC and other stakeholders

(source: http://www.pikaramagazine.com/2016/10/cuando-la-tierra-se-junta-con-el-mar/ >s<pub/16040122 0420-78aa50c297 2f85382 d60ee694e70 b72e/ jpg/page_1. jpgto-ara gc3b3n-libre-de-transgc3a9nicos.jpg)

2-The Global Justice and International Cooperation Department is in charge of:
• Support to education and raising awareness programme
• Support to international cooperation programmes mainly in Latin America, Africa and Mediterranean Areas
• Advocacy

1- The Department of Consumer Affairs is in charge of:
• Lead and promote urban food policies in the city
• Regular coordination meetings between different departments and Commissioners of the City Council to discuss and cooperate towards a common food strategy for the entire city.

Over nearly two decades since Barcelona's City Council began to carry out development cooperation actions, there has been a progressive evolution of the concepts and practices linked to a cooperation model. The model embraced by Barcelona is based on a vigorous community spirit of solidarity: one of Barcelona's distinctive features within the international sphere.

The direct municipal cooperation carried out by Barcelona's City Council by means of agreements with cities or networks of cities, is essential to the consolidation of the city's specific leading role in initiatives to do with the exchange of good practices and the transfer of knowledge. This specific and distinctive public policy of the City Council provides a large added value to Barcelona in this city's inter-relationship with the world.

2.4 Urban Agriculture from Europe to Barcelona

2.4.1 Urban Agriculture: Overview

When FAO estimates that in some developing countries, more than half of urban households practice some kind of urban agriculture in backyards, roofs, flower beds, community gardens, schools, hospitals and free public lands, or when it points out that urban agriculture also generates micro-enterprises, which are often engaged in the production of organic fertilizers, or the processing and sale of food, it is describing a reality that could also happen in the first world. However, when it points out that this production can contribute up to 60 percent of a family's nutritional needs, it improves nutrition substantially and allows them to spend a larger part of their income on other necessities, such as education and health, we understand that it is alluding to countries where part of the population has low incomes.

In this context, we believe that urban agriculture represents much more than a place of physical connection between cities, the rural environment and agriculture, because for the various reasons discussed it promotes the improvement of the quality of life in cities. As part of the solution to problems related to food insufficiency, food quality or environmental degradation caused by agricultural inputs, industry and trade of products through long circuits, the initiative to practice urban agriculture has been associated to many people and sparked debates for the search for an alternative economy in a society that is less consumerist and socially fairer.

Public policies, as well as the initiatives of social or private organizations and the latest technological advances in information and communication (ICT) such as the Internet and its social networks have contributed to this, making urban agriculture communities in different regions and countries Cyberspace an opportunity to exchange ideas and experiences.

In this direction, the debate on how to make cities more ecologically sustainable has made it clear that citizens' awareness and technology have a fundamental role and therefore, in this regard, must walk together and in a univocal way. Thus, individual or collective initiatives include, for example, the installation of photovoltaic panels, such as the construction of "green roofs" or vertical orchards in buildings and houses, and thus practicing some form of urban agriculture.

Urban Agriculture Practice: Where and How?

The two main urban agriculture types are indoor and outdoor. Regarding the outdoor agriculture practice, the common possible settings are fields with various types that we will present plus roofs. Indoor agriculture can take place in different settings like private houses, greenhouses, vertical farming buildings. Contemporary techniques evolved and are not restrained to aquaponic and hydroponic cultivation, but to aeroponic and grow light agriculture (Raviv, 2007).

Outdoor spaces

Exploring the outdoor opportunities, we begin by the types of outdoor spaces that can host urban agriculture activities, of which we present:

- home gardens,
- community gardens,
- market gardens,
- school gardens,
- rooftop gardens,

- windowsill gardens,
- aquaculture, and urban farms, (Viljoen et al., 2005).

Numerous cities have implemented the insertion of these garden types inside the city fabric, following a defined vision and set goals. For example, Barcelona city council started in 2001 a plan to insert community gardens in each district, and these exist nowadays and are increasing in number. Also, it started in 1997 a plan to involve the elderly over 65 to participate in agriculture activities, and the trend is still promoted today (Barcelona City Council, 2014). The city of Rotterdam has a similar experience in the promotion of the urban agricultural activities through its food policies.

Types of Urban Gardens

Depending on how we combine the various functions and the relative importance, we can talk about different types of gardens. So terms of government intervention on the existing allotments or how much the creation of new orchards publicly owned, it is especially useful to distinguish types of gardens as social functions that meet or they can be met. In this sense, we can distinguish types of urban gardens following functions not mutually exclusive:

Figure 2.8 Urban vegetable garden Baró de Viver, Barcelona

(source: http://eldigital.barcelona.cat/equipament/hort-urba-baro-de-viver)

- Gardens, traditionally oriented to supplement income
- Family or newly created as a result of the growing interest in organic farming and leisure linked to nature and health.
- Allotments for the elderly, created in recent years as an alternative to leisure and healthy practice for people of the third age in many cases life experiences related to a rural past.
- Orchards for educating children starting in the knowledge cycle of natural plants, bring the beats and rhythms of the seasons, make them aware of the origin of food and educate them about environmental awareness and healthy eating.
- Therapeutic gardens aimed at supporting targeted therapeutic processes for groups with specific medical or social problems (Addiction detoxification, rehabilitation of people with socialization, physical or psychological medical treatment, etc.).

- Allotments for social integration, designed to promote processes of social integration in communities at risk of exclusion (development communities marginalized by economic integration of supportive and encouraging the creation of a social fabric).

Roofs

As for roofs cultivation, the opportunities seem multiple. References can be made to several city strategies (Anony., 2007). The potentials found in roof cultivation can achieve more surprising results if invested with efficient techniques like aquaponics.

Controlled Environments

Basically, comparison studies favour these as potential future producers in urban environments (Viljoen et al., 2015). Although the yield seems optimistic, many question marks are raised about the last type's cost feasibility and the concern towards sustainability (Pearson, 2010).

Greenhouses are a common practice of the controlled environment agriculture. The approach we discuss here is integrating them in architectural contexts. The idea behind small-scale greenhouses integrated in buildings is more about local production for inhabitants (Viljoen et al., 2015)., and spreading the awareness for the promotion of urban agriculture in larger scales. The trend is extending to several types of buildings. One of the earliest developed systems incorporating greenhouses in houses with a complete ecosystem cycle study was presented by Rune Kongshaug in Montreal, Canada. The founder of the Produktif Project Design & Development studio designed an innovative housing project revolving around food production and the use of renewable energy (Kongshaug, 2006). The trend can be traced in numerous examples around the world, whether in housing, commercial, or other building types.

Figure 2.9 Maison Productive House, Montréal, QC, Canada; by Rune Kongshaug, Produktif Project Design & Development

(source: http://www.produktif.com/passive-house-ph/)

Various practices exist in numerous cities yet the effect on the global food chain seems little. Consequently, new techniques were developed trying to have an impact on the supply. Urban agriculture research introduced a while ago another form of controlled environment urban agriculture as in vertical farms (Viljoen et al., 2015). The vertical farm is a type of indoor farm that uses indoor growing techniques like aquaponics, aeroponics, or LED lighting. The vertical farm is considered a "plant factory". In a study carried out by Despommier, the results claim that a vertical farm covering the area only of a typical American city block can satisfy the yearly food needs for 50,000 inhabitants (Despommier, 2010),. The results seem promising, although the techniques to develop these types of efficient farming units are not until now the most economical solution.

Plant Production Unit

Figure 2.10 Angel Farm in Fukui, Japan

(source: http://techon.nikkeibp.co.jp/english/NEWS_EN/20080902/157304/)

Discussing the various indoor farming techniques, we would highlight the concept of a 'Plant Production Unit' using special lighting systems (Van Bijsterveldt e al., 2012-2013). Obviously with less surface area, less water and the LED lighting systems, make the growing of all vegetable and fruit types possible year round. The most important fact about these systems is the improvement in yield quantity. Angel Farm in Fukui, Japan, employs this system, and has multiplied the meter square yield of hydroponics by 8 times, rising from 19.35kg/m^2 to 165 kg/m^2 in a month.

Another R&D platform in Germany, 'plantLab', has successfully experimented the production units for yield quality and amount, giving evidence that these automated installations integrating LED systems can grow all types of vegetables and fruit, in addition to spices and medicine ingredients (Umsicht, 2016).

The integration of indoor farming in architecture has been developed through the past years. Small scale interventions aim to provide partly the needs of residents but mainly the spread of the urban agriculture practice. The bigger scale interventions employ the more efficient agriculture techniques, mainly aquaponics inside buildings, in separate independent buildings, or on roofs. ReGen Villages, designed by EFFEKT-a Dutch practice, is a pioneer project to create a village model that is self-sufficient in energy and food. The first village is in Almere, Netherlands, and its construction started in 2016 (Ehrlich, 2015). The water, energy, waste cycle was designed as closed loop minimizing any environmental effects. The curators have aspiring plans to spread their design to different countries, especially the most vulnerable to future energy and food crisis.

Figure 2.11 Project of ReGen Village, EFFEKT studio

(source: https://www.dezeen.com/2016/05/20/effekt-designs-regen-villages-produce-own-food-energy-danish-pavilion-venice-architecture-biennale-2016/)

2.4.2 UA in Europe

Aiming in this direction, Europe also increases the interest and the areas for private and community gardens in the cities are expanded. Mainly because of the concern for healthy habits and the need to be in contact with green areas, where the CO_2 indexes are small or non existent, where O_2 is abundant, as in forests, gardens and orchards; and which is associated with two fundamental types of projects. In one, there is environmental education and learning about the productive cycles in which children and young people participate; the other is related to leisure and the possibility of relating and associating through various activities carried out in parallel with agricultural practices, such as social gatherings, meals and parties. In both cases, the production of quality food with low cost and environmental commitment are implicit.

Figure 2.12 Project Capital Growth in London

(source: https://www.london.gov.uk/what-we-do/business-and-economy/food/our-projects-food-london/food-growing-london)

With this range of purposes there are many interesting experiences in Europe, although here we will cite some that we consider more representative, either by its public character, its specificity or because it encompasses broader areas. One of them is being produced in London, and aims to convert by 2012, a total of 2,012 farms in urban gardens. The project is called Capital Growth and is being driven by Boris Johnson, Mayor of the English capital. It aims to transform public spaces or private, empty or underutilized in oases of food growing in which up to now more than 35,000 Londoners have committed themselves.

In addition to this, the Making Local Food Work program, led by different associations, and the local initiative of Good Food Camden, which aims to increase the availability of fresh food among the population with lower incomes, also stands out in London. As a result of these initiatives, in 2006 there were 737 allotments in London that were distributed not only in the peripheral municipalities but also in 29 of the 32 municipalities of Greater London

In France, in the 1980s, Ceinture Verte was created with the aim of curbing the strong urban sprawl of the Paris region in the 1960s and preserving green spaces and other areas for urban and peri-urban agriculture. Located between 10 and 30 kilometers from the center of Paris .

Figure 2.13
Le Triangle Vert, Paris

(source: http://www.trianglevert.org)

He followed in 2001 another project called Triangle Vert, which covers a heavily urbanized area located less than 25 kilometers from Paris. Of its total area of 4,800 hectares, 1,716 are for agriculture and are distributed among about thirty farmers, most of them professionals, although retired people also work. The goal is to ensure the maintenance and development of agriculture favoured by the proximity to the city and at the same time recognize the environmental, landscape and cultural value of the place.

In Germany, a country with a long tradition of private horticultural gardens, the diversification of these gardens and the construction of urban gardens have been promoted in recent years. In addition, the Intercultural Gardens (Stiftung Interkultur) project has been in operation since 2003, which in May 2011 had 112 gardens in 14 Länders (federal states). As a result of this tradition and the initiatives of local community gardens associations and their associations, in 2005 4.5 percent of their area was occupied with orchards that were concentrated on the edges of Berlin, to the north (district of Pankow) and southeast (Treptow-Köpenik district), bordering on urban green areas, with large unoccupied or wooded areas of the north.

In Italy, north of Milan, urban orchards date back to the 1980s and aim to create a connection between the Parco Nord Milano and the city. In addition, the Orti Urbani project created in December 2006 by Italia Nostra, National Association for the Protection of Historic, Artistic and Natural Heritage Della Nazione has called on all owners of green areas across the country to join their cause and That transform them into "cultural" gardens, gardens or parks. With an environmental concern, it promotes seminars, conferences as well as disseminating experiences and making complaints.

2.4.3 UA in Spain

In Spain, from the 1990s, urbanites from different cities have agreed to apply for regulations that will not only allow but also promote gardens in urban lots. This has led some public administrations to begin the process of regulating the use of municipal land for urban gardens. But in many cases it is the associations, groups or communities of neighbours that on their own initiative take advantage of depleted plots or abandoned plots to organize orchards and other community spaces.

There are many such initiatives in Madrid. Some promoted by neighbourhood associations, others by educational institutions and foundations. One of them is located in the street Doctor Fourquet, nº 24, in the district of Lavapiés very dense and without green spaces. Driven by the group of neighbours called "This is a square!", The community garden works as a place of exchange and development of the social fabric with spaces of culture, sport and leisure. Before 2008 it was a space abandoned for more than 30 years. The strong support of the neighbours made in December 2009 the City Council give them a cession for 5 years.

Figure 2.14 Esta es una plaza!, Dr. Fourquet 24, Madrid

(*source:* https://citiesintransition.eu/place/esta-es-una-plaza)

In this sense, the alternative urban and counter-cultural movements that claim a fairer and more environmentally friendly society are important, such as the 15 M Movement that began in Madrid at Puerta del Sol on May 15, 2011. It is extended by the majority of Spanish cities and with the support of social organizations such as associations of neighbours (AA.VV.), groups of ecologists and anti-system, such as squatters, these movements promoted, during their camping, talks and workshops, and Built in the middle of the Puerta del Sol in Madrid.

Another initiative is found in the Barrio del Pilar, Madrid, where the Association of Neighbors La Flor has managed since 2007 the community garden Corcubión. In it the neighbours participate planting vegetables of season. It is located in Corcubión Square and was a formerly disused space .

We can also mention the Community Garden of Ventilla (Tetuán), promoted by the Ventilla-Almenara Neighbourhood Association and the Radio Almenara Association. It began in 2009 with a grant from the City of Madrid, and developed several projects and workshops.

With different characteristics, in 2011 the Carmen Pardo-Valcarce Foundation, which works with disabled people, has launched the Rus in Urbe environmental project. We refer to the Huerta de Montecarmelo located north of the city of Madrid which has 146 orchards of 20 square meters, which rent for € 85 a month and are partially worked by young people with disabilities. They also have experts who create and design urban gardens and advise people who want to get the most out of their gardens.

We have also found in Madrid, orchards whose purpose is environmental education. The Ecological Urban Garden Siglo XXI, in Moratalaz, the university orchard of the Higher Technical School of Agricultural Engineers and the group GRAMA (Action Group for the Environment).

Figure 2.15 Huerto Urbano Siglo XXI, Moratalaz, Barcelona

(*source:* https://www.agrohuerto.com/huertos-urbanos-en-el-distrito-de-moratalaz-madrid/)

2.4.4 UA in Barcelona: Background

Since the early 1980s, the city of Barcelona has been the scene and the protagonist of innumerable architectural and urban planning interventions considered of functional and aesthetic high quality so much that it has generated the well-known "Barcelona Model".

During this period, a profound process of transformation emerged, resulting from an urban regeneration strategy whose "main axis consisted in promoting major events. To foster dialogue between the social will of the public initiative and the interests of the private initiative, and to leave in the hands of technicians all the responsibility of the urban project "(Montaner, 2007).

The "Barcelona Model", as a paradigm of urban planning, has been used in different fields - architecture, urban planning, sociology, geography, local and cultural politics - on the wave of great success both in architectural and urban solutions as well as in institutional policies that have promoted and the impact this had on the population and the economy of the city (Balibrea, 2004).

Spread today, is that even though the "Barcelona Model" worked in the 1980s as an indispensable engine for "modernizing, updating and refurbishing the city" (Montaner, 2007), for more than five years, the model is obsolete given the strong changes that have suffered the economic actors, municipal management and the social composition of the city (ibid.).

In this context, an undeniable field of experimentation and creativity, whether it is seen in a positive or a negative way, was inaugurated in 1997 the Network of Municipal Vegetable Gardens, managed by the Municipal Institute of Parks and Gardens of the city and dedicated to senior retired 65 years. The project consolidates and extends to the 2004-2007 Municipal Implementation Plan with the creation of at least one productive green space for each district, all of which is included in the existing green spaces as an integral part of the city's environmental policies (Fernández, 2011) . Always within environmental policies, in particular Agenda 21, the municipality has since 2001 encouraged the creation of gardens in schools and today there are nearly 200 gardens of this type (Giacchè and Tóth, 2013).

Figure 2.16 Location of the municipal vegetable gardens in Barcelona

(source: http://guia.barcelona.cat/ca/llistat?pg=search&c=000010?011010*;001020?001001001019*&nr=50*)*

As regards peri-urban agriculture in the metropolitan area, the Baix Llobregat Agricultural Park was established in 1998, an area with a large vegetable and vegetable tradition that for centuries, up to the fifties of the last century, has been the main supplier of fruit and vegetables of the Catalan capital (Terricabras, 2005). In addition, in the north of the city is the Espai Rural de Gallecs, a small agricultural park cut out in an intensely urbanized area, run since 2006 by an integrated Consortium from several departments of regional and local administrations with the aim of protecting and to improve ecological, agricultural, forestry, landscaping and productive value of the territory (Safont, 2008).

But agriculture in Barcelona is not exhausted with these institutional initiatives. Increasing attention to the quality of food - which prefers organic and local production - and the spread of the idea of urban agriculture as a tool for sustainable development and the demand for urban spaces for meeting and sociality have led many groups of citizens to occupy empty lots and marginal areas for cultivation (Giacchè and Tóth, 2013). This expansion has accelerated over the last five years and at present there are at least thirty "informal" gardens. These gardens are in somewhat varied situations, for example, on empty private parcels waiting for better market conditions to be built, among the ruins of populated housing demolished for never-ending town planning renovations or public green spaces neglected by the administration.

2.4.5 Precedents

In Barcelona, as in Madrid and Seville, the initiatives are diverse and linked to popular demand, most often represented by neighbourhood associations. One of these initiatives is promoted by the City Council, through the Municipal Institute of Parks and Gardens of Barcelona implementing a program of orchards located on public land in 2011 with a network of 12 plots that are between 20 and 40 square meters and which have sufficient infrastructure for organic farming. Only retirees older than 65 can participate in the program.

In addition to this small network of municipal urban orchards, other experiences driven by neighbourhood associations and communities are important. Although this topic will be further explored later, we are dealing here with some more solid initiatives. One of them is located in the Can Masdeu farmhouse, occupied since December 2001 and which involves many families and groups of Nou Barris. In their communal orchard formed by plots around the farmhouse, about 80 people between 20 and 85 years old, cultivate in groups or individually vegetables, various types of vegetables, medicinal and aromatic herbs, etc. They develop an environmental education project for children and youth and other social activities of a playful type.

Figure 2.17 Can Masdeu farmhouse, Barcelona

(source: https://en.wikipedia.org/wiki/Can_Masdeu*)*

In the gardens of Plaza Cataluña in Barcelona, urban gardens known as "orchards of the indignant", symbolized, according to their organizers, on the one hand, the need to introduce environmental issues at the centre of the political agenda; and on the other, they represented the possibility of creating new green zones that would diversify the urban landscape and promote inter-class and intergenerational spaces of encounter and citizen participation, as well as being a tool to promote environmental education.

Another initiative is located in the historic centre of Barcelona, in the district of Sant Pere, in the square Pou de la Figuera, and is called L'hortet del forat. Its origin is linked to the process of redevelopment of the area and to the neighbourhood claim of common spaces. It is located in a space that was abandoned and it was considered the construction of a hotel and a parking lot. The orchard is community-based and aims to promote a change of attitude regarding environmental issues, for this they promote awareness talks, organize workshops that include learning different aspects inherent to the crop, including the composting process. With the products harvested they produce popular foods.

Figure 2.18 Hortet del Forat, Barcelona

(*source:* https://desirelinesblog.wordpress.com/tag/forat-de-la-vergonya/)

Eco-systems services of urban agriculture

Among the most common functions we can mention:

- The productive function of consumption: the reason for the orchards. Traditionally represented a mutual adaptation between the place and agricultural practices to achieve maximum productivity there.
- The environmental function: related to the potential for orchards preserve the values and ecological functions, cultural and landscape open spaces, especially in suburban areas.
- The planning function: associated contribution made gardens maintenance systems and peri-urban spaces.
- The social function: social cohesion linked to the potential of the orchards through activities of educational institutions, recreational, therapeutic, etc., largely explain the renewed interest out there for social these areas.
- The function favourable to health: the numerous benefits derived orchards personal welfare, health and food.
- The role of cultural tradition is deeply rooted horticultural both rural and urban populations around the world and is part of popular culture, lifestyle and even the genius loci or character of each place.
- The aesthetic function: despite the diversity of the formal gardens at different cultures generally constitute a reference variety, wealth and harmony and play a major role in the collective imagination urban societies.

2.4.6 The Current Municipal Framework and Future Strategies

The Green Plan and Biodiversity has two actions identified with this theme:

- To promote organic farming in peri-urban areas and
- To Design and implement a program of orchards and gardens shared com-

munity management

Both actions are also included in the roadmap of the Project Management Assistant 2013-2015. The management and promotion of urban agriculture activities in the City Council is currently distributed between various managements. Also districts, especially the technical area, have knowledge of important unregulated gardens that are scattered throughout the territory, often occupying land and residual spaces public and private.

As mentioned, it is expected that the demand for space to practice urban agriculture are increasing significantly, given that almost converge multiple agents and resources and generate profits and counting activities.

Figure 2.19 Cover of the Barcelona green infrastructure and biodiversity plan 2020

(*source:* http://ajuntament.barcelona.cat/ecologiaurbana/sites/default/files/Barcelona%20green%20infrastructure%20and%20biodiversity%20plan%202020%20%28Summary%29.pdf)

The city council is aware of more work needed for promoting urban agriculture beyond what has been done so far, among others, we can mention the following:

- Assessment of the effects of environmental pollutants on crops and consequently, the health of people
- Advance in the practices of organic farming
- Search for new areas in public green spaces, unused public and private spaces and culture in roofs, terraces and walls
- Identifying groups of beneficiaries of agricultural practice with transversal policies with social welfare and districts

2.4.7 Cooperators

- IRTA is the Agri-food and Technology Research Institute, part of the Agricultural Department of the Catalan Government.
- Fundació Agrícola Catalana, which constitution is:

Catalan Foundation
College of Agricultural Engineers of Catalonia

College of Agricultural Engineers of Catalonia
College of Veterinarians of Barcelona

The original objectives are:

- The promotion, assistance and scientific and technical assistance on issues related to farms and livestock, environment, nature and utilization of water resources.

- Cooperation with entities administrative, economic, scientific and educational, public and private, domestic and foreign, that could help achieve the objectives.

- Dissemination of studies and results in order to profit from their actions have the greatest extent possible, and for this purpose to promote and contribute to conferences, symposia, courses, conferences, seminars, training technical and scientific , etc. publication of books, articles and newsletters; awarding prizes, scholarships, grants and other aid that the Board deems appropriate.

2.4.8 Urban agriculture on municipal land in Barcelona

The programs and projects of urban agriculture on municipal land in Barcelona , promoted and managed by Urban Habitat today are:

- 13 municipal allotments managed by the Department of Education of Intervention and Environmental Innovation of MASU, with 5 people assigned to the department.

- In Collserola, the Directorate of Green Spaces and Biodiversity is building the Hort de Can Pujades, promoted by the District, which will have a management model different from urban gardens, since 50% of the space will be of management shared by the neighbours, and the other 50% will follow the urban garden model. The project is being led by the Department of Education of Intervention and Environmental Innovation MASU.

- Horts dels Pla Buits consists of 19 lots that participated to the contest Pla Buits, 14 of them received concrete proposals, while 11 of these proposals were shared gardens and orchards managed by city entities who submitted a project management of free lots assigned for a period of two years. The project depends jointly from the Territorial Coordination and Participation of HU.

- Support Schools Agenda 21 for Schools: Department of Education of Intervention and Environmental Innovation of MASU has a counselling program in schools to make vegetable gardens. In Barcelona, there are more than 200 school gardens. Also, the MASU Department launched in late 2013, a program sponsored by the Caixa consisting of the installation of vertical gardens in school playgrounds.

Figure 2.20 Realisation of an Horts dels Pla Buits in Poblenou neighbourhood, central Barcelona

(source: http://ajuntament.barcelona.cat/ecologiaurbana/ca/pla-buits/espais-en-actiu/connecthort)

- Linked to Agenda 21 and to the civic engagement of citizens, there is a virtual map of vegetable gardens, so that all those who have or manage a garden in Barcelona, can include it in one of the following categories: community, school, municipal or privat.

- Farmlab is an urban agriculture project conceptualized from two studies, the feasibility study of the use of unused municipal spaces for the introduction of urban farming in the city of Barcelona, looking for a model operation that provides economic and ecological benefits, and study of recovery and implementation of agricultural terraces on Collserola. The project is coordinated jointly by the Planning and Coordination of Participation. Eight sites were selected in locations near Collserola and Besós River, and is expected to launch the project and the implementation of it in 2014.

- Rooftop gardens on socially protected housing: The Housing Board has launched roof gardens on the buildings for the elderly in the streets of Valencia and Navas de Tolosa, in collaboration with the Institute of Quality Life, Equality and Sports.

- Finally, some have municipal gardens managed by entities related to the activity carried out, such as community centres, the Zoo and the Botanical Gardens, it has also to be noticed that Barcelona is part of a European project called EUGO (European urban Garden Otesha) that aims the exchange of best practices of urban gardens between five European countries. The garden Can Masdeu is part of this network.

2.4.9 Types of urban agriculture on private land in Barcelona

There are many experiences of private urban agriculture, which benefits are difficult to estimate quantitatively. The following list shows the types of garden, living in Barcelona, in private spaces:

- Private family gardens on balconies, terraces, rooftops and gardens for family consumption throughout the city
- Community gardens: vegetable gardens managed by groups, organizations, neighbours, often divided into collective or individual plots on private plots
- Orchard education: orchards are located in private school facilities throughout the city

2.4.10 Food movements: The eco-village of Can Masdeu

Located on the footsteps of Corserolla Natural Park, the low mountain range surrounding Barcelona, Can Masdeu (CMD) represents one of the most emblematic places for economic and socio-ecological transformation in town. What firstly strikes you when visiting the ample mansion squatted for the last 15 years are the nicely ordered terraces, or community gardens. These are managed by a mixed group of elderly people living in the local neighbourhood. Some of the other physical elements of the project are its social centre/bar which can easily accommodate about hundred people, a free shop, a yoga room and a library. Walking through the past track of the project, one finds an impressive array of events, campaigns and educational activities roaring through a diversity of actors and issues, from permaculture groups working on the creation of a forest garden, activist gatherings on anti-fracking, water-privatization, agroecology, climate justice (among the rest) and academic courses in association with various universities.

Figure 2.21 Agricultural gardens in Can Masdeu

(http://www.naturalenda.com/2015/06/)

If one intends to define what makes Can Masdeu different among the myriads of Spanish community-based initiatives in two simple words, these could probably be: diversity and openness.

Diversity is present in the rural and urban interfaces of the project; but also in the amplitude of strategies where building alternatives goes hand-in-hand with opposing the destruction of Corserolla; as well as a diversity of activities and of groups that organize events on the premises of the project; a diversity of social actors, including political leaders working in the Municipality of Barcelona. Indeed, few projects manage to successfully integrate organic agriculture with political campaigning and academic research in one physical space.

Can Masdeu openness, on the other hand, is felt and seen on Sundays, the open-doors day, when hundreds of people come up to take a walk through the gardens and communal spaces of the house, learn about its ways and whys of working, join for lunch and participate in the programmed social and educational activities. Coming up on Sundays is one easy, friendly and fun way to get in touch with the newly emerging culture of socio-economic transformation and critics of consumerism, and to get inspired for your community oriented project along the way.

Figure 2.22 Community eco-friendly lunch in Can Masdeu

(source: https://labcoalghero.wordpress.com/cosa-succede-altrove/nel-mondo/can-masdeu-barcellona-spagna/)

Hence what is it that makes Can Masdeu so successful, popular and attractive?

It is inhabited by only about 30 residents, but visited by hundreds – and known by, and serving as a source of inspiration, by thousands of people. One might give multiple answers here, but from our perspective, the trigger has to do with the unique combination of factors in one physical space. One of these is physical geography and presence of Barcelona on its footsteps, another – the societal context and history of social organizing in which it is submerged, a third – the presence of active social actors, united in multiple inter-related networks, a fourth is the multiple identities of its members, many of whom are simultaneously politicians, activists and researchers. This junction of ingredients makes Can Masdeu a fertile space, where new ideas and forms of socio-economic organizations are continuously emerging and spreading.

The implications of Can Masdeu, however, go far beyond their physical existence and mode of operation. The project demonstrates that alternative, more ecologically and socially sustainable ways of organizing life and work are possible here and now, without sacrificing on quality of life. Actually – on the contrary – enhancing quality of life. Resource wise, this implies living within nature's limits – using dry toilets, recycling materials, producing more than 30% of fruit and vegetables annually consumed, harvesting water and treatment of grey waters, using principles of ecological building among many other practices. Lifestyle-wise, this implies finding the right balance between living and working, between contributing to social struggles (by the provision of free space, for example) but also caring for the sustainability of personal lives (caring for one's relationships and body-health). For these projects to flourish the presence and complicity of multiple skill and profiles is fundamental: including people skilled in manual works, people good at public and inter-personal relations, those good at campaigning and political activism, as well as those who are good at gardening, music and arts. Each of these profiles is indispensable for the integrity of the project and the co-constructs its success.

CHAPTER 3 – LOCAVORE DISTRICT IN CANYELLES

"We're only truly secure when we can look out our kitchen window and see our food growing and our friends working nearby."

Bill Mollison

3.1 Linking Competition Given To Problematic

3.1.1 Competition Given

Figure 3.1
The neighbourhood of Canyelles, Barcelona

(source: http://www.obrabcn.cat/images/vis>ites/3c795-D45-01-117.jpgites/3c795-D4 5-01-117.jpg)

Site definition

The site is in Barcelona's northern Nou Barris District. It sits at the top of an old valley on the Collserola mountain, the starting point of a watercourse, now channelled and buried. The site is bounded by the Canyelles, Roquetes and Ronda de Dalt Districts, and backs onto Collserola mountain.

This topography is an important aspect to be taken into account in both the project and the overall strategic areas. At present, it is an empty space with parking lots, bowls courts and sports facilities. It is also being claimed by local citizens as a new space for neighbourhood facilities

About Canyelles

The former Can Guineueta farm, built in the 18th century, included fields that spread to the present-day site of the Canyelles market. This cropland underwent a radical transformation in the 1940's. After the Civil War, the area around the farm became occupied by huts and small houses that ended up as the initial Guineueta Vella district. These 250 homes had no services, electricity or sewerage.

In the mid-1960's, the new Ronda de Dalt bypass project sentenced this shanty suburb, and the land was expropriated to build a housing estate. The farmhouse was demolished and replaced by high-rise apartment blocks. The neighbourhood's activism nevertheless managed to rehouse Guineueta Vella's inhabitants in 3,000 apartments in the new district, built on the site of their former homes.

This new suburb, officially inaugurated in 1978, was called Canyelles.

The Canyelles district, built in 1974, was the last housing estate to be built in the pre-democratic period. It consists of large apartment blocks built using prefab modules. Despite its relatively recent construction, for a long time it suffered an almost total lack of infrastructure and services. In recent years, Canyelles has benefited from major urban improvements: the Ronda de Dalt by-pass built in 1991, the extension of Metro line 3 and other public transport services, several parking lots and many other urban development initiatives.

Figure 3.2
The neighbourhood of Canyelles, Barcelona

(source: http://w ww.o brab cn.cat/images/ vis>ites/3c79 5-D45-01-117.jpg ites/3c79 5-D 45-01-117.jpg)

Competition Theme: How is production considered in the urban diversity program?

In Barcelona, production is considered to be equivalent to urban complexity. We have now moved a long way from the old zoning and urban segregation models which proposed separate residential and production areas. The Barcelona model interrelates and complexities the territory. It creates spaces where housing, leisure and work are unequivocally interrelated. This generates quite intense contemporary spaces that have to be created using new design tools.

The proposed project includes a programme of urban vegetable gardens, which defines a basic, classic type of production. However, a productive urban area should be regarded as a complex space with opportunities in which the interrelations amongst its residential citizens are also part of its productivity, and the ability to attract outsiders is considered to be a key element as well.

Other aspects will had to be considered, such as an enlargement of green zones, biodiversity, water self-sufficiency and potential energy generation, amongst others

Competition Program

Total project area: 23,500 m2

– Outdoor sports facilities: outdoor sports circuit, playing courts, etc. Surface area for outdoor sports: 7,000 - 8,000 m2

Figure 3.1
Site in Barcelona - map

Figure 3.2
Project site: the border between Canyelles and Les Roquetes

(source: europan competition brief)

– Urban vegetable patches for over 65: 7,000 - 8,000 m2.

– 2,000m2 (minimum) to 5.000 m2 will be set aside for public spaces that will interconnect all the proposed activities and link the Canyelles District to the planning proposal

– At present, there are several bocce or petanque courts totalling 3,500 m2 at the bottom end of the project area. Proposals must relocate them and at least maintain the same area.

– Social Housing: maximum land occupancy: 2,500 m2, buildable area: 11,500 m2t, number of dwellings: 125 - 150. Dwelling floor area: 60 - 80 m2. The ground floors of this building/buildings will be set aside for community and/or shop uses. – Essential social housing. Social dwellings to be rented. 40 - 50 m2 floor area, for elderly people. Maximum land occupancy: 1,500 m2, buildable area: 2,800 m2t, maximum number of dwellings: 50. The ground floors of this building will contain

spaces for community and/or neighbourhood uses.
m2 = square metres of land
m2t = square metres of floor space

Figure 3.3 Required project program

Total strategic site area 112,000 m2

This area includes the project site, the surrounding areas zoned as reserves for facilities, green areas and part of the mountain. Attention to the areas under municipal ownership will be appreciated.

Special attention will be given to proposals for connections between the planned facilities and the Canyelles and Roquetes districts, as well as the proposal's ability to connect the city to Collserola mountain.

Aspects to take into account in the strategic site:

1. A fixed plot (orange rectangle in the next picture) is where the existing sports centre must be constructed and expanded. This will be a new indoor pavilion that need not be designed, but considered as pre-defined.

2. Two areas reserved for local facilities and neighbourhood uses are also pre-defined (Annex 2, lilac colour). Buildings and/or outdoor spaces can be envisaged to generate leisure and meeting activities for young and senior citizens, neighbours, playgrounds, etc. The highlighted proposal must act as a catalyst for participation with the neighbourhood to decide on the definitive activities. We suggest that the two areas be used in an alternating, complementary way and that construction should not build on more than 30-40% of the total land area.

3. Finally, connections and potential relationships between the Canyelles and Roquetes districts, as well as between Collserola mountain, Ronda de Dalt and Guineueta park, should be considered.

Parking:

The municipal planning regulations envisage the construction of 1 parking space for each dwelling to be built, or 1 space for each 4 dwellings in the case of essential social housing. The rest of essential dwellings can be catered for with spaces of mo

Figure 3.4 Strategic Site divisions

(source: europan competition brief)

torcycles and bicycles. These parking spaces can be built in the basements of the buildings.

Community spaces for essential social housing:

Essential social dwellings are considered to have a minimum surface area, 40 - 50 m2. The idea is to restrict their private space in exchange for the inclusion of community elements in the buildings, and thus facilitate social relations. Such envisaged community facilities can be: a laundry room, a multipurpose room (sitting/leisure area, TV, computers, library, etc.), an area for a concierge and medical care, since the homes are intended for senior citizens, and other spaces to be considered such as a gym, interaction with neighbours, etc.

Sustainability, Environment and Health aspects envisioned

Figure 3.5 Barcelona - Placa fotovoltaica del Fòrum

(source: http://www.panoramio.com/photo/87401251)

Sustainability is a priority for the Barcelona City Council. A series of policies and projects have been defined to encourage a trend towards a city with a high-quality environment and public spaces. It aims to generate a breathable, clean, comfortable, healthier city, in which we can live and coexist with the natural elements near our homes; a city that is more efficient in its resource usage, in transition towards more sustainable generation and consumption models. For this reason, EUROPAN 14 proposals for the Canyelles site must include urban sustainability criteria that reflect the new socio-economic and environmental context.

Barcelona has drafted a "2012-2022 Citizen Commitment to Sustainability" which aims to generate a more sustainable city through a shared project. This charter is a frame of reference for all citizen organizations that wish to contribute to the achievement of its objectives. The Commitment is set out in a document of strategic value, aimed to act as inspiration, which defines 10 major objectives, with 10 lines of action for the 2022 horizon.

Figure 3.6 Bike Sharing systems in Barcelona

(source: http://www.ingdemurtas.it/senza-categoria/bike-sharing-love-it-or-hate-it-2/)

Sustainable aspects to be considered:

The following are just some of the aspects that may be taken into account :

1. More green areas and biodiversity: • Enlargement of public green zones, including proposals for green roofs on new buildings and vertical gardens on walls. • Diversity and stratification of tree species and other types of vegetation. • Generation of areas that can attract fauna, especially birds, amphibians and insects.

2. Sustainable mobility and generation of public spaces: • More pedestrian precincts. • Less spaces for vehicle traffic and deterrent measures to pacify and reduce traffic. • More bike lanes. • More space for public transport.

3. Environmental quality and health: • Corrective measures to improve air quality. • Corrective measures to reduce the impact of noise and improve acoustic comfort. • Corrective measures to reduce heat islands.

Figure 3.3 Planned green Corridors of Barcelona

(source: Barcelona Green and Biodiversity Plan 2020)

4. Efficient, productive and zero emission city: • New water management and consumption in public spaces and green zones. Water self-sufficiency: management, collection and use of rainwater, groundwater and greywater. Use of sustainable drainage. • Proposals to implement ICT in public spaces (Wi-Fi, motorization of environmental solutions, etc.).

5. Rational resource usage: • Implementation of measures to promote a circular economy: materials from renewable resources, materials made from recycled material, low carbon materials, etc. • Waste minimisation measures (composting, recycling, etc.) • Selective rubbish collection.

6. Good governance and social responsibility: • Suitable spaces for promoting citizen participation, shared projects, provision of spaces for short-term activities. • Implementation of criteria for gender equity. • Universal accessibility.

7. People's well-being: • Housing renewal. Increased percentages of social housing in the neighbourhood. • Generation of new urban facilities and provisions for neighbourhood uses. • Generation of new jobs (street-level shops, urban vegetable gardens, cooperative economy, etc.) • Projects that increase citizen quality of life and satisfaction.

8.Progress and development: • Urban innovation. Measurement points for urban standards, street-level electrical recharge points, public Wi-Fi, etc.

9. Education and citizen action: • Spaces for schools to implement environmental territorial recognition projects.

10. Planetary resilience and responsibility: • Passive systems that facilitate lower demand. • Energy efficiency. • Energy generation. • Green or reflective roofs, water tanks. • Soil permeability. • Increased true green areas. • Adapted vegetation.

3.2 Urban Anatomy

3.2.1 Historical Background - The evolution of urban morphology in Barcelona

- I sec. b.C. :

Barcelona was founded by the Romans, that named it Bancino. It had the typical structure of the Roman encampments ("castrum") with perpendicular axis and a central square ("forum") overlapping the actual Plaza de Sant Jamie, in the gothic district. The area consisted in 104 000 m2 and was surrounded by a wall and hosted around 5000 inhabitants.

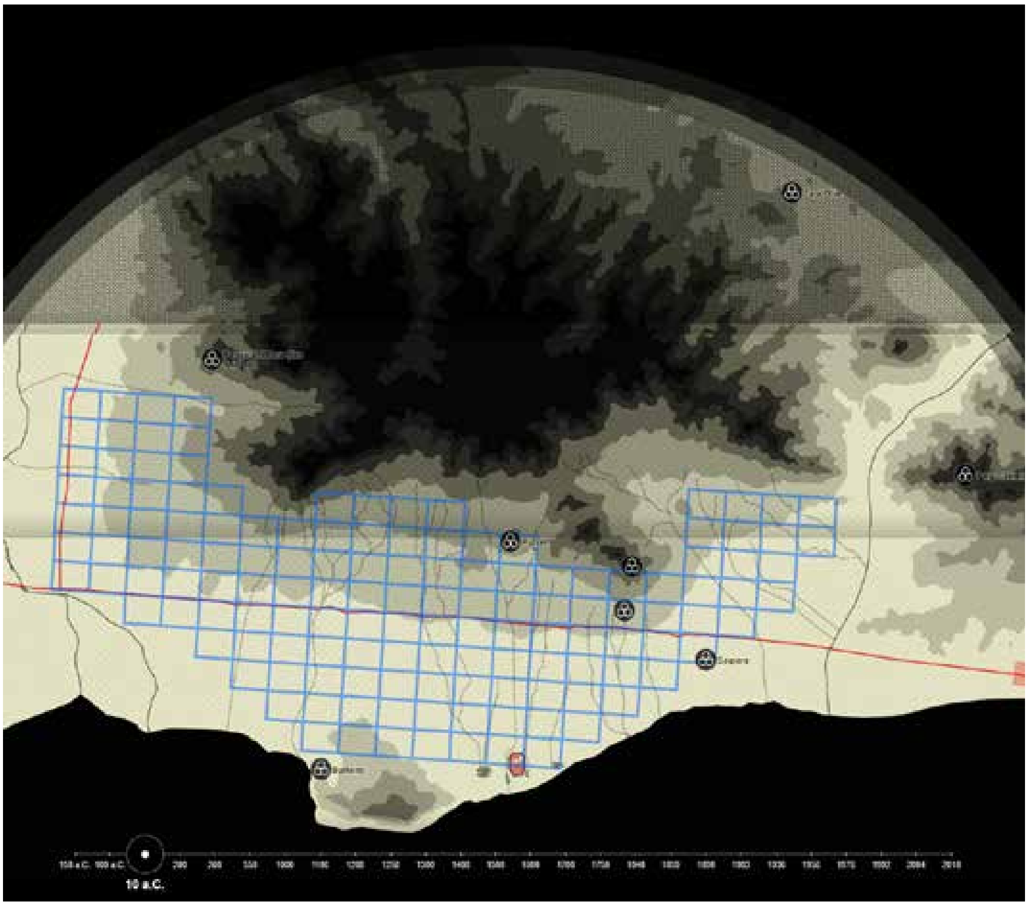


Figure 3.4
10 B.C. Barcino, an Imperial foundation structured following the existing road along the coast as a line of reference

(source: http://cartahistorica.muhba.cat

- After the Romans,

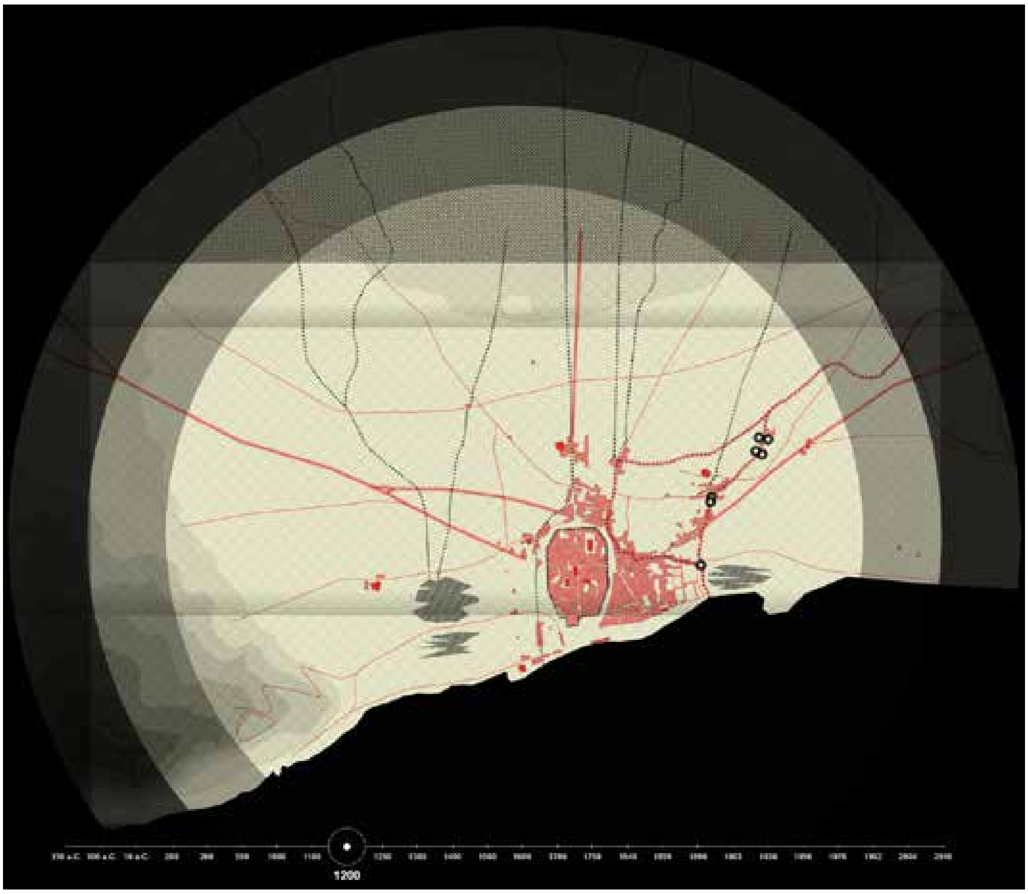
the city was dominated by Visigoti, Arabics and the Carolingian empire. They basically used the structure of the roman city, but later the growth of it lead to an expansion of the perimeter and the birth of the first suburbs.

- Middle Age:

Barcelona became a county, later part of the Aragon Reign.
After a destruction in 985, the city was rebuilt starting from the roman nucleus.
Outside of the walls of the city, the land was dedicated to agricultural fields that produced fruit, vegetable and wine. The agricultural area was confined by the river Horta, the river Sants, Collserola mountain, Puig Aguilar and Coll de Codines and the Mediterranean see. In the middle of the 10th C. two canals were built to bring the water of the rivers Llobregat and Besos near the city. (one of them was flowing parallel to the Strata Francisca).

Later the city started to develop outside the walls, initially only made by religious buildings and fields, and slowly the district of Raval was born.

Figure 3.5
1200. Neighbourhoods outside the walls start to grow
(source: http://cartahistorica.muhba.cat



In 1260 a new wall was built, surrounding an area of 1,5 km2, with 8 towers and some fortifications outside to protect the city.

In 1265 the Concejo de Cento was founded to administrate the city and therefore was responsible of the for management and street maintenance. It also defined the first models of urban buildings, the Consuetuds di Santacilia.

The mediaeval urban texture is characterized by irregular streets and squares that are just enlargements of the "calles". Buildings were mainly of "tipo artisanal" with the laboratories at the ground floor and two more floors for residential use, with an average footprint of 4x12 meters and later a small garden aside. Other buildings were churches, palaces and institutional headquarters. Concerning planned urban developments, there was the building of the calle the Montcada in 1209 and the plaza Nueva in 1355

Figure 3.6
1300. Growth in the late Middle Ages with new walls, towers and hospitals

(source: http://cartahistorica.muhba.cat

- In the 15th C.

the city expanded up to 25000 inhabitants, occupying the nowadays Gothic district and the district of Raval, with a wall containing 2000000 m2 of land. Also a street called "Rambla" became part of the city, initially it was occupied by religious buildings, but became soon a popular public space for markets, shops and other activities.
During the middle age was developed a wide street network to connect Barcelona to the surrounding villages.

- Modern Age

Concerning urban transformations, there were not many in this age. One was the construction of the wall towards the sea and some bastions in the first half of the 16th C.
In 1438, with the permission of the king, the works of the new arbour started, and in the 16th C. the dock was 180 m long and 12 m wide.

Figure 3.7
1500. Construction of the port and expansion of the wall around Raval

(source: http://cartahistorica.muhba.cat

In 1546 a square, Plaza de la Seo, was created in front of the cathedral, and also Palacio Real Major was erected. The water supply and depuration system was improved in this age.

In the 18th C. many military constructions were built under the Bourbons orders, like the castle od Montjuic and the Citadel fortress.

The construction of the Barceloneta neighbourhood started in 1753, with a project of orthogonal streets made by the engineer Pedro Martín Cermeño.

In 1771 there was the first municipal ordinance to control the buildings layout according to the streets direction. Later was introduced also a height limit.
The typical house moved from the mediaeval “tipo artisanal” to “casa plurifamiliar” that hosted some families, so the working place was separated from the residence one.

During this age, the city expanded only towards the sea, occupying also the nowadays “La Barceloneta” neighbourhood. Anyway, the population increased up to 100’000 inhabitants.

- The 19th Century

The industrial revolution characterizes this century, especially concerning the textile industry, and this lead to a cultural rebirth. Many textile and metal factory opened inside the city, like “El Vapor” and “La Barcelonesa”.

Important is also the migration of the population from the rural areas to the city.
The urban police established a disposition of the buildings, the maintenance of the public spaces and later also a proportion between street width and building height.

Concerning urban developments in the first part of the century, there was the opening of the "calle the Fernando", the expansion of the "Pla de Palau". In addition, some public spaces such as the market of Boqueria and plaza Real, were constructed after the confiscation of some parcels in 1836, while some squares like San Jaime were built to substitute cemeteries, moved outside the city for hygienic purposes.

In 1842 appeared the first illuminated streets: Rambla, the calle de Fernando and the square plaza de San Jaime.

The first railway arrived in Barcelona in 1848, that connected the city with Mataró, and consequently the train stations of Francia, Sants and later Norte were built.
In this Century there was the creation of the first green public spaces, because the industrial revolution was contaminating the environment, so many parks were opened.

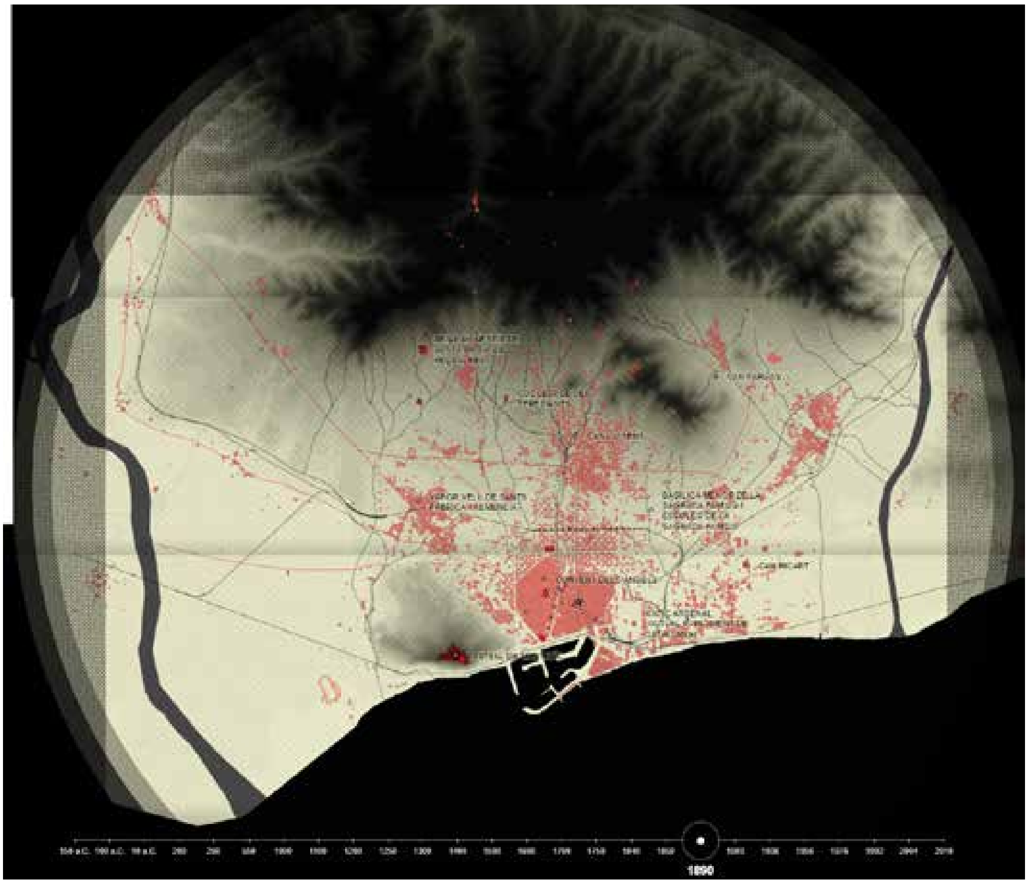
Between 1854 and 1859 there was finally the demolition of the walls, so Barcelona was free to develop and expand in the surrounding area, following the Ildefonso Cerdá's project, called "Ensanche".

The project consisted in orthogonal streets 20 meters wide, a part parallel to the shore and the Colserola and the others in direction southwest-northeast, in an area between the Montjuic and the river Besos. Between the streets was planned a system of squared blocks with each side of 113,3 meters. Inside them the buildings should have occupied only 2 sides, leaving the rest for public green spaces, but this did not happen and in 1891 the superficial occupation allowed in the parcels was incremented from 50% to 70%. The buildings were therefore constructed with an octagonal plan, so the smoothed corners could allow a better circulation around the block, and a courtyard in the middle in order to have a building depth of 10-20 meters. The height was restricted to 16 m. According to Cerdá's project, 20x20 blocks should compose a sector containing a park, every 10x10 blocks a district with its market, and every 5x5 parcels created a neighbourhood with school, civic centre, church and health centre. But the majority of these dispositions were not respected. Cerdà studied a lot the project evolution, and wanted to create a new urban plan based on 3 pillars: good hygienic condition (inside the walls the hygiene was very poor), good circulation for cars and pedestrians, and a polyvalent design.

Also some main streets as the Avinguda Diagonal and Avinguda Meridiana were planned by Cerdà, and they are cutting the grid regularity following a diagonal direction.

Figure 3.8
1890. Growth of the Eixample around the old town after the demolition of the walls

(source: http://cartahistorica.muhba.cat



Inside the old part of Barcelona there was also a need of urban planning to have a better access to the city centre, but all the project proposed were not accepted or postponed.

In 1888 the Universal Exposition took place in Barcelona, improving and modernising the area around the Citadel park, with a project made by Josep Fontserè.
At the end of the Century there was also a requalification of the sewer network by Pere Garcia Fària, that lead to a great improvement of the hygienic conditions of the city.

- The 20th Century

The population grew rapidly in this Century, and passed from 530'000 inhabitants in 1900, to 1'000'000 in 1930 and reached 1,5 million at the end of the '900.
Between the end of the 19th and the beginning of the 20th Century, Barcelona annexed many neighbouring municipalities, expanding the city area that reached 77,8 km2.

There was therefore a need of connecting the new neighbourhood to the old parts of Barcelona, so a new urban strategy was planned by Leon Jaussely to improve the plan Cerdà, based on the creation of new infrastructures, the zonation of activities and the creation of green spaces. This was however only partially realized, although it had a big impact on influencing new urban ideas in Barcelona.

In 1908 a new street was opened inside the center of the city: via Laietana. It connected the Einsanche with the sea passing throw the old part of the city, according to the 19th C. plan of Baixeras that aimed a better mobility inside the Gothic neighbourhood.

There was also an expansion towards the mountains, with the urbanization of the mountain Tibidabo and the creation of the funicular of Vallvidrera.
In 1920 started the works to construct the subway, inaugurating the first 2 lines some years later.

The first years of the century are also characterized by the construction of new schools and the improvement of the education.

The problem of the green spaces was again faced in this time and a director of parks and gardens was created. A big park network was planned, but only partially realized; in any case the amount of green spaces had an expansion.

The international exposition in 1929 lead to urban improvements in particular around the Montjuic area, but also in all Barcelona.

The amount of public works required manpower, so many immigrants moved to Barcelona from the rest of Spain. These immigrants were very poor and therefor there was a massive edification of low price houses forming the labour class districts (like the nowadays Can Peguera neighbourhood and others), but also the creation of many shacks, especially in San Andrès, Montjuic and Barceloneta areas.

In 1932 there was the first zoning program of the entire Catalunia.
During Franco's dictatorship there was a massive expansion of the city, involving an area of 25'000'000 m2 (almost the double of the einsanche) that developed mainly in three different ways: suburban sprawl, self-developed areas and parcels for mass housing. Buildings were constructed with no urban planning and with low price and low quality materials. This lead to the creation of many new districts (Carmel, Nou Barris, El Guinardó, El Valle Hebron, La Sagrera, Clot and Pueblo Nuevo).

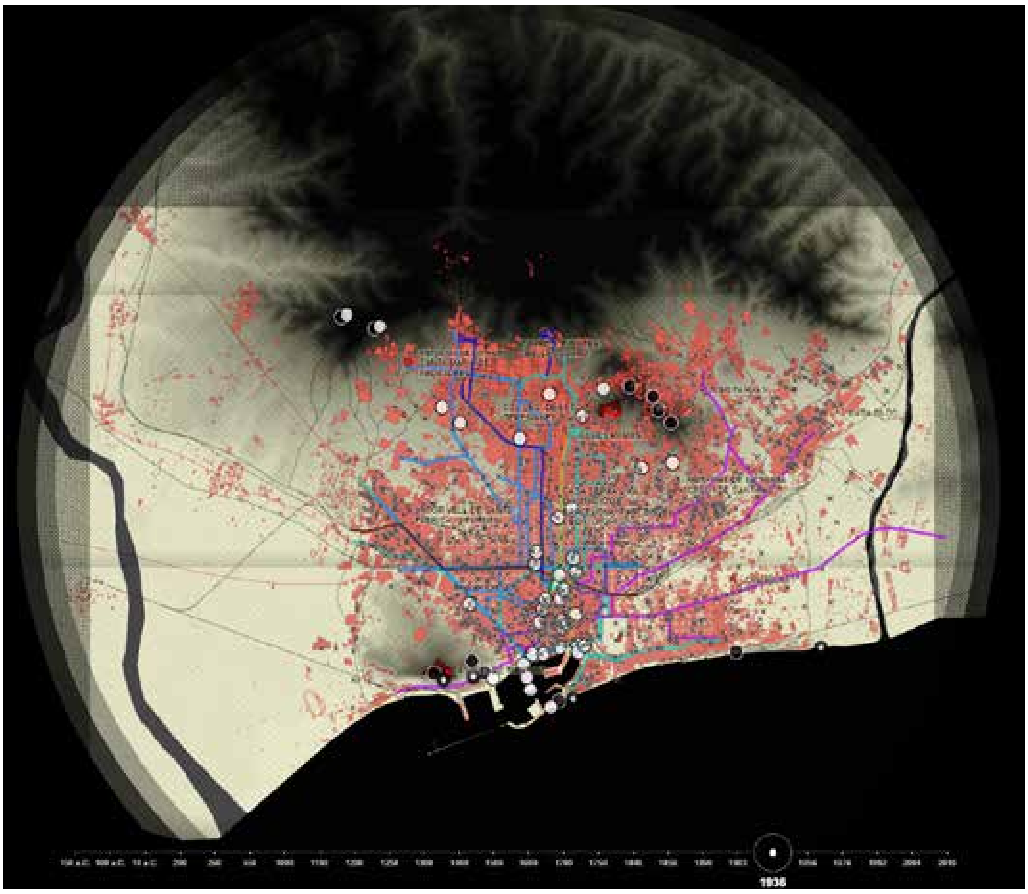


Figure 3.9 1936. Barcelona before the Civil War, with the first subway lines and many slum housing in the periphery

(source: http://cartahistorica.muhba.cat

From 1942 on was also incremented the maximum building height, so in 20-30 meter wide streets it was possible to build up to 24,4 m (6 floors) and in streets wider than 30 m the height could reach 27,45 m (7 floors).

Between 1957 and 1973 the mayor of the city implemented many speculative edification and infrastructure projects, like the residential area in Canyelles. That resulted in a popular dissatisfaction that lead to the creation of the so called “urban social movements”, which combined the discomfort generated by the degradation of the urban periphery and the political protests against the Franco regime. One of these associations was called “Nueve Barrios” and it is from it that comes the name of the Nou Barris district.

With the beginning of the democracy a new series of urban reforms started, increasing the number of streets, schools, green spaces, squares and sport centres. Between 1983 and 1989 there was the purpose to create areas of new centralities, regenerate the urban texture and connect better the periphery with the centre. This was realized throw the opening of new streets and public squares.

For the Olympic games of 1992, a urban transformation in the area of Montjuic was held and was created the Villa Olimpica de Poblenou. For the games were realized also the ring streets around the city, to allow a better circulation.

At the end of the Century the sustainable development started to be taken in consideration more and more. For example in 1993 the first bike path was created.

Figure 3.10 2010. Remodelling Barcelona’s eastern sector with new urban interventions

(source: http://cartahistorica.muhba.cat

- 21st Century:

New technologies and sustainability are the key word of the development in the actual century.

Barcelona is also now connected with the high speed train with Madrid and Paris.

Many new green areas were created, including also the Nou Barris Central Park (opened in 2007) and the first big dog park located in Nou Barris.

A new plan started in 2016 consists in limiting the car assess between the blocks, combining the blocks by four, and having inside the fout only pedestrian paths and public spaces.

3.2.2 Morphological Analysis of the Context

Looking at the solid and void plan reported in the following pages, it's clearly visible the area enclosed between walls before 1850s, that forms what is now the Barris Gothic and the Raval District, and the area related to the Plan Cerdà, with orthogonal streets and squared blocks.

Figure 3.11
Natural Setting of Barcelona

(source: http://www.obrabcn.cat/images/vis>ite s/3 c795-D45-01-117.jpgites/3c795-D45-01-117.jpg)

The old part of Barcelona, although developed starting from the regular roman settlement, is characterized by very high density, narrow street and lack of urban planning, because it was formed by a disorganized expansion. The Eisanche, on the other hand, it's characterized by regularity and order and the density is a bit lower, even if it's much higher that what Cerdà planned at the beginning, so many blocks contain buildings even in the central area.

Figure 3.12
Natural Setting of Barcelona

(source: http://www.obra bcn.cat/imag es/vis>ites/3c795-D45-01-117.jpgites/ 3c795-D45-01-117.jpg)

Outside the Plan Cerdà, it is visible in some areas the attempt to continue the regular scheme, but continuing towards the Collserola, there are mainly disorganized settlements, apart from some plots that underwent a planned residential high density development.

The project site is located at the border between Barcelona and Collserola in the Nou Barris district.

Figure 3.13
The solid/void ma of Barcelona

(source: http://www.obrabcn.cat/images/vis>ites/3c795-D4 5-01-11 7.jpgite s/3c795-D 45-01- 117. jpg)

The surrounding area used to be eminently rural until the middle of the 20th Century, when it begun to be transformed and developed on the arrival in the 1950s and 1960s of numerous migrants looking for work in Barcelona, which was facing at that moment a strong industrial growth.

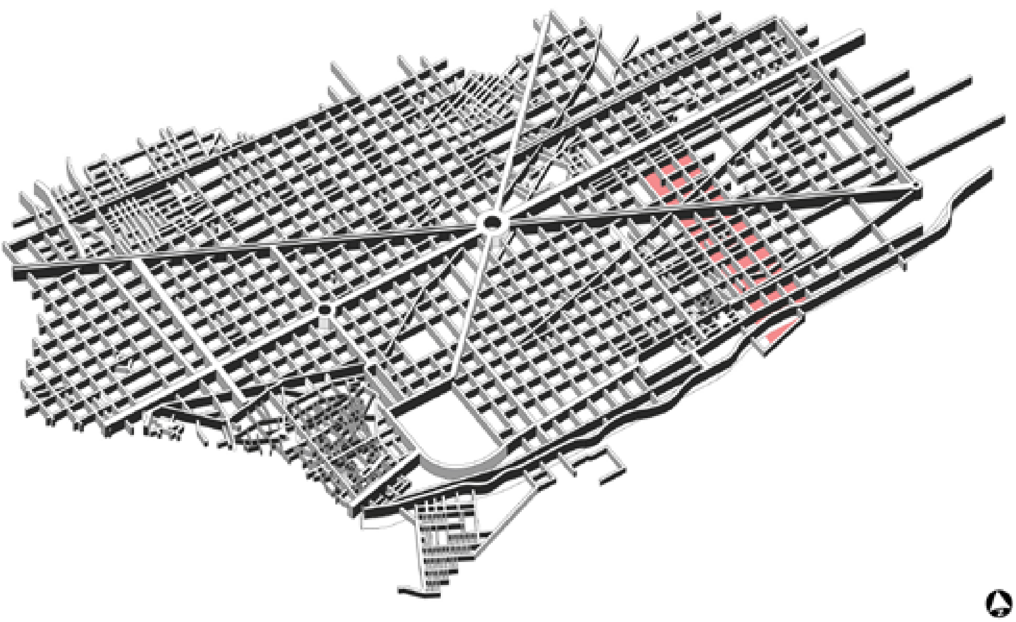


Figure 3.14
Streets shaping urban blocks

(source: http://www.obrabcn.cat/images/vis)

Nou Barris was born from the union of poor buildings, at the beginning there were just poor houses made of low cost and low quality materials constructed often without legal permission, creating a massive disorganized urbanization. Later on, the inhabitants joined together to improve the condition of the district, creating a sewer network and other infrastructures.

In 1984, Nou Barris became officially one of the 10 districts of Barcelona, separated from the Sant Andreu district.

Since that time, the district has improved a lot in terms of infrastructures, transportations and quality of spaces. Nowadays Nou Barris is one of the greenest districts in Barcelona and it's the home of many families.

The district consists in 13 neighbourhoods: La Guineueta, Les Roquetes, Verdun, La Prosperitat, La Trinitat Nova, Torre Baró, Ciutat Meridiana, Vallbona, Canyelles, Vilapicina i la Torre Llobeta, Porta , El Turó de la Peira e Can Peguera .

Figure 3.15 Districts of Barcelona

(source: https://commons.wikimedia.org/wiki/File:Barcelona_Districts_map.svg)

Canyelles

The Canyelles neighbourhood, built in 1974, was the last housing estate to be built in the pre-democratic period and it was constructed inside the estate surrounding the Institut Mental de la Santa Creu.

It consists of large apartment blocks built using prefab modules. Despite its relatively recent construction, for a long time it suffered an almost total lack of infrastructure and services. In recent years, Canyelles has benefited from major urban improvements: the Ronda de Dalt by-pass built in 1991, the extension of Metro line 3 and other public transport services, several parking lots and many other urban development initiatives.

Canyelles Topography: The district is located on a hill called "Turo de Les Roquetes" therefore the terrain is very irregular with steep slopes. The altitude is between 80 and 190 meters a.s.l. and the average slope is greater than 20%

Les Roquetes

Before the 20th Century, where there's now Les Roquetes there was an uninhabited area covered by a forest.

In the 20th Century the owner of the majority of the area, Marqués de Sivatte, imagined an urbanization of the area following the garden-city style, but the idea was not successful, so the Marqués sold the terrain to the city of Barcelona.

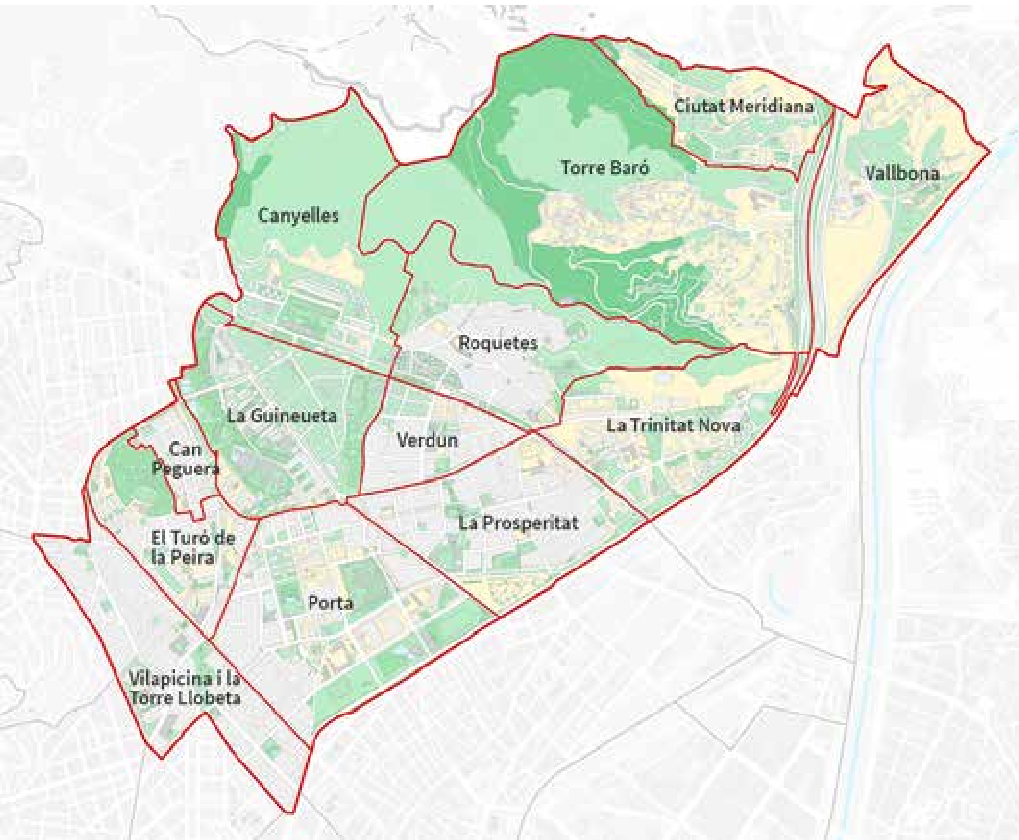


Figure 3.16 Neighborhooods of Nou Barris, district where the site is located

(source: http://www.obrabcn.cat/images/vis>ites/3c795-D45-01-117 .jpgites/3c795-D45 -01-117.jpg)

Figure 3.17 The neighborhood of Canyelles, Barcelona

(source: http://www.lavanguardia.com/vida/)

In the 1920s a nucleus of bungalow was born around the nowadays calles de Pla dels Cirerers and Vía Favencia and in the 1950s more low price houses were built. In addition, numerous migrants looking for work in Barcelona decide to construct there their houses, even without legal permission.

To improve the conditions of the neighbourhood the inhabitants joined together to create a sewer system and other facilities

Figure 3.18
The neighborhood of Les Roquetes, Barcelona

(source: https://jebxl.files.wordpress.com/2015/ 03/img_4841.jpg)

3.2.3 Environmental Analysis

Location Information:

Latitude: 41,444° N
Longitude: 2,1694° E
Altitude: 134 m asl

Climate

Barcelona has a Mediterranean climate, but there are some differences form the typical Mediterranean climate, like the presence of precipitations spread generally all along the year, even in summer.

Temperature

December, January and February are the coldest months, with a temperature that can get until 4 °C, but the average winter temperatures are around 7-12 °C during the day, so there's a relatively mild winter. During the night the temperature gets lower and can reach the minimum values. It's very rare to have snowy days.
In summer the temperatures can rise up to 35 °C and the high humidity makes the heat even less bearable. Only the sea breeze can mitigate the summer heat.
The daily thermal excursion is generally low (around 7 degrees) since Barcelona is bounded by the Mediterranean see on one side and the Collserola mountain on the other side. For this reason, extreme values of temperature are not common in the city.

Precipitations

Rainfalls are distributed along the entire year, even if in summer the precipitation quantity is lower. The rainiest months are September and October.
In summer the meteorological events can be strong and generate heavy storms and sometimes even cloudbursts.

Radiation

Due to the latitude of the location, the sun radiation is quite high and the sky is mainly clear, also in winter the mean cloud cover doesn't exceed the 50%. Therefore solar and PV panels can be a relevant energy resource.

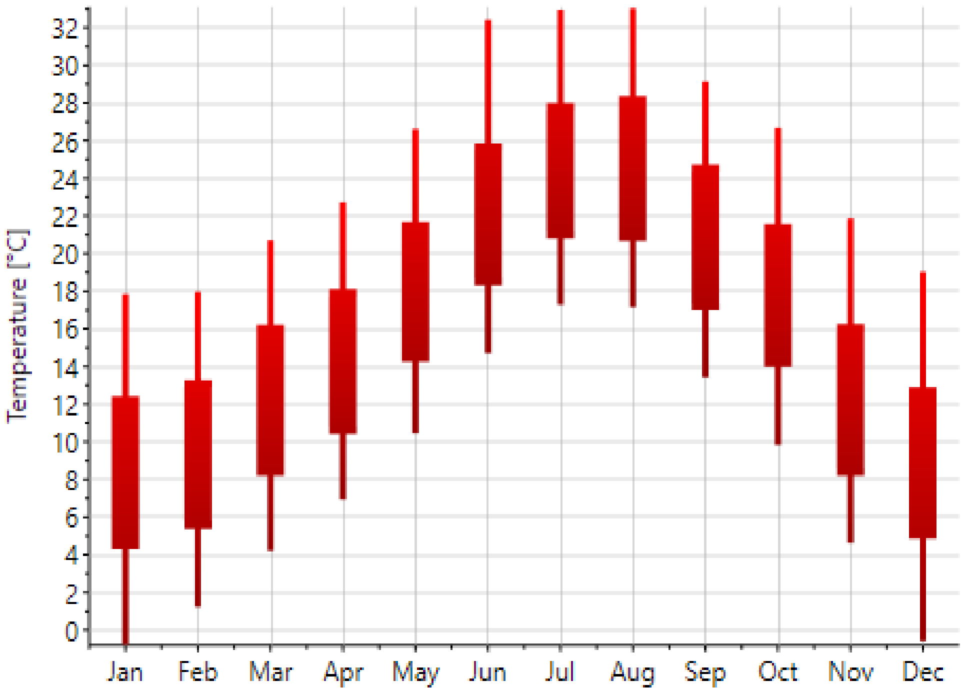


Figure 3.19
Monthly temperature in Barcelona
(source: meteonorm)

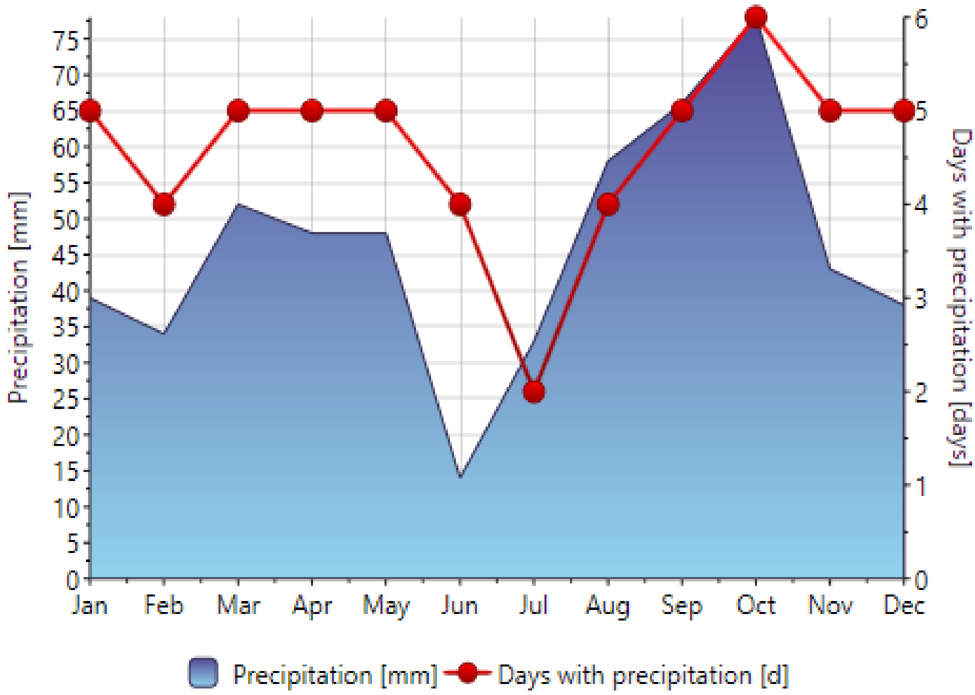


Figure 3.20
Monthly preciptation (amounts and days) in Barcelona
(source: meteonorm)

Noise pollution

The noise pressure comes mostly from road traffic, air traffic, railways and construction activity
The province of Barcelona is host to some 1,900,000 vehicles, representing a ratio of 0.4 vehicles per inhabitant. And the effect of noise is aggravated by the high population density 30,000 persons/km^2.

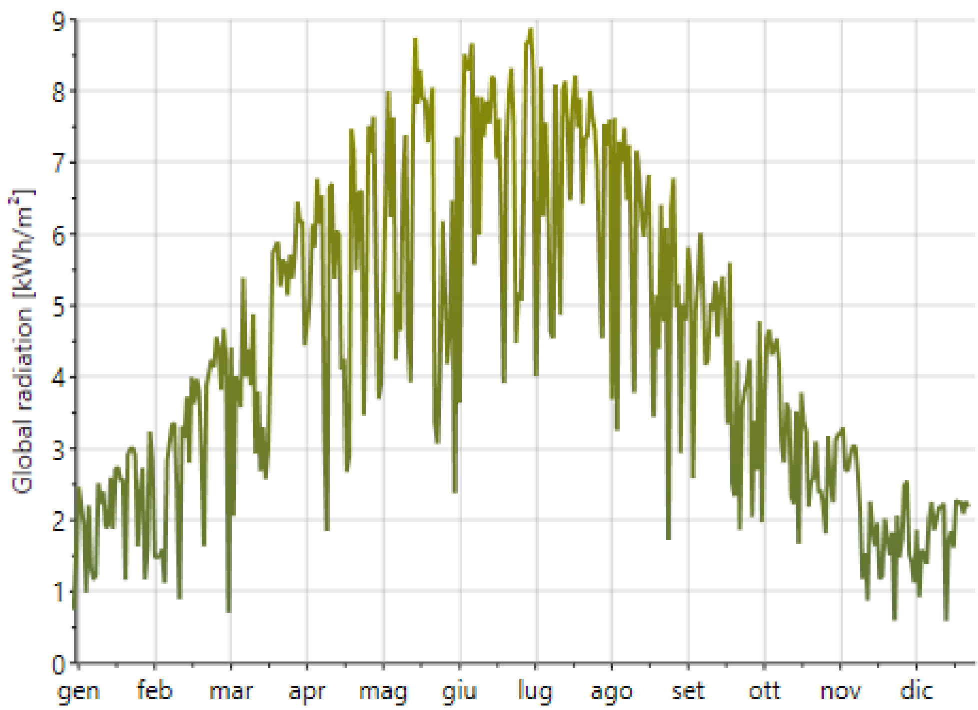


Figure 3.21
Monthly Variation of Global Radiation in Barcelona

(source: meteonorm)

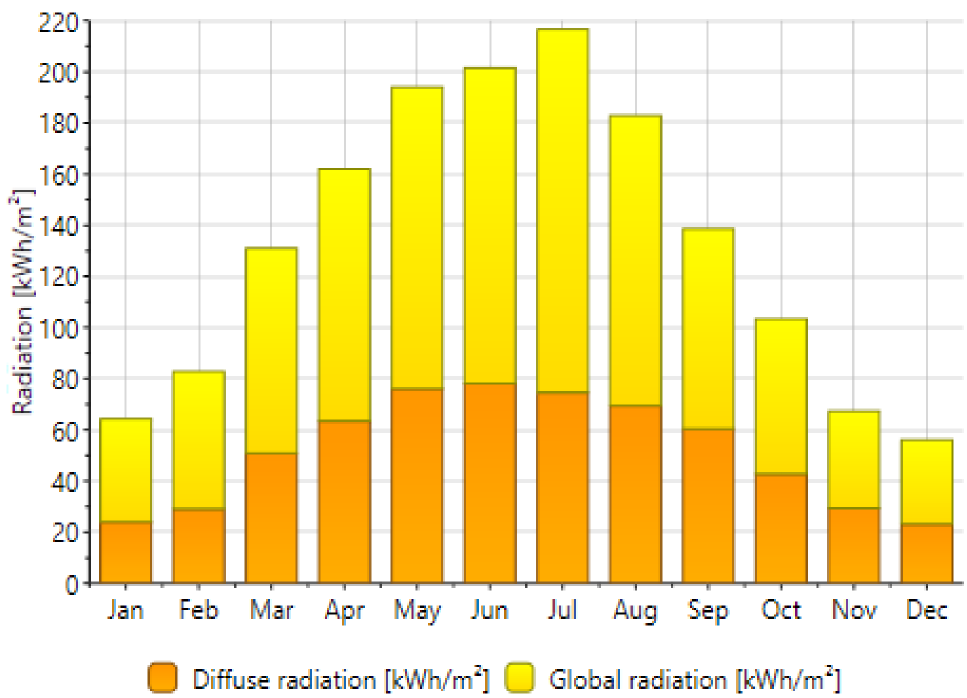


Figure 3.22
Monthly Variation of Radiation in Barcelona

(source: meteonorm)

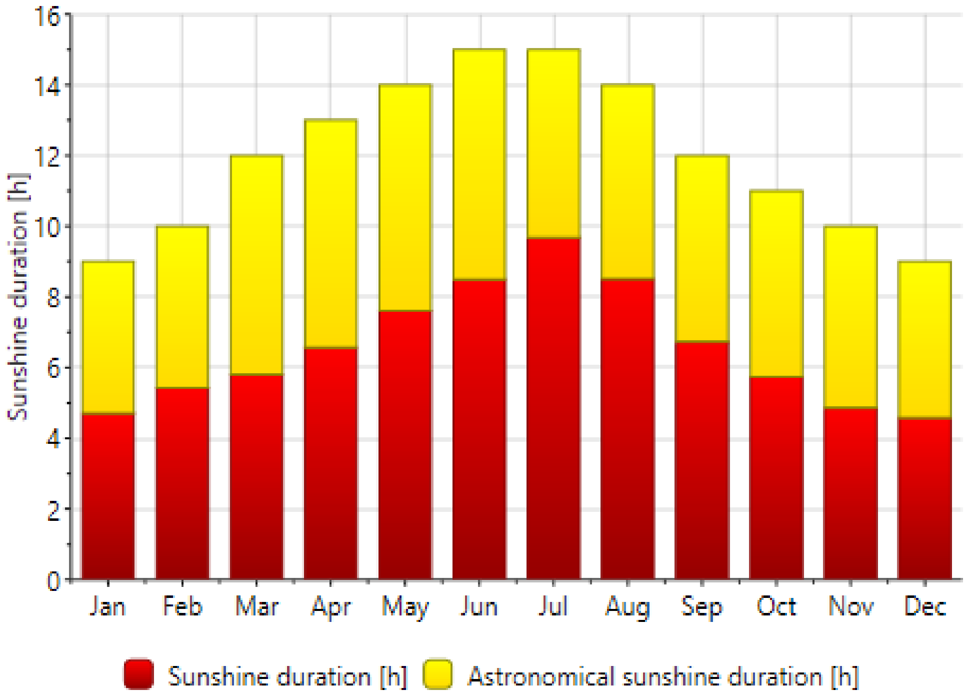
Also the fact that tourists frequently stay late into the night playing music in the squares has an effect on the noise level in the Old Town (Ciutat Vella)

Harmful environmental noise is defined as daytime, evening and night-time noise levels exceeding 65 - 60 - 55 decibels, depending on the source of noise. Over half of Barcelona's population is subjected to noise levels over 65 decibels during the entire day (0800-2200 hours).

Air pollution

The industries in the Besòs area have largely been replaced by service companies, producing a marked drop in atmospheric emissions for the whole area.

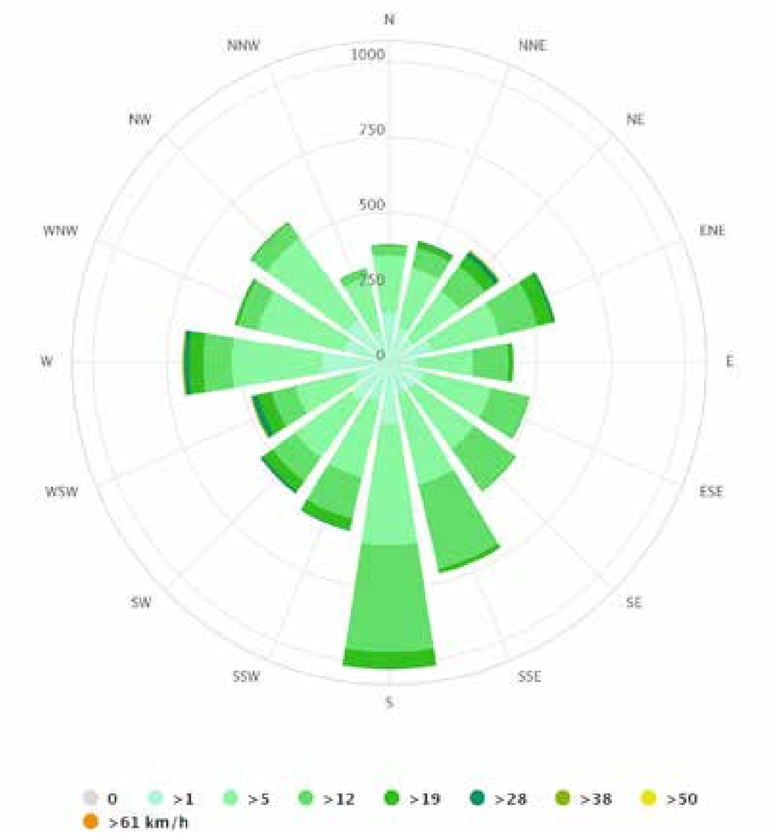
Figure 3.23
Monthly Variation of Sunshine duration in Barcelona
(source: meteonorm)



Nowadays private traffic is the main producer of pollution in the Barcelona Region. The number of private vehicles on the road grows every year. Although older vehicles are being replaced by newer, less polluting ones, the increase in the number of cars on the road has more than offset cleaner combustion. Gas-fired heating systems also cause air pollution.

The main environmental problems associated with air emissions are harm to human health, the acidification and eutrophication of water and soils, and damage to natural ecosystems, buildings and crops.

Figure 3.24
Monthly average wind velocitites in Barcelona
(source: meteoblue.com)



During Barcelona summer period, it is estimated that over 66% of the population are affected by ozone levels higher than 180ug/m3, and that over 66% of the population have been exposed to a NO2 level over 200 um/m3, so above the recommended WHO levels.

Almost three times a year, happens an event of air pollution above the WHO limits. Concerning NO2 levels, this means NO2 > 200 mg/m3 (hourly data), while speaking about PM10 the event occurs with PM10 > 80 mg/m3 in one day or PM10 > 50 mg/m3 for more than three days in a row.

These situations are likely to occur in a specific environmental circumstance, that is an anticyclonic climatic event with absence of wind and precipitations.
To face this problem the ajuntament de Barcelona introduced different measures to reduce the problem, like urban planning guide lines and vehicles restrictions.
Barcelona is also part of the Ambit40, a territory that counts 40 municipalities that have their atmospheric environment under protection, in order to reach step by step a better air quality for the inhabitants.

Also inside Barcelona, the area between Ronda de Dalt and Ronda Litoral, where the pollution is generally higher, is a low-emission zone with specific measures to protect the air quality.

The vehicle classification system DGT aims to recognize the vehicle that respect a good pollutant emission standard. There are 4 categories and the transportations that don't reach such a target, are the one mostly subjected to circulation restrictions during the periods of high air pollution, and they'll also be permanently restricted in the future.

Land based pollution

Industrial sites deposit pollutants on the ground they occupy by leaks from tanks and underground pipes and this causes soil pollution that comes to light when industrial areas are dismantled and given over to other uses.
Another soli pollution problem is due to waste refuse spilling from the bins onto the streets.
When there is torrential rain Sewer system's capacity can be surpassed causing surface flooding and direct discharges to the sea via the overflows. Raw sewage is therefore washed onto the beaches.

Geological collocation

Barcelona is located on the northeast coast of the Iberian Peninsula, facing the Mediterranean Sea, on a plain approximately 5 km wide, limited by the Sea itself to the south-east, the mountain range of Collserola to the north-west, the Llobregat river to the south-west and the Besòs river to the north-east. This plain covers an area of 170 km2, of which around 60% is occupied by the city itself.
Barcelona is peppered with small hills, most of them urbanised, that gave their name to the neighbourhoods built upon them, such as Carmel (267 metres), Putget (181 metres) and Rovira (261 metre). The escarpment of Montjuïc (173 metre), situated to the southeast, overlooks the harbour and is topped by Montjuïc castle.

Hydrology

Fluvial networks of the Barcelona metropolitan region:

River	Basin area (km2)	Annual mean average flow (m3/s)	Minimum flow in a dry year (m3/s)	Maximum flow (m3/s)	Date of maximum flow
Llobregat - Matorell	4 561	20.7	1.69	3 080	21-9-1971
Besos - Montcada	1 032	3.88	1.8	2 345	25-9-1962
Ripoll - Montcada	242	1.19	0.40	1 234	25-5-1962
Tordera - Can Serra	802	5.65	0	1 280	20-9-1971

Floods

Floods and droughts are a common characteristic of Mediterranean water cycles. In the Barcelona region, there have been major floods in 1962 (with possibly 1 000 people dead), 1971, 1988 and 1994. Local flash flooding is becoming increasingly important, especially in the rapidly growing coastal plains north and south of the city. Diffuse inundation after storms with intensities of 200 mm/day or more is also becoming common.

The Government of Catalonia through the Catalan water Agency has elaborated an inundation management plan, Inuncat22, where all the inundation areas corresponding to rivers in Catalonia have been produced. Barcelona is enclosed between the river Llobregat and Besos, so the areas mostly subjected by floods are the one along these rivers. In the site project there are some areas susceptible to inundations by heavy rain, due to the morphology of the Collserola in correspondence to concavities where the water gets collected.

Water shortage

Another Problem in Barcelona is water shortage. In particular in 2005 Barcelona has been effected by the worst drought since last 60 years. After months without adequate rainfall, the reservoir only had a quarter of what it was actually supposed to hold and restrictions on tap water usage were introduced. To face this problem, it was necessary to ship water from Tarragona and Marseille to Barcelona.

Energy in Barcelona

In the metropolitan area of Barcelona there are three main types of energy infrastructures: the electricity grid, infrastructures related to natural gas and those related to oil products. The management of these infrastructures is regulated by the Government of Spain and the Catalan Government, and it is carried out by various companies, such as Red Eléctrica Española, ENAGAS or Compañía Logística de Hidrocarburos (CLH).

3.2.4 Socio-Economic Analysis

Demography

Barcelona is the capital of the autonomous community of Catalonia and is the second largest city in Spain.
The province area consists of 7'733 km2 with a population of 5'540'000 inhabitants, while the Barcelona metropolitan area occupies 4'268 m2 and 5'355'127 citizens and it's the 6th most populous urban area in the European Union.

The municipality of Barcelona has a surface of 101 km2 and 1,7 million inhabitants. The density varies inside the metropolitan area, decreasing towards the periphery. The population density in Barcelona municipality is very high, with 16000 people/km2, the first zone outwards has 3000 p/m2, the second one 1000 p/km2 and the third zone only 300 p/km2.

Also in the case of Barcelona municipality, the land distribution is extremely uneven. Half of the municipality or 50.2 km2, all of it located on the municipal edge is made up of the ten least densely populated neighbourhoods containing less than 10% of the city's population, the uninhabited Zona Franca industrial area and Montjuïc forest park. Leaving the remaining 90% or slightly below 1.5 million inhabitants living on the remaining 52 square kilometres at an average density close to 28,500 inhabitants per square kilometre. But in the Sagrada Familia neighbourhood the density rises even up to 50'000 inhabitants per square meter.

62% of the inhabitants of Barcelona were born in Catalonia, while almost 24% come from other areas of Spain. Over 17% of the residents come from other countries, a percentage that is up significantly from less than 4% in 2001. Most come from Pakistan, Italy, China, Ecuador, Bolivia, and Morocco. Barcelona is home to Spain's largest Jewish community with about 3,500 Jews.

The city of Barcelona's population remains relatively stable as it is already extremely densely populated while the metropolitan area continues to grow steadily. This trend will continue over the next few decades.

Barcelona urban agglomeration's 2017 population is estimated at 5,356,000. In 1950, the population of Barcelona was 1,809,000. In the last year Barcelona has grown by 98'000, which represents a 1.90% change. (data and projections from the UN World Urbanization Prospects)

The project site is located at the boundary of the Barcelona municipality in the Nou Barris district, that has a surface of 8 km2 and around 140000 inhabitants, that makes a density of 17000 inh/km2.

The Nou Barris district had a strong demographic growth during the 20th Century and reaching almost 170000 inhabitants in 1998, then the population decreased by 30000 people in the next six years. In the last years, the population started to increase and became the destination of immigrants, due to the relatively low prices of the apartments. This lead to an ethnic change inside the district and the birth of new multicultural shops. The highest number of immigrants are gitans, Philippines, Pakistanis and Ecuadorians.

Figure 3.25
Age pyramid of Canyelles

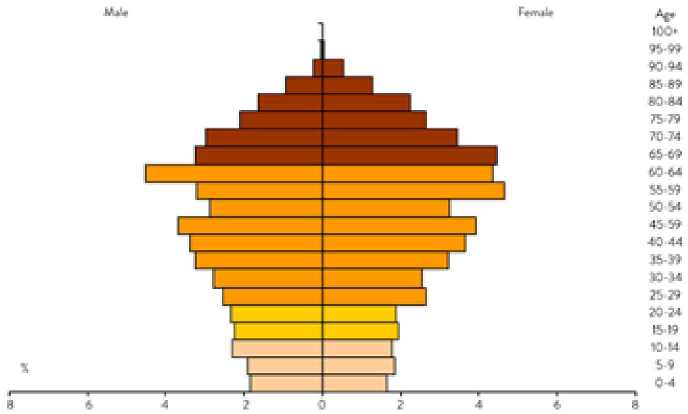
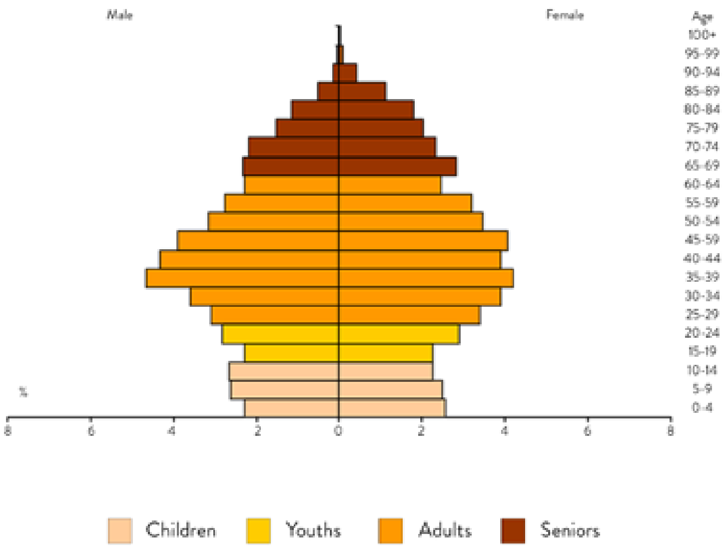


Figure 3.26
Age pyramid of Les Roquetes



“In essence, Nou Barris is a multicultural melting pot” (Walking the city. Barcelona as an urban experience, By Estanislau Roca, Inés Aquilué & Renata Gomes)

It must be noticed that the project will be inside a very multicultural district, where immigrants represent a big part of the population, thus it is important to consider that integration and cultural exchanges need to be valorised and encouraged.

Focusing on the two neighbourhoods that are containing the project area, Canyelles and Les Roquetes, it’s possible to make some considerations regarding the population study looking at the following graphs.

The strangers’ percentage is higher in Les Roquetes, reaching more than 19%, while in Canyelles is only the 4%, even less than in the entire Barcelona. It can be noticed that in Les Roquetes there’s a relevant presence of people from Honduras, that covers almost the 25% of all the strangers in the neighbourhood.

Concerning about people’s age, the two neighbourhoods have a quite different age pyramid, showing that in Canyelles the population is relatively old, with a pyramid that has its larger part in the 55-70 years old range. On the other hand, Les Roquetes has a younger population, that have its peak between 30 and 50 years of age. Also the natality graph confirms this observation, in fact in Les Roquetes the birth rate per 1000 inhabitants is higher than the one of Canyelles and Barcelona. Even if it had a decrease in 2014, it’s now again over 10 births every thousand people.

This means that the two neighbourhoods we're dealing with have a quite different population and therefore different needs. Since the project area will involve both communities, it is important to remember this fact.

Economy

Barcelona is a leading cultural, sports, economic, tourism, arts, science, fashion and commerce centre. It's the fourth most economically powerful city by GDP in the European Union, with $34,821 in per capita terms, 44% more than the EU average and the 35th in the world, and one of the world's most successful city brands.

Furthermore, Barcelona was Europe's fourth best business city and fastest improving European city, with growth improved by 17% per year as of 2009.

Catalonia is one of the richer regions in Europe and the fourth richest region per capita in Spain, with a GDP per capita amounting to €28,400 (16% more than the EU average).

Nou Barris was born from the union of poor buildings edified in the second half of the 20th Century by families coming from all around Spain that were looking for a job in Barcelona, which was facing at that moment a strong industrial growth. Since that time, the district has improved a lot in terms of infrastructures, transportations and quality of spaces. Nowadays Nou Barris is one of the greenest districts in Barcelona and it's still the home of many families.

3.2.5 Urban Mobility

Spatial network analysis for multi-modal urban transport systems

One of the studies the analysis depends on is (SNAMUTS) The Spatial Network Analysis for Multimodal Urban Transport Systems methodology which has been developed as a planning and decision-making support tool. It determines accessibility performance from a user perspective, bearing in mind that different users sometimes have different needs. Some may value speed more than anything else, some may require barrier-free access as their priority, others may be drawn primarily to services that are legible and have a high profile in the urban realm. The SNAMUTS has 8 key indicators: Service intensity, Closeness centrality, Degree centrality, Network coverage,30-minute contour catchments, Betweenness centrality, Network resilience and Nodal connectivity.

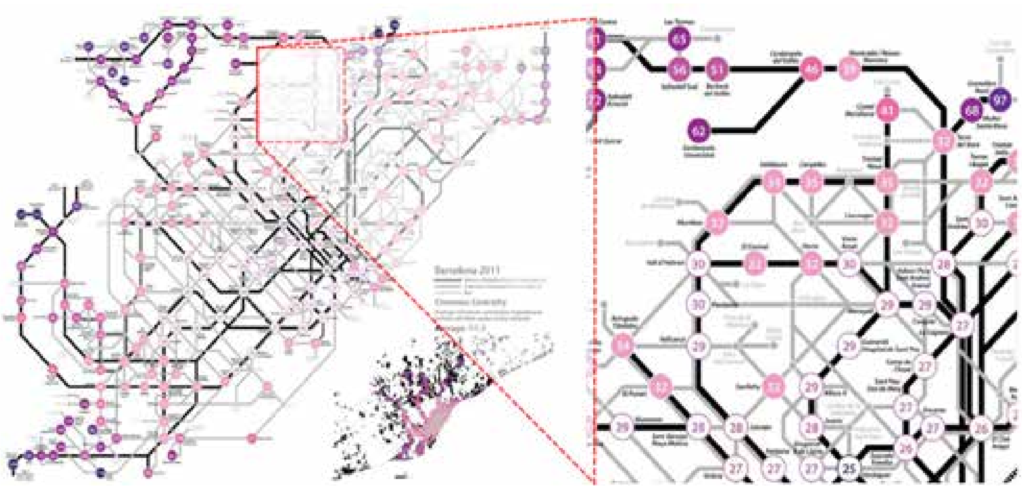


Figure 3.27 Mobility network of Barcelona: closeness centrality

(source: http://www.snamuts.com/barcelona.html)

Closeness centrality: What is the ease of movement between a node and the rest of the network?

It describes the ease of movement along the public transport network, in terms of speed and service frequency. It is a metric network indicator, measuring the minimum cumulative impediment value between each pair of activity nodes in each direction. It makes use of a GIS wayfinding tool which, out of all possible paths between the two nodes, automatically determines the path with lowest impediment while allowing up to three transfers. Closeness centrality is shown as an average across the network and as an average for each activity node. Lower values indicate greater centrality.

Ease of movement: Closeness scores are a spatial separation measure for the activity centre network. They are inflated by dispersed settlement patterns, detours forced by geographical barriers or missing links, slow travel speeds, low service frequencies, or a combination of several of the above.

Network size: Larger networks with a greater number of activity centres will generally produce higher (poorer) average closeness centrality scores than smaller ones. The Closeness centrality value calculated from the Impediment value of route segment between nodes, Travel time between nodes and minutes and Service frequency in departures per hour per direction between nodes (SNAMUTS, 2011)

Per SNAMUTS, the project site connected to the public transportation through the station of Canyelles, that connected to Roquter station by metro and bus lines, and to Virreimat, Llucmajor stations by bus line. Closeness centrality value for

Canyelles is 35 from the average 44.8 for whole Barcelona.

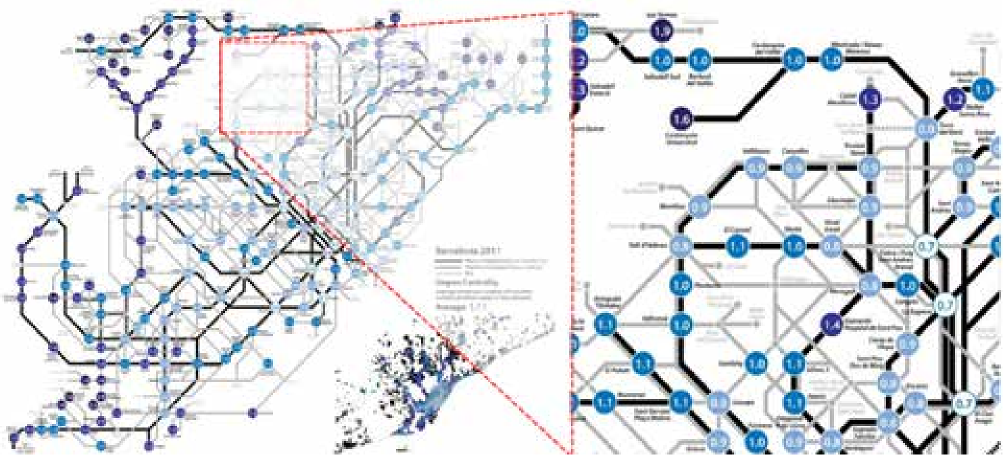


Figure 3.28 Mobility network of Barcelona: degree centrality

(source: http://www.snamuts.com/barcelona.html)

Degree centrality: How many transfers separate a node from the rest of the network?

It describes the directness of journeys along the public transport network. It is a topological network indicator, measuring the minimum number of transfers between each pair of activity nodes. It makes use of the same GIS wayfinding tool as the previous indicator, only here the tool determines the path with the minimum number of transfers, even if this leads to a greater cumulative impediment value. Degree centrality is shown as an average across the network and as an average for each activity node. Lower values indicate greater centrality.

Network organisation Is the public transport network organised around a modal hierarchy with lower-capacity modes acting as feeders and distributors to higher-capacity nodes (greater transfer intensity). According to SNAMUTS studies, Degree centrality value for Canyelles station is 0.9 compared to the average for whole Barcelona which is 1.1 it is consider high and need to be reduced.

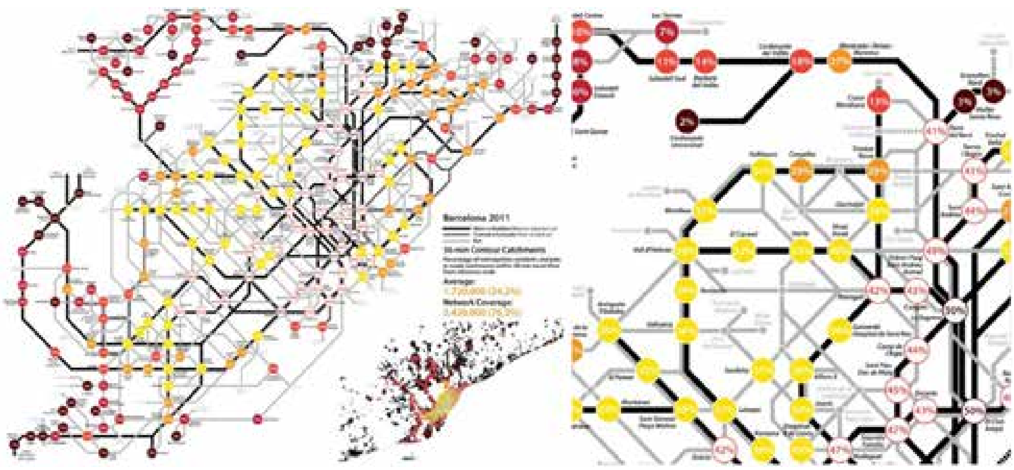


Figure 3.29 Mobility network of Barcelona: 30-minutes contour catchments

(source: http://www.snamuts.com/barcelona.html)

Catchment size of 30-minute travel time contour: How many residents and jobs are accessible within half an hour?

One transfer is allowed within 30 min, but only between services that both run at least every 15 min A flat deduction applies for making the transfer, equivalent to the actual average transfer time across the network (usually between 6 and 8 minutes) Network coverage describes the quantity of people with access to public transport, while the contour catchment measure expands this with a qualitative message (how many people can you access within 30 minutes?) Ideally, a city would score 100%

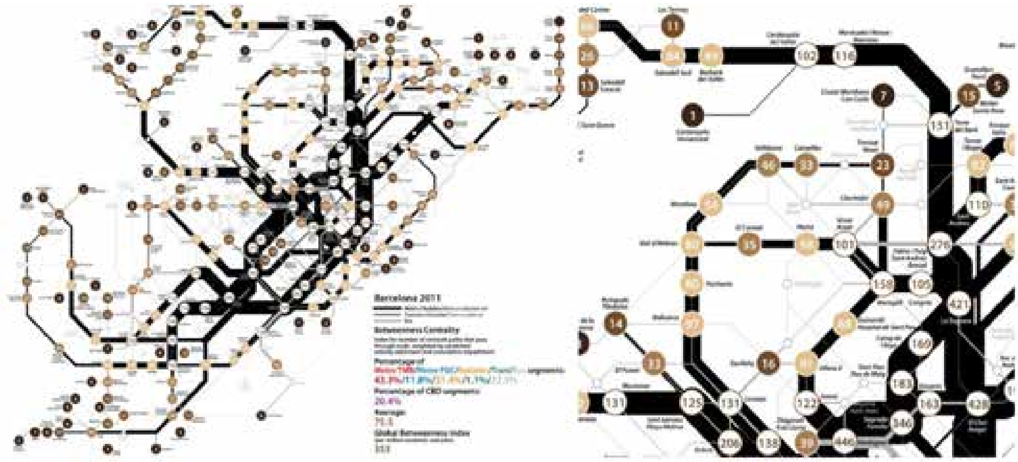
on both counts. What are the barriers in each metropolitan region that currently work against this (or merely separate present conditions from world best practice)? And what are the levers a city has to close these gaps?

Contour catchments measure the combined effect of public transport speed and land use intensity. This index determines the number of residents and jobs within the walkable catchment areas of activity nodes that can be reached within a kerb-to-kerb public transport travel time of up to 30 minutes from the reference node. This indicator is expressed as a percentage of the total number of metropolitan residents and jobs and is shown as an average for each node. Higher values indicate greater accessibility.

Contour catchment measured for Canyelles station is 29% and it is higher than the total average of Barcelona (24.4%)

Figure 3.30 Mobility network of Barcelona: Betweenness centrality

(source: http://www.snamuts.com/barcelona.html)



Betweenness centrality: How are travel opportunities geographically distributed across the network?

Betweenness centrality defines preferred travel paths between each pair of nodes, and counts them at nodes and route segments to determine their strategic significance

Public transport 'movement energy': Betweenness centrality attempts to quantify the presence of public transport opportunities in each centre, and across the metropolitan area, as well as visualise how this presence flows across the network.

Balanced and unbalanced nodes/places, stressed locations and routes: Betweenness can help identify pressures on network elements originating from either their land use or their transport function (or both in conjunction).

Betweenness scores are not necessarily proportional to usage levels, but correlations with usage can point to under- or over-utilised potential for public transport movement.

Betweenness centrality captures the geographical distribution of attractive travel paths between each pair of nodes across the network. It shows concentrations of 'movement energy'generated by the travel opportunities the network provides, or in other words, to what extent an activity node is located 'at the crossroads' of public transport supply. This index is weighted by the catchment size of activity nodes as well as their proximity (travel impediment), following the logic that larger nodes and nodes more accessible to each other generate more travel opportunities between them than smaller nodes and nodes with greater spatial or network separation. The scale of this indicator is arbitrary but is kept constant for easy comparisons with future scenarios or between cities. It is shown for each node as well as aggregately across the network. Higher values indicate greater centrality.

Betweenness Centrality is separated into two separate indicators, Nodal Betweenness and Segmental Betweenness. The only difference between the two indicators is that in the formula below the 'i' in segmental betweenness stands for 'segment' instead of 'node'.

Percentage for CBD segments 33% from the average for the whole city is 20.4%

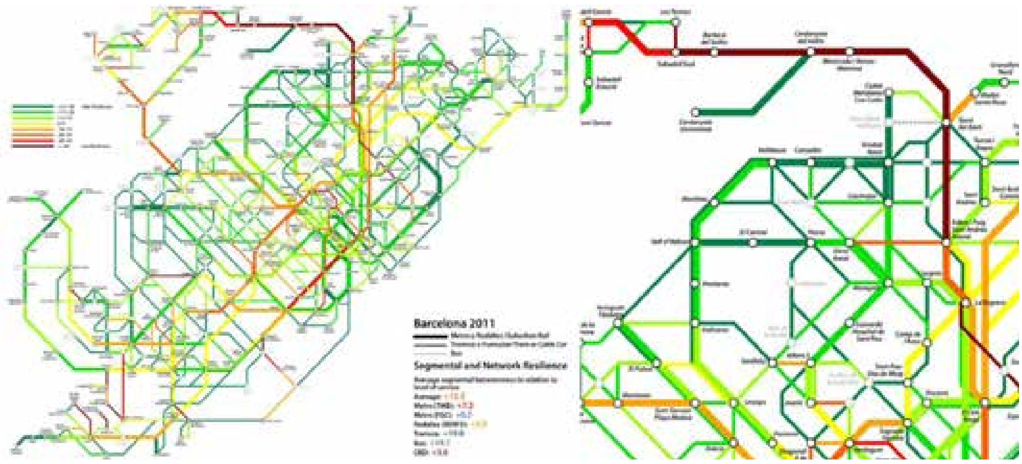


Figure 3.31 Mobility network of Barcelona: segmental and network resilience

(source: http://www.snamuts.com/barcelona.html)

The SNAMUTS resilience measure provides a comparison between the significance of a route segment for the land use-transport system (betweenness) and the level of service provided (capacity). Where the ratio between segmental betweenness and route capacity appears to be well-matched, the network elements can be considered resilient. Where the betweenness score appears to overwhelm the carrying capacity, network elements appear to be under pressure or stress.

Note that such pressures do not necessarily manifest in instances of actual overcrowding of public transport vehicles or interchanges. A poor resilience score on a service with sparse real-life patronage may also be indicative of 'latent demand'. Conversely, a good resilience score on this index is no guarantee that overcrowding will never occur on the segment; for instance, it may derive from travel generators other than residences and workplaces.

Network resilience is visualised on a network map using traffic light colours and a scale where a positive score between 0-30 (green) is considered resilient, a negative score between 0 and -30 (yellow-orange) a cause for concern and a score below -30 (red-maroon) under stress.

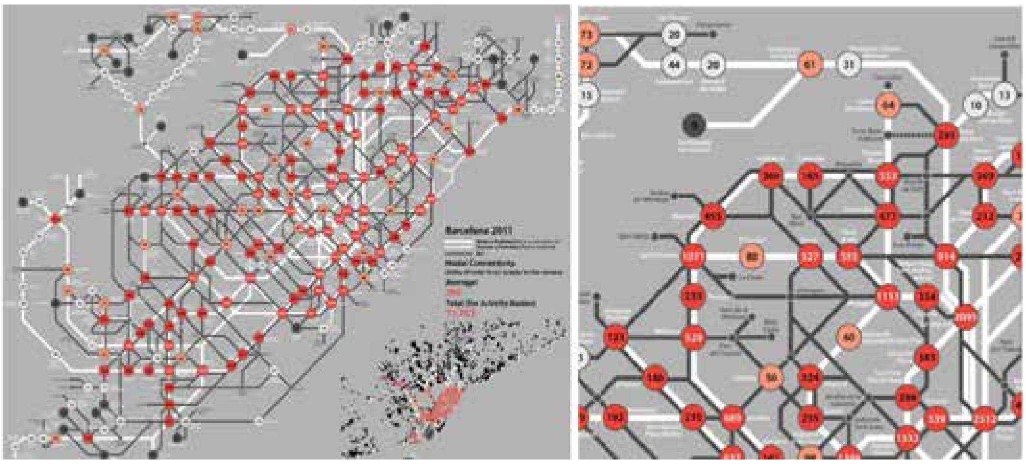


Figure 3.32 Mobility network of Barcelona: nodal connectivity

(source: http://www.snamuts.com/barcelona.html)

Nodal connectivity: How are activity centres placed to act as hubs for the network? Nodal connectivity To what extent do network nodes function as hubs for movement?

The connectivity index measures each node's connectedness to other nodes, and its capacity for making transfers or stopovers.

This index measures the strength of each activity node for integration of multi-modal public transport services, and by extension, the flexibility of users to move around the city on public transport. It captures the suitability of activity nodes for making transfers or breaks of journey with minimal disruption to the flow of movement.

The nodal connectivity index expresses the attractiveness of a place for land use development that depends on good access by public transport, and can also be seen as a proxy for the confidence that can reasonably be exerted by urbanites to build their activities around public transport use, or by businesses around public transport access.

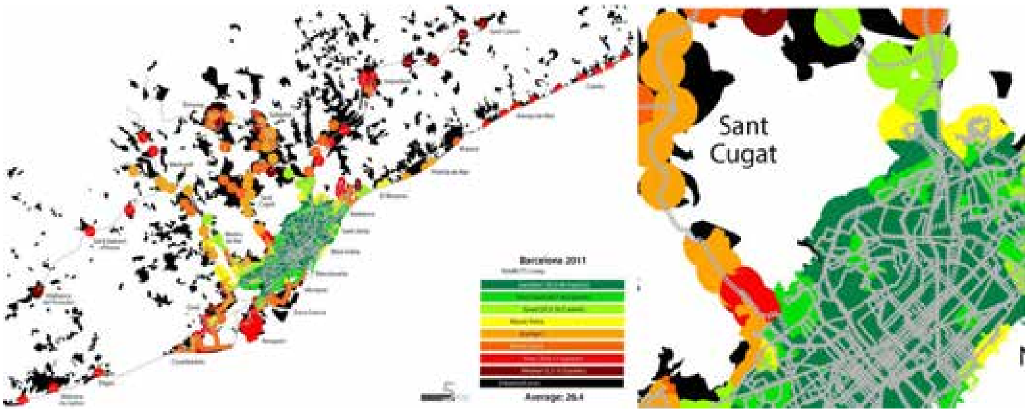


Figure 3.33 Mobility network of Barcelona

(source: http://www.snamuts.com/barcelona.html)

Good, average and poor public transport accessibility on a scale map

The composite index provides an overview of public transport accessibility, combining the results of the closeness centrality, degree centrality, contour catchment, nodal betweenness, nodal resilience and nodal connectivity indicators in a comprehensive visualisation. To calculate it, between 0 and 12 points for each component index are allocated except for the resilience index, which leads to deductions for nodal averages with negative values. Thus, the highest possible composite score for an activity node is 60. The results are further moderated by an international benchmarking coefficient that includes network coverage, global betweenness, average network resilience and a factor for the degree of contiguity of the urbanised area (in partial compensation for the adverse accessibility effects from public transport networks extending across scattered settlements).

The composite index remains cursory, however, because this calculation procedure invariably leads to subjective assumptions regarding how different component indicators are converted and weighted, and how the benchmarking coefficient is constructed. We therefore do not conceive of the composite index as a precise numerical instrument of inter-city comparison and for the same reason, refrain from presenting it as a network diagram with individual nodal values like the component indicators. Rather, we produce a scale map with nodal catchment areas shaded in traffic light colours according to performance brackets, and use it primarily as a visualisation tool to draw generalised conclusions and to engage with stakeholders in debates about public transport accessibility.

3.2.6 Ecological Analysis

Figure 3.34 Las Ramblas, Barcelona

(source: http://www.obrabcn.cat/)

Biodiversity

Barcelona is home to the following natural heritage:

- Collserola: 1,795 ha in the municipal district with more than 8,000 ha in total.
- Two rivers and the sea forming its borders.
- 1,076 ha of public parks and gardens, 30 ha of beaches, 30 ha of crops and 740 ha of private greenery.
- Montjuïc, Els Tres Turons and Parc de la Ciutadella are its main natural strengths. 53 local listed areas of natural interest.
- Constructed space serving as a habitat for fauna.
- Plant heritage with exotic and native species in the parks and gardens with nigh on 77,000 trees (excluding forest areas).
- 153,000 street trees from 150 species.
- Aquatic flora and fauna in naturalised ponds.
- 103 native species of vertebrates in the city centre.
- 75 native species of common birds in the city centre.
- Barcelona's birdlife: swifts and other birds, as well as bats.

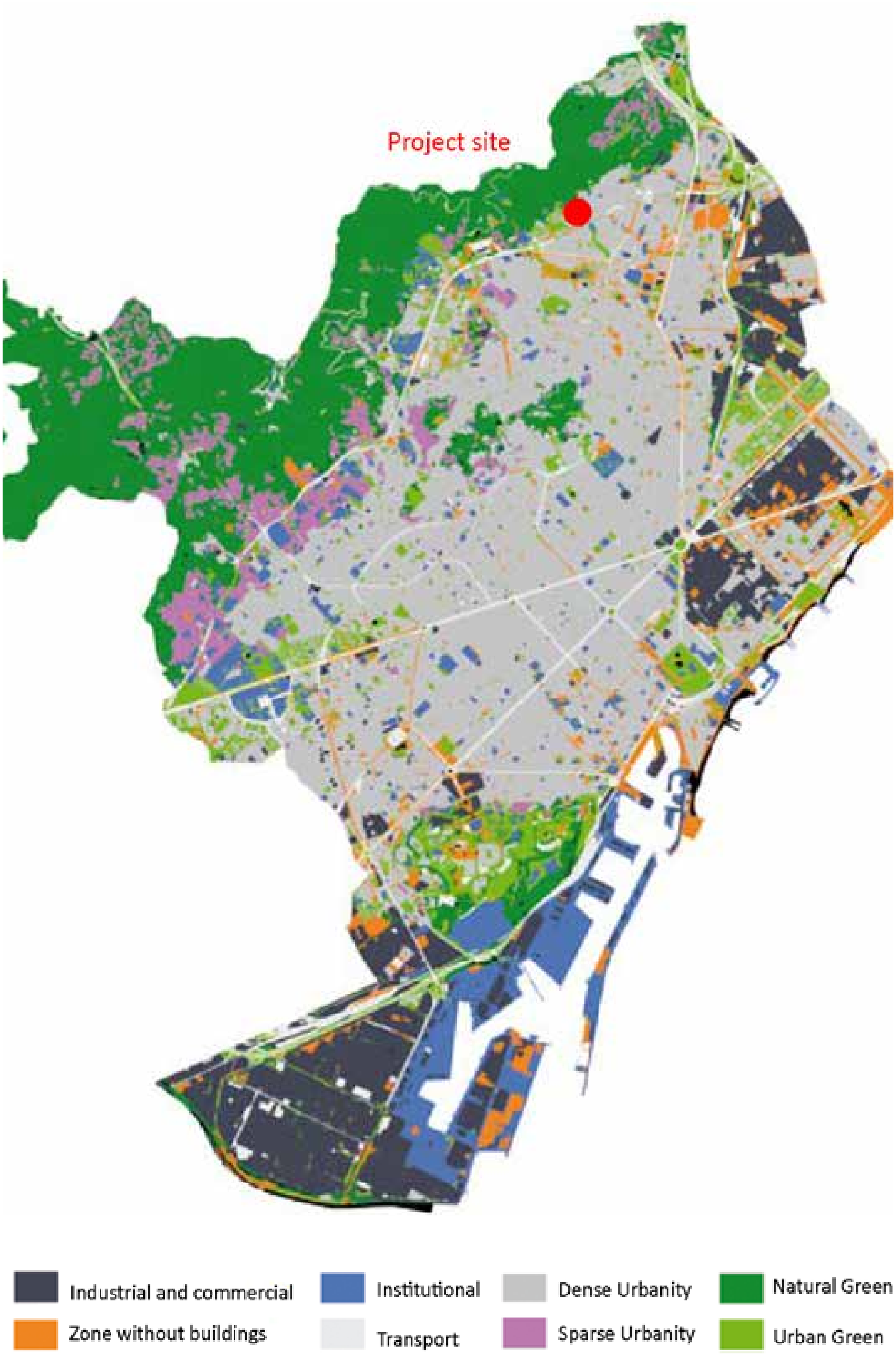
- Migratory birds.
- Key vertebrates: falcon, jackdaw, heron, alpine swift, squirrel, hedgehog, owl, amphibians, etc.

Formally recognised values of Barcelona:

- Collserola incorporated into the Natura 2000 network and recognised as a nature park.
- Three kinds of habitats designated as needing preservation in the EU Habitats Directive from 1992: holm-oak forests, pine forests and dry grasslands.
- Cliffs of Montjuïc included in the Inventory of Areas of Geological Interest of the Government of Catalonia with initial approval as a protected natural open space.
- 72 vertebrates protected by law in the city: 55 birds, 2 amphibians, 8 reptiles and 7 mammals.
- 138 trees in the Listing of Trees of Local Interest in Barcelona.

Figure 3.35 Ecological Map of Barcelona issued by CREAf and Barcelona Ciy Council in 2006

(source: http://www.creaf.uab.es/Global-Ecology/index.htm)



Natural green	Bosque	Encinar
		Robledal
		Pine grove
	Denuded soil forestall	Pine grove
		Plantation of non native conifers
		Plantation of bananas
	Matorral	Matorral
	Vegetation on banks	Vegetation on banks
	Prado	Prado
Natural zone without vegetation	Roquedo or denuded soil forestall	Roquedo
		Denuded soil forestall
	Cauce natural	Cauce natural
	Playa	Playa
Natural water	Municipal maritime area	Natural pond
		River
	Waters continentals	Municipal maritime area
Cultivation	Cultivation	Herbaceous crop
		Woody crop(not vine)
		Vine
		Greenhouse
Abandoned Cultiv.	Abandoned Cultivation	Abandoned Cultivation
Urban green	Green zone	Park, garden
		Other green areas
	Sports Zone	Sports Zone
Urban Water	Pool, raft, artificial pond	Pool Raft
		Artificial pond
Urbanized fabric	Housing 1-2 families with orchard or small garden	Housing 1-2 families with orchard or small garden
	Housing 1-2 families with large garden	Housing 1-2 families with large garden
	Large property with isolated buildings	Large property with isolated buildings
Dense urbanity/densified usage	Building with various plants and gardens	Building with various plants and gardens
	Densely built with green spaces	Densely built with green spaces
	Densely built without green spaces	Old Town
		Ensanche
		Other densely built houses
		Large set of high-rise buildings
		Skyscrapers
	Industry, workshop, warehouse	Industry, workshop, warehouse
	Port Area	Port Area
	Shopping area	Shopping area

Figure 3.36 Ecological Classification key (highlighted categories are foun d in project site)

(source: http://www.creaf.uab.es/Global-Ecology/index.htm)

Dense urbanity/densified usage	Building for public use	Mercato	
		Education Center	
		Hospital	
		Sports Zone	
		Land or sea passenger station	
		Prison	
		Monumental building	
		Cemetery	
		Military Barracks	
Zone of intese use without building	Parking and Garage	Parking and Garage	
	Main Road	Motorway	
		Roads	
		Main Urban Road	
	Pedestrian Area	Pedestrian Area	
	Railway Zone	Railway Zone	
	Landfill	Landfill	
	Mining extraction zone (quarries)	Mining extraction zone (quarries)	
	Zone without building or in transformation	Zone in transformation	
		Building with PVC	

The mentioned ecological categories cover all the area of Barcelona. However, our project site has its specific characteristics that we highlighted in the figure below. The map shows that the dominant natural green areas have: Robledal, Matorral, And Prado, and urban green constitutes parks and gardens(will be specified later). The other built zones are classified: urbanity with urban green, and densely built with green, in addition to 'highly dense urbanity'

Figure 3.37 Ecological map of Canyelles

(source: http://www.creaf.uab.es/Global-Ecology/index.htm)

The plant and animal species found in Barcelona can be spotted as followed:

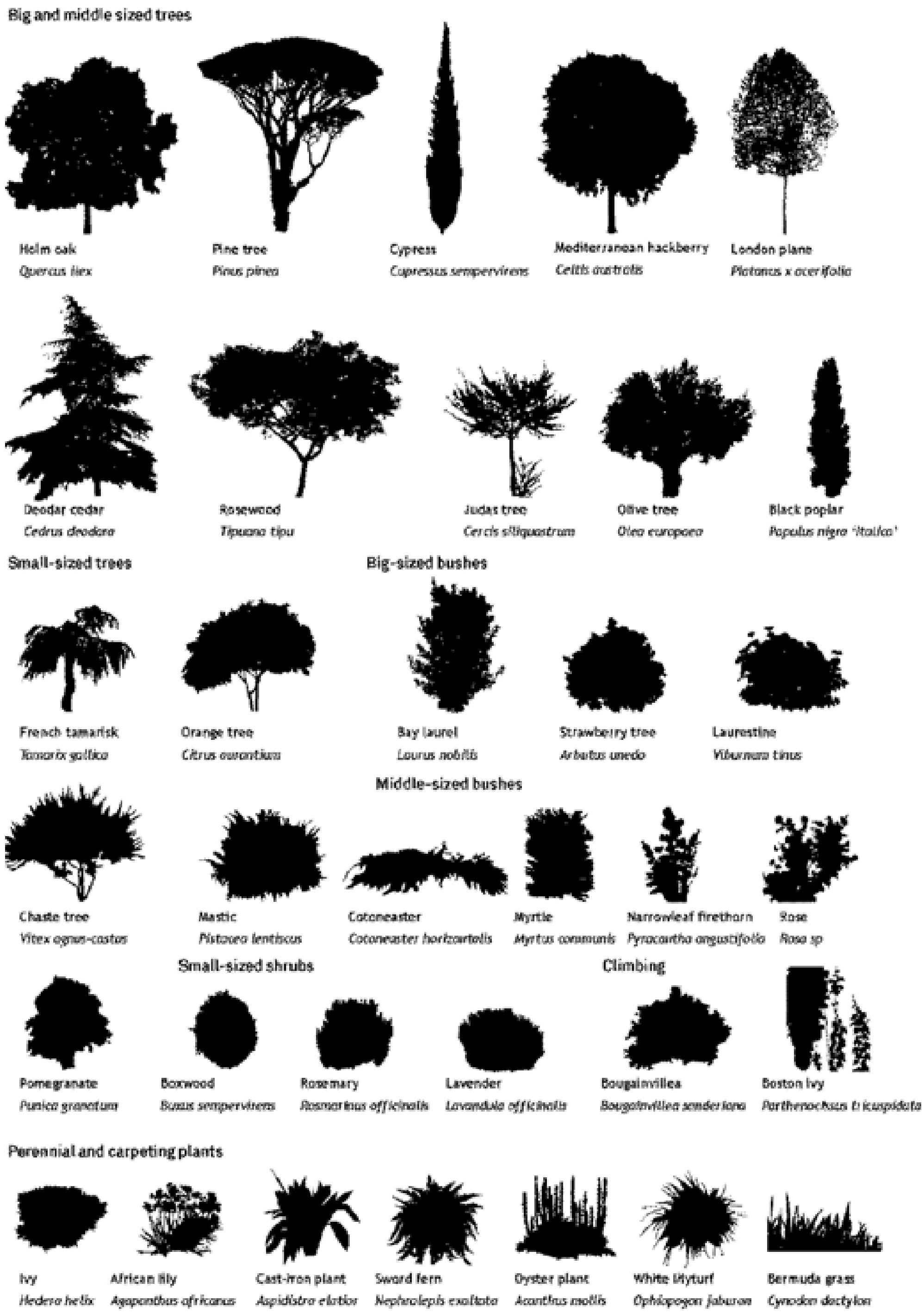


Figure 3.38 Variety of Plant species in Barcelona

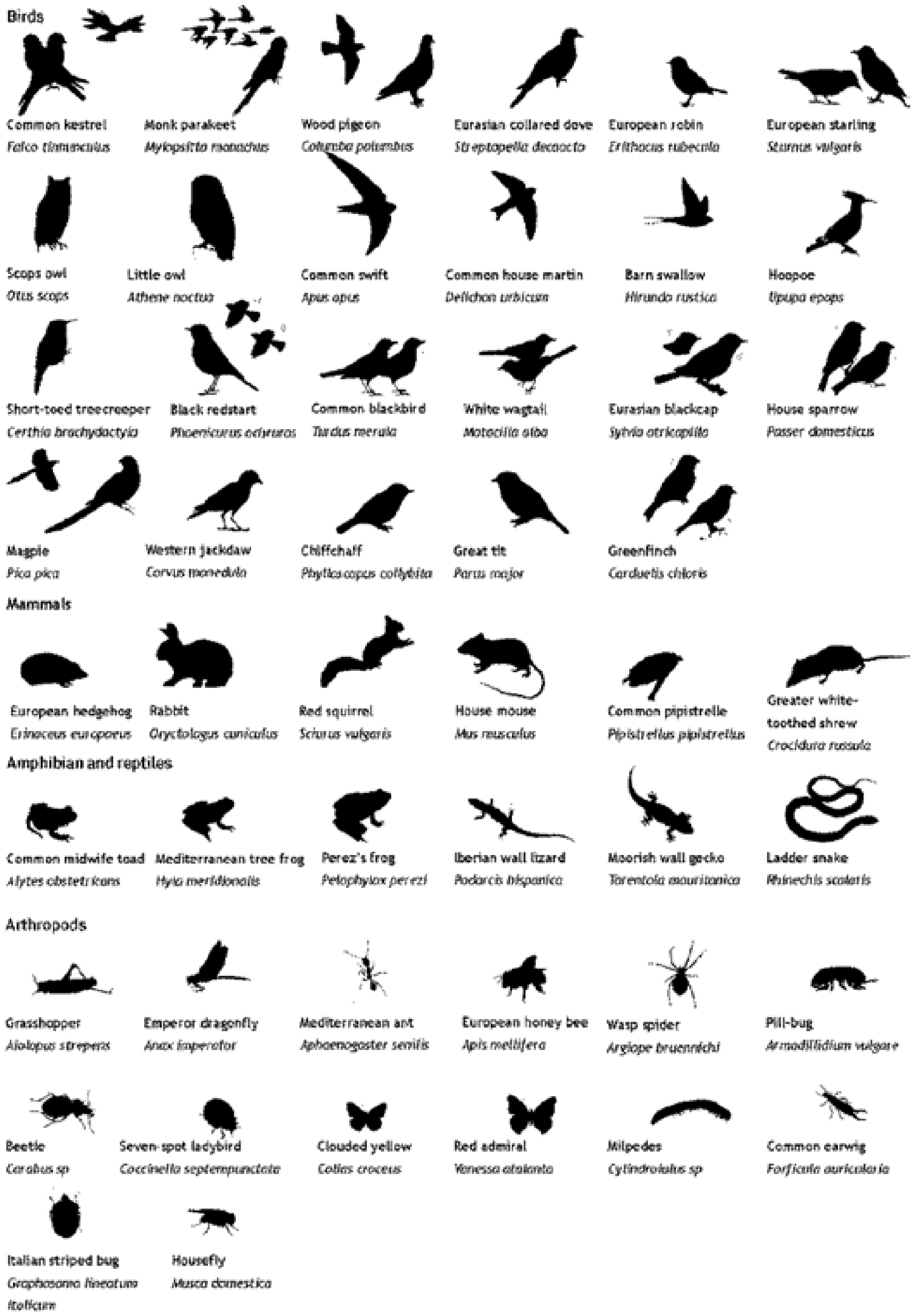
(source: Barcelona green infrastructure and biodiversity plan 2020)

The green center of Barcelona consists of 1,419,823 trees (which corresponds to 194,340 trees planted in the streets and squares of the city), covering 2535 hectares (25.20% of the area of Barcelona including Collserola). The species composition obtained from the fieldwork is 35 138 species of trees and shrubs. Trees with a DBH (diameter of the trunk at 1:35 m) less than 23 cm constitute 70.6% of the population. The four most common species are: Quercus ilex (22.1%), Pinus halepensis (20.5%), Platanus x acerifolia (6.6%) and Pinus pinea (4.9%). You can find more information about the species and number of trees in each Appendix X.

Among the different uses of land, the largest tree densities are within the categories of natural Green (377 trees / ha), Urban green (264 trees / ha) and Built lax (205 trees / ha), as shown in Figure 4. This last category corresponds to one or two families houses with garden or orchard and usually found in the upper part of Barcelona or in residential developments located in Collserola with a garden plot or very often similar to that found in natural green. The land use categories Area undeveloped heavy use (relevant for most pedestrian areas), followed by transport Built dense, owe their tree density (87, 61 and 55 trees / ha respectively) for street trees, present in most of the sidewalks of Barcelona.

Figure 3.39 Variety of Animal species in Barcelona

(source: Barcelona green infrastructure and biodiversity plan 2020)



Much of the tree population (48%) is in the category of diameter between 2.5 and 15 cm, followed by the diameter of 15.1 to 30 cm (38.1%) and 30.1 45 cm (10%).

Industrial land use is presented more saplings and therefore small diameter, while Institutional, followed by Transport and undeveloped area of intense use, have higher proportions of individuals of large diameter.

The data collected in conducting this study on vegetation of Barcelona come from a stratified random sample of 579 plots randomly distributed between different land uses in the city. The results obtained in these plots, which have a combined total of 23 sampled must have been extrapolated to 10,121 are forming the total area of the municipality of Barcelona.

The urban forest covers 25.20% of the entire study area and has 1,419,823 trees (approximately 14% of these are road). Platanus x acerifolia, Pinus halepensis and Quercus ilex, are the dominant species, accounting for 49.2% of all trees, 50.6% of the tree leaf area and 43.1% of total tree biomass. If there was a disease, parasite or pathogen, or some other process that adversely affect one of these species, the green of Barcelona would be seriously affected. Therefore, we consider this as a weakness of the system.

The most common tree in urbanized areas inside the city, namely in the categories Built dense, heavy use area undeveloped and Transport, is Platanus x acerifolia. Its population consists mostly of trees ranging between 15.3 and 38.1 cm in diameter, the higher value of the average is between 7.7 and 15.2 cm.

Overall, the trees of Barcelona are quite young (70.7% of individuals have less than 23 cm in diameter) and young trees that comprises 122 species, 148 species of trees that exist in the whole territory. This not only will provide in the future a greater variety of mature trees, which are currently young trees that increase the Shannon-Wiener index (3.27, a value that can be considered high), but increase the woodland cover in the city.

However, as we have seen in the results, the categories of urban Green, Built dense and intense use undeveloped area, are those individuals most exotic species, including some of these species are naturalized, but other species are presented as invasive, and they are often very large and reproductive offspring that can compete and displace the native flora. These species are Acacia dealbata, Elaeagnus angustifolia, Eriobotrya japonica, Eucalyptus camaldulensis, Eucalyptus globulus, Gleditsia triacanthos, Parkinsonia aculeata, Schinus molle and Ulex parviflorus and Ailanthus altissima, Opuntia ficus-indica and Robinia pseudoacacia.

Green infrastructure

Types of spaces that make up the city's green network:

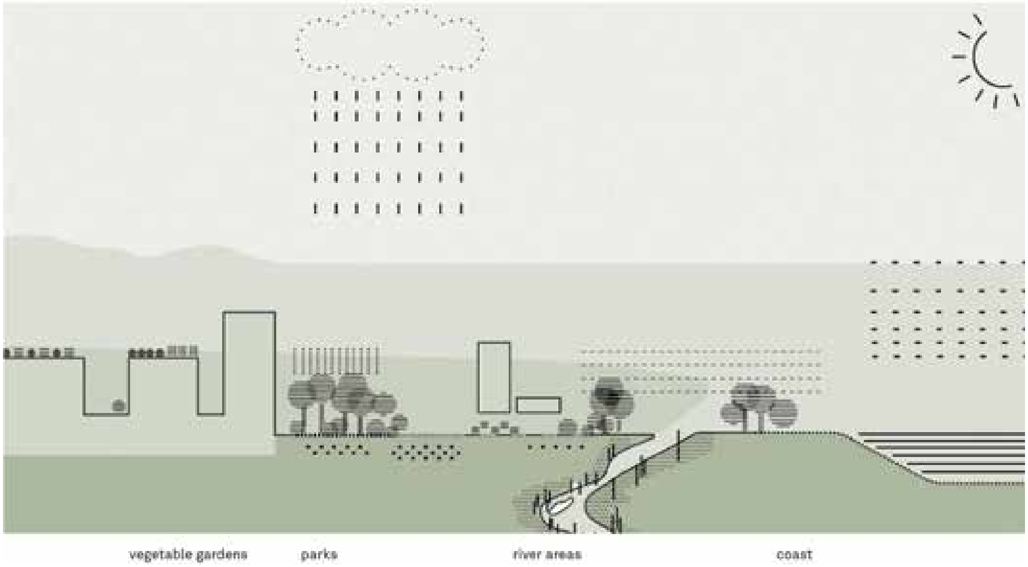
Natural open spaces, river areas, forests, parks, gardens, squares, vegetable gardens, tree-lined streets, street greenery, ponds, roofs and walls.

Two instruments define the basis to achieve the model green city:

- Urban green corridors, to constitute a real, robust and functional network of green infrastructure.
- Opportunity areas, of varying kinds and sizes ranging from unoccupied plots to green roofs and balconies which can be identified in all neighbourhoods in Barcelona and are likely to be subject to re-naturalisation and revitalisation.

Figure 3.40 Types of green infrastructure elements found currently in Barcelona

(source: Barcelona green infrastructure and biodiversity plan 2020)



64% of the land of Barcelona is impermeable materials such as asphalt, cement and others, being the remaining 36% mainly soil with woody vegetation, pastures and lawns, and in low proportion, water ponds or artificial lakes. The proportion of impermeable material would be much higher if the report had not included the area of Collserola, which occupies an area of 1795 ha. The plant has space for only 3.6% of the total area. But even the little open space that is permeable in the city, this figure corresponds to more than 200 thousand new trees could be planted to reach Barcelona, i.e. , twice as street trees we currently have.

Thus, the Urban Green of Barcelona could increase:

- Compared to other cities, coating tree of Barcelona is already very important: 25.2% compared to 21.2% of Boston, or 21% of Oakland, cities with a number of trees similar to Barcelona (1,183,000 and 1,590,000 respectively). Now these results in Barcelona, which seem high, if not in this study would not have been included in the Collserola belonging to the municipality, as announced earlier.

- Another possibility to enhance the green, although very little used in Barcelona but which are already experienced in other cities, involves the creation of plant walls and facades, dividing walls and green roofs. Promoting this kind of green, achieved a greater presence of vegetation within the dense urban areas. There are companies that can provide solutions that naturally must be adapted to the specific conditions of Barcelona regarding water balance, salinity in coastal areas, etc.

This type of construction not only beautify the city, but also:

- actively participate in direct benefits such as prolonging the life of the roof; act as a sound barrier;
- improve the climate of the building
- reduce heat loss and energy consumption in winter; but also reduce the heat island effect in the city
- regulate temperatures and consequently also the energy cost; as well as offering a capacity of leisure (cultivating fruits, vegetables, flowers ...).
- In addition to these benefits, offer other environmental services of great importance, such as filtering pollutants;
- reduce the risk of flooding in the city, thanks to the interception of the water and plant cover;
- provide more habitats and consequently more biodiversity, etc.

Figure 3.41
The urban green integrated in the city fabric patterns
(source: Barcelona green infrastructure and biodiversity plan 2020)

There are technical difficulties. The most important thing is that in a country with long droughts, maintenance can be provided only with the rainwater. An appropriate choice of species must be accompanied by structures that would maximize precipitation and, in some cases, non-drinking water channelled.

The present gardens have a high plant biodiversity, as each tree or shrub can in principle be different neighbour. However, diversity is not functional, i.e., like a museum. Such complex plants do not have high levels of interaction, and therefore are not true ecosystems. In general, the gardens have little value as functional systems which may cause significant ecological processes. Its main function is another, more aesthetic and recreational. However, the gardens can provide shelter, food or be of a scale step for different species of birds, insects or other, thus increasing animal diversity associated vegetation.

Figure 3.42 Distribution of public green spaces by district(Nou Barris highlighted)

(source: Barcelona green infrastructure and biodiversity plan 2020)

1. Ciutat Vella	63.32	-	63.32
2. Eixample	49.47	-	49.47
3. Sants-Montjuïc	300.29	-	300.29
4. Les Corts	73.2	41	114.2
5. Sarrià-Sant Gervasi	95.04	1,171	1,266.04
6. Gràcia	38.87	-	38.87
7. Horta-Guinardó	122.27	409	531.27
8. Nou Barris	112.18	175	287.18
9. Sant Andreu	55.02	-	55.02
10. Sant Martí	167.07	-	167.07
Total	**1,076.74 ha**	**1,795 ha**	**2,871.74 ha**

District	Public green area per inhabitant in m² (1)	Total public green area per inhabitant in m² (2)
1. Ciutat Vella	5.89	5.89
2. Eixample	1.85	1.85
3. Sants-Montjuïc	16.46	16.46
4. Les Corts	8.82	13.77
5. Sarrià-Sant Gervasi	6.6	87.97
6. Gràcia	3.15	3.15
7. Horta-Guinardó	7.14	31.03
8. Nou Barris	6.67	17.07
9. Sant Andreu	3.75	3.75
10. Sant Martí	7.3	7.3

But the parks and urban forests in Barcelona are often too small to maintain a varied flora and fauna in themselves. Therefore, the increase of urban green spaces, offer a variety of habitats and have a large number of ecological niches that could be occupied by many different species and thus would increase biodiversity. But to have a high diversity of plants and species in the city, the connections between the green spaces inside Barcelona and ecosystems that surround the city should not be interrupted, so, and as said, should promote green corridors and rings also use the space to plant.

In conclusion, Barcelona has features of compact, with low density Urban green, similar to other major cities in the world but has a periphery wooded important is still in the town, which highlights the importance of the Collserola Park in whole territory and opportunities to enjoy nature and biodiversity conservation, which advises the utmost care to protect this unique nature reserve in an urban network so immediately. What is proposed here is to increase the green inside the compact, integrated spaces that make the urban environment and infrastructure, especially transport routes and block interior, permeable plants and consequently the animals. This would ensure public access to the enjoyment of the vegetation within a widely asphalted city.

Urban Green Corridors

Speaking about a clear definition we can say that a green corridor in the city is a continuous strip of vegetation dominant presence and exclusively, or at least priority to pedestrians and bicycles crossing the urban parks and connects urban ecosystems and the environment. The urban green corridors play a strategic role in environmental health and social cities face a more sustainable future. Symbolize continuity solution with nature, free and fluid, preferably for use by pedestrians, it provides better conditions biodiversity and habitat and reduces maintenance costs.

The study of Green Corridors Definition of Barcelona was commissioned by Barcelona City Council's Urban Ecology Agency under the Agreement Towards Sustainability, Agenda 21 of Barcelona.

First, it was needed to establish lines of action to improve the connections between the green spaces and urban peripheral areas, through green corridors and walkways. The aim of the study is the definition of green belt in Barcelona to create a network of quality public spaces, the possible large green spaces that link the city to the lines the coast and the mountains of Collserola and the rivers.

Figure 3.43 Green Corridors over the metropolitan area of Barcelona

(source: Barcelona green infrastructure and biodiversity plan 2020)

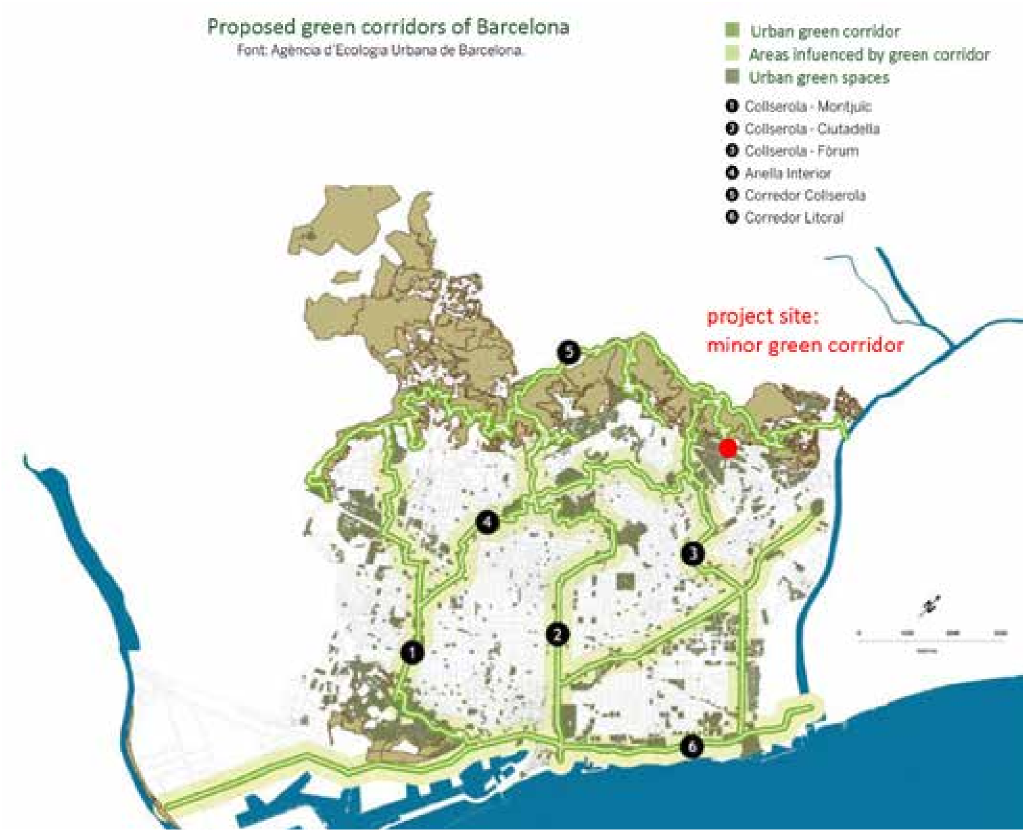
The proposed urban green corridor is made on the basis of Barcelona requirements for connectivity of green areas (soil permeability, linear continuity, species richness, etc.) and green connection possibilities in height (street trees and green roofs) from the structure of the different urban areas and its interrelationship with mobility networks (private vehicle public transport, bicycle and pedestrian).The goal is to bring nature in the city for the enjoyment of its citizens, social requirements are taken into account (public transport accessibility, proximity to the priority areas for pedestrian, bicycle network connection, etc.)

Using geographic information systems (GIS), it is possible to analyse the various parameters that make up the urban fabric and determine the degree feasibility of transforming the road space (length and section of street, building, green spaces, private green, soil permeability, accessibility, equipment, public transport, cycle paths, etc.).

According to this diagnosis, urban green corridors were drawn to form a network with three axes (Collserola Montjuïc, Ciutadella-Collserola Collserola-Forum) connected by three more axes (the inner ring, the coastal corridor and the corridor representing the natural park of Collserola). The corridor Ciutadella-Collserola identified as the first to be implemented to connect different natural areas of the city, now isolated, facilitating, thus the displacement of the fauna and flora of the park between Ciutadella Park and the Collserola connection with a sea-mountain tour friendly for citizens. The following maps illustrate the proposed different routes in the city of Barcelona. Observed as functional continuity, green areas become urban parentheses creating a layer continuous vegetation making use of existing parks, street trees and potential greening of the major streets and avenues which should reduce traffic passing motor.

Figure 3.44 Minor and Major Green Corridors in the city of Barcelona

(source: Barcelona green infrastructure and biodiversity plan 2020)



Design criteria for green corridors:

The design criteria and methodological tools represent strategic solutions to design urban green corridors in Barcelona. Just as an urban planning that incorporates the complexity of the processes regulate the natural elements can overcome the conception isolated green healthy and physically transform the urban environment. There are 12 detailed criteria to be taken into account in the design of Barcelona urban green corridors.

Objective criteria of green corridors:

- Create continuous ecological connectivity
- Create wealth stratified layers of vegetables
- Being naturalized nature in the city
- Biodiverse accommodate diversity of plant and animal species
- Regulatory Maximize urban comfort
- To reflect the dynamic evolution of nature and its cycles
- Create attractive landscapes and perceptual identity
- Provide silence Pacific City
- Welcoming complex urban social diversity
- Create healthy therapeutic areas
- Outreach generate interest in nature
- Increasing the unique natural and cultural heritage value of the city

The urban green corridor is wide enough to generate continuous connectivity ecological city overcome barriers (roads, walls, streets, lots, walls, etc.) and avoid isolation and fragmentation of green spots. In addition, the larger these green areas are, the higher the number of species that can endure. The continuity is obtained by connecting urban and peri-urban spaces through open spaces (squares, parks, gardens, patios inner courtyard, gardens or urban areas abandoned and covered by spontaneous vegetation), street trees and vegetation, existing roofs, terraces and balconies areas. The establishment of this network provides habitat, food and shelter for the life of the flora and fauna adapted to urban areas.

Figure 3.45 Minor and Major-Green Corridors in the city of Barcelon with the green network showing their functionality

(source: Barcelona green infrastructure and biodiversity plan 2020)

The urban green belt comprises a series of layers in the vertical dimension. A coating plant with the presence of three layers (The tree, shrub and herbaceous) develops a role in maintaining ecological corridors. The layers of vegetation green roof acts as a permeable space to provide natural shelter for species. T

The green corridor is an area where the imitation of nature becomes progressively the urbanized areas and encourages the establishment of new communities habitats The use of permeable paving and the creation of water reservoirs or zones wet or semi-drainage areas can increase the effectiveness of infiltration water aquifers, surface evaporation and humidity, reduce the degree of soil compaction.

The urban green corridor encompasses a wealth of plant species that favours the presence and maintenance of wildlife. For example, old trees are particularly interesting for wildlife.

More diversity of habitats helps create robust and complex food webs and ecosystems. It also improves comfort and generates urban heritage value. The diversification of species, in turn, helps to withstand any pests or extreme climate.

Figure 3.46
The projet site showing the green corridor

Figure 3.47
The projet site showing the green corridor's connection to Collserola

The plants can be native or non-native, but must be adapted to urban conditions. Adapted native species are very interesting because they can create ecosystems similar to natural capital of the country, with the relationships between the characteristics of species of flora and fauna.

For each runner must seek the species better adapted to the climate and urban conditions. Adaptability refers to the ability of an organism to adapt to biotic and abiotic environmental conditions and depends on their own

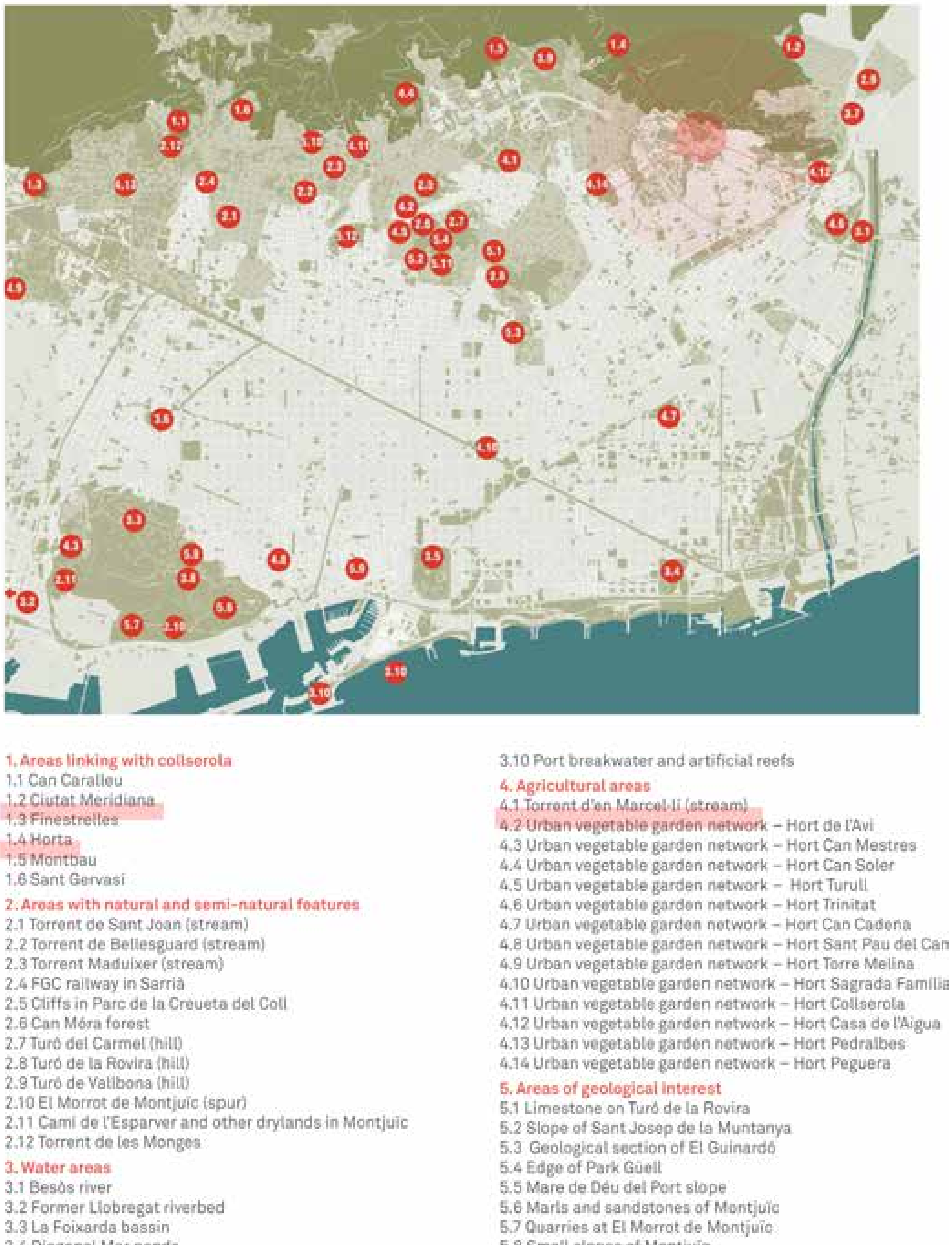


Figure 3.48
The project site in the map of natural green interest points of Barcelona
(source: Barcelona green infrastructure and biodiversity plan 2020)

Summary:

The environmental services of urban green
- Reduce air pollution
- Reduce CO2 emissions with greenhouse
- Attenuate noise pollution
- Rebalance the water cycle
- Regular microclimate
- Save energy
- Create horizontal and vertical connectivity
- Attracting biodiversity

Social services of urban green

- Improving the mobility of pedestrians and cyclists

- Foster relationships, socialization and participation
- Providing entertainment and recreation
- Generate physical and mental well being
- Improve knowledge of nature in the city

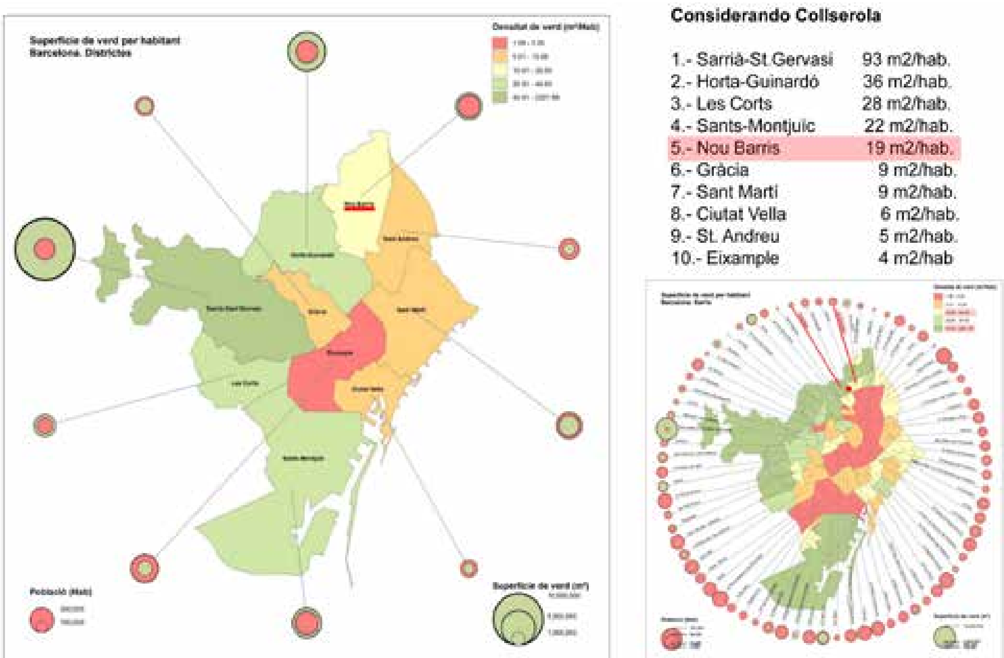


Figure 3.49 Share of inhabitant of the green areas by district(project site indicated)

(source: Barcelona green infrastructure and biodiversity plan 2020)

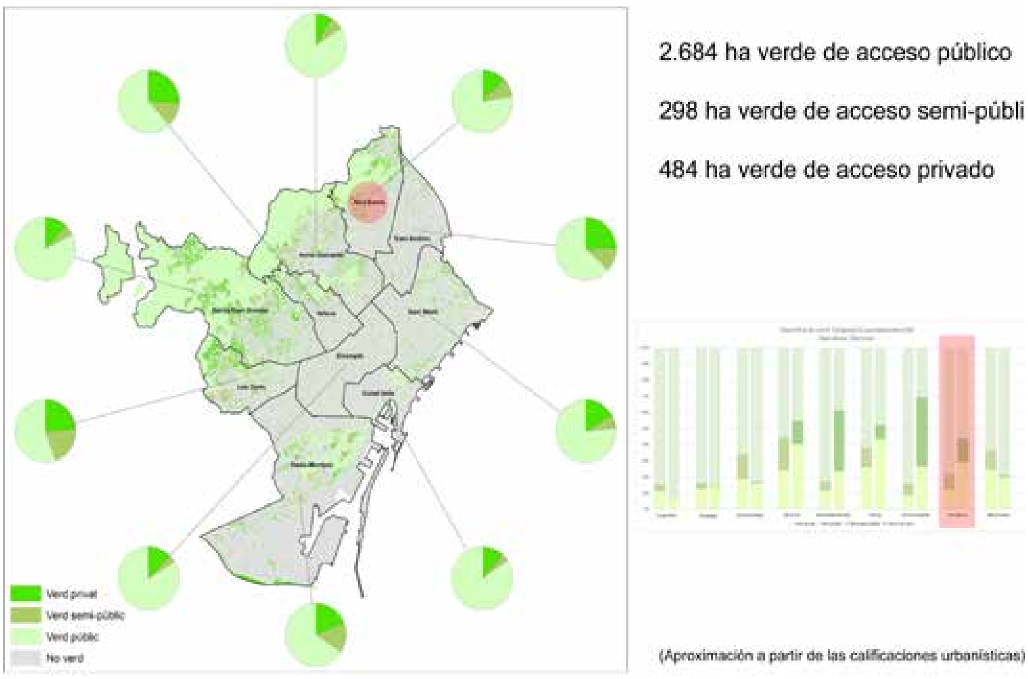


Figure 3.50 Access to greenery per district: private, semi-public, and public(project site indicated)

(source: Barcelona green infrastructure and biodiversity plan 2020)

Urban Gardens

Urban gardens are elements that can contribute to the improvement of the quality of life and the social and physical fabric of a place or an environment, and can be defined in multiple ways depending on the objectives that are sought in their insertion in a place . In this way, it is necessary to know the typologies and the various functions that these elements offer as possibilities for improvement, as well as the definition of quality objectives, which these must comply in order to achieve positive results in their insertion, and thus generate a real improvement of the place or environment.

These characterizations or general aspects that are associated with the definition of Urban Gardens and which will be mentioned below are data taken from the book "Horts Urbans y Periurbans" by J. Busquets and Fábregas and correspond to Types, Functions and Quality Objectives that Must fulfill the orchards, for their insertion as instruments of urban rehabilitation.

1. Productive function of self-consumption: In order to achieve greater productivity, there is an adaptation between the place and the agricultural practices.
2. Environmental Function: Specifically refers to the conservation of ecological values, which promote orchards in place.
3. Urbanistic function: it is associated with the contribution that the orchards generate to the maintenance of the place where it is located
4. Social function: promoting the social cohesion promoted by orchards, and more essentially the activity of work and permanence (cultivar), derived from educational, therapeutic, etc. activities. That in these spaces are developed.
5. Healthy Function: derives from the beneficial effects that the orchards produce on personal well-being, food and health.
6. Cultural function: the horticultural tradition is rooted in both rural and urban populations, is part of the popular culture and gives character to each place.
7. Aesthetic Function: there is a formal diversity of orchards in different cultures are a reference of diversity, variety, harmony and stand out in the collective imagination of cities

Huerto	Año de Construcción	Huerto	Año de Construcción
1. Hort de l'Avi	1986-1997	7. Hort Sant Pau del Camp	2006
2. Hort Masia Can Mestres	1997	8. Hort Casa de l`Aigua	2007
3. Hort Masia Can Soler	2001	9. Hort Collserola	2007
4. Hort Trinitat	2003	10. Hort Sagrada Familia	2007
5. Hort Turull	2003	11. Hort Pedralbes	2008
6. Hort Masia Can Cadena	2004	12. Hort Camí de Torre de Melina	2006-2009

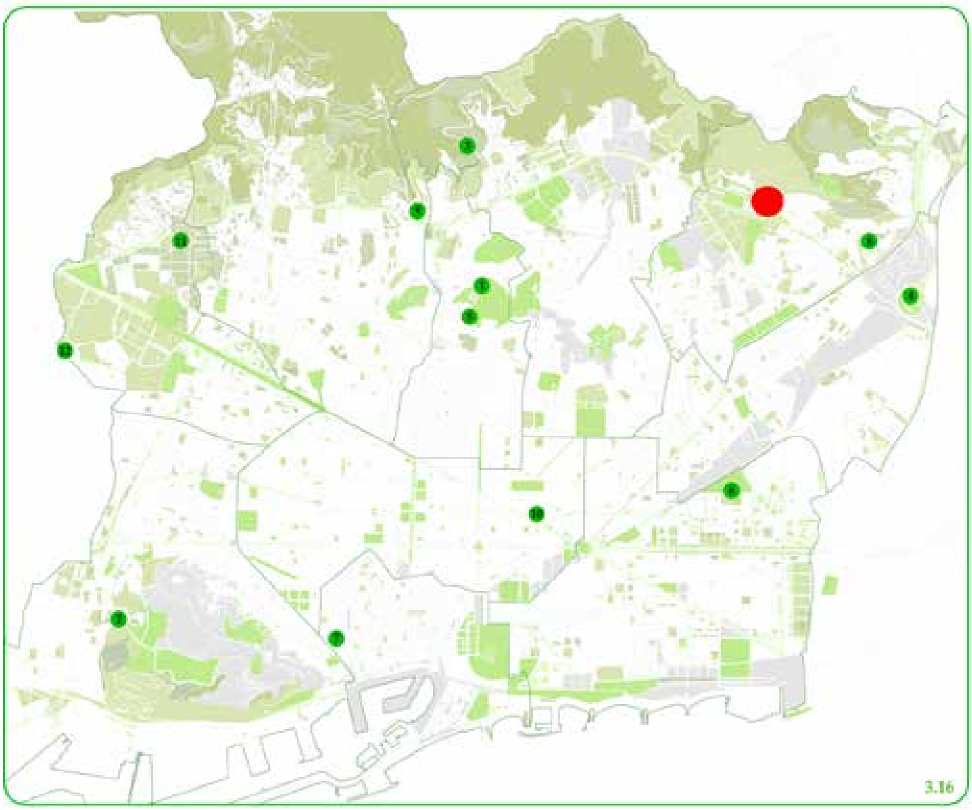


Figure 3.51 Normal Urban Agriculture practice in urban gardens

(source: Barcelona green infrastructure and biodiversity plan 2020)

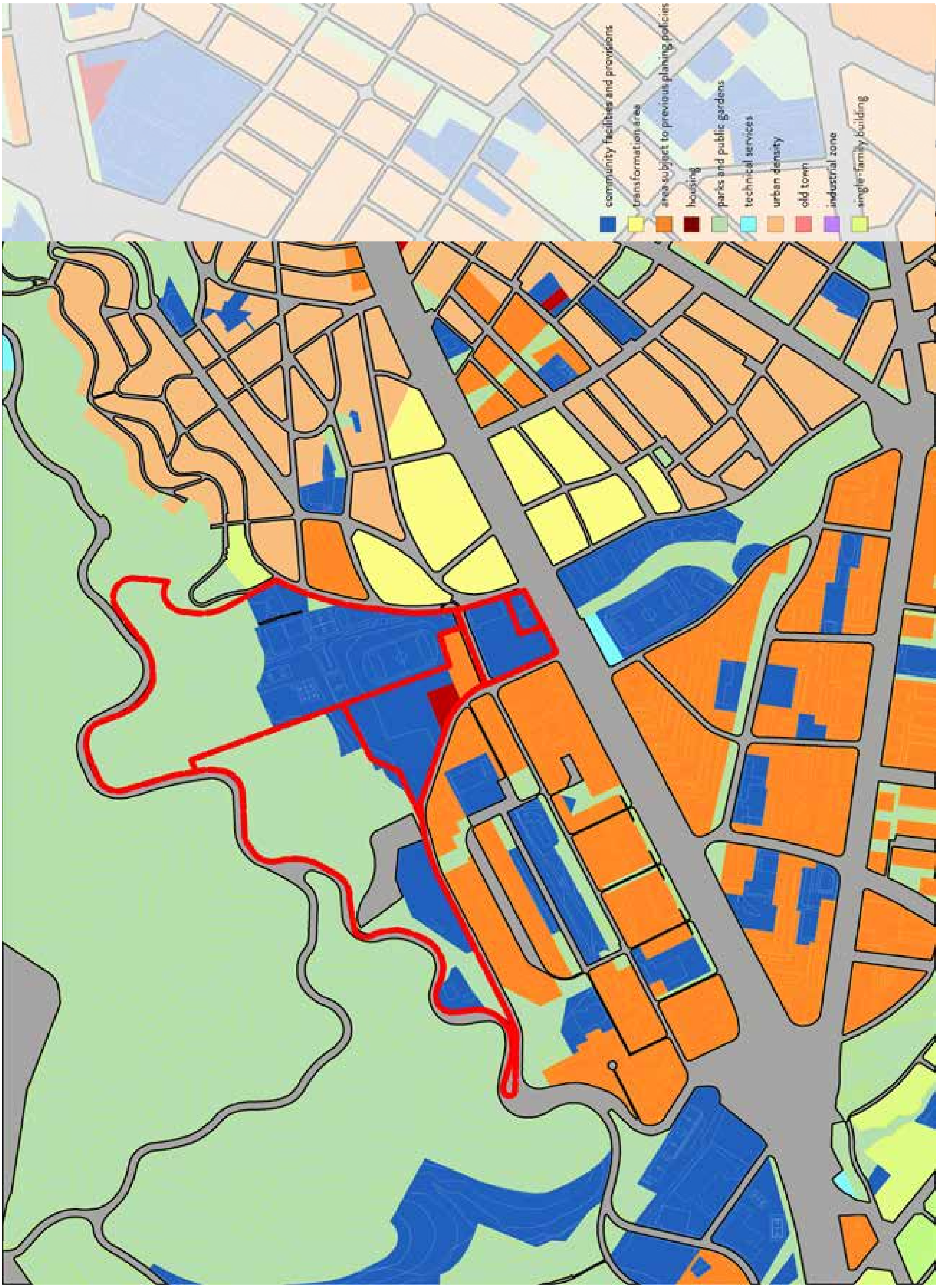
Urban gardens in Barcelona are an instrument that is used as a flexible element that can be adjusted in situations, to be attributed as possible urban solutions, specifically for its condition of responding to problems directly related to people and citizenship. This condition allows that, as a spatial solution, the orchard also allows characteristics of appropriation and membership over the space in which it is located, possibly favouring the rehabilitation of its surroundings

In sustainable aspects, under the current criteria of sustainability, the Urban Gardens share, support and collaborate with the sustainability of the green spaces to which they are associated, contributing in:

- physical aspects, recovering spaces for public use, providing a new activity ;
- social aspects, enhancing human relations
- leisure, meeting and meeting, around the crop;
- environmental and ecological aspects, involving the insertion of nature in the city and promoting environmental education between generations

3.2.7 Land Use Analysis

The land use distribution is reported in the following map that shows with different colours the housing areas and the facilities zones. Around our site there are many sport facilities and a large mainly residential area, subjected to a past planning policy.



3.2.8 Facilities Network analysis

In the first map the facilities were subdivided into six main categories in order to understand better the situation of the area of interest.

- Culture and education (museums, schools, libraries, theatres)
- Religious
- Sport
- Health (hospitals, clinics, medical centres)
- Tourist attractions
- Commercial activities (restaurants, supermarkets)
- Governmental facilities
- Security facilities

After that, were analysed more in details the interesting points of the area and the organization of commercial activities offered around the project site.

Attracton Points

Some of the most interesting points shown the attractions map are reported and described below. They characterize the project area and the lives of the inhabitants:

- Parc Central de Nou Barris

The park occupies a part of the land once part of the estate surrounding the Institut Mental de la Santa Creu, that offered the chance of opening up the city's second most extensive urban park (16 hectars), after the Ciutadella Park.
The Nou Barris Central Park negotiates the distance and difference in levels between the Plaça Karl Marx and the old hospital by means of a series of terraces (occupied by fields, ponds and more or less paved zones) separated by retaining banks and connected by ramps.
An old aqueduct that used to supply water to the hospital has now become a footbridge, joining the system of ramps and steps that unite the different levels.
Beneath the park's surface there is a large underground tank that accumulates rainwater and supplies the irrigation outlets and a fountain from which a cascade spouts.
Like the bonding material that joins bricks, the Nou Barris Central Park constitutes a flowing, almost liquid presence that slips between the blocks and high-rise buildings of the estate to fill its interstitial spaces and give them cohesion.

- Castell de Torre Baró

Although it has a mediaeval appearance, the castle was built at the beginning of the 20th Century to create an hotel. The project was then abandoned and the building remained uncompleted until 1989, when the castle was refurbished and became a panoramic point to enjoy the view of the city and the info point of the natural park of Collserola.

- Parc de la Guineueta

The park is located between La Guineueta and Verdun neighbourhoods, in an area that was previously a gorge. There are soccer and golf fields, a green walking area, playgrounds and a lake.

- Ateneu popular 9 de nou barris

The Popular Academy was created in 1977, when the inhabitants of the district laid claim to a dismissed asphalt plant in order to transform it into a cultural centre.

Since that day the Ateneu developed artistic and social activities for the population. It offers education in the social and artistic fields, in particular a circus school, and organizes shows.

- Mercat de la guineueta

The building was constructed in the 1960s during the period of strong immigration as an answer to the needs of the inhabitants, it was until the 80s the only big shopping mall of fresh foods of the area, so it became an important centre in the commercial life of the district.
After the refurbishment, it was expanded and has now a surface of 6500 m2, a modern façade with led lights that invites people to enter inside and a covered open space that is a meeting point of the inhabitants. It hosts many shops opened every day that offer different products.

- Casa de l'aigua

The building was built in 1917 to improve the hygienical condition of the water supply system and it's one of the first buildings of Barcelona made of reinforcement concrete.
Nowadays it's a public place for events open to the city and hosts gardens where the population can grow their own vegetables.

- Can Masdeu

It's a squatted social centre, residence and community garden in the Collserola Park on the outskirts of Barcelona, developed around an abandoned hospital. There are also guided tour in which residents explain community living, consensus-based decision-making, ecological gardening and living, and the functioning of the social centre.

- Collserola

The mountain chain that surrounds Barcelona on the north-west side is called Collserola. It offers many routes in its natural environment and is the home of different species of animals and plants.

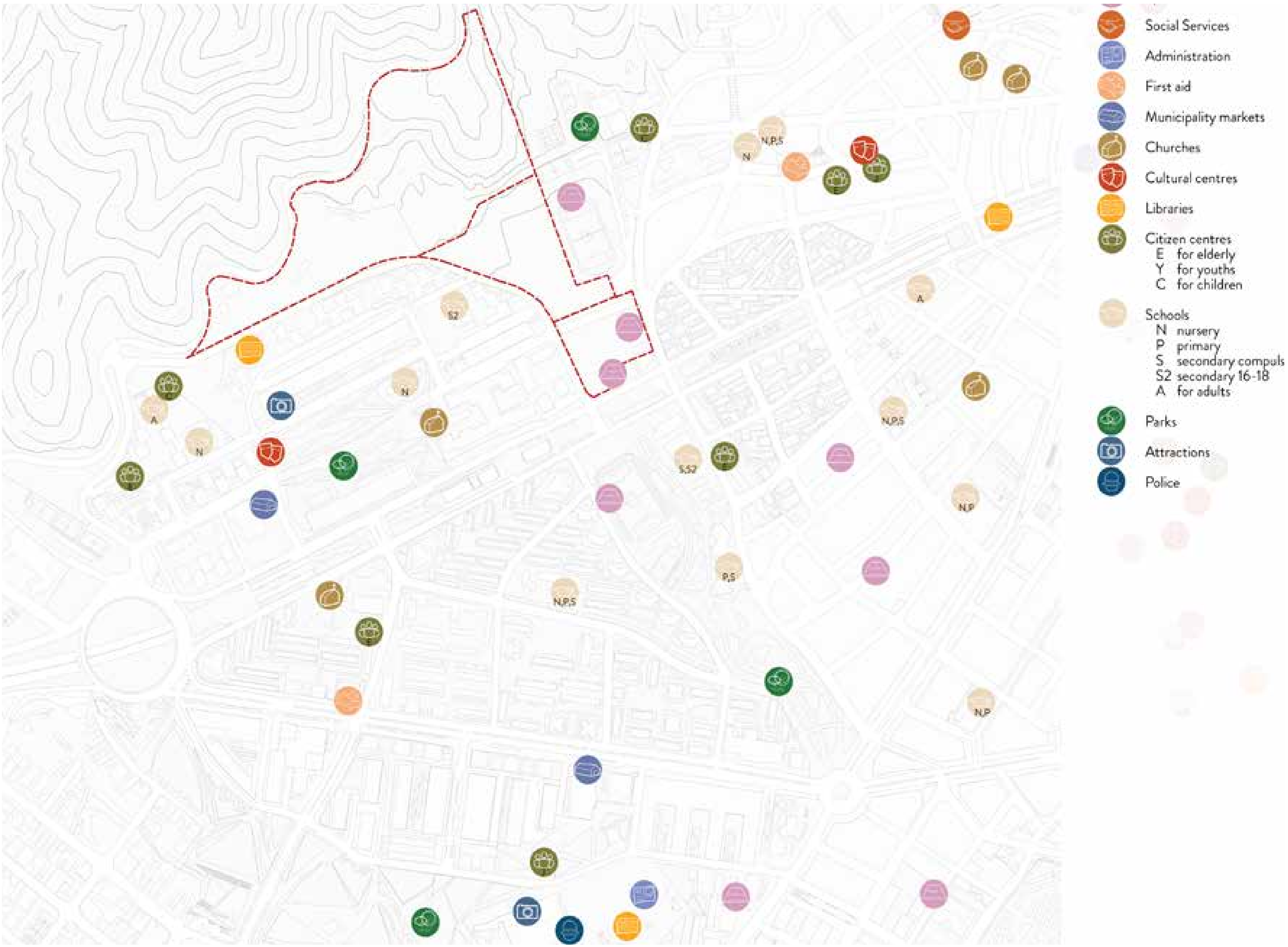
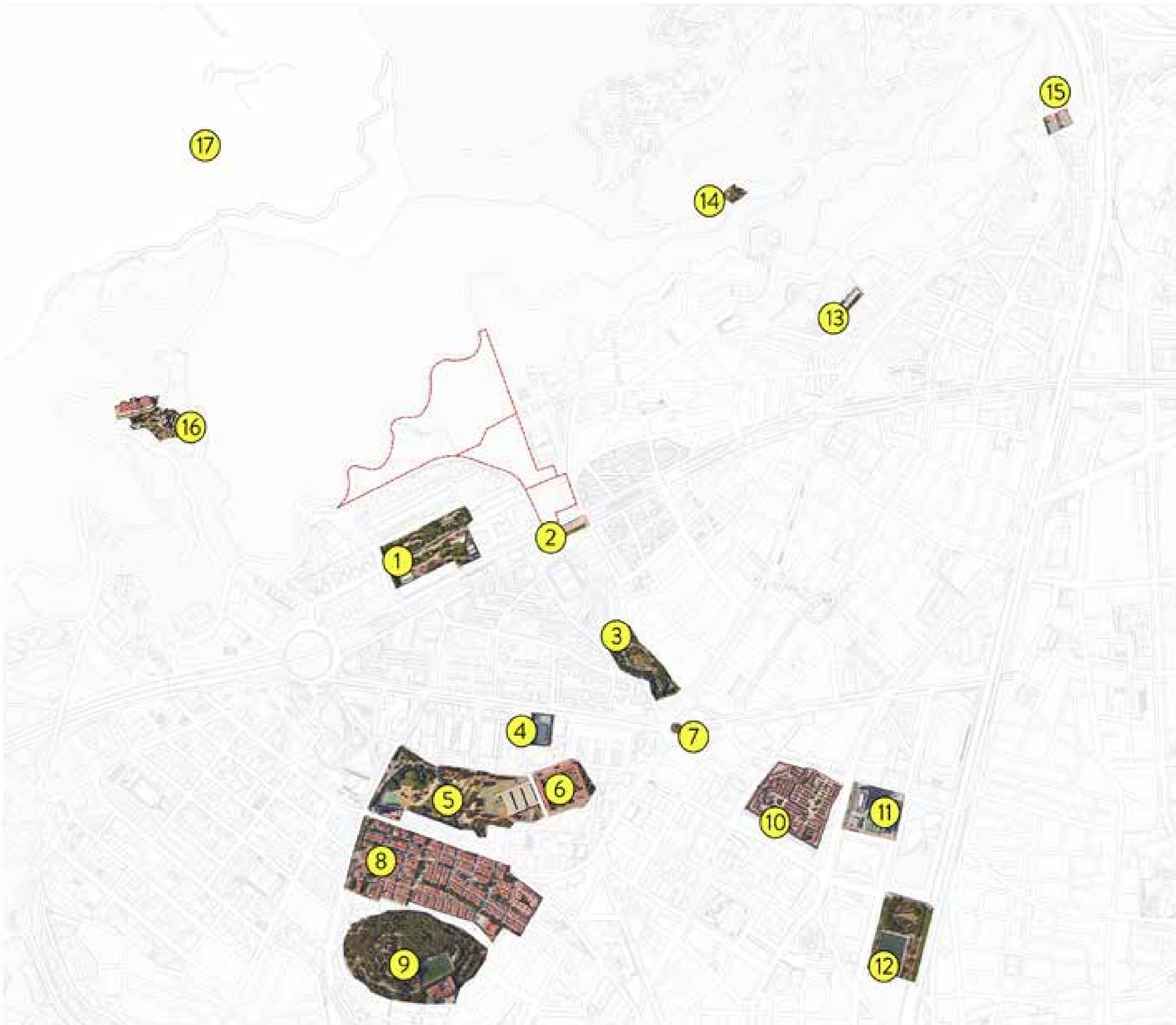


Figure 3.52
Facilities network around the project site

(source: own elaboration)



1 Parc de Josep Serra Martí
2 Skatepark Favència
3 Parc de la Guineueta
4 Mercat de la Guineueta
5 Parc Central de Nou Barris
6 Seu del Districte de Nou Barris
7 Estàtua de la República
8 Can Peguera
9 Parc Turó de la Peira
10 Cementiri de Sant Andreu
11 UNED Barcelona Nou Barris
12 Parc de Can Dragó
13 Ateneu Popular 9 Barris
14 Castell de Torre Baró
15 Casa de l'Aigua
16 Can Masdeu
17 Collserola

Figure 3.53 Main attraction points in the vicinity of the project site

(source: own elaboration)

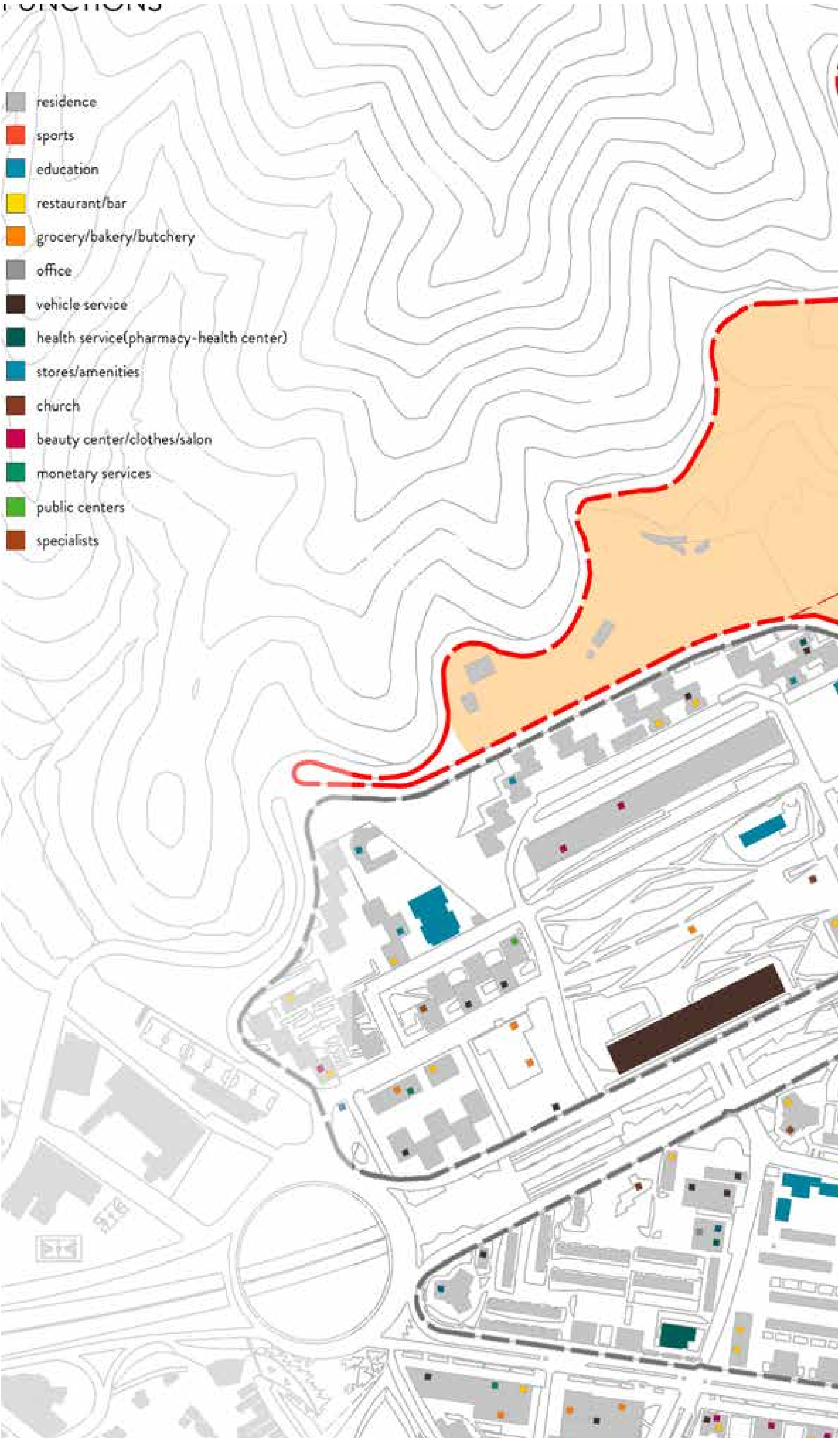
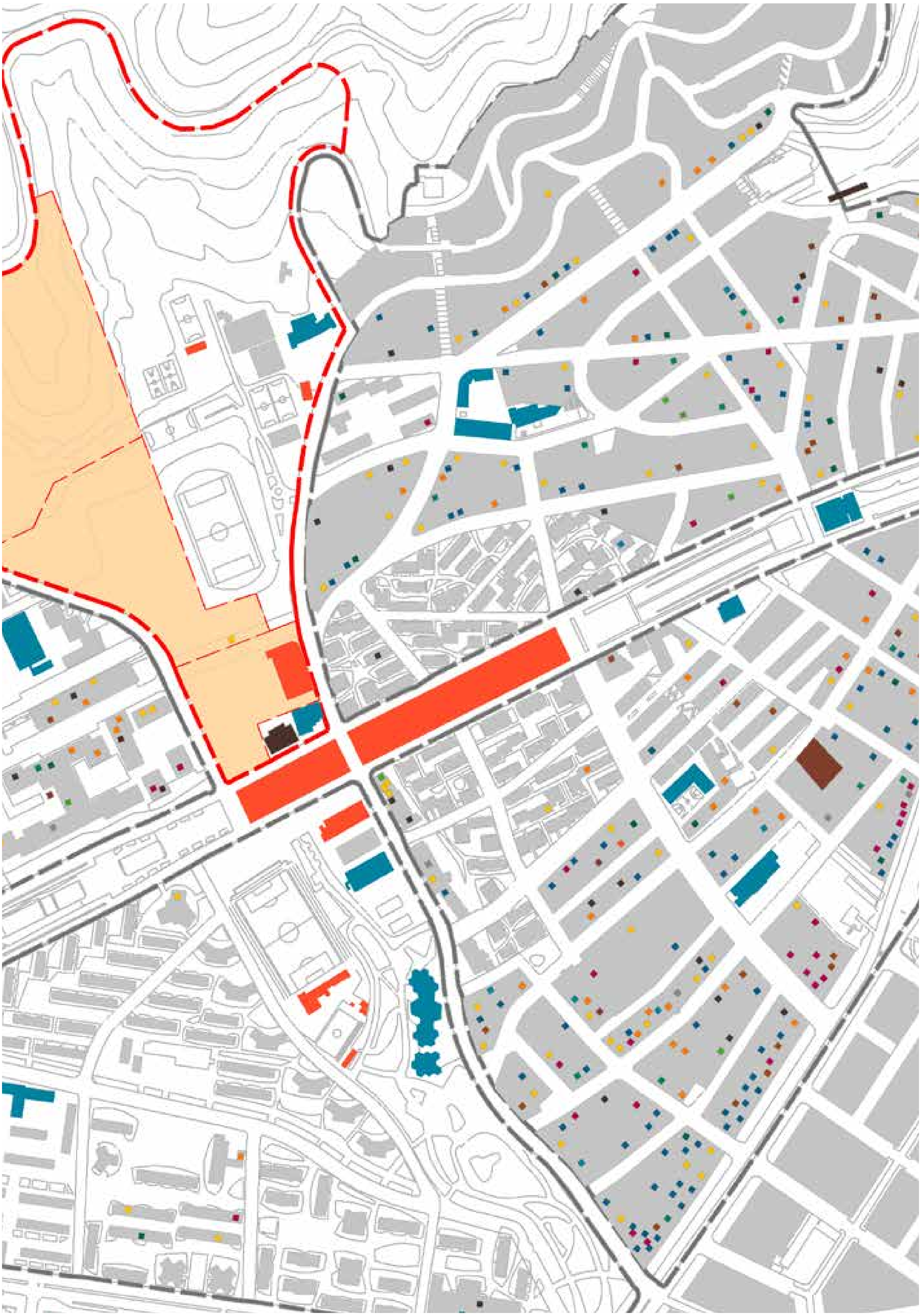


Figure 3.54 Distribution of different commercial activities near the project site

(source: own elaboration)



3.3 URBAN SYNTHESIS

3.3.1 Multi-scaler Conclusions: Site's Pro's and Con's

The dissection of the urban layers of the site, starting from Barcelona to the level of the Nou Barris district, until the Canyelles and les Roquetes, lead us to a good understanding of the urban, architectural, and socio-economic situation of the context. It is good to point out that some conclusions had to be drawn in the light of comparing the data about the site in the light of the different districts of Barcelona, and then, by comparing the two or more districts.

Thus starting the analysis from the level of Barcelona helped us draw conclusions about the following main design aspects:

- the green corridors,
- the urban agriculture practice in urban gardens in different districts,
- the urban agriculture practice and importance for the citizens of Barcelona,
- the social engagement in this practice,
- the share of green spaces,
- the role of Collserola,
- the mobility network modality, centrality, and effectiveness

However, some conclusions were based on a closer look at our district, and more close to the neighbourhood. And this lead us to derive pro's and con's of our site based on this multi-scaler conclusions from the analysis of Barcelona, Nou Barris, and Canyelles and its surrounding neighbourhoods.

We categorized the Pro's and con's according to their relevance. For the pro's, we derived advantages to use in our design from the environmental, energetic, transportation, and functional perspectives.

- From an environmental point of view, Collserola presents an important element on site , as does the planned green corridor. Also, it was detected a good potential for a seed project about urban agriculture. The green space share was also a strong point .
- From an energetic point of view, it was detected the possibility to promote a more green energy-waste cycle on site
- From a mobility point of view, the public transport showed a high capacity
- As for the available services, they proved effective in serving the popoulaion in Canyelles and Les Roquetes.

As for the Pro's, we derived challenges from the environment part, along the transport, and socio-economic situations.

- Regarding the location of the site, it has to abide by the design considerations for an urban green corridor. These considerations were highlighted by the Barcelona city council plans and Barcelona's Ecological centre. However, the formal issued documents ask to refer to international design standards.
- Regarding the mobility, the transportation faces some challenge related to multi modality of public transport, and non-motorized modes of transport
- And finally, the economic situations of the district as a whole, and affected by that of Barcelona. On the other hand the social presented a challenge as the social entities that make up the neighbourhoods are divers and not well integrated.

Figure 3.55
The project site con's

CON'S

1- **Peripheral location :** The site's location on the farthest periphery of the city, that makes it segregated from main attraction points, administrative points..

2- **Green Corridor Design Requirements:**

1-The urban green corridor is wide enough to generate ecological continuous connectivity and overcome barriers (roads, walls, streets, lots, walls, etc.)

2- Non segregated green areas (linear continuity of permeabe soil , species richness, etc.)

3- Connection possibilities by Green height (street trees and green roofs)

4- Interrelationship with mobility networks (private vehicle public transport, bicycle and pedestrian).

5- Stratified greenary: A coating plant with the presence of three layers (The tree, shrub and herbaceous) develops a role in maintaining ecological corridors
6-The use of permeable paving and the creation of water reservoirs or zones wet or semi-drainage areas

2- **Mobility Restrictions:** Low catchment size of services or functions within 30 minutes by using public transportation, compared to highest value in the city.

-low availaibity of multi-model public transport compared to most zones of the city.

-Difficulty to get into rest of the network of mobilty.

-Absence of non-mtorized modes of transportation.

-Lack of parking areas and low capacity of streets to meet it

3- **Economic opportunities:** knowing the area is only residential with services(education,sports, amenities)

4- **Economic crisis:** and its impact on on peripheral areas (like canyelles, roquetes, verdum,...) that limit the growth of the district, especially as for employment, gdp,..

5- **Social situation** of the inhabitants: mainly foreigners, who are not strongly involved in the dynamic life of the rest of the city

Figure 3.56
The project site pro's

PRO'S

1- **Collserola Mountain** : Location of site at the feet of the Collserola mountain is an oppurtunity for the continuity of the **biodiversity** into the urban parts inside the neighbothoods (Barcelona Biodiversity and Green infrastructure plan), in additiont to the use of **the view** in the design of the buildings.

2- **Urban green corridor** : Location of site on a planned minor green corridor (Barcelona Biodiversity and Green infrastructure plan) imposes an ecological importance to the site as a component of the **green infrastructure** of the city, and **water catchment** zone

3- **Agricultural Potential** : Location of the site in a **naturally rich context** makes the agricultural practice that needs land and water, which can be used for contributing to the **local food needs** citizens and creates **job oppurtunities** especially for the elderly.

5- **Green Space Share** : the share of inhabitant of green space(public) in Nou Barris is among the best in the ditsricts in Barcelona. in addition, the site is served by a well serving park-Parc de Josep Serra Martì in Canyelles.

5- **Energy Cycle on site** : Land availabiltiy and the possibiltiy to use **clean energy**(solar, water catchment,geothermal) in addition to **waste** (domestic, agricultural) allows to create energy cycle on site(using biogas cogeneration plant.

6- **Mobilty Capacity** : The project site is **well-connected** to the main street network There is also a high degree of **centrality** of the mobility station compared to the average centrality of the city, and a **high capacity** of the mobility system (low available, low stress), that permits to increase the flow load on the mobility system, due to its assessed resilience

7- **Services and Facilities:** The site is well served by diverse, accessible, and sufficient basic services for the residential buildings of the Canyelles, Les Roquetes, La Guineueta(neighborhoods surrounding the project's site.

VISION: -----------

GOALS

ENVIRONMENTAL:
Development of Green Corridor-
Creating an Agricultural Productive Hub

STRATEGIES

- Connecting the green areas in the project site to develop the green corridor
-Managing the continuity of biodiversity
-Managing water systems (collection, treatment,..)
-Benefeting from renewable energy sources (geothermal) as potential sources
-Benefiting from the soil in mountain base for agricultural activities
-Enhancing non-motorized mobility through the green corridor

- Revivinng the movement of local food production by promoting it among residents
-Using agriculture as an economic catalyst
-Creating oppurtutnities for experimenting and researching agricultural technology
-Integrating agricultural energy needs and waste outputs in the enrgy cycle of the site
-Creating facilities that allow a closed loop cycle of energy-water-waste on site (biogas cogeneration, Photovoltaic elecrticity generation, water recycling facility,..)

ACTIONS

- Create a food production hub of components that work with eachother (reasearch, training, experimenting, collection, waste management,...) in our site at Ronda Da Dalt.
-Map the available spaces for practicing urban agricultural activities in the neighborhoods of Canyelles, Les Roquetes, Verdum, and La Guineueta
- Provide crop investment ways like a local food market for the neighborhood of Canyelles in the central area of our site , or ways to sell to distributors in other neighborhoods.
- Use different methods of agricultural production like installing greenhouses in our proposed buildings, using aquaponics in buildings, hydroponics,...

SOCIAL Creating a Meeting Hub for Canyelles and Les Roquetes	ECONOMIC Creating Economic Oppurtuni-ties
- Enhancing the social mix - Creating and integrating vibrant cultural/ entertainment hubs Enhancing sports activities as social interac-tion spaces -Creating social venues in education facilities - Enhancing multi-age activities - Using abandoned spaces for social /public activites(markets, concerts) - Bridging the seperation created by Ronda D'alt among the neighborhoods	-Inclusion of sports activities in touri-stic purposes to generate income for curators. -Incorporation of agriculture activities in the neighborhoods surrounding the site. - Reviving local handcrafts and local markets. - Encouraging the initiation of small and medium entrprises through go-vernmental policies, promotions, in-
- Establish cultural/ entertainment centers aimed at different ages and interests in zones along the corridor - Revitalize the present public spaces and parks in Cnayelles na dthe neighborhoods - Connect the neighborhoods near our site by walkable and cyclable paths , along with Coll-serola, overcoming highway barriers.	- Establish a market for locally made items and creating venues in central public spaces in Canyelles and Les Roquetes - Create touristic attractions, with with local citizens, along the way to Collserola - Create service centers for economic de-velopment, enterpreneurship, trainings in central zones of the neighborhoods

3.3.2 Defining the vision:
Canyelles: The Locavore Neighbourhood

The conclusions derived from the urban analysis showed us our site's potentials that we have to make use of in the design, as well as challenges that we have to solve. Based on these outcomes, we developed our vision for the area; and what we envisioned this zone of Canyelles to become was based on its biggest potentials in the environmental aspects: the green corridor and the agricultural potentials. So our vision for Canyelles was ' an agricultural Hub " where citizens start to rely on their own food production, and partly energy and waste treatment with the potentials found.
The name we gave to our new portion of the neighbourhood was : "The Locavore District".

To reach this vision we set our goals that we have to consider to achieve, and classified them in three categories:

- Environmental: Development of green corridor- Creating an Agricultural Productive Hub
- Social: creating a meeting hub for Canyelles and Les Roquetes ,
- and Economic: creating economic opportunities

For us the environmental goal was the dominant, because it embedded aspects of the other two goals. So we defined strategies for the three of the goals and then actions to be taken to achieve them. Then we matched the similar ideas and found out that working for the environmental goal will include contributions to the social and economic aspects that can still be enhanced later by individual strategies and actions .

For the development of the green corridor and the agricultural hub, our strategies focused on ensuring the continuity of the greenery and the biodiversity and making use of the clean energy sources, in addition to making use of the corridor to catch water. Among strategies relate to the agricultural hub, were promoting the local food movement and mapping the potential land or space for agriculture, training citizens and getting them engaged in the movement, in addition to integrating the agricultural needs and outputs in the overall energy cycle of he neighbourhood. Of the actions we mention creating the necessary buildings and facilities for the hub and the energy cycle, in addition to a local food market, local restaurants, integrate greenhouses.

For creating a meeting hub for Canyelles and Les Roquetes, our strategies focused on finding common spaces to practice common activities that interest the different group ages and interests. In addition, examining physical connections between the two neighborhoods along with the green corridor and La Guineueta and Verdum. Actions included building cultural and entertainment centers in a central place for both residents, in addition to enhancing the role of the public spaces (park of Canyelles and Les Roquetes), creating walkable paths between the two neighbourhoods through our site.

For creating the job opportunities, we thought of strategies that aim at generating employment for local residents through sports activities integrated with tourism, agriculture practice in our project site, reviving the local crafts, and making encouraging policies for small and medium enterprises. The actions focused on establishing a market for local products in the central space of our design, in addition to creating centres for economic development , creating venues to attract tourists on the way to Collserola

3.3.3 Concept Map

Design Principles:

The design of the concept plan is based on the vision we developed for the site after the urban dissection carried for the Strategic site and for the city of Barcelona. We envisioned the site in Canyelles to be a green pole connecting the mountain Collserola with the rest of the urbanity. The environmental goal of emphasizing the green corridor and creating an agricultural hub on site was our main focus. Nonetheless, the other goals, the social and the economic goals, were embedded inside the environmental one. And some strategies and actions to be taken, as seen, could serve both the environmental goal on one side and the socio-economic on the other hand. Starting to define the first design lines, we set some principle points that we took into account primarily to reach a conceptual diagram of the vision we had for the site. This conceptual diagram is the first design step that started to evolve to reached the first sketched of the masterplan that we present thereafter.

To reach the conceptual diagram we had to define the following points. The first was the scope of the study, which was an important element knowing the complexity embedded in the real-life situation of the neighbourhoods, and considering the requirement of the Europan competition. Then we defined the main urban components: Axes(major and minor), connections, functions, and public spaces. In what follows we explain how we defined each and which criteria we were based on. Moreover, in some points we had to modify some requirements of the competition to meet our goals. We will point this out also.

Scope of Study

The strategic site (23,500 m2) is based administratively in the borders of the neighbourhood of Canyelles. However, it is bordering the neighbourhood of Les Roquestes. In the same time the main road Ronda Da Dalt is the separating line between Canyelles and Les Roquetes on one side(Collserola side) and Le Guineueta and Verdun on the urban part. It was crucial to study these borders and analyse the four neighbourhoods from urban and socio-economic viewpoints.

In the conceptual map these borders are pointed out as areas of intervention. all the goals we set for our masterplan, the environmental, social, and economic, are related to the four entities that surround this site. The corridor is the meeting plane between these four neighbourhoods, and consequently its development embeds a physical and social solution of the social problems in the site.

Main Axes

The main axis in the conceptual design shows our main interest azis to develop where the consequent transformations can start to take place. Definitely, our main axis is the green corridor, where we point out our ideas about its development in each longitudinal part (the green corridor is the transversal connection between Collserola and the urbanity. In our design of masterplan this is the central urban space that performs not only environmental functions, but also contributes to the social unity of the neighbourhoods

Minor Axes

The minor axes are the axes that still have a big role in the urban intervention, and play a complementary role in achieving our environmental and socio-economic goals. We defined our minor axes as the Ronda da Dalt (an existing axis) and one we proposed which is the axis connecting Canyelles an d Les Roquetes. The Ronda Da Dalt currently plays a separating role in the urban context. although there are some activities implemented in it (park, sport activities, and skate park) The separating role it plays is due to its physical aspects, not its functional one a s a public space. the other axis we propose is the Connection that we believed can bring the interaction between Canyelles and its neighbouring Les Roquetes. Although we propose this function of connection through the green corridor , the minor axis Canyelles- Les Roquetes has a big impact in establishing connections between the two neighbourhoods, that needs to enhanced along with the connection of each to the corridor.

Connections

Connections represent both the physical connections (roads, walkable paths, cycling paths, bridges) and non-physical ones (visual axes, functional ones, voids). since our goals revolve about establishing ecological continuity and social integration, connections are numerous in our conceptual design. These connections have hierarchy and defined as direct or indirect according to the importance of the impact established.

As seen in the conceptual diagram, connections are emphasized around the main and minor axes(The green corridor, ronda da dalt, and Canyelles- Les roquetes axis) We need to point out here that the connection to Collserola(connecting greenery and physical connections) were found to be as important.

On the other hand, some connections already exist, but we highlight because we believe they need to be emphasized(width, texture, walkability and cycling, user's perception) These mainly are the connections between the public spaces inside the neighbourhoods and the transportation stations. This will enhance the role of the transportation and these spaces to be used efficiently by the residents.

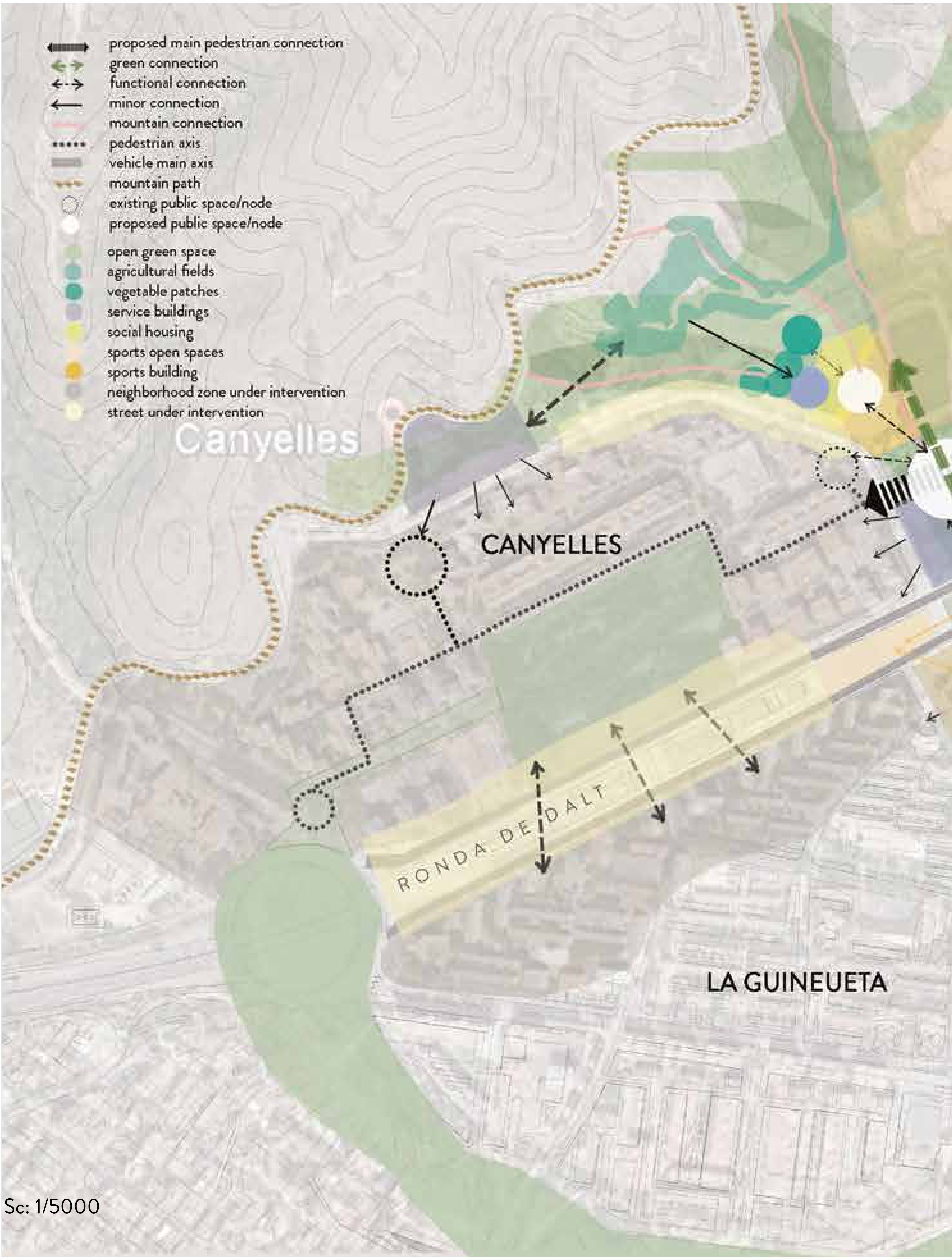
Public Spaces

Public Spaces are spaces already existing and open for the residents(parks,urban gardens, public sports centres, event venues..) Our site has a good presence of the public spaces mentioned. However, the problematic lies in their connectivity that makes them more effective. It is highlighted the connections extended to strengthen in order for these public venues to be more effective.

On the other hand, we propose new public spaces in our strategic site because it is intended to be hub for agriculture practice, and engaging the local people is a must for the hub to be functioning well. After all, our main urban design component is the green corridor that we propose its enhancement, and it is functioning as a public space, but with restrictions so that it plays its environmental role also and not be restricted form playing this role by excessive public uses over all its area.

Functions

The Europan already defined the needed functions based on urban and socio-economic studies, and this is what we found out when investigating the neighbourhoods and the districts. However, since our goal was to create a different type of 'production', we designed of what was required the social housing units, commercial activities, and public spaces, but preferred to suggest our own functions(agricultural hub buildings, energy generation and waste management) on the account of the sports activities required.


proposed main pedestrian connection
green connection
functional connection
minor connection
mountain connection
pedestrian axis
vehicle main axis
mountain path
existing public space/node
proposed public space/node
open green space
agricultural fields
vegetable patches
service buildings
social housing
sports open spaces
sports building
neighborhood zone under intervention
street under intervention
Canyelles
CANYELLES
RONDA DE DALT
LA GUINEUETA
Sc: 1/5000


LES ROQUETES
RONDA DE DALT
VERDUN

3.3.4 Locavore Habitat

Design Principles:

Moving to a more detailed approach to the design of the site, we moved from the conceptual diagram to the definition of the components discussed before: the main and minor axes, the connections, the public spaces, functions, and later the buildings we designed thoroughly for the architecture design phase. Since the conceptual map highlighted our zones and interest and our possible interventions(more showed strategies), in the master plan design we showed the actions. What to do with the axis: to emphasize them, or strengthen their functionality? What is the type of the connection we pointed out in each part of the site? What types of public spaces we will create in each zone dedicated to this function? What are the functions involved in the new areas of our design, or what is exactly the new function we propose in the place of an existing one?

The first step of the detailed design of the masterplan was defining our scope of intervention, just as we defined it in the conceptual design. Then we started underlining the proposals for each component. In what follows we explain what is our intervention for each element, and we highlight some precedents that helped us to understand more what could happen of our site and what is the best solution for it.

The design of sustainable neighbourhoods may seem a contemporary trend of city design. Nonetheless, what everywhere designers are aiming is at creating these cities or neighbourhoods that are liveable , resilient , harmonizing with ecological systems, and above all can sustain themselves over the time. The branch of this design termed under 'eco-district design' is not literally an introduction to the urban design studies, because all design basically that ever existed needed to be ecological. In the few previous centuries, designs may have deviated from the fact that the cities and buildings are part of a large system and that they should be in harmony with it . But that doesn't mean that the design of cities and buildings was ever not 'ecological'.

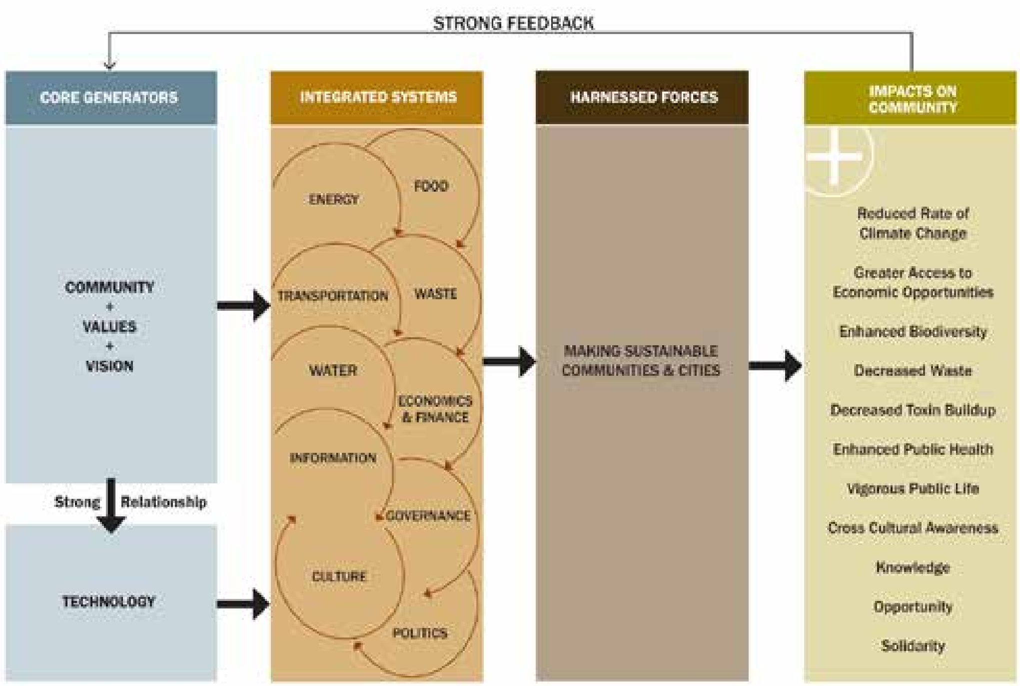


Figure 3.57 The civic ecology paradigm

(source: https://ecodistricts.org/wp-content/uploads/2013/03/making_ecodistricts_concepts_and_methods_for_advancing_sustainability_in_neighborhoods.pdf)

Nowadays, we read about many urban and architectural design termed 'green' and ‘eco-’ , which we regard not as a privilege; it is the normal state of the building ideology. However, since cities today are facing numerous challenges that start by environmental difficulties, to economic, social and food security challenges, the trend of creating eco- cities, neighbourhoods , and buildings has basic points to be considered while designing these spaces. Again we would not name our design as an eco-neighbourhood, but would highlight what are the design principles we, and all contemporary designs of cities and buildings may follow to help alleviate the numerous challenges we are facing on multi-disciplinary levels.

Civic Ecology Framework: Design for People

“In a sustainable society, nature is not subject to systematically increasing:
...Concentrations of substances extracted from the earth’s crust,
...Concentrations of substances produced by society,
...Degradation by physical means,
and in that society... ...people are not subject to conditions that systematically undermine their capacity to meet their needs “
(Cook, 2004)

The requirement of the design of Canyelles is aiming at creating and spreading ecological practices in the neighbourhoods along with the other districts. We have been able to take a deeper look into core concepts underlying the notion of pursuing citywide sustainability through neighbourhood-scale action. The question becomes: What needs to be done to enable communities to self-manage their resource using behaviour by creating community-inspired interventions that change relationships between people and between people and place?

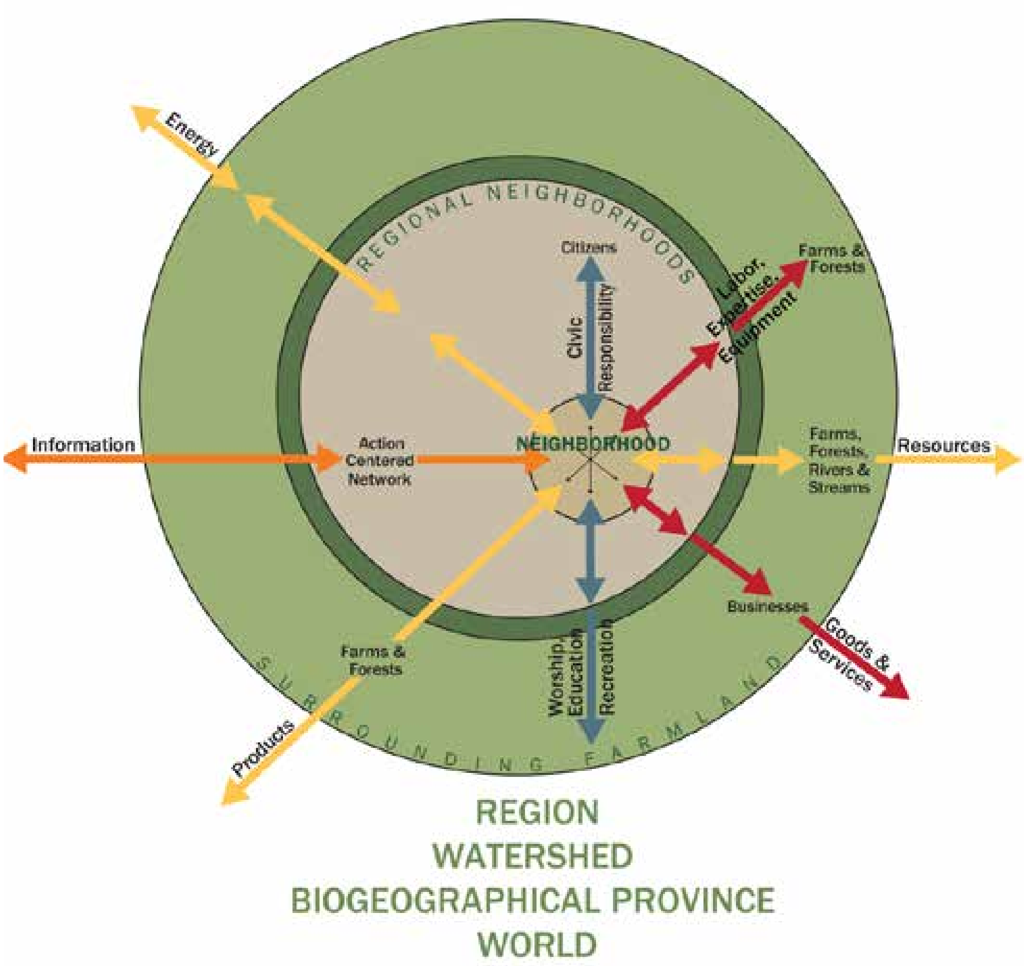


Figure 3.58
The civic ecology model

(source: https://ecodistricts.org/wp-content/uploads/2013/03/making_ecodistricts_concepts_and_methods_for_advancing_sustainability_in_neighborhoods.pdf)

Tim Smith, describes what he terms “Civic Ecology” as the basis for EcoDistrict practice. He writes that:

“Civic Ecology is the integrated web of energy, nutrient, resource, financial, information, and cultural flows and interactions that are envisioned, created and managed by citizens acting for the common good within a geographically-defined community and its city-region. It is a human ecology of place, intimately integrating both natural and social/ culture systems. “

And:

The five pillars of this civic ecological framework lies in:

1) Holism: a whole systems approach to community making;

2) Community: a focus on community place;

3) Social Capital: a requirement for the creation of a new social contract that empowers stronger democracy and social capital in the community-making enterprise;

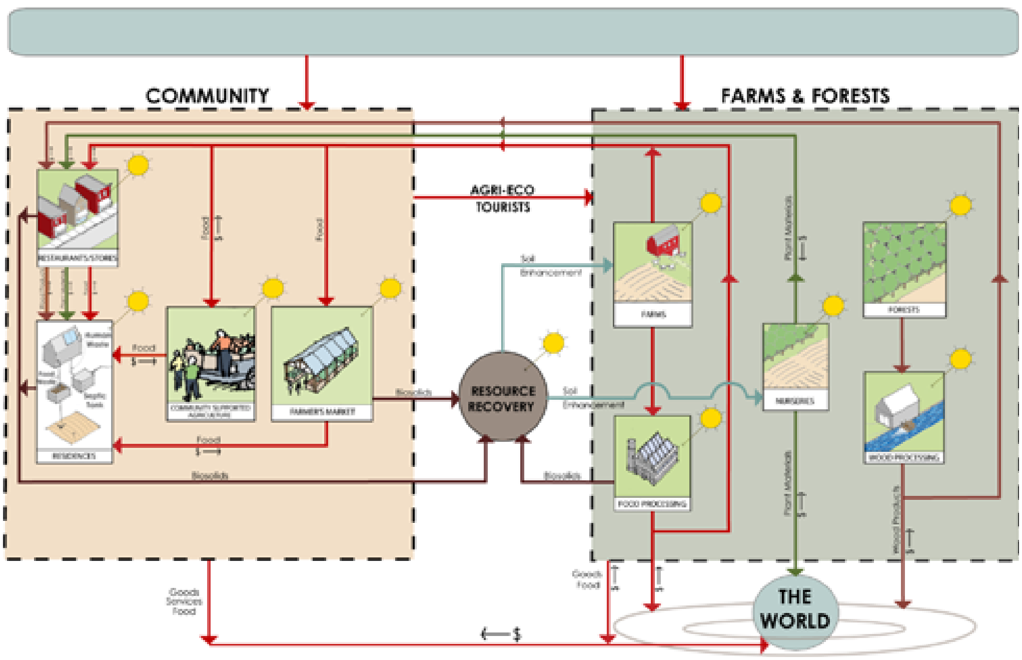
4) Identifying needs: a focus through these means on identifying shared community needs and capacities as a basis for action;

5) Adaptability: identifying specific strategies for maintaining the open-ended, adaptive capability critical to achieving community sustainability.

So, based on this framework of considering our case study as a ‘civic ecology’ study, people come first, as a main operating components of the ecosystem because they are the only component who can do a change at will. Having this approach in mind, the spatial (morphological), economic, and social aspects of the design become one entity working together, believing the transformation of one can affect the others And this was pointed out in our main goals framework

Figure 3.59 Community Flows and interactions

(source:https://ecodistricts.org/wp-content/uploads/2013/03/making_ecodistricts_concepts_and_methods_for_advancing_sustainability_in_neighborhoods.pdf)



A shift to 'Locavore'

Figure 3.60
Locavore

(source: https://i.pinimg.com/474x/c8/b5/a4/c8b5a462cbd414c26e-b19a2ea1b59916--locavore-vivre.jpg)

As a response to future food crisis, many movements have emerged to anticipate this crisis. Our idea came out as a result of the civic ecology framework that put social capital as the main concern of the design of the ecological systems. Emerging from people's needs and future problem, the civic ecology framework made us think: if we are designing for people, and we are aware of this future food crisis, how can agriculture be about people?

The "Locavore', as we mentioned in the opening chapter, is the person who eats what he produces locally. So, the main point here is to promote the approach among citizens. This approach will promote local food production methods, and consequently its integration in the urban morphology. Then this shift will transform the other urban, social, and economic values involved.

About the Locavore:

- English; Noun; (en-noun): One who tries to eat only locally grown foods.
- Was mentioned in Literature since 2007:
- * 2007 March 12, James Daley, quoted in 2007 Farm Bill Opportunities for Vermont and the Northeast: Hearing before the Committee on Agriculture, Nutrition, and Forestry, United States Senate, One Hundred Tenth Congress, First Session ,U.S. Government Printing Office, ISBN 1-4223-2002-2, pages 32–33,

'So I do think that there is a wonderful opportunity for us to find a carbon-neutral energy source where it is not only a beneficial model environmentally but we are sort of becoming forest and energy locavores , if you will, and so that is what we are trying to establish through this idea of a community wood energy program where we would be using, you know, town forests to actually supply town energy needs so that people can actually see the costs and the impacts of where their energy is coming from.'

Figure 3.61
Locally grown food: the locavore's idea

(source: https://www.alimillerrd.com/wp-content/uploads/2013/10/ThinkstockPhotos- 450798 979-11 40x642.jpg)

- * 2007, Brenda Berstler, Home Plate: The Culinary Road Trip of Cooperstown: A Guidebook for the Discerning Visitor ,Savor New York, ISBN 0-9796802-0-4, page 243,

'They are a locavore 's (someone who eats food produced within 100 miles of he lives) paradise.'

- * 2007, Leslie Garrett, The Virtuous Consumer: Your Essential Shopping Guide for a Better, Kinder, Healthier World (and one our kids will thank us for!) ,New World Library, ISBN 1-930722-74-5, page 54,

Become a Locavore
Try to eat foods grown close to your home, which helps to reduce greenhouse gas emissions from transport as well as supporting your neighbors. [...]

- * The variant (term) is also attested: ** 2007, Rebecca Kneale Gould, "Binding Life to Values", in Jonathan Isham and Sissel A. Waage (eds.), Ignition: What You Can Do to Fight Global Warming and Spark a Movement Island Press, ISBN 1597261564, page 123, **: The idea of eco-kosher both draws on and contributes to organic, slow food, and "localvore " movements, but it grounds these ideas in an ancient tradition that has always understood eating to be a sacred act that must support the principles of the flourishing of life and the establishment of justice.

- Antonyms: * distavore
- Derived terms: * locavorism * locavorous

The Corridor : Habitat for Locavore, Flora, and Fauna

The Green corridor is the main component of the site. It can be considered as the 'catalyst' for our transformation. The development of the green corridor will enhance the environmental, social, and economic aspects of the site, that based on our approach to design for the Locavore inhabitant. The corridor will serve as what follows:

- Model Urban Agriculture hub for the surrounding neighbourhoods
- Meeting point for people of Canyelles-Les roquetes-La Guineueta -Verdun
- Natural Gate to Collserola
- Model for the promotion of Waste-Water-Energy Cycle on-site

Continuous Biodiversity

Undoubtedly, firstly the design took into account the basic approach to designing urban green corridors, following the Barcelona model, since the site is on a minor corridor, and the Barceona city council is already working on the major corridor design. The following aspects generated the design of the corridor area:

- Maintaining the necessary width for the greenery and animals to thrive.
- Continuity is a crucial point. Not only was the initial situation separating the corridor by Ronda Da Dalt , but the part between La Guineueta and Verdum was occupied by buildings that segregated the continuity of the corridor
- The design recommends the wealthy stratification of the corridor. However, agriculture is promoted in it, and this adds to this stratification
- Attraction of citizens to nature through the promotion of diverse activities (market, agricultural hub, sports, agricultural practice)
- Promoting a healthy therapeutic approach, where the elderly are devoted vegetable patches to cultivate

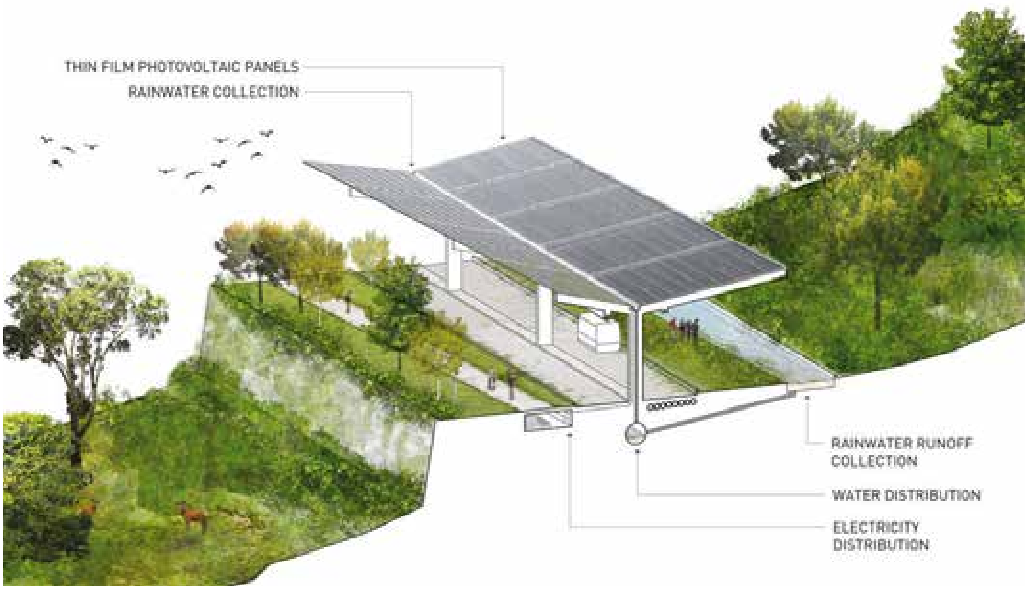


Figure 3.62 Section in the green corridor

(source: Zoological Garden in Dochodo, South Korea by JDS Architects)

Agri-Hub; Locavore destination

The proposed agri-hub constitutes the core new function implemented that does not comply with the given of the competition. the Agri-Hub as we propose is the main attraction point to the neighbourhood of Canyelles, and not only. The hub will combine activities for the residents and functions that can be used to make the site a start-up for the agricultural activities n the district of Nou Barris.

The hub is intended to bring about economic and social benefits. The functions that it will host are:

- Agri-research centre and experimenting areas to explore the local food production potentials. Moreover, it will be the place where different methods of urban agriculture practiced, like the aquaponics that will be promoted in the social housing building(to be detailed later).

- The described building will be accompanied by a Closed Local Market Area and an adjacent open space that will host the market in other times (depends on the size and time of the year) these public venues will play the role of the meeting point between the citizens of the Canyelles and Les Roquetes. The accessibility of this market area is intended to be at a walkable distance from the two neighbourhoods and the connection over the Ronda Da dalt wil enhance the participation from La Guineueta and Verdun.

- The Food Court Building: in the area of the markets, serves the local food, and plays the role of the promoter of the Locavore movement intended to spread in the area.

- Vegetable Patches for the elderly and Agricultural Fields for the residents. The design requirement asked for these spaces, both units in the social housing and patches a s part of the city's policies to promote urban agriculture. The vegetable patches are located in the social housing areas in proximity to the elderly residents. The agricultural fields intended to be used by residents are in connection to the Collserola and are provided by their service buildings.

Figure 3.63 Spanish-Portuguese agricultural research centre (CIALE), Slamanca, Spain

(source: Archello.coms)

Agricultural Practice in Canyelles and Les Roquetes

The design proposes the optimization of the agricultural practices in potential sites outside the project strategic site(level of neighbourhoods) As part of the urban agricultural promotion for residents, it is proposed to spread the practice in the available spaces in the neighbourhoods.

This optimization is a practice that was practised in other cities. We based our proposals on different approaches that suggested mapping the land on the level of the city and calculating the crop production in different scenarios: Cultivating abandoned lands, roofs of public buildings like schools and sports centres, commercial facilities..

In a recent study performed on Cleveland -a post-industrial American city, the planned optimization of urban agriculture in the city showed that a total food self-sufficiency strategy (in all categories) was feasible. That was made by optimizing the potentials to grow food in the city's vacant land and different types of rooftops. This study indicates that yield is the key factor in determining what level of self-reliance is possible. However, self-sufficiency is not our aim in this case. The spread of the practice is.

In a study entitled "Mapping urban agriculture potentials in Rotterdam", the author focuses on the qualitative optimization of urban agriculture practices in the city. The study resulted in mapping agriculture potentials in Rotterdam based on assessing simultaneously the physical, economic, and social potentials (Dumitrescu, 2013). The physical potentials included the study of uncovered/unsealed land where the soil is feasible for agriculture activities. The economic criteria distinguish the ownership type as for public and private, the farm size, the state of commercial. Activity as for whole sale and retailer distributions, in addition to energy needs and costs to support agriculture activities. As for the social criteria, income ranges, age groups, educational levels, and lifestyle were the points discussed. After mapping the previous criteria in the city, four scenarios were hypothesized and their potential mapped by superposing the criteria maps prepared The result is mapping the potential sites of each scenario on the map of Rotterdam.

Figure 3.64 Communty Garden in Barcelon, Spain

(source: http://environmentjournal.online/articles/community-gardens-spreading-environmental-word/)

Energy-Water-Waste Cycle on site

The proposed design suggests an approach where the energy-waste-water cycle will be fed from each other on site. Closing the cycle will require studies beyond the scope of this design, and the requirements that go beyond the basic capabilities of the citizens. However, the management of energy and waste on site is a first step for reaching higher levels of self-management. The following will explain how each source will be managed

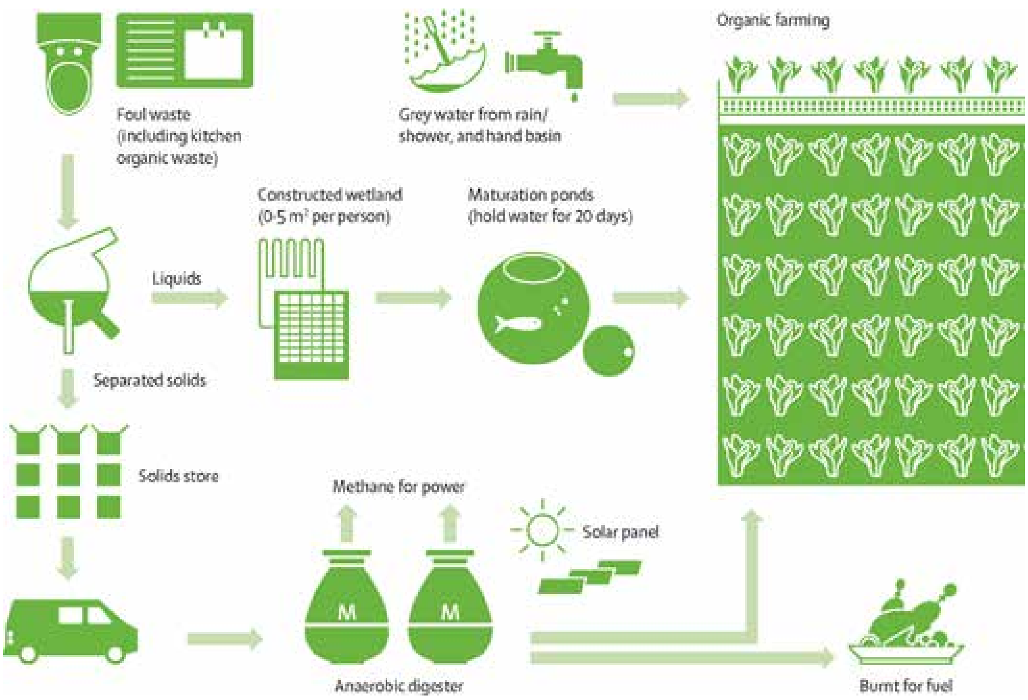
- Water The urban studies showed that water resources in Barcelona cover the basic needs of the citizens. However, the future expectations for water needs and demands projects worries. The design proposes making use of the green corridor to for water catchment. The green layers of the corridor are stratified vegetation layers that constitute natural water filtration. The ecological design of the green corridor necessitates that the layers that compose it be made of permeable materials(on contrary to the sealed surfaces that make the normal asphalt streets and concrete surfaces) This will facilitate the water catchment. The water storage is located near the agricultural fields.

- Waste and Energy: The proposal suggests establishing a co-generation biogas plant . The plant will make use of the agricultural and organic domestic waste toproduce bio-methane. This energy source will be used in domestic uses also in the district heating and cooling facility. The geothermal heat pumps will make use of the wasted heat from the co-generation facility and will function as heat pumps in winter, as well as refrigerant in summer. The photovoltaic cells are also distributed on site and will contribute to the generation of electric energy

So the design notices the possibility to establish energy ad waste management facilities that cover the demands of the neighbourhood These facilities are highlighted in the master plan.

Figure 3.65 The creation of a virtuous cycle of connections with urban agriculture

(source: ucl-lancet-commission-report-healthy-cities-published-2nd-june-2012)



Locavore Dwelling

The major building developed in our design constitutes the social housing buildings: 'The Locavore Dwelling'. The social housing units were a requirement of the Europan competition that we maintained. The studies generated by the district governances showed that there is more need for housing units. And the required units are of different types, mainly, for families of 5-6 persons and the elderly (Canyelles is a relatively aging neighbourhood compared to Les Roquetes).

The design of the Locavore Dwelling constituted our main architectural design goal. The building comprises 95 units of different sizes and architectural typologies. the building also is place for commercial activities on ground floor(on different levels), in addition to services like: local canteens, laundry, kindergarten, gym, entertainment activities, multi-purpose hall, and above all agricultural practice spaces.

The agricultural practices have different modes. The biggest part takes place in aquaponic cells inserted in each floor. In addition agricultural terraces that have aquaponic cells and traditional agriculture practice. The aquaponics system is inserted also in the circulation corridor in the side facing the mountain. The last mode is the roof cultivation, which is based on traditional cultivation mode. The elderly vegetable patches are located in the terrain below the building, to enable the elderly a close relationship with their cultivation site.

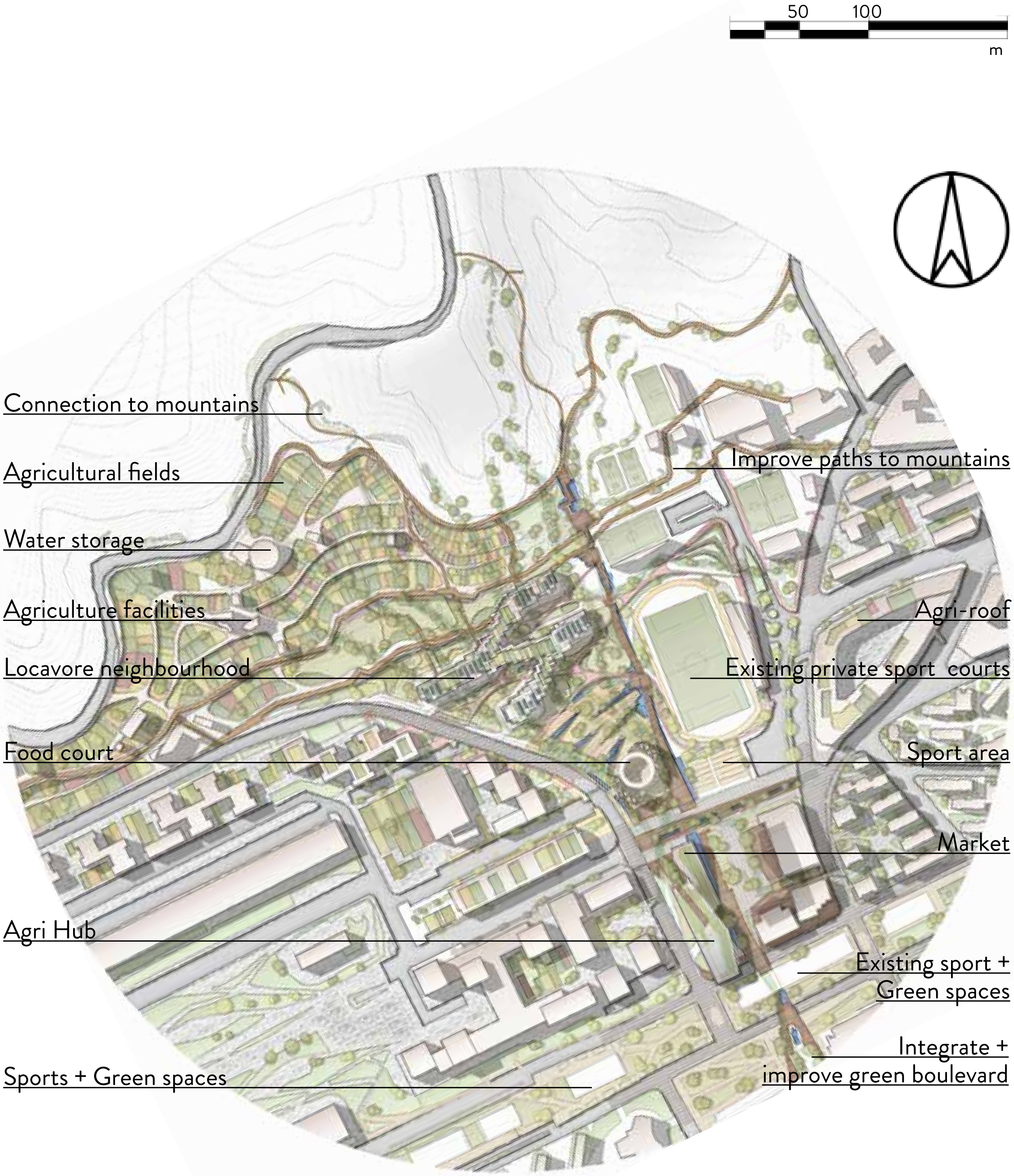
The building is designed with cross-laminated timber, and reinforced concrete in some parts. It is designed taking into account the environmental measures of the area, with sustainable strategies to be detailed.

The subject of the following chapter will be the detailed design of the building with its urban, architectural, structural, and technological aspects.

Figure 3.66 Masterplan evolution

Figure 3.67
Masterplan

Figure 3.68
Masterplan zoom on the project site



CHAPTER 4 – THE LOCAVORE DWELLING

"The concept of being a locavore, or one who chooses whenever possible to incorporate locally grown or locally produced food into one's nutrition plan, is of great importance."

Tyler Florence

4.1 Architecture Analysis

4.1.1 What does “Locavore dwelling” represent in masterplan?

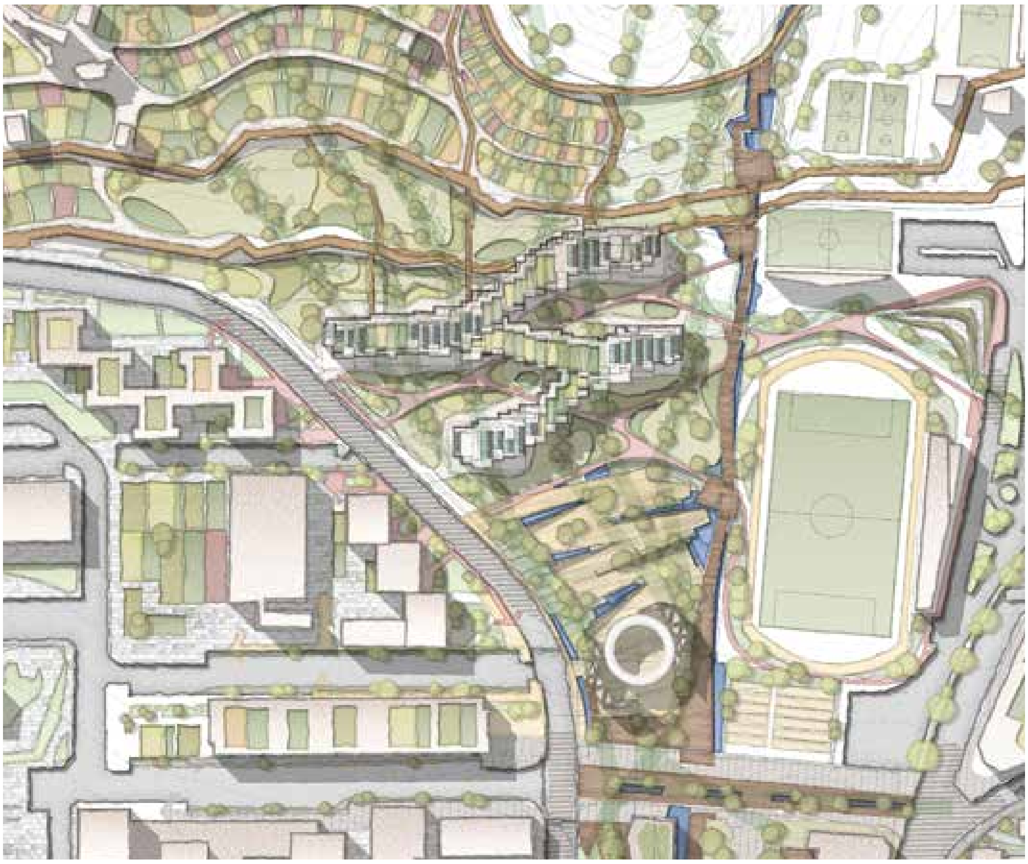


Figure 4.1 Housing complex in the masterplan

The choice of the social housing units, that we name “ Locavore dwelling”, is a result of our belief that the idea of the Agri-hub we implement and that revolves around the people; i.e., the Locavore, is best demonstrated by designing a model housing complex where the Locavore practice their food production as part of their house management. This proximity of their practice to the dwelling represents the manifestation of their dedication to their approach. In our case where we aim to promote the practice among the new comers to our housing building, the new Locavore will be spread out this building, where inhabitants are in contact with the idea of growing food just in their terrace, corridors, and common spaces.

Density of residents

The Agri-hub is the main theme implemented in the master plan design. However, the buildings comprising this hub have diverse functions and consequently capacity of attracting audience. The Agri-Research and experimenting have a limited capacity to involve people who are not strictly involved in the functions they promote. The market comes second with the local food court which targets audience from Canyelles and Les Roquetes and has a more public access. The Housing units represent the buildings with the more private access and more involved users.

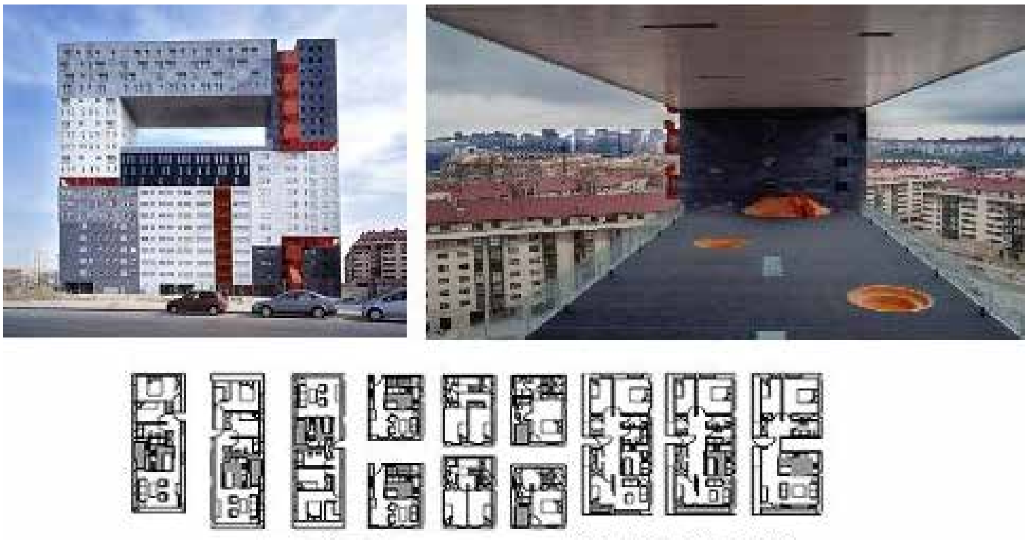
The design provides a total of 95 units of different types:

-76 units Typ A-family units for 4-5 persons (80 m2)

-12 units Typ D for the Elderly single or a couple (35-40 m2)
- 3 units: Typ B - Duplex family units for 4-5 persons (110-120 m2)
- 4 units Tyb C - Duplex single units for 2 persons (70- 80 m2)

This density of users, we believe, will be the best way to involve the residents to get involved in growing food just next door. The success of the involvement of the residents in becoming the future Locavores, starts from their doorstep. And for that reason, we place high priority on the dwelling unit buildings.

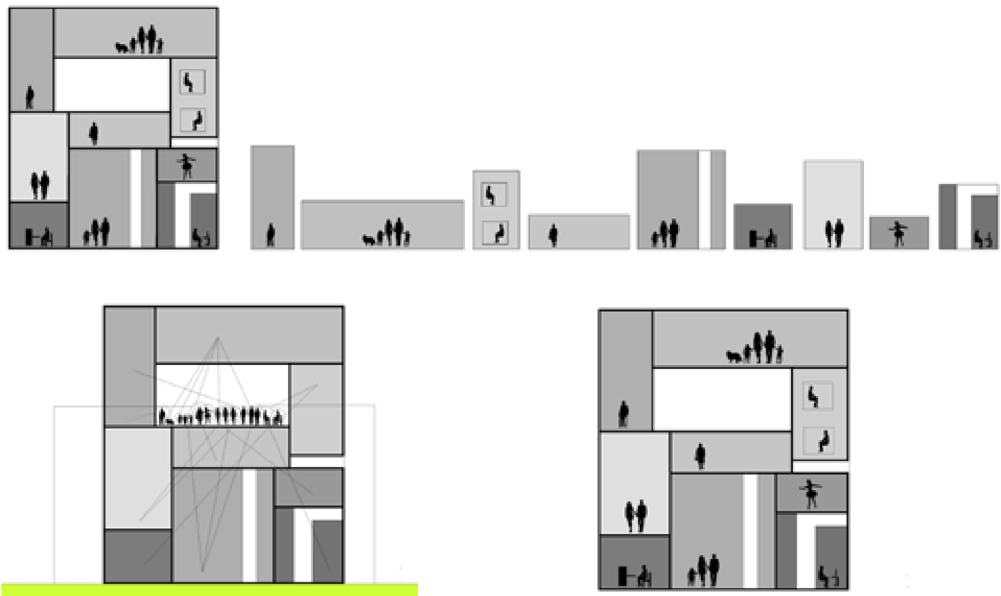
Figure 4.2
Social housing complex in Madrid, by MVRDV
(source: MVRDV)



Mixed use complex

Although the requirement of the competition was involving services for the social housing units, we explored new and diverse ways of involving residents in common functions tat we believe are the core of a successful atmosphere in such buildings. The term 'mixed-use' can have different connotations, and for us, mixed-use implies more social cohesion and more resident involvement in making the complex an enjoyable experience for our future locavores. We will detail the functions we found to be most needed to achieve this among the residents.

Figure 4.3
Diversity of functions in the Mirador building by MVRDV, Spain
(source: http://mirador-mvrdv.blogspot.it/)



Model Social houses of the Agri-hub (agriculture practice inside)

Figure 4.4 Community gardens at Agrocité—an agro-cultural unit within the R-Urban network in Colombes, June 2013.

The approach is what we intend to spread in Canyelles and the neighbouring contexts.
The current social housing buildings present in Canyelles, though undergoing continuous development by the municipality, didn't provide us with a model to get inspired by. The architecture of social housing that is needed is a radical one. This typology of buildings that has always presented challenges for architects especially in the previous century, has an intricate analysis and implementation for it to succeed after its construction.

Based on our look into precedents from different times, most of the times, the factors neglected lead to a great failure thereafter and these cases are still present. The social housing design is more than apartments for residents. The social aspect is a crucial aspect to think of. The usual social housing implement common services(kitchen, laundry) but that is not the key. The key is the sense of community that brings together people living in a typology of affordable buildings like this and makes them perform community duty out of their will. The common functions that we implemented that are based on agricultural practice we believe can make residents have a sense of communal life

Figure 4.5 'Mesh boxes' in the Social houses of Sham Shui Po, Hong Kong

(source: http://www.viralsoma.com/over-100000-people-found-living-for-decades-inside-horrifying-ldquocaged-cityrdquo.html)

Environmental building technology implementation

The environmental aspect seems an aspect taken for granted, as the designed building is site responsive building that is based on the environmental analysis we presented. The basic idea in this section is that we intend to present this aspect in simple and affordable way because the typology of the building necessities to abide by sustainable building measures but still be affordable for the new residents. Applying what we term as 'sustainable strategies', can go in ways that make a simile housing unit even not afforded by the owner.

Figure 4.6 Social houses of Sham Shui Po, Hong Kong

(source: http://www.viralsoma.com/over-100000-people-found-living-for-decades-inside-horrifying-ldquocaged-cityrdquo.html)

4.1.2 Design Principles

Green Corridor integration/ natural land lines

The main design consideration of the housing units is the integration with the natural setting of the Collserola and the green corridor. The green corridor that we explained lengthily in the urban analysis is a feature of the site that represents a challenge to buildings that are inside of it. The basic design criteria of the green corridor is the continuity of the greenery and biodiversity. However, the Housing building(s) is located at the very border between Collserola and the rest of the buildings in the masterplan design, so the design was at a critical point here.

The approach was to ensure the continuity of the greenery through the terrain, and if not possible through voids made into the volume of the building, and through green(cultivated) roofs. Eventually, the biodiversity will thrive in these minor green passages that meet at Collserola.

Figure 4.7
The project site in Bracelona, next to a green corridor
(Photo: MVRDV)

Maintaining threshold relationship collserola- urbanity

The location of the building at the threshold with Collserola put high priority on maintaining harmony with the natural surrounding. Threshold relationship is critical design to maintain both characters of spaces. The other consideration is that our masterplan design proposes physical connections with the mountain starting through our design site.

The approach was to integrate the green corridor sub-passages (ensure continuity of biodiversity_ with physical connection with Collserola where possible. If the approach doesn't allow going through the building, the connection can still be applied through more public spaces.

Figure 4.8
The continuity of the Lush Park in the same project by MVRDV.
(Photo: MVRDV)

Developing mixed- use vibrancy

Avoiding the creating of a night-use residential neighbourhood was a point to be taken into account through the functions implemented. The analysis of precedents allowed us to highlight major functional typologies that will be included in our housing building to create vibrancy and liveliness in different times, as well as on the scale of the neighbourhood and all Canyelles which now actually is a nearly night-use residential neighbourhood.

Figure 4.9
Underground Shopping Mall Topped With a Lush Park in Barcelona near a green corridor by MVRDV.
(Photo: MVRDV)

Designing by orientation

The first environmental consideration specific to the site is the orientation of the building façades. This design principle is exceptionally important for residential buildings as the future users' comfort and building energy demands will be regulated by this. However, some considerations may hinder the perfect compilement with the right space orientation. But in any case, trying to ensure that the main residential spaces(living areas, bedroom) are facing south, south-east or -west, or east is a necessity.

The new thing to take into account was the orientation of the agricultural spaces. As its known, practicing traditional agriculture(terrain, greenhouse) or a -ponic one requires abundant presence of sunlight. Taking into account that these practices need to be oriented by south or south-east or -west was another design criteria.

Max Exploitation of view

The view is a criteria dictated by the site, and has a big importance in residential buildings specifically. Since the building is on elevated land compared to the down part area of the site, it meant the buildings of the agri-hub will not block its site. The challenge was ensuring a good portion of the view over Bracelona to the big number of units without having to compromise the orientation, or end up with units not able to access any portion of the beautiful scenery over the city.

Figure 4.10
View from the site over Barcelona

(source: http://www.gasnaturalfenosa.com/servlet/ficheros/1297152420293/Canyelles.png)

Ease of access and circulation

The ease of access for pedestrians and cars is an important architectural aspect that the future users will experiment on daily basis. The pedestrian part was ensured by the pedestrian connections that ensure that walkability is implemented on site, and a resident can get from the metro station or bus station to his house in a safe pleasant path. On the other hand, cars were to be considered, as residents cannot be denied access through cars to the housing units in a certain range of distance(where after they can walk) . The car access and parking was an issue that we did many iterations to consider in the best way possible that we explain in the design development

Figure 4.11
The view from one social housing buildings in Canyelles

(source: https://www.spotahome.com/barcelona/for-rent-:rooms/84872)

4.1.3 Social Housing of Canyelles

The actual situation of the social housing residential blocks is analysed by the responsible City Council Bodies in order to improve their situation. In a study published by the Ajuntament de Barcelona in 2011, the building typologies are described and the improved forms are shown. The study mentions facts about the current buildings in the neighbourhood, like the number of units, ownership, building problems.

Building Classification:

- 65 Blocks
- 2524 Housing
- 101 Commercial facilities

Structural pathologies includes:

- Oxidation,
- Carbonation,
- and Humidity

Different communities of owners exist:

- 60% General,
- 25% City Council
- 15% Private Owners

The municipal plan is to improve not only the structural problems mentioned , but also improve the energy efficiency of the buildings. The materials and especially insulations of walls and roofs, the window layers, and also heating and cooling systems. So we can deduce that the topics of sustainable building technology in construction is already on the agendas of the governmental bodies. This gives our design approach a credibility.

Figure 4.12 Our project site and the studied buildings in Canyelles

(source: BCC)

Figure 4.13 Canyelles social housing by typology

(source: Reforma-Rehabilitació i eficiència energètica. El cas del Patronat Municipal de l'Habitatge de BCN)

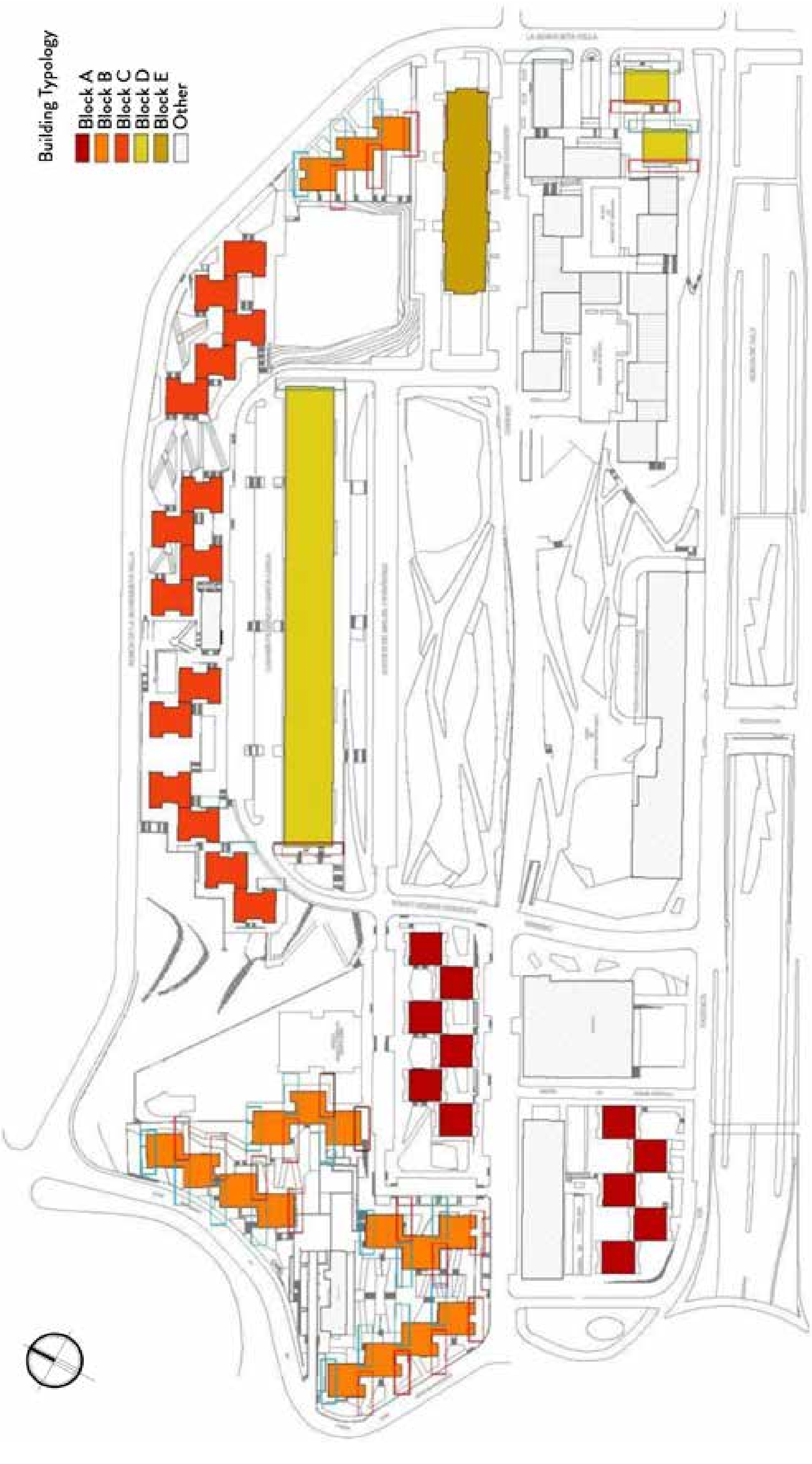
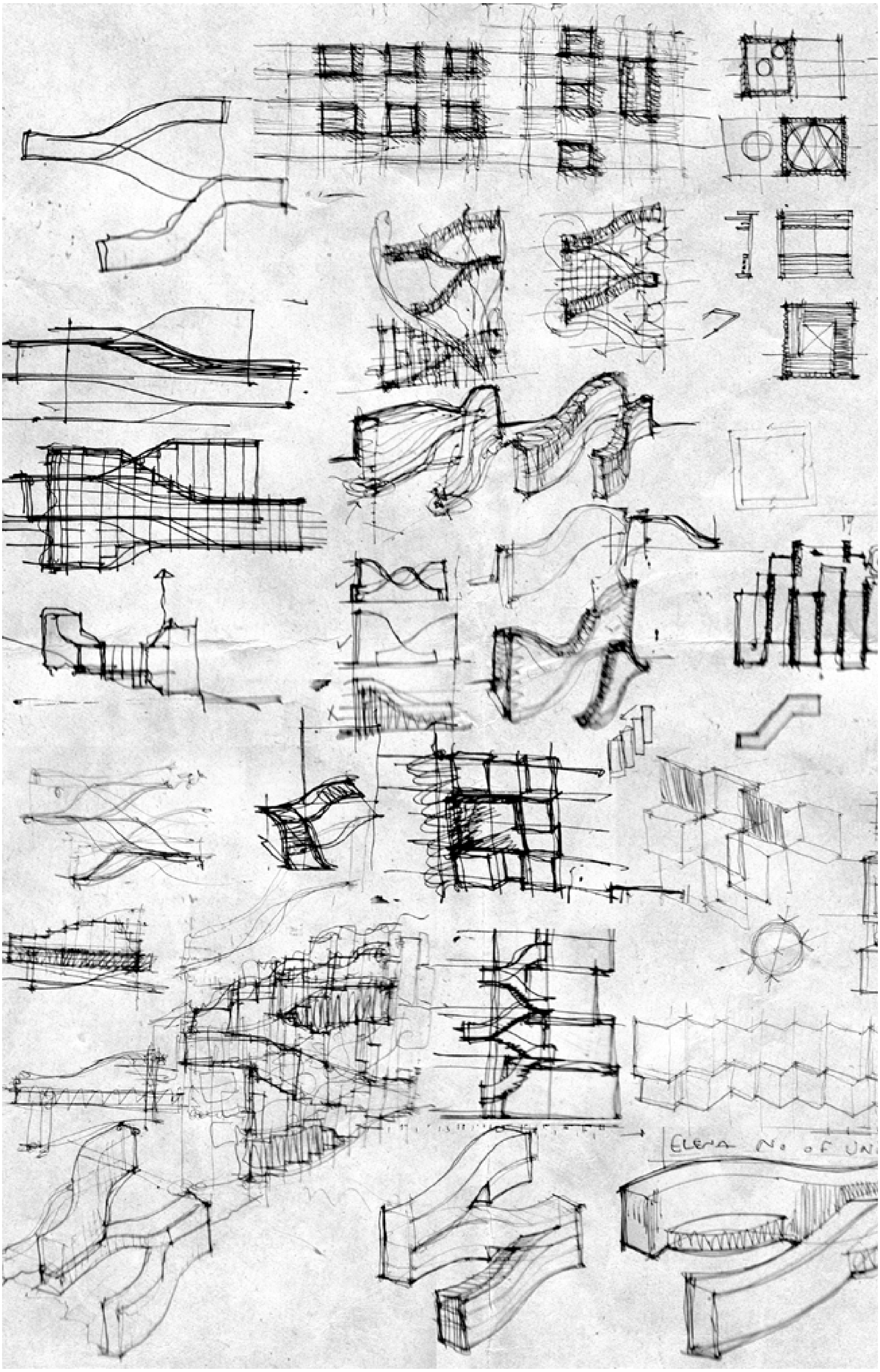


Figure 4.14 Social housing buildings in Canyelles

(source: Reforma-Rehabilitació i eficiència energètica. El cas del Patronat Municipal de l'Habitatge de BCN)

Figure 4.15 Social housing buildings in Canyelles

(source: Reforma-Rehabilitació i eficiència energètica. El cas del Patronat Municipal de l'Habitatge de BCN)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4.2 Design Development

4.2.1 Building Typology:

Agritecture: Architecture with urban agriculture, essential for any resilient city.

Urban agriculture is a trend many cities are experiencing. Spurred on by the drive for countries to be able to feed themselves, feed more people, import less and serve the increasing preference for food that's local and seasonal, urban agriculture is having more than just a practical impact on built up areas. It's changing the face of cityscapes as we know them.

Urban agriculture is not a new invention, but it has taken off in popularity in the past few years due to a combination of factors including advances in technology and a slowdown in real estate development due to economic recession. Architects have embraced the trend, with proposals for vertical farms and landscape urban plans for vast tracts of urban agriculture appearing in competition entries and student projects around the world. Looking at a variety of installed examples around the world shows that progress has been made and the reality of ubiquitous urban agriculture may be just around the corner.

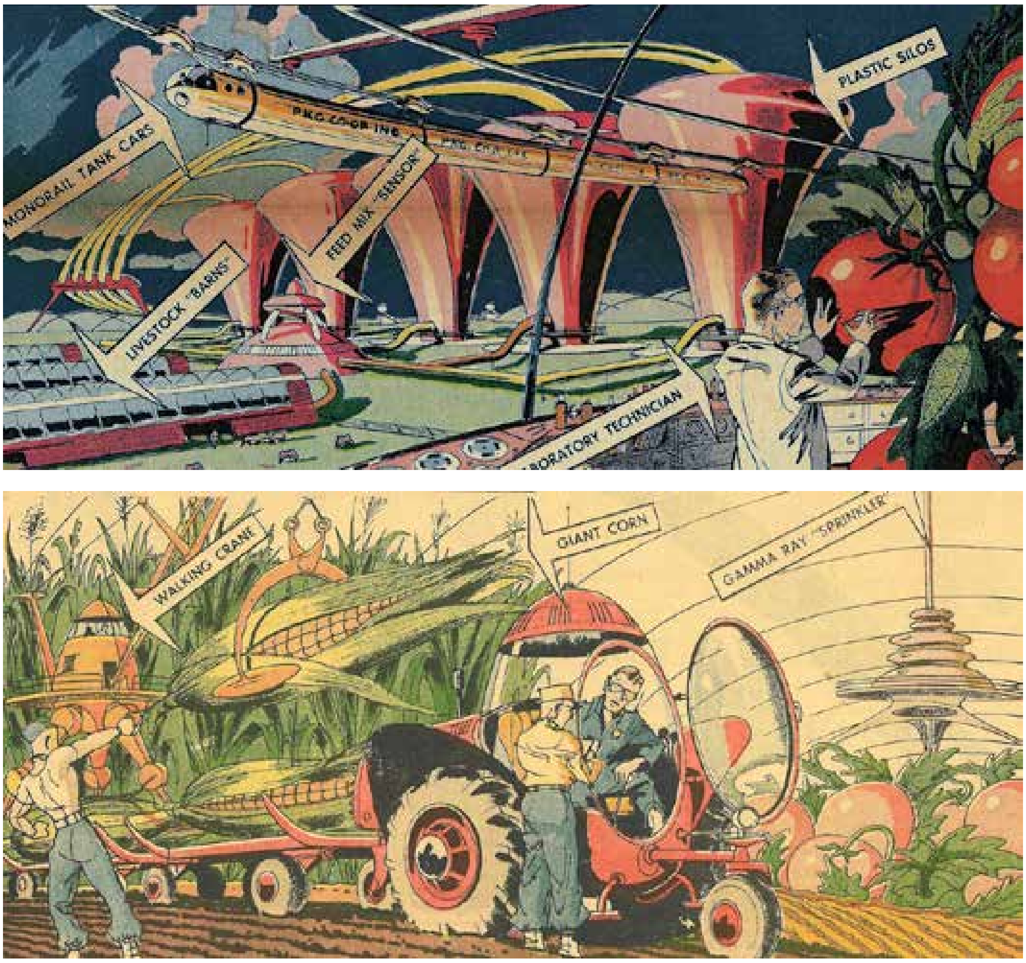


Figure 4.16 Series of futuristic drawings popular in 1958 about integrating urban agriculture with architecture: A long envisioned concept

(source: https://paleofuture.gizmodo.com/super-sized-food-of-the-future-512620688)

-Precedents

Locavores of London

Capital Growth is a campaign to create 2,012 growing spaces in London by the end of 2012. One of the most innovative examples is FARM:shop in Dalson. Created by Something & Son LLP, “an eco-social design practice,” the enterprise seeks to develop a network of city residents growing their own productive crops and turning a profit doing so. They also intend to link farms in the countryside with cities, and to grow food commercially through their own network of FARMs and sell the produce through the FARM:shops. Their current location in Dalston produces agricultural products sold in the on-site cafe. There is an on-site aquaponic fish farm, rooftop chicken coops, and indoor allotments.

Figure 4.17 Farm:shop design by Something and son, in Daltson, London

(source: http://somethingandson.com/wp-content/uploads/2013/02/10.jpg)

David Baker and Partners Architects of San Francisco has used this approach on numerous high-density residential projects in California. The most notable example is on the roof of Curran House, a social housing project in the centre of San Francisco’s gritty Tenderloin neighbourhood.

Figure 4.18 Roof of Curran House a social housing project San Franciscon designed with David Baker Architects

(source: Andrea Cochan Landscape Architects)

Plant Chicago

Plant Chicago represents the opposite approach to urban farming, where the food production network thrives within one large building instead of being distributed throughout the city. Located in a vacant four story meatpacking plant in Chicago's Back of Yards neighbourhood, the focus is on creating a zero energy incubator for urban agriculture. One third of the building is devoted to aquaponic growing systems with the rest of the building providing low-cost space for sustainable food businesses served by low-cost power and a shared licensed kitchen.

Figure 4.19
Plant Chicago

(source: https://www.atlasobscura.com/places/the-plant)

By reusing a very durable existing building, the owners not only have saved money but have conserved the energy invested in constructing the building. Spurred by $1.5 million grant, The Plant will go off the grid via an anaerobic digestion and a combined heat and power system that will take waste from the building and surrounding food businesses to generate electricity and heat. While the sturdy brick exterior doesn't look groundbreaking, The Plant is taking advantage of cutting-edge technology to economize food production and eliminate waste in the process, breaking new ground for systems thinking in architectural projects elsewhere.

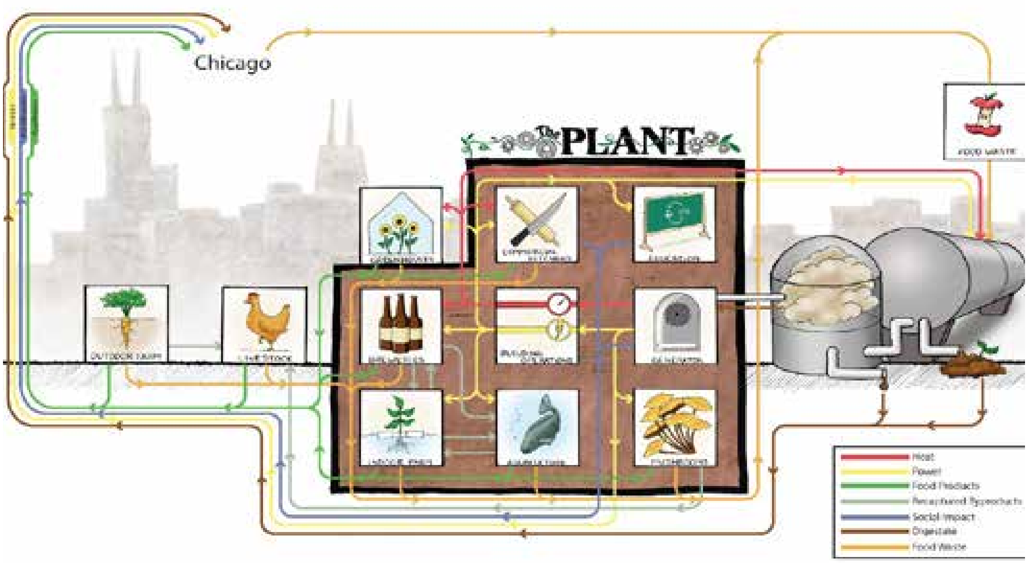


Figure 4.20
Closed-loop cycle of enegry-waste on site

(source: https://www.greenbiz.com/article/circular-economys-missing-ingredient-local)

Pasona 02

Pasona 02 takes a similar approach to reusing obsolete space, but does it underneath the city of Tokyo. Located in a square kilometre of underground bank vault, this project seeks to address Japan's food deficit and train youth in food production in a country where most farmers are elderly. A variety of crops, including rice, tomatoes, and flowers are grown under artificial light. Little attention has been paid to energy efficiency, but efficiency of production is a priority through use of high-tech, fertilizer-free systems.

Figure 4.21 Pasona 02, UA in the heart of Tokyo

(source: https://metropolisjapan.com/pasona-o2/)

The Living Tower

The concept of the Living Tower's aim is to associate the agricultural production, dwelling and activities in a single and vertical system. This system would allow to make the city denser meanwhile a greater autonomy could be gained reliance in agricultural plains, reducing the need of transportation between urban and extra-urban territories. The yet unusual superimposition of these programs finally makes it possible to consider new practical and energetic relations between agricultural culture, tertiary spaces, housing and trade inducing a very strong energy saving.

Figure 4.22 The living tower by Soa ARchitects in Rennes, Frannce

(source: http://it.archello.com/en/project/la-tour-vivante-living-tower)

4.2.2 Building Layout v/s Hierarchy of Goals

Approach

The layout of the building is the result of the superposition of achieved goals. As we described our design principles that were reached by the site analysis on the urban and architectural scales, the layout of our building(s) is decided by these principles. We laid the possibilities of the building layout with the program of functions that we set. As the housing units constituted the biggest proportion of spaces and consequently the volume of building(s), we started the layout thinking of the units. Since it will be an affordable housing building, the ease of construction, transport, field work, and time factors, we considered modular units of different types, but based on a unique construction/ assembly system. After this decision we started to think of the combination of this modular housing units versus the set of goals we had to meet

The unit: the project cell

The first design sketches focused on the unit design. The main design consideration in this case is fitting the needed spaces in a design that can be adapted to modularity. Then the correct orientation and maximum use of the view. Thinking of natural light, ventilation,and circulation of users, furniture design, and the ability to aggregate these units were driving our design development. The result of trials lead us to preliminary unit design, that will be aggregated in the site taking into account other design principles related to the macro-site.

Evolution of building configuration

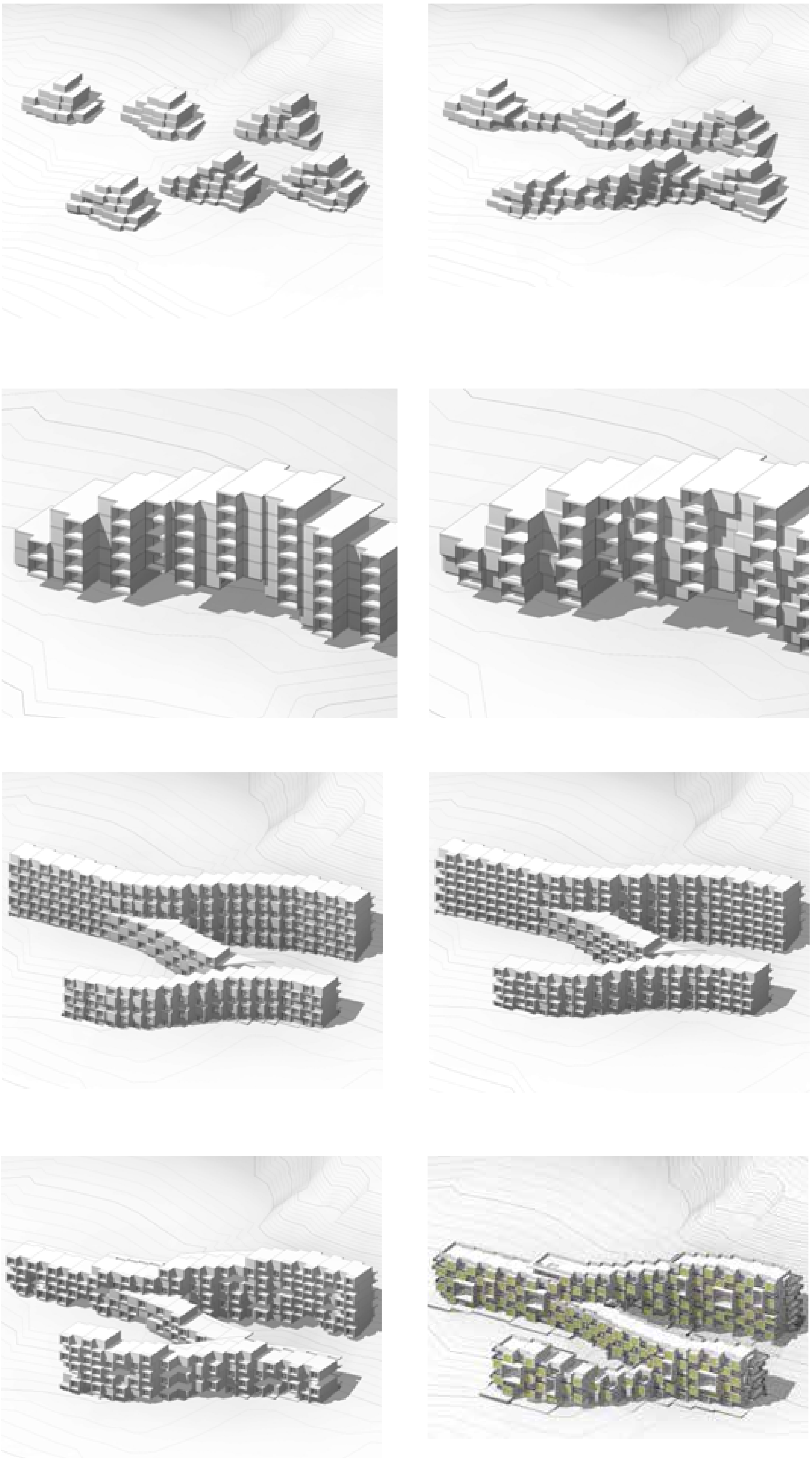
The first design layout was to aggregate the units in a simple linear way:

The first unit designs were the project nucleus that needed to be put in the layout most suitable to the different design principles we analysed. The first design layout was to aggregate the units in a simple linear way in two or more blocks located on different levels of the site. For us, it was a fixed point of the design to set living areas facing the view, which is south-east oriented(perfect for the users). However, the inside layout of each building, was subject to trial also: will the circulation corridor be single loaded(with 2 rooms of the unit facing the view, or double-loaded, with one unit not benefiting from the view?

The design development to this stage had to lead to an important decision about the exploitation of the view over the city. Single-loaded meant all units benefiting from view, while the double-loaded meant a more compact design, and consequently the ability to limit the number of blocks.

We believed the view was a big attribute to the site. The location we chose for the housing building(s) was on an elevated area of the site, that could make use of one of the scenarios of Barcelona, and consequently we opted for single-loaded, and started to look for methods to achieve compactness of the building in other ways.

Figure 4.23
First building layout development: different trials and evolution



The other approach was non-linear; what if the aggregation was central with a core element?

Another way of aggregating the units was by placing them in a concentric way. That meant, speaking about a footprint, each sum of units will be collected around a central space that we proposed as a courtyard, or an agricultural court. This proposal was inspired by the classic urban layout of the Barcelona Grid. However, this layout is of an introverted nature that will serve our sense of community purpose but will be deteriorating the state of compactness of the blocks. What is more important is the exploitation of the natural view that we just discussed its uniqueness, and centralizing units around several courtyards or even single or double courtyards will take the importance of the view. Another important consideration is the orientation. In this manner the units will have different orientations, and that is not the best solution for residential units.

The principle of compactness is an important one in this design that needed to be achieved in this stage, for two reasons:

- Energetic considerations: The compactness of building units meant less environmental interactions, and that will present a contribution to its future energy performance.

- Social aspect of the housing units: the sense of community is a crucial one to consider to promote community movements like the locavore movement we intend to implement on site. This social aspect is created by architecture layout. Placing residents in separate units with no opurtunity of interaction will not aid in bringing residents to practice a common activity like cultivation. The same idea applies to the neighbourhood scale.

So in the end, we dismiss the non-linear central configuration, due to the restrictions to:

- building Compactness
- use of the View
- proper Orientation of all units

Our conclusion from this stage is that:

- The housing units, which are modular in nature and will be in 2 basic areas: family size and couple/single size, with possibility to have more than a layout for each, in addition to the possibility to have a bigger module. All this implies that our basic unit is the smallest: the unit for couple/ single person.
- The aggregation of the units takes place in linear manner, to preserve a degree of compactness necessary for the project, in addition to making use of the view and proper orientation of all the units to the maximum. These three elements of compactness, maximum view, and proper orientation were our main design principles

The next idea was, what if we want to achieve maximum compactness?

As we mentioned, the compactness of the project is a major concern for our design. Our next idea was how to achieve a maximum amount of compactness (considering that the project can cover a certain footprint with limited number of floors) the approach was to create a one single aggregation of housing units. So we maintained a linear configuration, but made a link between the 2 blocks we created in the first trials.

The final list of benefits we gained from this configuration:

- Space enclosed between buildings to create community
- Maximize the view of Barcelona from the apartments
- Good shape integration both with mountain and city
- Repetitive from to allow modularity
- Integration with the agricultural landscape
- Good internal room disposition (south living room)
- Good energy performance

What about the natural topography ?

The next idea was, how to make the building more in harmony with the natural topography of the mountain. The neighbouring buildings didn't provide a good example if integration with their massive blocks of high rise buildings. Indeed the human scale was not also considered in these constructions (refer to "Social housing in Canyelles" paragraph). It was necessary for the building layout to take into account the curvilinear nature of the mountain lines. This curvilinear configuration was subject to study for optimization as our ultimate building layout. The optimization was carried out to check the first data about energy performance.

4.2.3 Mass development and Energy pre-design

The use of the software Sefaira allowed to make some preliminary energy analysis on the building, in order to design it in the best way.
In particular it was decided to compare first of all different building shapes and after that also different windows configurations for the selected shape.

Shape comparison

As mentioned before, the choice of the shape was made starting from a list of goals that were aimed to be achieved in the building project:

- Space enclosed between buildings to create community
- Maximize the view of Barcelona from the apartments
- Good shape integration both with mountain and city
- Repetitive from to allow modularity
- Integration with the agricultural landscape
- Good internal room disposition (south living room)
- Good energy performance

Between the possibilities explored in the design phase, the energy comparison was made between a squared shape with internal courtyard (A) and compact rectangular units overlapped and placed one beside the other (B).

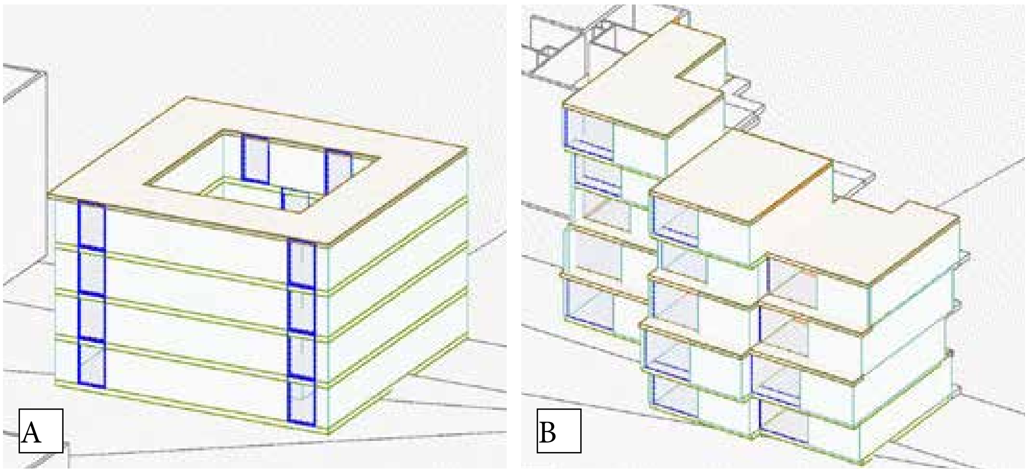


Figure 4.24 Shape options analysed with Sefaira: A) square plan with courtyard, B) overlapping of units side by side

For the analysis of the two options some factors were kept constant in both cases to allow a better comparison:
same total floor area: 1060 m2
same window area: 12,8 m2 (with same exposition: south)
same floor height
same settings for envelope, loads and systems

Parameter	Value
U wall [W/m²K]	0.29
U roof [W/m²K]	0.23
U floor [W/m²K]	0.36
U windows [W/m²K]	2
Solar Hear Gain Coefficient	0.5
Infiltration rate [l/s m]	2
Occupant density [m²/person]	20
Equipment Power Density [W/m²]	2
Lighting Power density [W/m²]	3
Outside air rate per person [l/s]	10

Table 4.1 Baseline settings for the preliminary energy simulations

Note that the envelope settings are according to the suggested values reported in Appendix E of the Documento Basico table E.1 [CTE DB-HE, 2013] for Barcelona climatic zone and the internal loads and occupancy schedules set are for a typical residential building also taking into account the annex C of the "Documento Básico HE Ahorro de Energía".

The results show that the energy performance the two shapes is extremely similar (around 70 kWh/m2 y), with a difference of only 3% in the total annual energy consumption. This means that in both cases is possible to reach a good energy performance working on the envelope and on passive and active strategies, as it will be seen later in further analysis of the final building.

Study of the living room window facing south

According to architectural decisions the favourite shape is the one made by the ensemble of units, so for that configuration were studied some openings options.

The window of the main living space of the apartments is particularly important, because it has to guarantee a good view of the city, give light to a deep space (living room and kitchen), allow winter solar gains and avoid summer overheat and glare.
A preliminary analysis was made comparing different sizes of it and then applying some shading strategies observing the effects in terms of heating and cooling consumptions.

For the analysis with the software Sefaira it was chosen the same baseline used for the shape energy comparison.

The windows configurations studied are:

- 4m x 3.2m window: full glazed living room wall
- 2.5m x 3.2m window: narrow window
- 2.5m x 1.2m window: minimum size window to guarantee the ratio WindowArea/FloorArea=1/8 as the normative imposes

These configurations where analysed for the Basecase (following the baseline), with an additional overhang of 2 m above the window and reducing the SHGC of the glass to 0.3 (presence of blinds).

The first graph shows the energy consumption for heating and cooling and how it changes in the different combinations. It's clearly visible that for the Basecase (indicated as "no shadings" in the graph) the energy consumption for cooling increases quite much with the increment of the opening size, due to the large amount of radiation entering from the window in summer. On the contrary the heating consumption reduces with the increasing of the window size benefiting from the solar gains in the cold season, but the rate of the reduction is much lower than the consumption increment in summer.
The effect of overhang (2m) and blinds (SHGC=0.3) is very limited for the smallest window, but the slope of the cooling consumption line is reduced drastically, so that the large window cooling consumption gets closer to the one of the small window case. Concerning the winter season the effects of overhang and blinds are quite similar for all the cases, increasing the consumptions but just slightly.

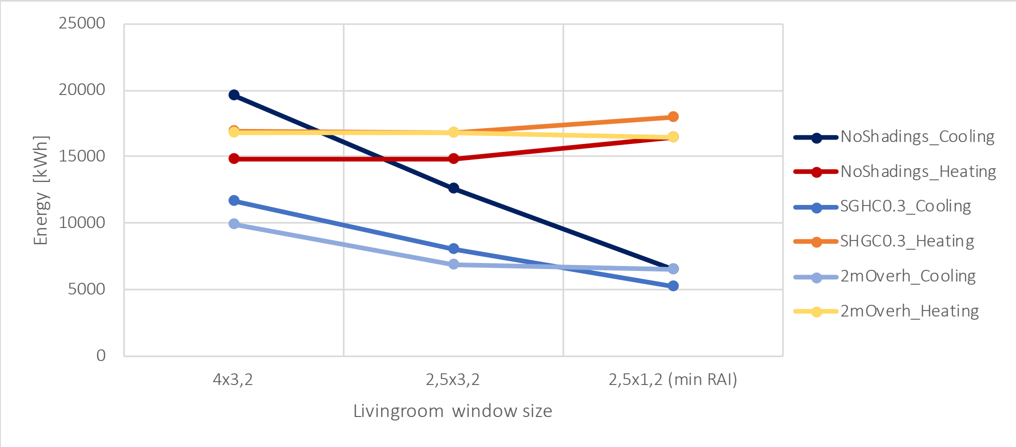


Figure 4.25
Comparison of the heating and cooling energy consumption changing the living room window size and adding strategies

So looking now at the total energy graph below it can be seen that with the integration of an overhang and/or blinds (lower SHGC) it's possible to reach for a big window a consumption similar (only a bit higher) to the one with a small window, but with the advantage of a better visual comfort due to higher daylight and a nice view of Barcelona.

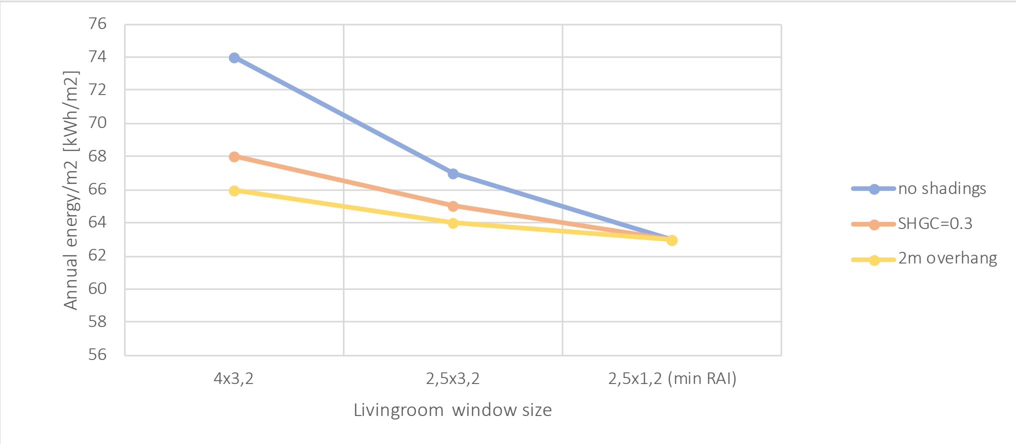
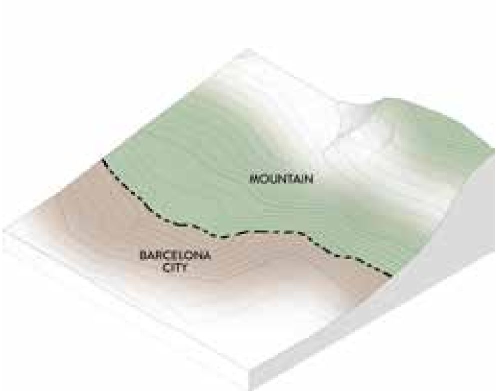


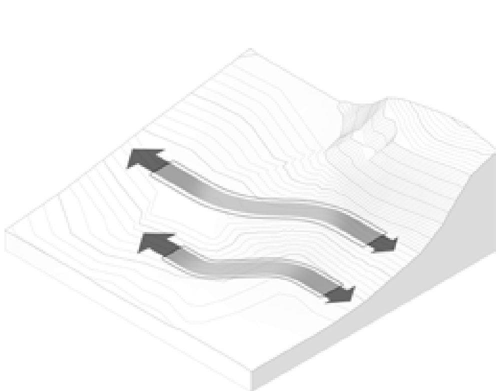
Figure 4.26
Comparison of the annual energy consumption changing the living room window size and adding strategies

We can say therefore that the opening of large windows on the south-east facade facing Barcelona is energetically acceptable only if there's the presence of shadings or blinds.
Between blinds overhangs it is preferable the use of overhangs because they stop the radiation outside the building and have a better effect in mitigating the summer heat.

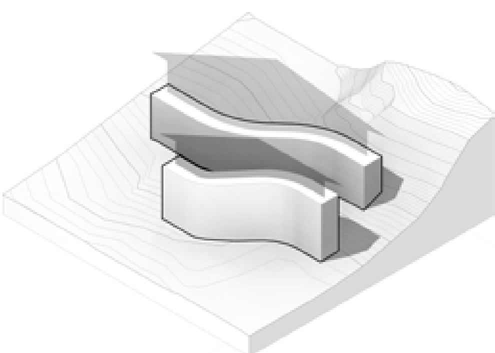
Figure 4.27
Mass concept of the building



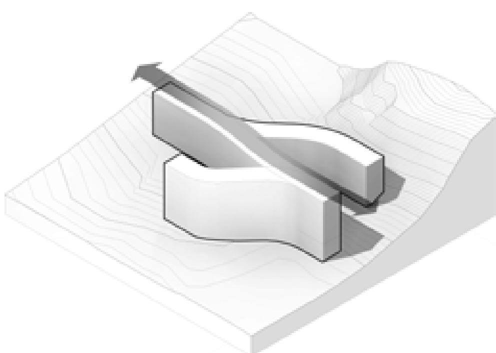
1. The site: threshold between city and mountain



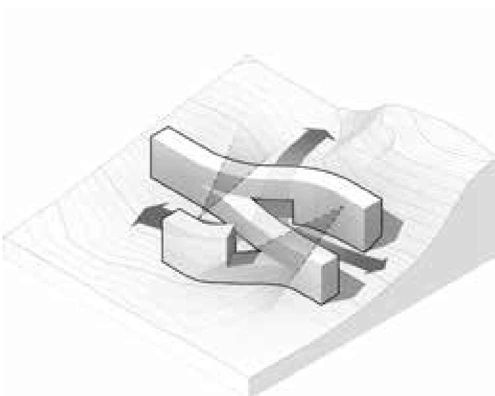
2. Following the topography to get the base lines



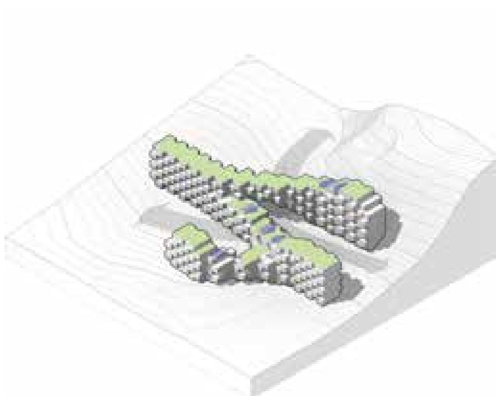
3. Extrusion of the base lines to get the first volumes



4. Connection of the volumes to create unity and enclosed common spaces

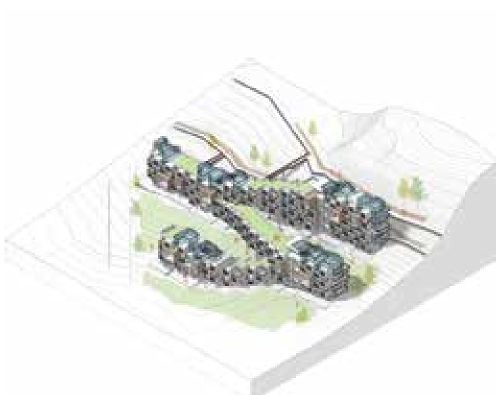


5. Reshaping the volumes to maximize the view of Barcelona



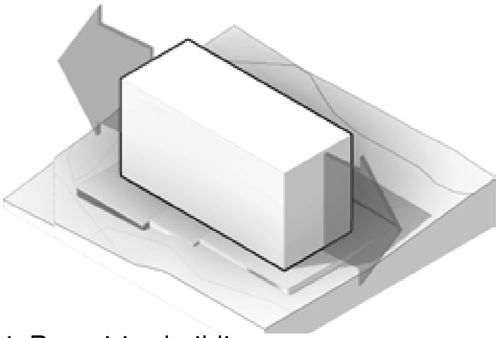
6. Discretization of the volume using the unit module

7. Perforation of the building with voids to be filled with greenery

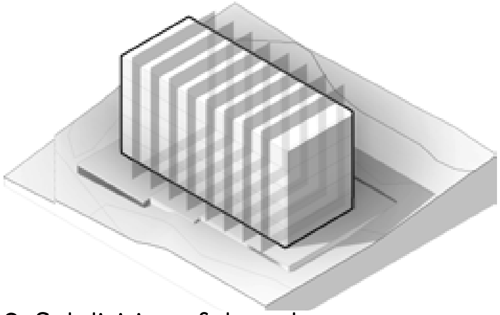


8. Addition of greenhouses and connection with the mountain

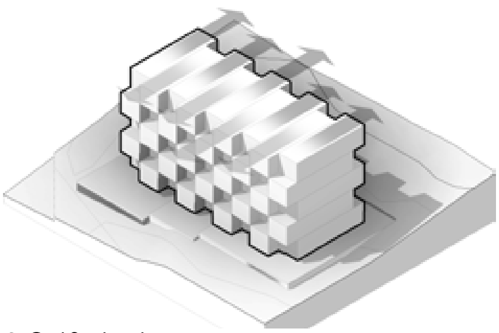
Figure 4.28 Generation of the mass focusing on a generic building part



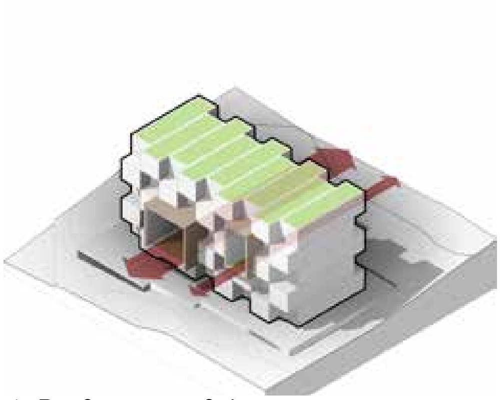
1. Repetitive building part



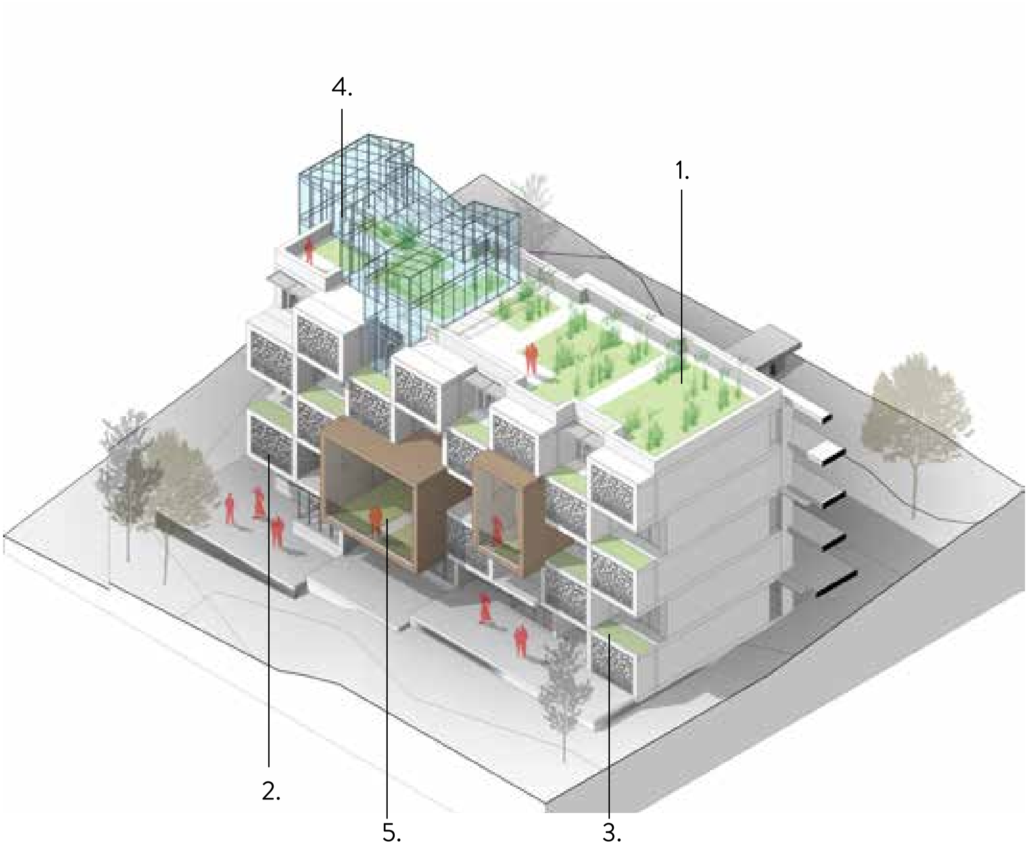
2. Subdivision of the volume



3.Self-shading movement



4. Perforation of the mass



1. Green roof
2. Voronoi shading
3. Shaded terrace
4. Greenhouse
5. Green voids

4.2.4 Functional and spatial analysis

Functional Relationships

The three main functional components are: the residential units, the common services, and the agricultural practices

The residential units

The residential units are the main function spanning all the floors. the units are of 3 main types:

- Family units of two unit cells (each 40 m2) totaling 80 m2, designed for 4-5 members, count 76 units, constituting 6,000 m2, with 3 configurations differing by a shift between the 2 unit cells.

- Elderly units of one unit cell of 40 m2, designed for 1 -2 members, count 12 units, constituting 2,000 m2
- Duplex units of 2 or 3 unit cells totaling 80 or 120 m2, count 7. These duplexes are accompanied by greenhouses on certain floors(refer to plans)

The common services

The common services are of 2 types: commercials and communal.

- The commercial functions are shops for amenities and are on the ground floor of each block(in three levels)
- The communal services are: local food cantin on floor 1, laundry(floor 3), kindergarten (floor 4), gym (floor 6), entertainment rooms (floor 4,6), seed exchange and food bartering (floor 1,2,3)

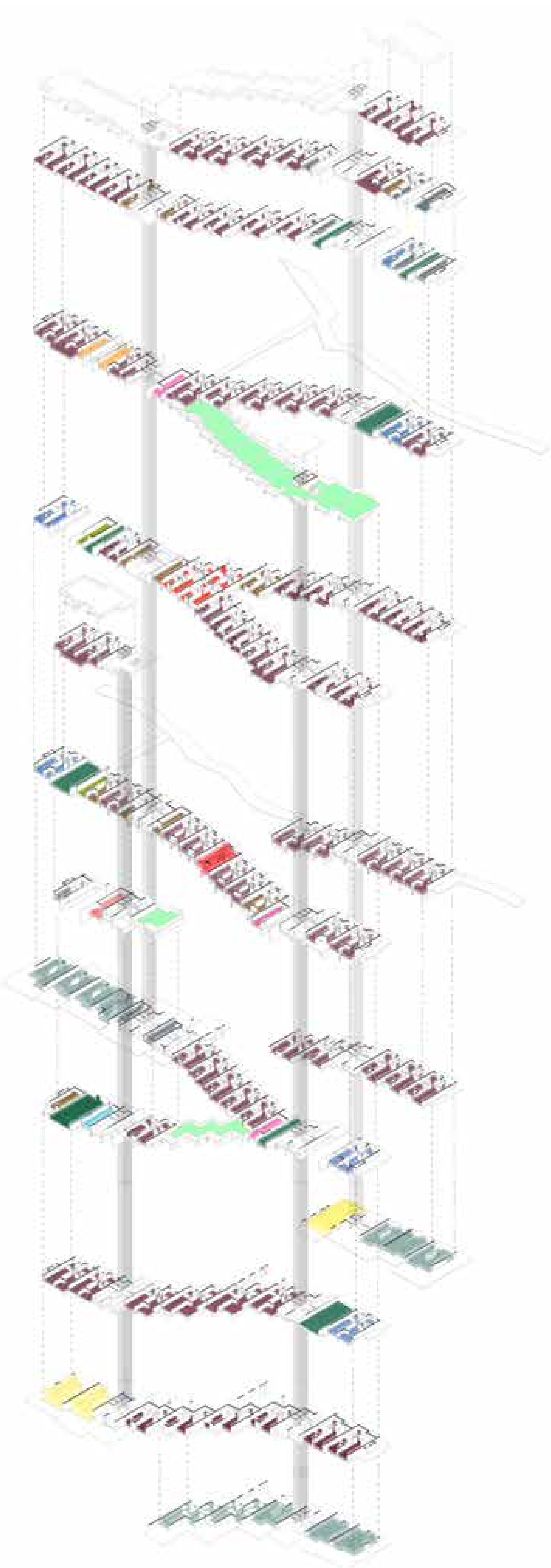
The agricultural practices

The agricultural activities occur in 5 spaces:
- The cores in each floor(count 16 spaces in total) with an area of 18 m2 each. The agricultural practice is mainly aquaponic, with a vegetable patch of variable areas.
- The void spaces that constitute the visual connections into the Collserola. These spaces are double volume spaces with aquaponic and traditional agriculture practiced in each. They amount to 8 unit cells on double height.
- The back corridor of the circulation part facing the mountain directly. The aquaponic system is incorporated in to the handrails.
- The greenhouses, oriented south to allow maximum exposure to the sun. The greenhouses are accompanying the duplex floors, and are extensions to staircases on roofs.
- The roof, where traditional agriculture is practiced.

The circulation and technical spaces

The cores constitute the stairs, elevators, and technical rooms. The cores are connected by corridors in the back part of the project

Figure 4.29
Exploded geometry of functions



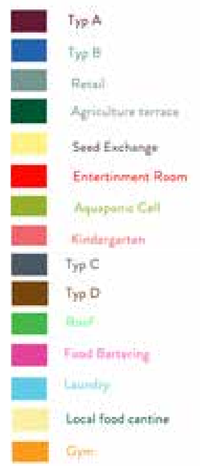
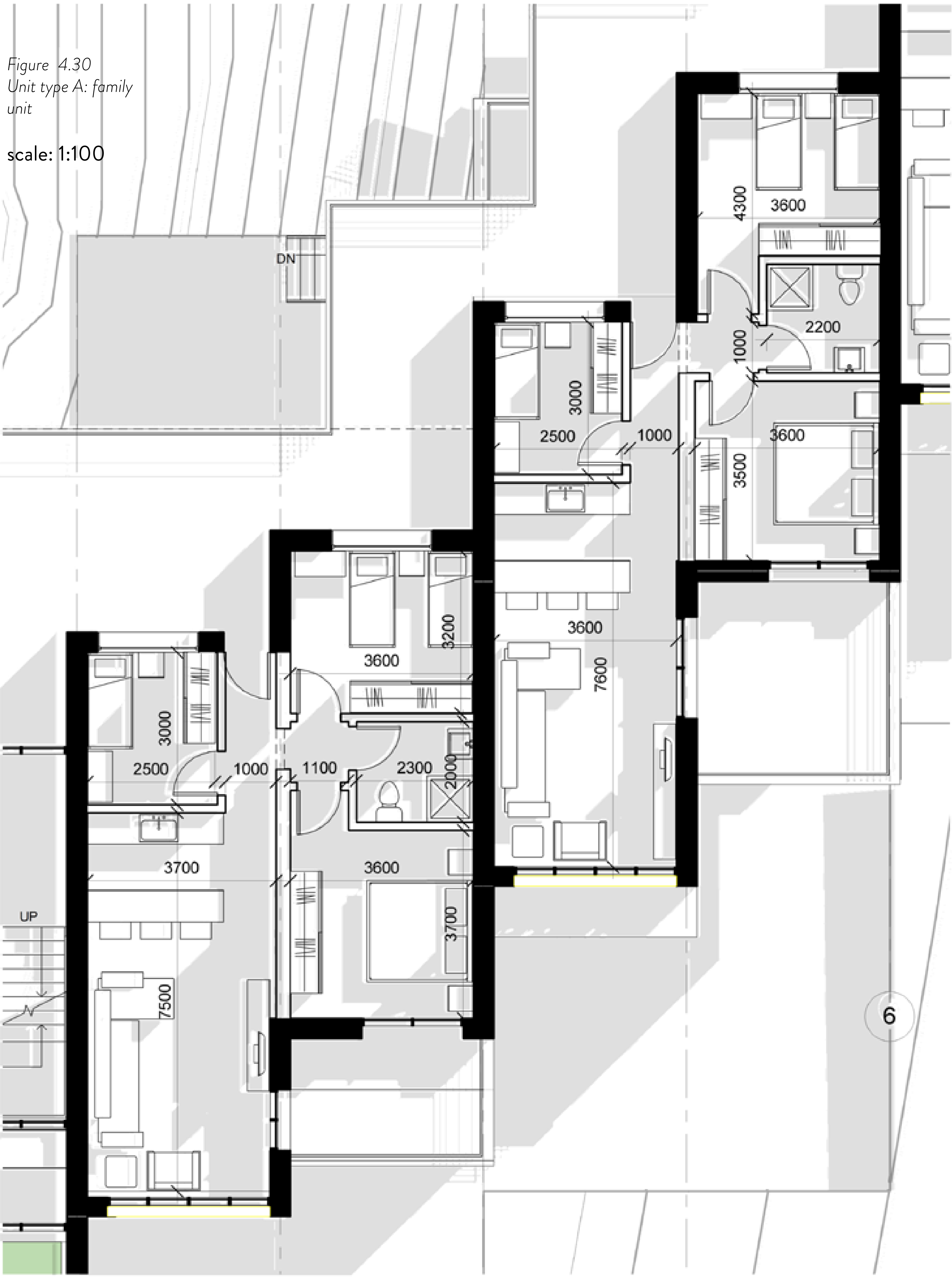


Figure 4.30
Unit type A: family unit

scale: 1:100



TYPE A : Family Unit

Area: 80 m2

- Lobby
- living+Kitchen
- Bedroom
- Bathroom
- Terrace

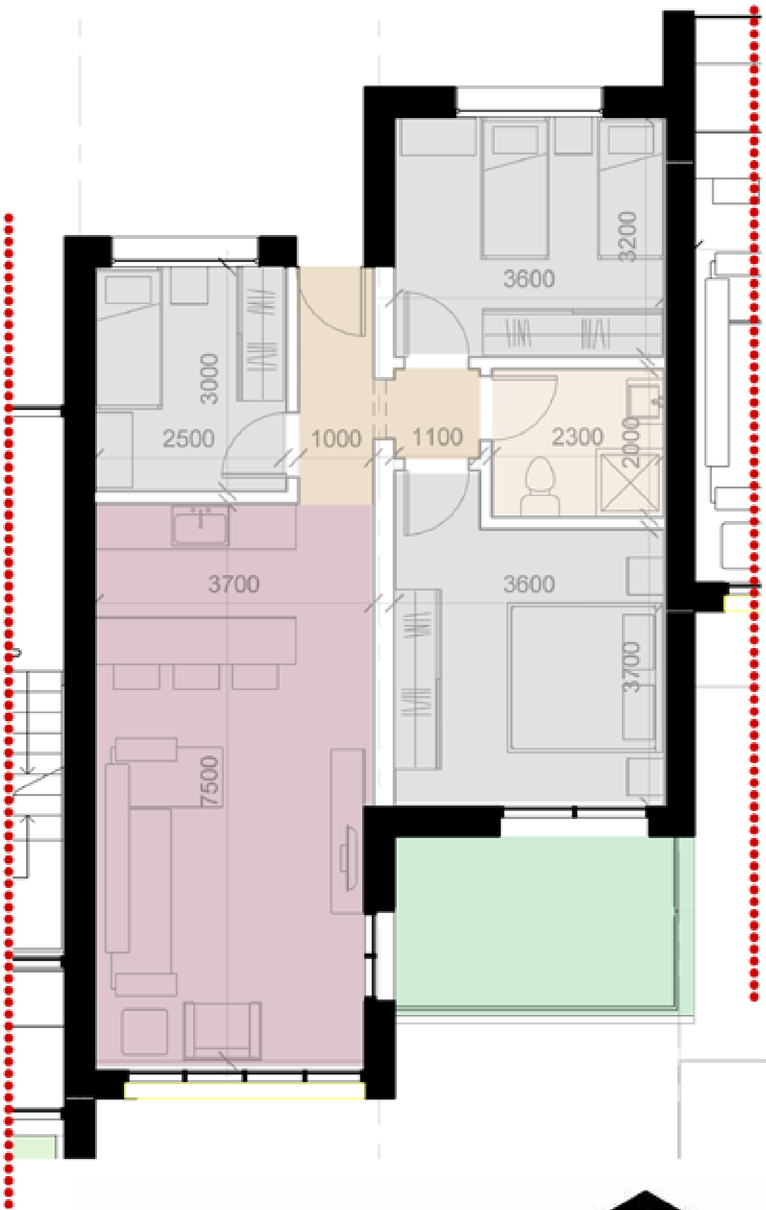


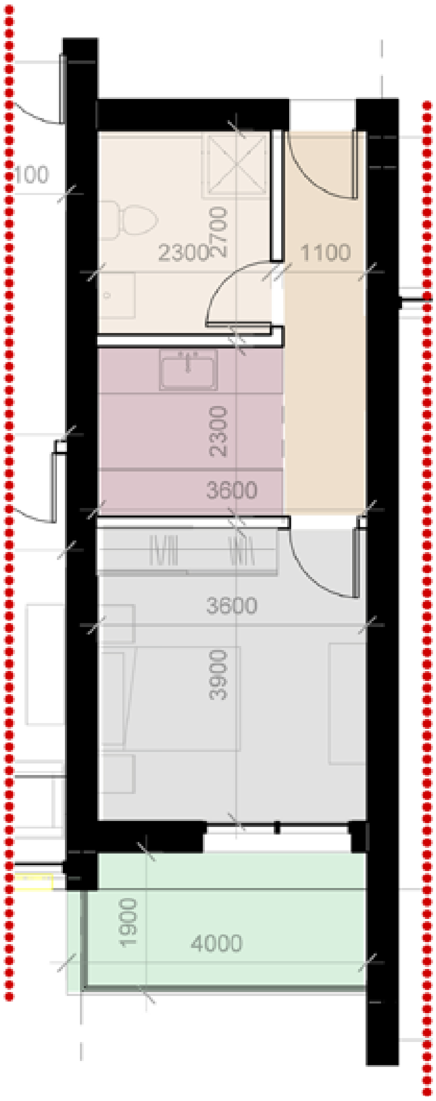
Figure 4.31
Unit type D: elderly unit (single or double)

scale 1:100

TYPE D : Elderly Unit(Single/Double)

Area: 30-45 m2

- Lobby
- IKitchen
- Bedroom
- Bathroom
- Terrace



Social Consequence: A community of Locavores

Figure 4.32 Locavore community space

We highlighted several times the importance of the social aspect in the design of the social housing buildings. Since our core idea lies in the identity of the users; the Locavores, it was important for us to envision the sense of communal life in the building and assess the contribution of the agricultural practices and other common activities to the sense of community of the new dwellers.

First, how will the sense of community be enhanced?

The sense of community is a feeling of identification associated with the place he lives. It's based in common activities, interests, and feeling of impact that a person can contribute to the improvement of his/her place. The sense of community is not only in the meeting in entrances and circulation areas. The agricultural practice is an activity that will combine common interests; ie, growing the food and taking care of the plant, then collecting the crop and storing or transporting it outside the building if it's needed, all these activities means continuous interaction. These activities entail common interests and benefits. The engagement in these activities will encourage the new locavore to pursue their practice, and spread their enthusiasm to different citizens in new neighbourhoods.

Second, how will architectural layout encourage this?

The first approach was to place agricultural practices in the most visited areas by all residents: the circulation areas. This will make all the citizens aware of them and encourage them to develop interest in it even if initially they don't seem engaged.

On the other hand, the agri-terraces in the voids present a more diverse opportunity for bigger number of residents. The common activities are designed near these agri-terraces for the same purpose mentioned up for the circulation areas. Practicing your favourite sports while looking over the residents practicing their agricultural activities, will impact their approach to the movement taking place in their building. The same goes for children in kindergarten, or in the local canteen, and entertainment rooms.

The practice in roofs and greenhouses will be an extension of this interest that will grow among residents, and eventually push the newly-encouraged ones to explore more opportunities to practice agriculture. The building tries to present different opportunities in order to encourage the biggest number of citizens to try and get involved in the practice.

Targeting all age groups is another approach to make the new movement successful. When residents see the elderly cultivation their patches around the building, they will probably be even more tempted to try their own practice. The youth in gyms and entertainment rooms will be noticing people in the agri-terraces. The children in kindergartens will be observing and participating in the agri-activities.

The new approach is creating new functions strictly connected to agriculture practice: the seed exchange cells and food bartering. These spaces are purely dedicated for the Locavores interests. This will also encourage the rest of citizens to get involved in these uniquely designed activities for the Locavores.

Figure 4.33 Locavore community space between the units

- Design elements

- Commercial Base

The commercial base is the most public zone of the building that intends to attract the people of the neighbourhood in order to get acquainted with the rest of the agricultural practices happening in the building. The commercial zone will host amenity shops mainly concentrating on local food produced(grocery, food products) and others(bakery, butchery) in addition to agricultural facilities(seeds, equipment, technical assistance) and agri-business start-ups.

Figure 4.34 Commercial functions highlighted in the render

- Housing cells

Each housing cell has a Barcelona-facing window living room, that is characterized by the Voronoi pattern shading device, that can be seen in the following figure.

Figure 4.35 Apartment units highlighted in the render

- Agricultural Cells

Agriculture cells put together agriculture practices with common functions. The goal is to create vibrant cells in the residential complex, engaging the residents in diverse activities. The agriculture practice is aquaponic with traditional cultivation practice. The common functions vary between gym, entertainment, food bartering, laundry, kindergarten.

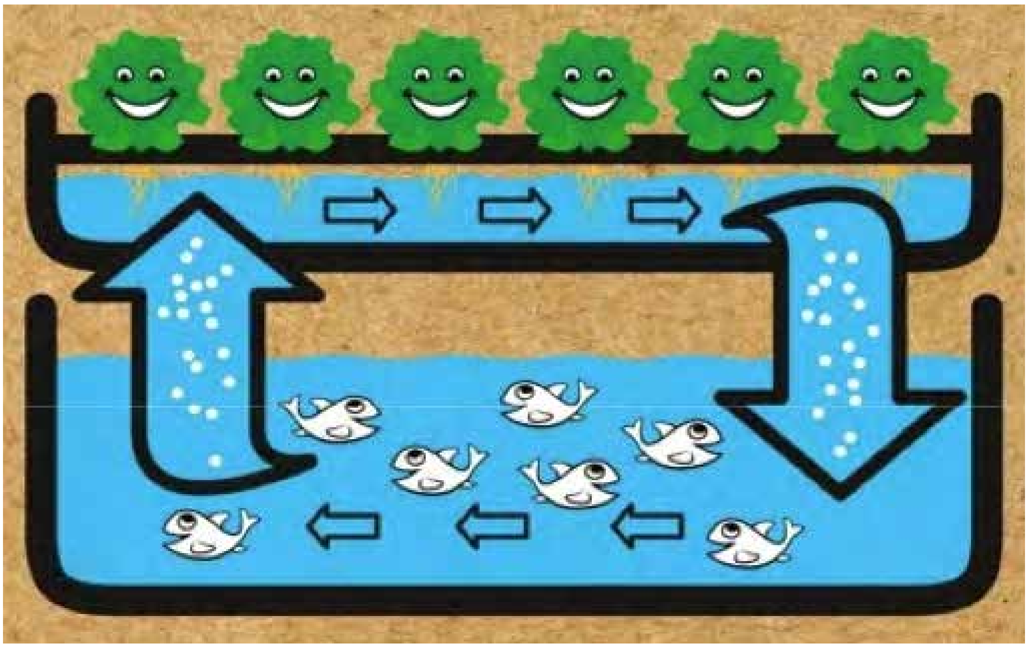
Figure 4.36
Agricultural cells highlighted in the render

Why aquaponics?

Aquaponics uses fish to create soil-less farms that can fit into cities much easier.

Figure 4.37
Aquaponic cycle

(source: Courtesy of Urban Farmers Ltd)



The farmer cultivates freshwater fish (aquaculture) and plants (hydroponics) in a recirculating water system that exchanges nutrients between the two. Wastewater from the fish serves as organic fertilizer for the plants, while the plants clean the water of fish faeces and urine.

- Water: The net result: a 90 percent reduction in freshwater use compared with conventional fish farming.
- Soil: The fact that the method requires no soil makes it particularly suitable for urban environments. Large amounts of fresh and healthy food — including fish — can now be grown sustainably on urban rooftops, parking lots, or any vacant plot in the city
- Fertilizers: What's more, the extensive use of chemical additives, fertilizers, pesticides, and antibiotics has become an indispensable part of conventional agriculture today. The system can be run without pesticides and, because the fish environment is spacious and clean, without antibiotics.

Figure 4.38 Commercial-scale Aquaponic farm on a Basel rooftop, 2011

(source: Courtesy of Urban Farmers Ltd)

250 m2 of an aquaponic greenhouse roof on a roof top ------> feeds 100 persons year round by producing 5 tons of vegetables and a ton of fish

These methods of urban farming allow the farmer to avoid the hugely complex, costly, and polluting distribution and refrigeration system through which city food otherwise travels. Therefore, the farmer also enjoys a competitive advantage in delivering truly fresh, tasty, and nutrient-rich food to customers' doorsteps.

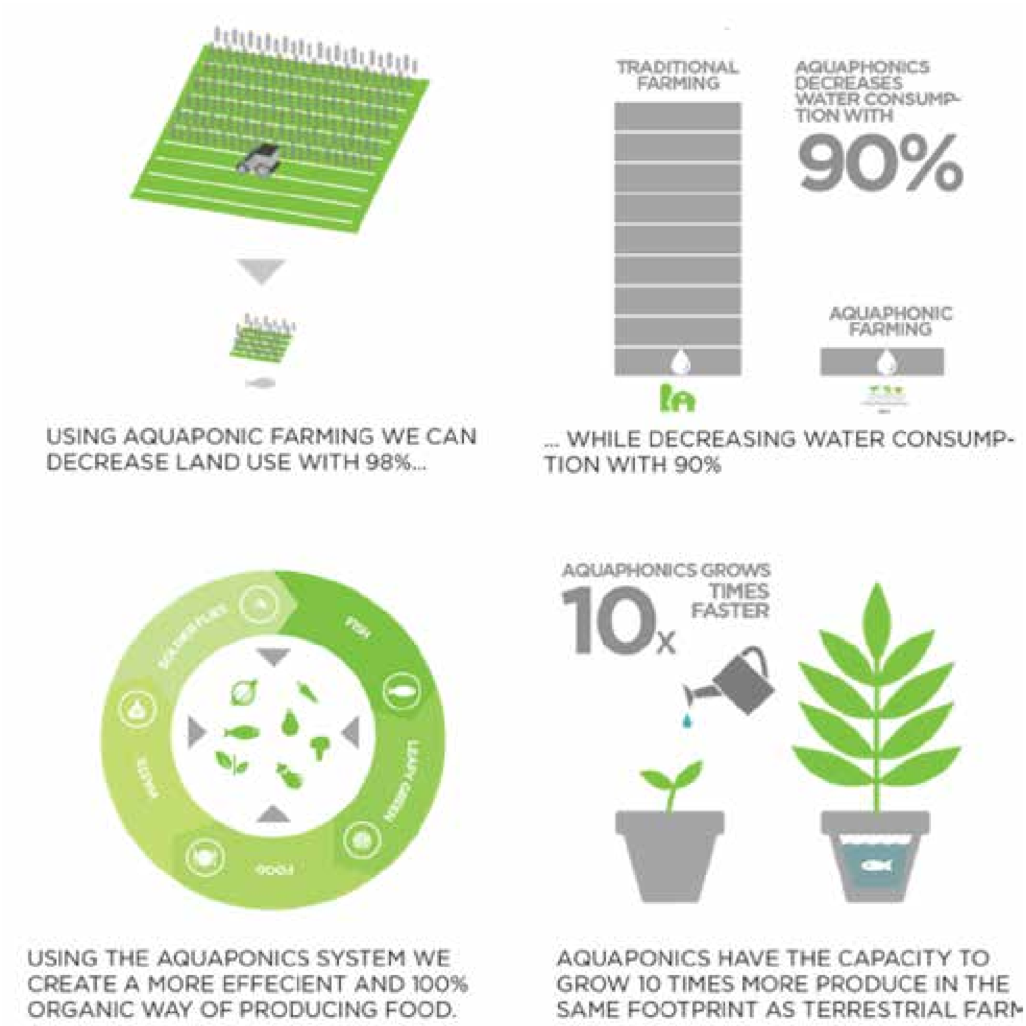
Urban farming also helps cut way back on food waste — which currently represents about one-third of all food produced worldwide.

Drawbacks

We must remember that commercial-scale aquaponics is a delicate technology requiring a sensitive balance between the cultivation of fish and vegetables. You cannot maximize yields for either part without creating problems. Maintaining food safety and quality in these systems is critical. It won't replace our conventional food system but could achieve a sizeable urban market share. With populations already large and still exploding, growing food in the city for the city makes sense not only environmentally but also commercially.

Figure 4.39
Why to use Aquaponics?

(source: Regenvillages.com)



-Cultivated Roof and Greenhouses

Another cultivation area is the roof, where are present also some green houses that can allow cultivations also in the winter season.

Figure 4.40
Cultivation area on roof and in the greenhouses highlighted in the render

-The green corridor through the building

Since the building lot is standing on a green corridor, it was important to keep the continuity of the greenery also through the building. The main elements for this purpose are the green roofs, the apartment terraces, but, more important, the voids created in the volume, that are used for acquapnic cultivations and standard agriculture.

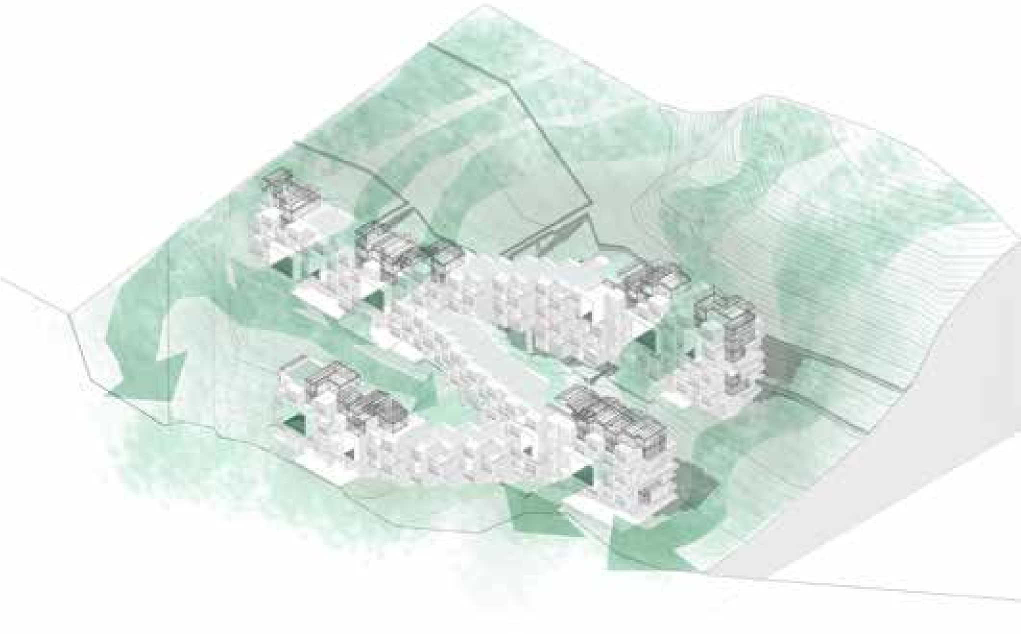
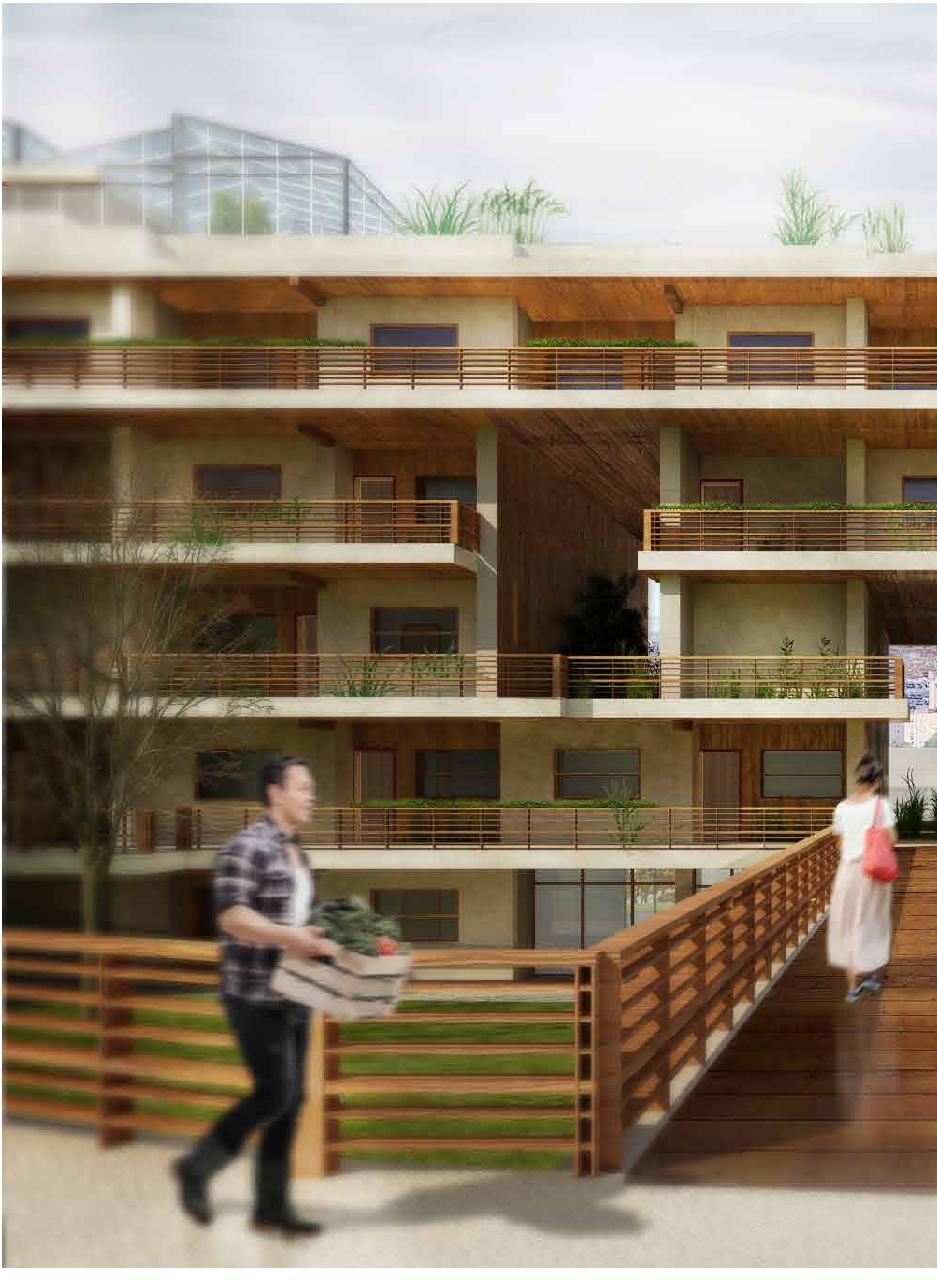
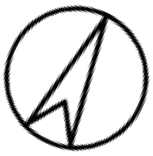


Figure 4.41
The continuity of the green corridor through the building

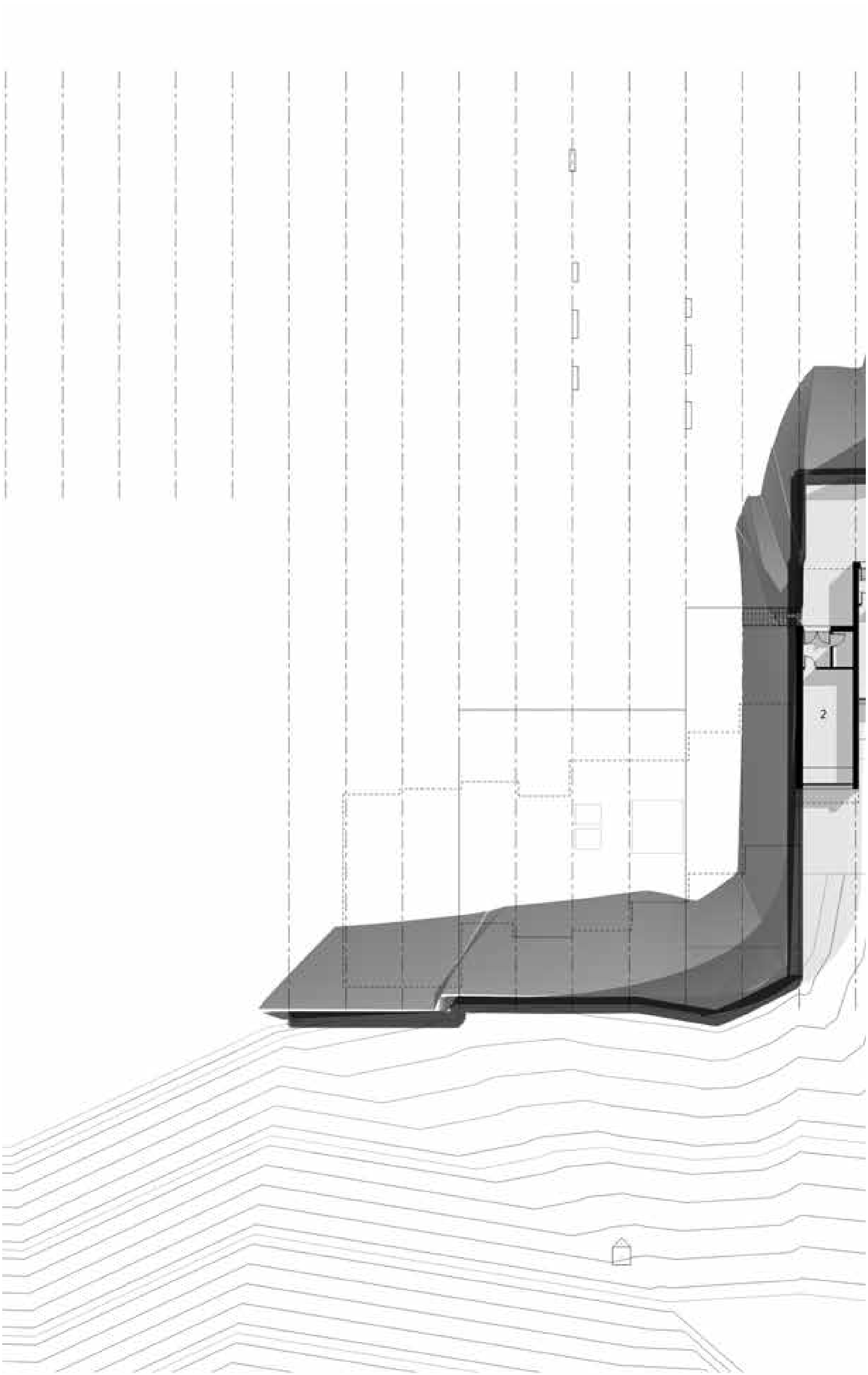


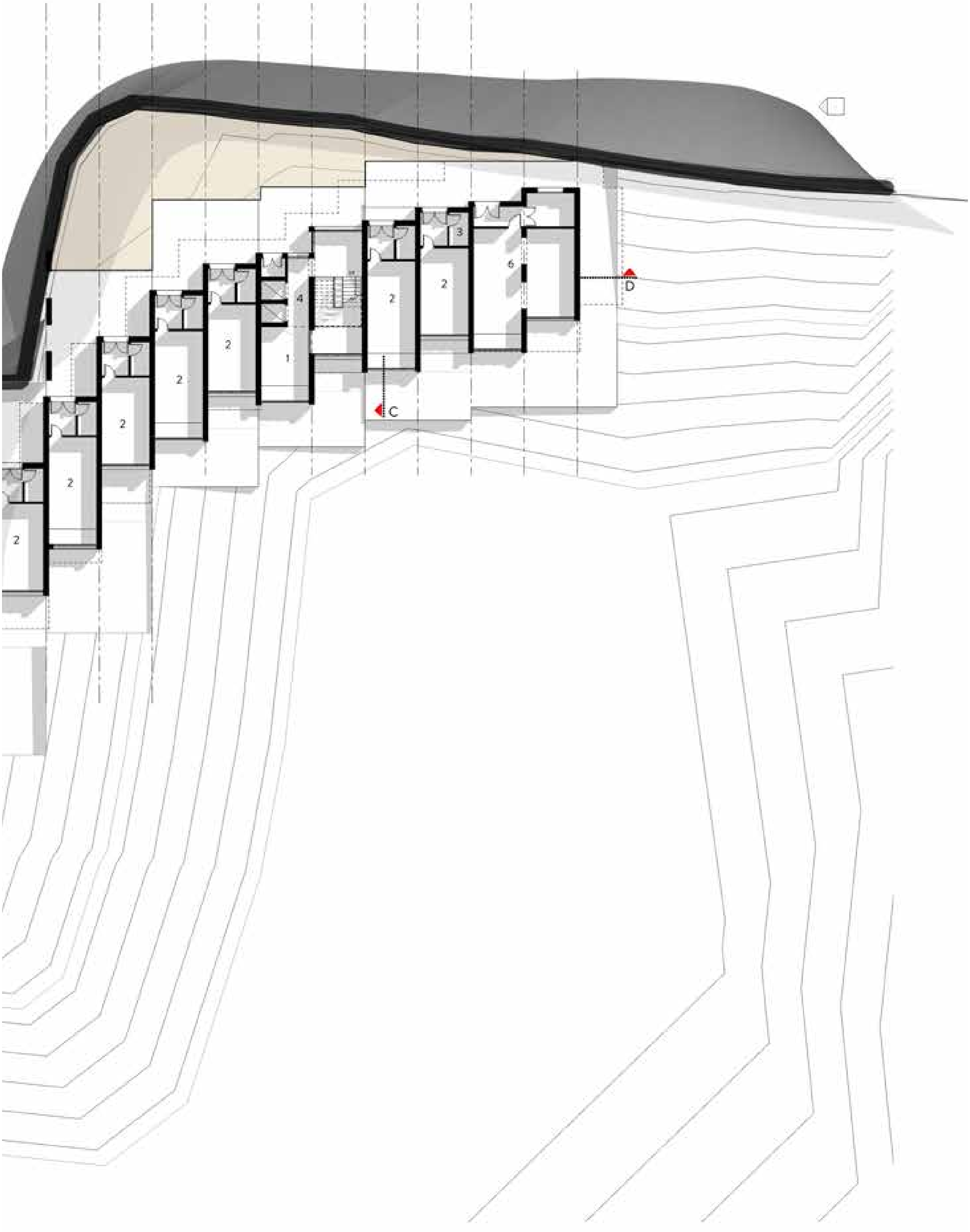
Board 4.1
Plan of the ground floor

Scale 1:400



1: Entrance
2: Retail 1
3: Retail service
4: Circulaton
5: Technical Room
6: Retail 2





2
2
2
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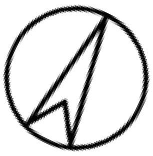
6
C
D

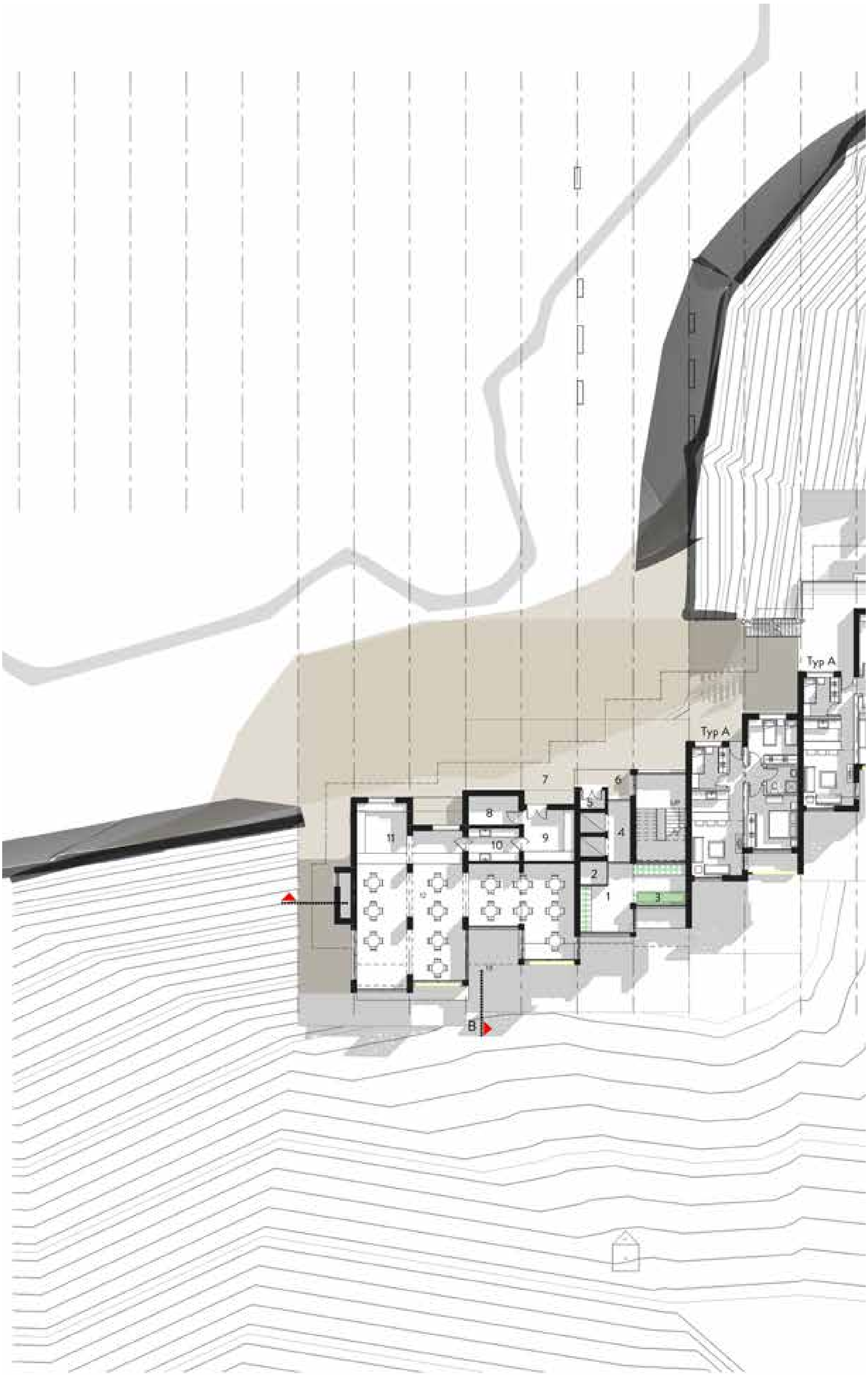
Board 4.2
Plan of the first floor

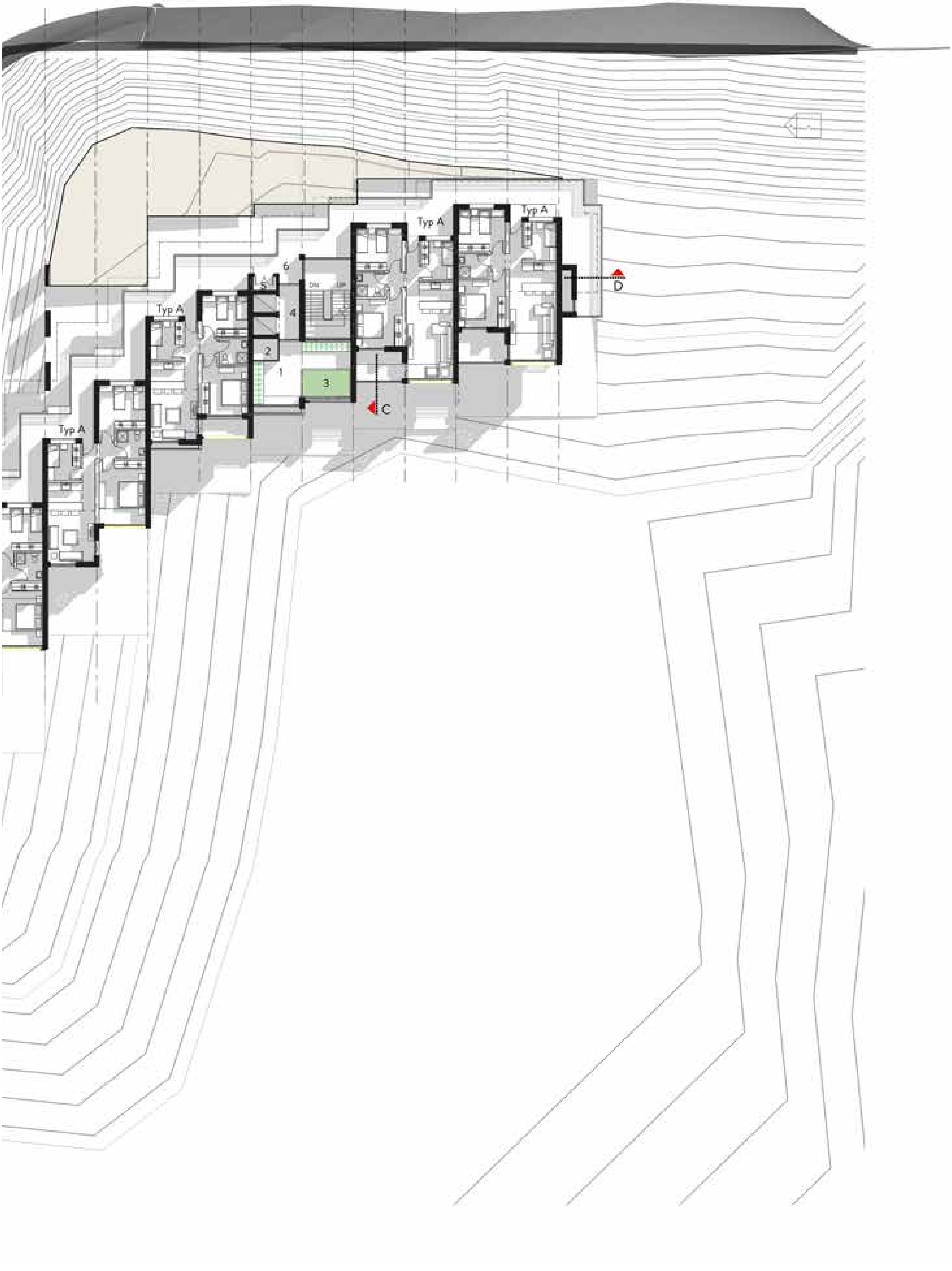
Scale 1:400



Typ A: Family unit (living, kitchen 3 bedrooms, bathroom, terrace)

1: Aquaponic stands
2: Fish aquarium
3: Agricultural patch
4: Circulaton
5: Technical Room
6: Circultaion corridor
7: Sevice entrance
8: Crop storage
9: Crop Sorting
10: Food preparation
11: Food counter
12: Local food canteen
13: Outdoor extension




Typ A
Typ A
Typ A
Typ A
Typ A
1
2
3
4
5
6
DN
UP
C
D

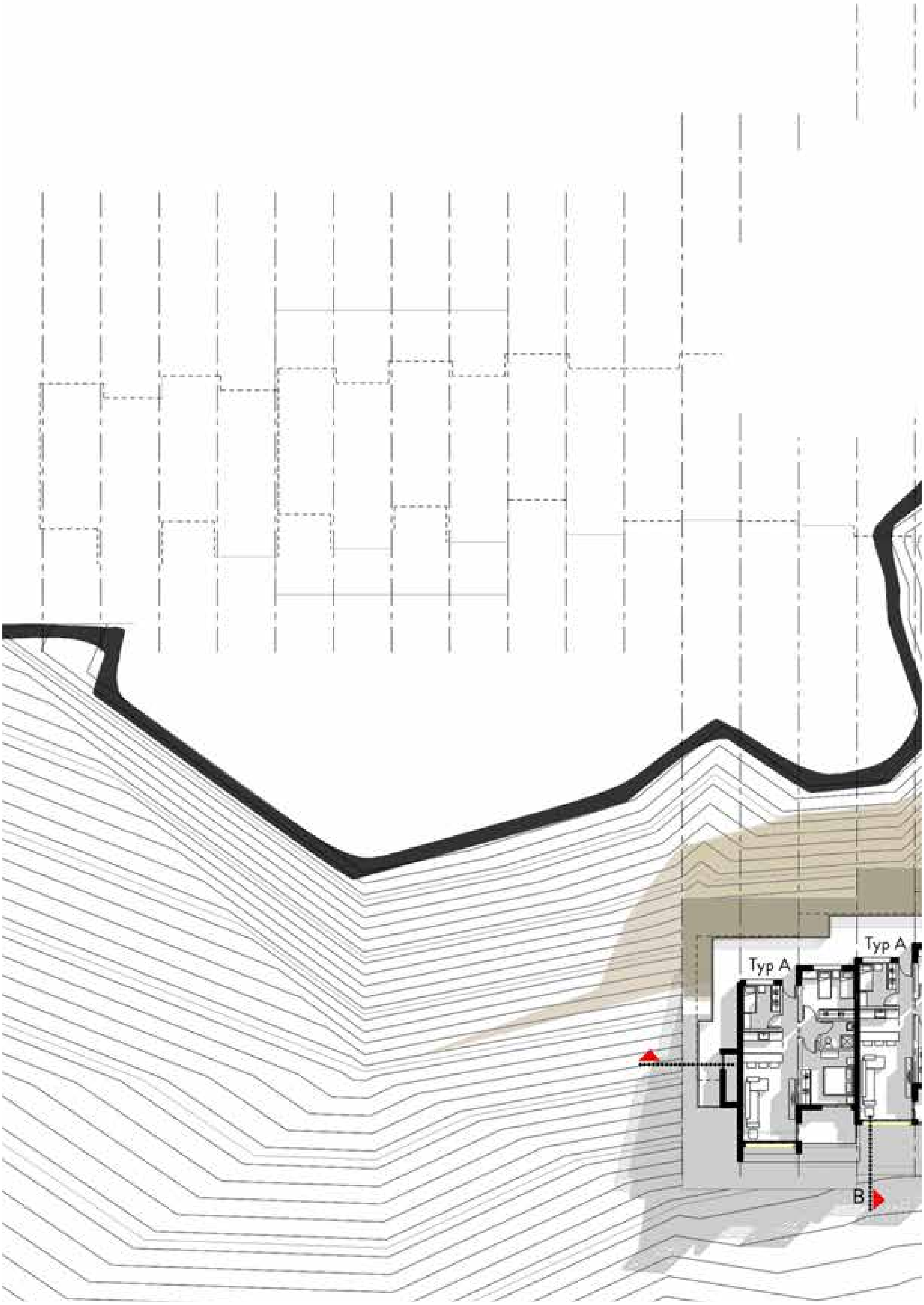
Board 4.3
Plan of the second floor

Scale 1:400

Typ A: Family unit (living, kitchen 3 bedrooms, bathroom, terrace)

Typ B: Duplex Family unit (living, dining, kitchen, 2 bedrooms, bathroom, terrace), Greenhouse

1: Aquaponic stands
2: Fish aquarium
3: Agricultural patch
4: Circulaton
5: Technical room
6: Circultaion corridor
7: Agriculture sevice area
8: Retail
9: Entrance




C
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D
Typ B
Typ A
Typ A
Typ A
Typ A
6
7
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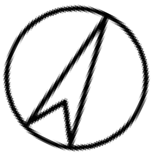
Board 4.4
Plan of the third floor

Scale 1:400



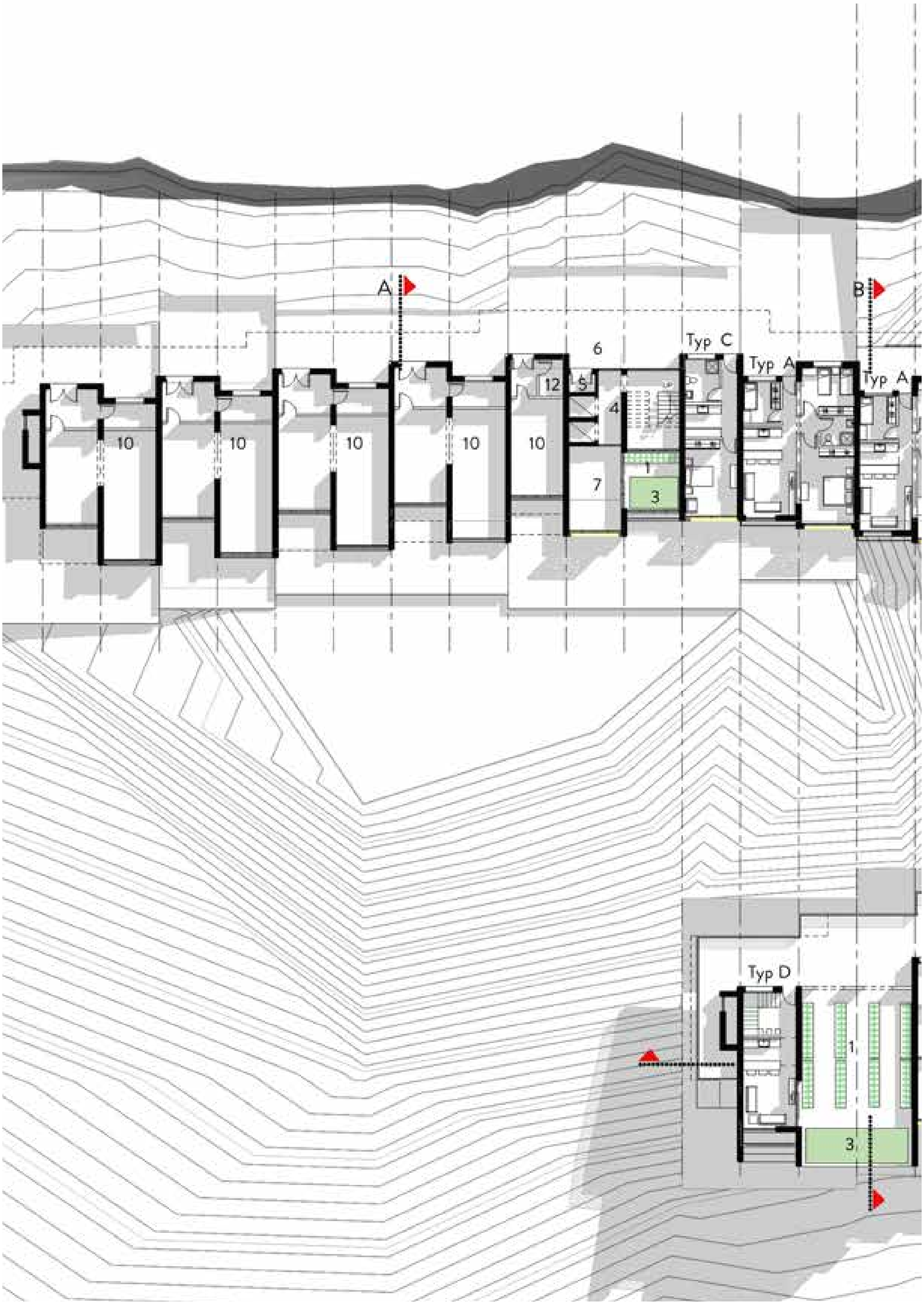
Typ A: Family unit (living, kitchen 3 bedrooms, bathroom, terrace)

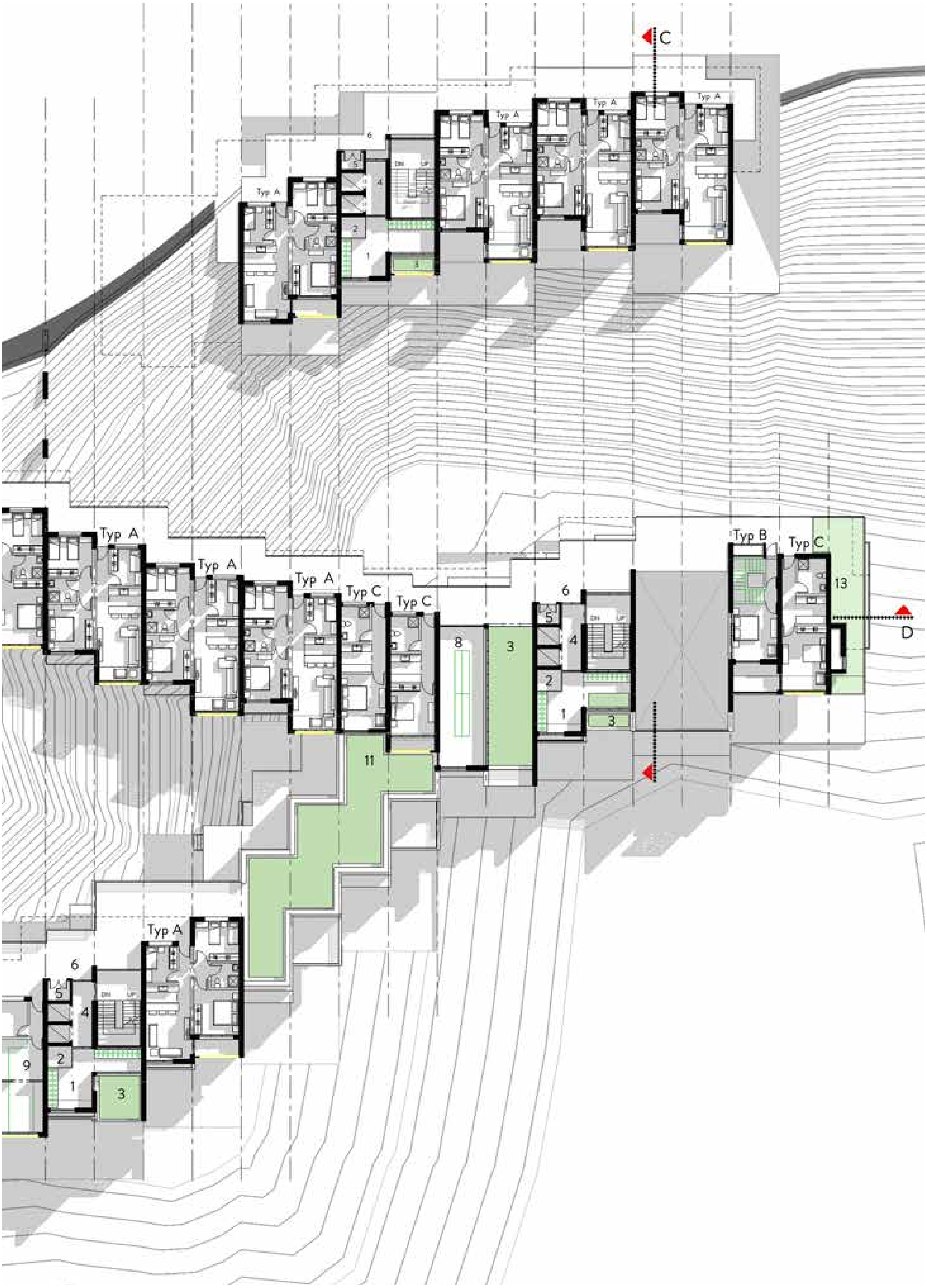
Typ B: Duplex Family unit (living, dining, kitchen, 2 bedrooms, bathroom, terrace), Greenhouse

Typ C: Single unit (kitchen, 1 bedroom, bathroom)

Typ D: Duplex Single unit (living, kitchen, 1 bedroom, bathroom, terrace), Greenhouse

1: Aquaponic stands
2: Fish Aquarium
3: Agricultural patch
4: Circulaton
5: Technical room
6: Circultaion corridor
7: Main Entrance
8: Food Bartering
9: Laundry
10:Local Food Retail
11: Green Roof
12: Retail Service
13:Greenhouse





C
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Typ A
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Typ A
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Typ C
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Typ B
Typ C
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Typ A
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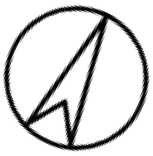
Board 4.5
Plan of the fourth floor

Scale 1:400



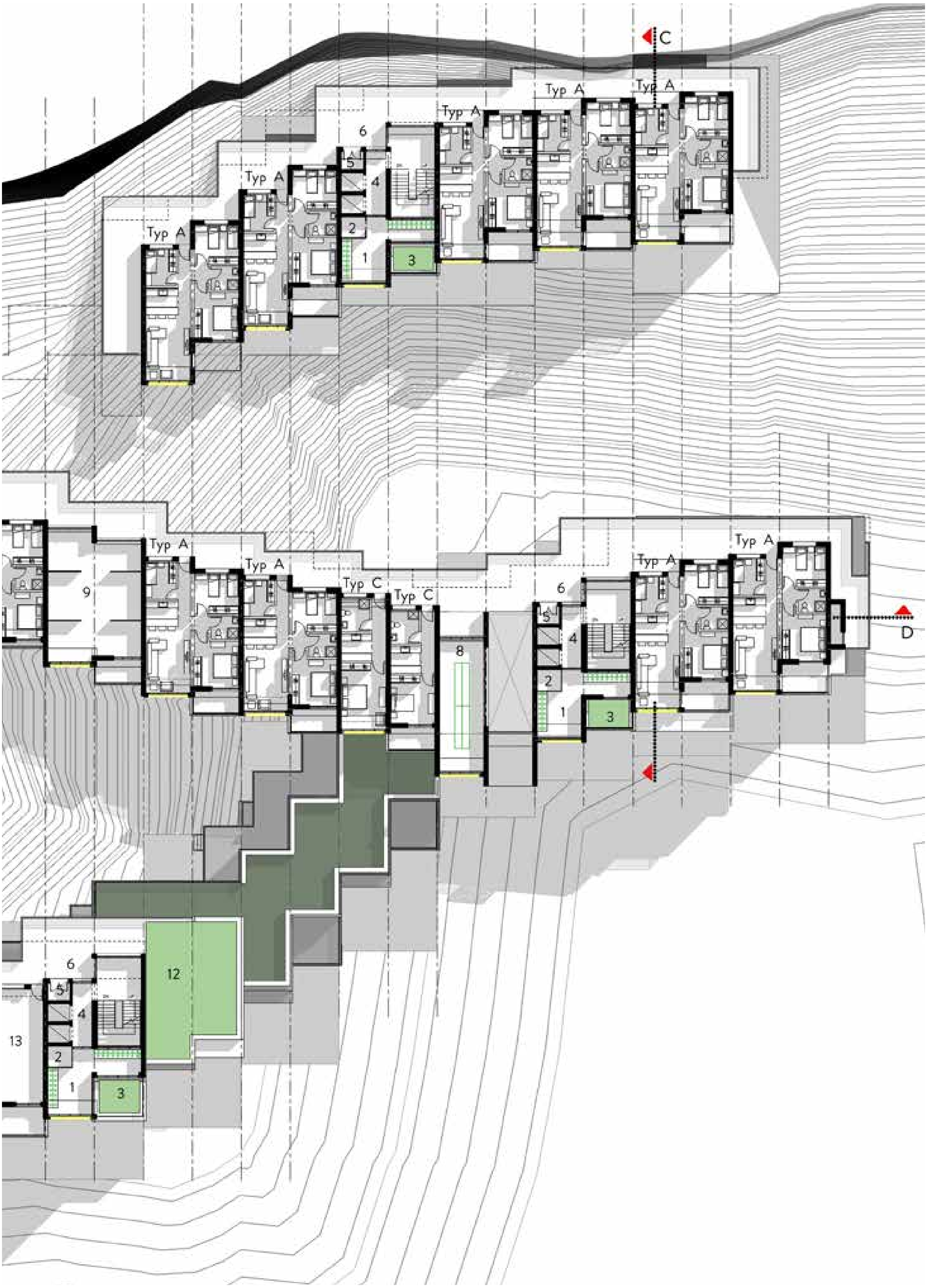
Typ A: Family unit (living, kitchen 3 bedrooms, bathroom, terrace)

Typ B: Duplex Family unit (living, dining, kitchen, 2 bedrooms, bathroom, terrace), Greenhouse

Typ C: Single unit (kitchen, 1 bedroom, bathroom)

Typ D: Duplex Single unit (living, kitchen, 1 bedroom, bathroom, terrace), Greenhouse

1: Aquaponic stands
2: Fish Aquarium
3: Agricultural patch
4: Circulaton
5: Technical room
6: Circultaion corridor
7: Main Entrance
8: Food Bartering
9: Entertainment Space
10:Hydroponic Cell
11: Greenhouse
12:Green Roof
13: Kindergarden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Typ C
Typ C
Typ A
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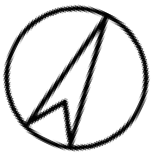
Board 4.6
Zoom on the acquaponic cultivations of the second floor

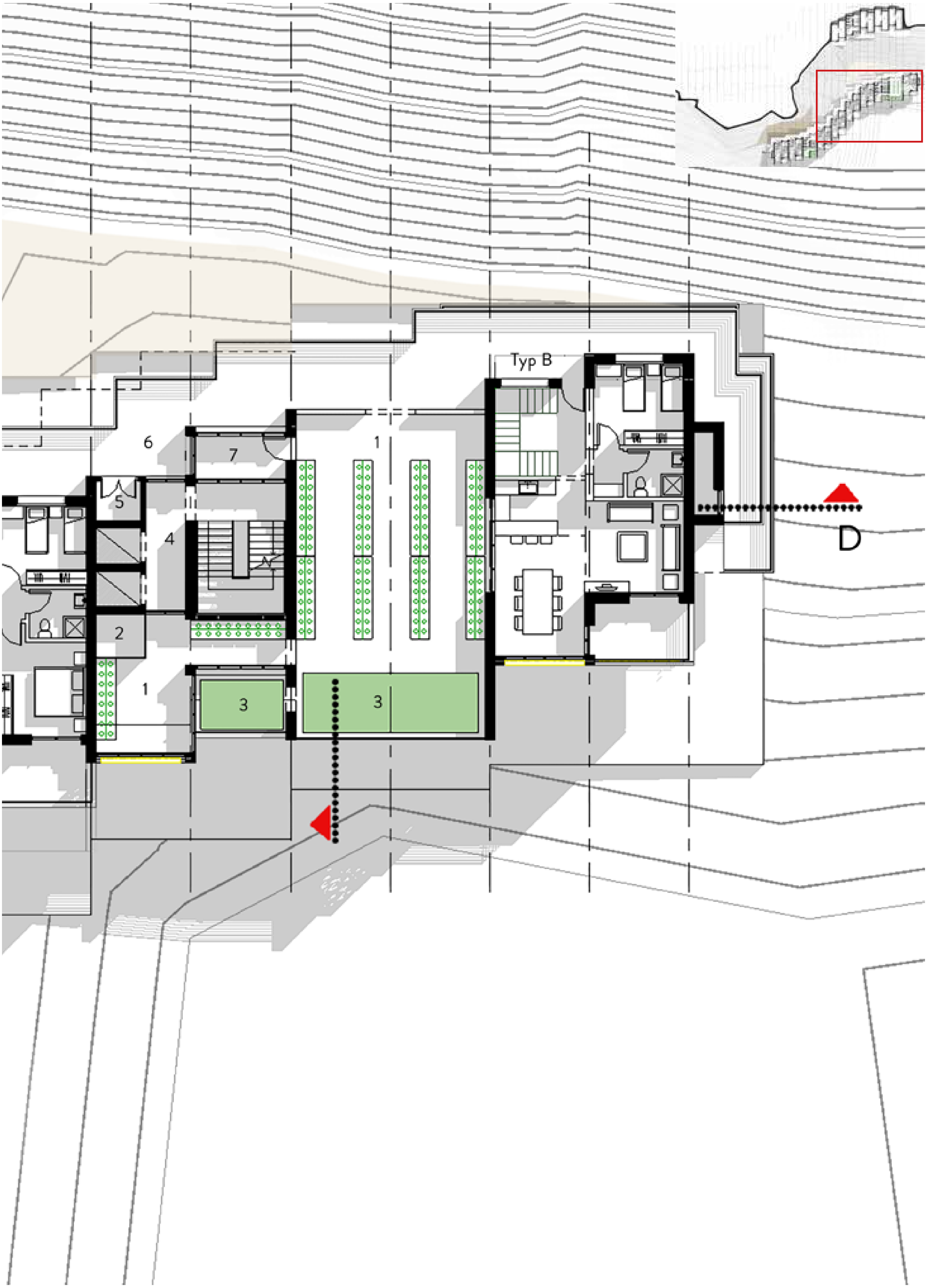
Scale 1:200



Typ A: Family unit (living, kitchen 3 bedrooms, bathroom, terrace)

Typ B: Duplex Family unit (living, dining, kitchen, 2 bedrooms, bathroom, terrace), Greenhouse

1: Aquaponic stands
2: Fish aquarium
3: Agricultural patch
4: Circulaton
5: Technical room
6: Circultaion corridor
7: Agriculture sevice area
8: Retail
9: Entrance



Typ B
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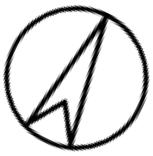
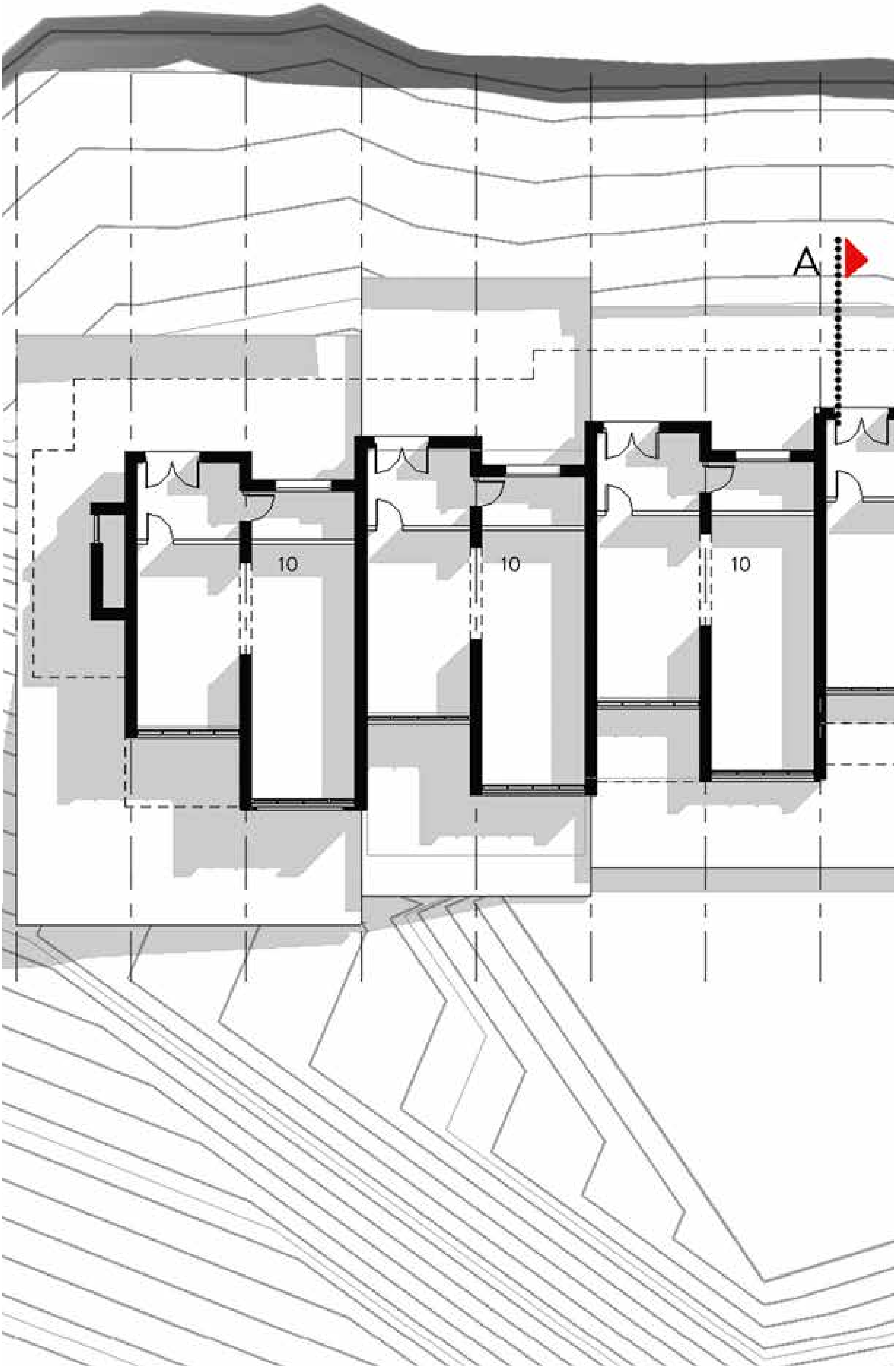
Board 4.7
Zoom on the shops area of the third floor

Scale 1:200





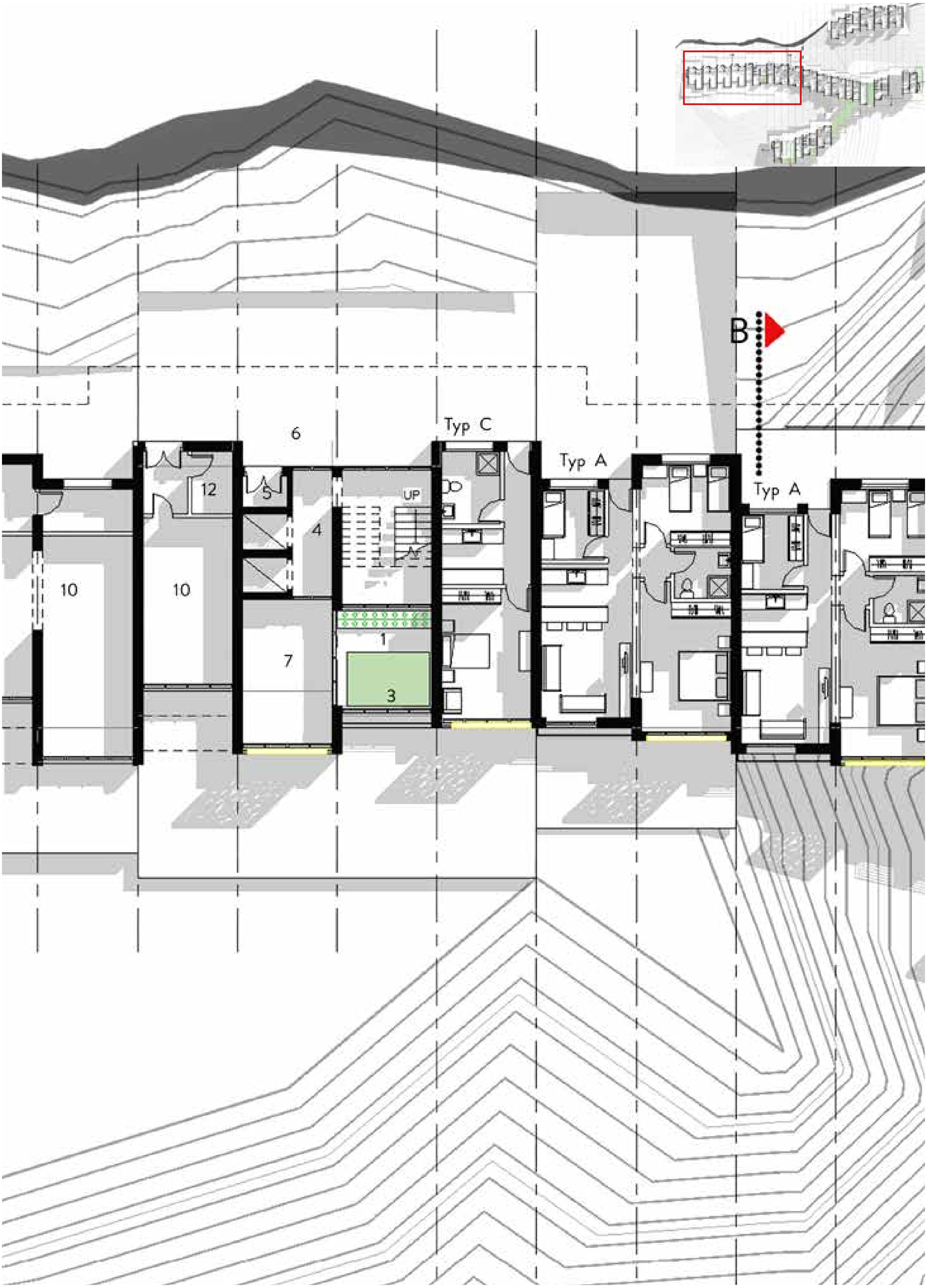
Typ A: Family unit (living, kitchen 3 bedrooms, bathroom, terrace)

Typ B: Duplex Family unit (living, dining, kitchen, 2 bedrooms, bathroom, terrace), Greenhouse

Typ C: Single unit (kitchen, 1 bedroom, bathroom)

Typ D: Duplex Single unit (living, kitchen, 1 bedroom, bathroom, terrace), Greenhouse

1: Aquaponic stands
2: Fish Aquarium
3: Agricultural patch
4: Circulaton
5: Technical room
6: Circultaion corridor
7: Main Entrance
8: Food Bartering
9: Laundry
10:Local Food Retail
11: Green Roof
12: Retail Service
13:Greenhouse


B
Typ C
Typ A
Typ A
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UP
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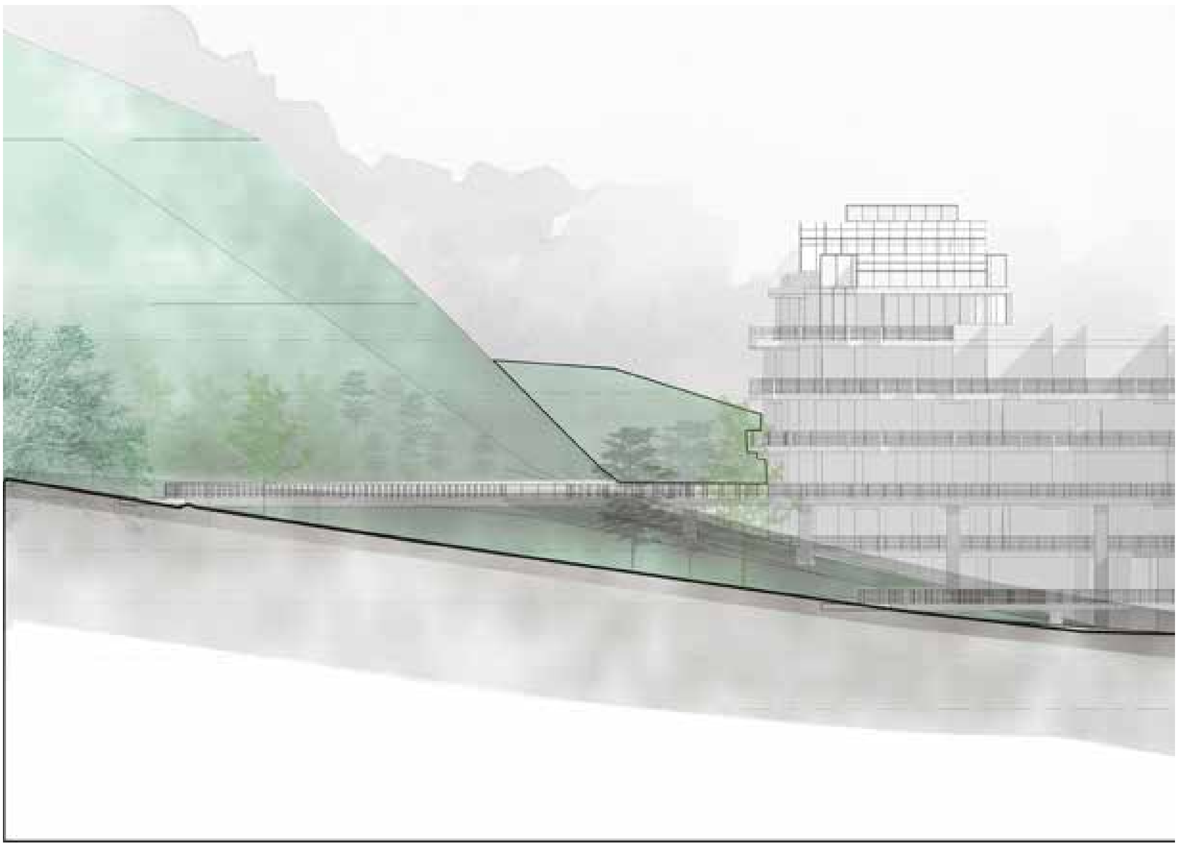
1
3

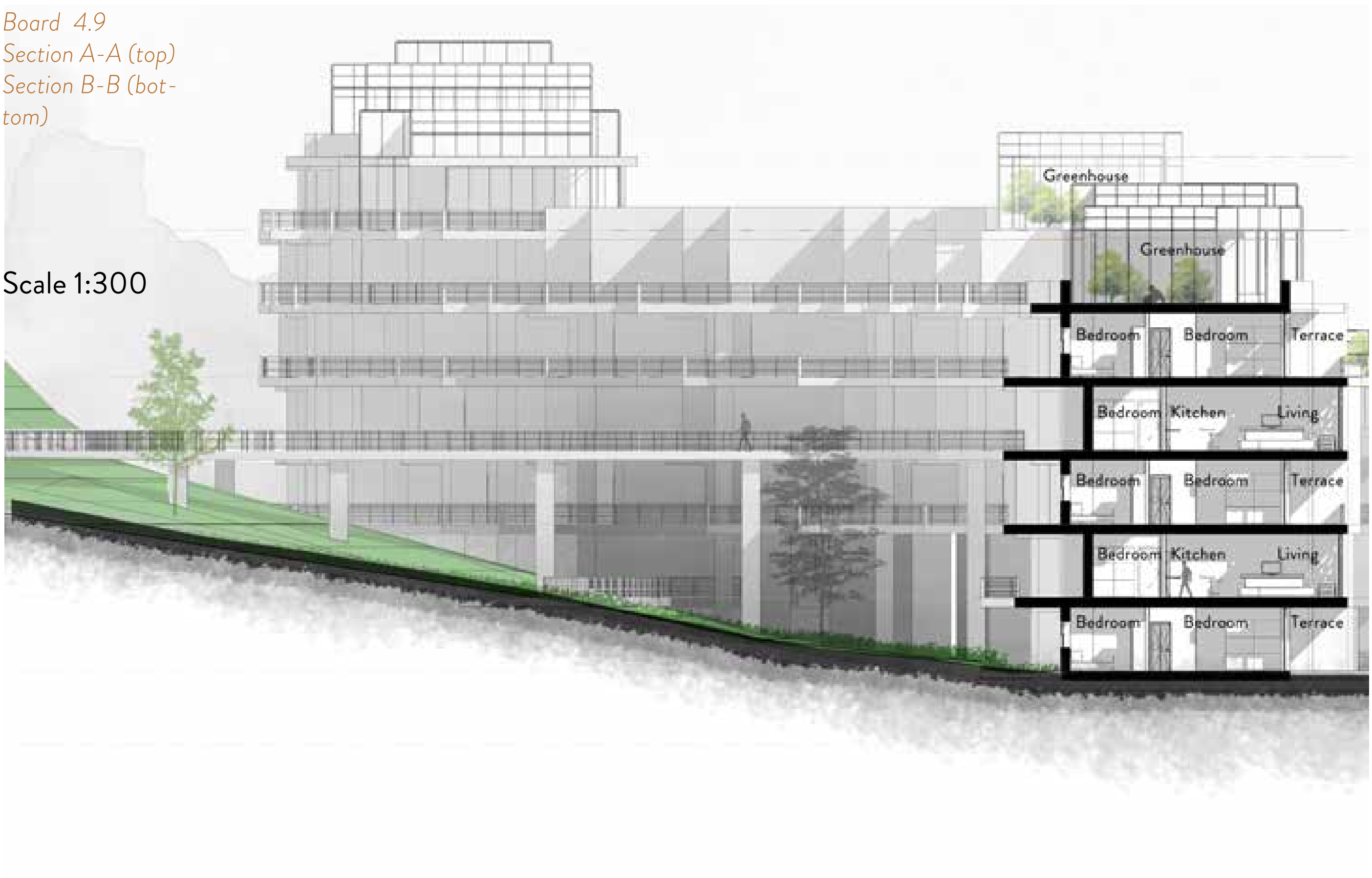
Board 4.8
South elevation (top) and west elevation (bottom)

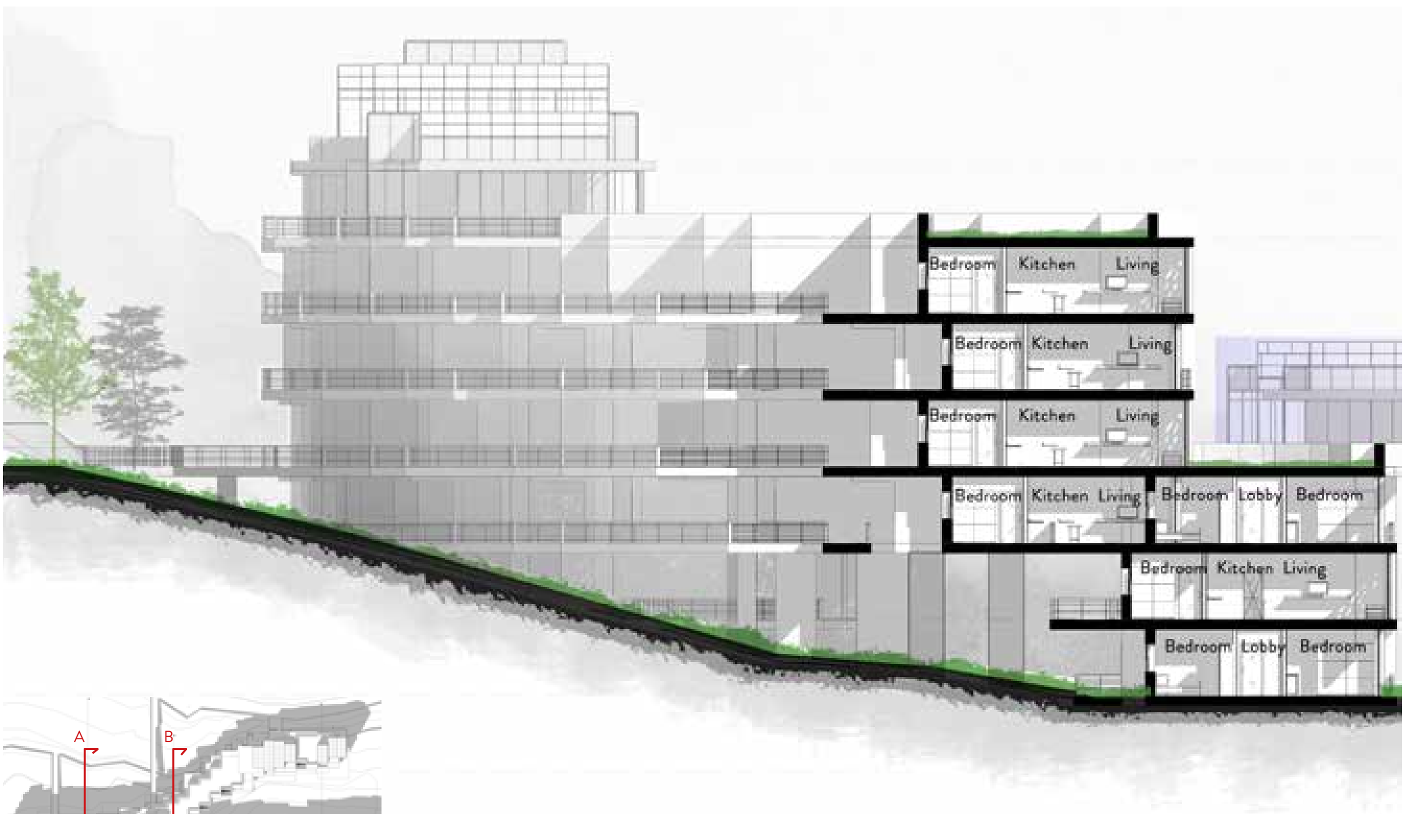
Scale 1:500

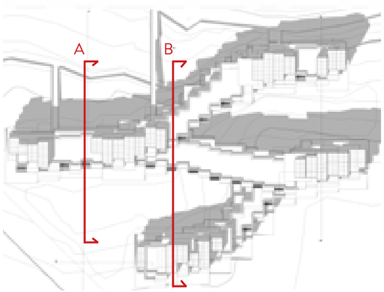


Board 4.9
Section A-A (top)
Section B-B (bot-tom)

Scale 1:300





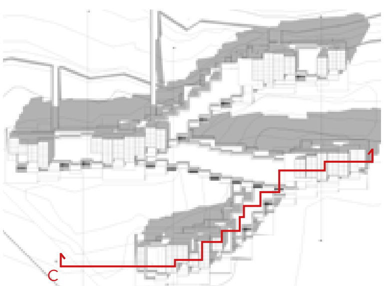


F 10
161.10
F 9
157.80
F 8
154.60
F 7
151.40
F 6
148.20
F 5
145.00
F 4
141.80
F 3
138.60
F 2
135.40
F 1
132.20
F 0
129.00

GreenHouse
Bedroom
Bedroom
Aquaponics Agriculture
Bedroom
Kitchen
Living
Retail
F 10
161.10
F 9
157.80
F 8
154.60
F 7
151.40
F 6
148.20
F 5
145.00
F 4
141.80
F 3
138.60
F 2
135.40
F 1
132.20
F 0
129.00

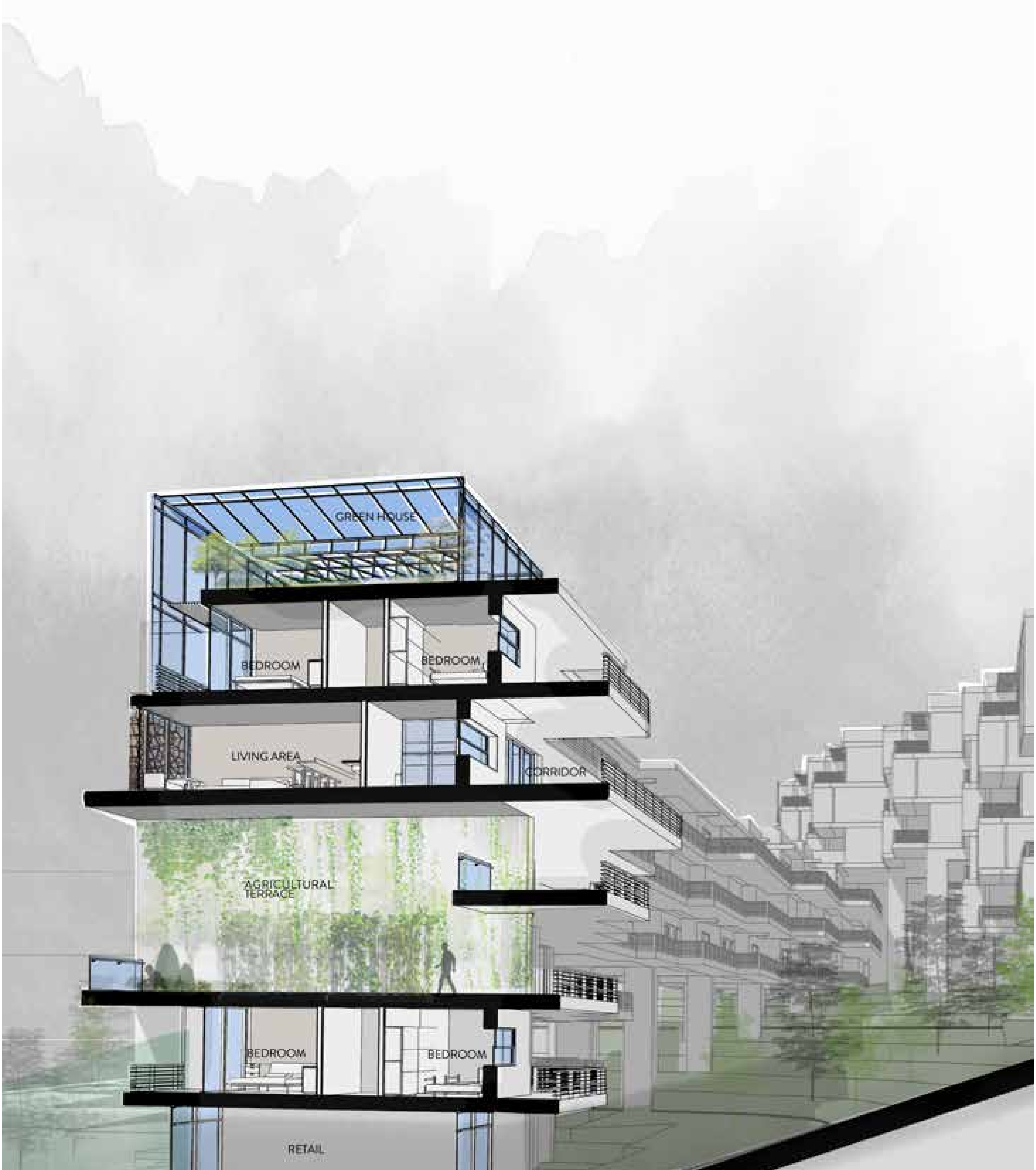
Board 4.10
Section D-D

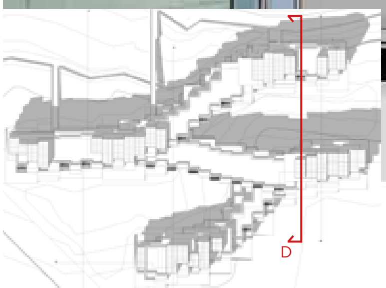
Scale 1:400




Circulation
Greenhouses
Bedroom
Circulation
Bedroom Kitchen
Bedroom Kitchen
Green Roof
Bedroom
Circulation
Bedroom Kitchen
Kitchen Bedroom
Green Roof
Circulation
Bedroom Kitchen
Kitchen Bedroom
Kitchen Bedroom
Kitchen Bedroom
Kitchen Bedroom
Circulation
Aquaponics
Kitchen Bedroom
Bedroom Kitchen
Kitchen
Kitchen
Bedroom Bedroom
Circulation
Bedroom Kitchen
Bedroom Kitchen
Kitchen Bedroom
Bedroom
Entrance Hall
Circulation
Retail
Retail
F 10
161.10
F 9
157.80
F 8
154.60
F 7
151.40
F 6
148.20
F 5
145.00
F 4
141.80
F 3
138.60
F 2
135.40
F 1
132.20
F 0
129.00

Board 4.11
Section D-D






BEDROOM
BEDROOM
AGRICULTURAL TERRACE
LIVING AREA
BEDROOM
BEDROOM
BEDROOM
LIVING AREA
LIVING AREA
BEDROOM
RETAIL

4.3 A Natural Skeleton: CLT structure

4.3.1 Choice of the Material

For the structural design there were some specific requirements that we, as designers, wanted to be satisfied in the building:

- good thermal behaviour of the building
- modularity in the construction to reduce time and costs
- low carbon footprint
- structural freedom to fit the architectural design and therefore column free structure
- competitive price

After the rejection of other possibilities,the two option that were evaluated to respond to the needs are Precast Concrete and Cross Laminated Timber.
The two elements were studied and compared and in the end it was chosen to adopt a CLT structure for the peculiar properties that it offers (as explained in the following paragraph).
Comparing CLT to Precast Concrete, some points that made us choose the first one are not only its low specific weight and the good seismic behaviour but also the environmental benefits both in terms of recyclability and carbon footprint and even in terms of internal building environment quality.

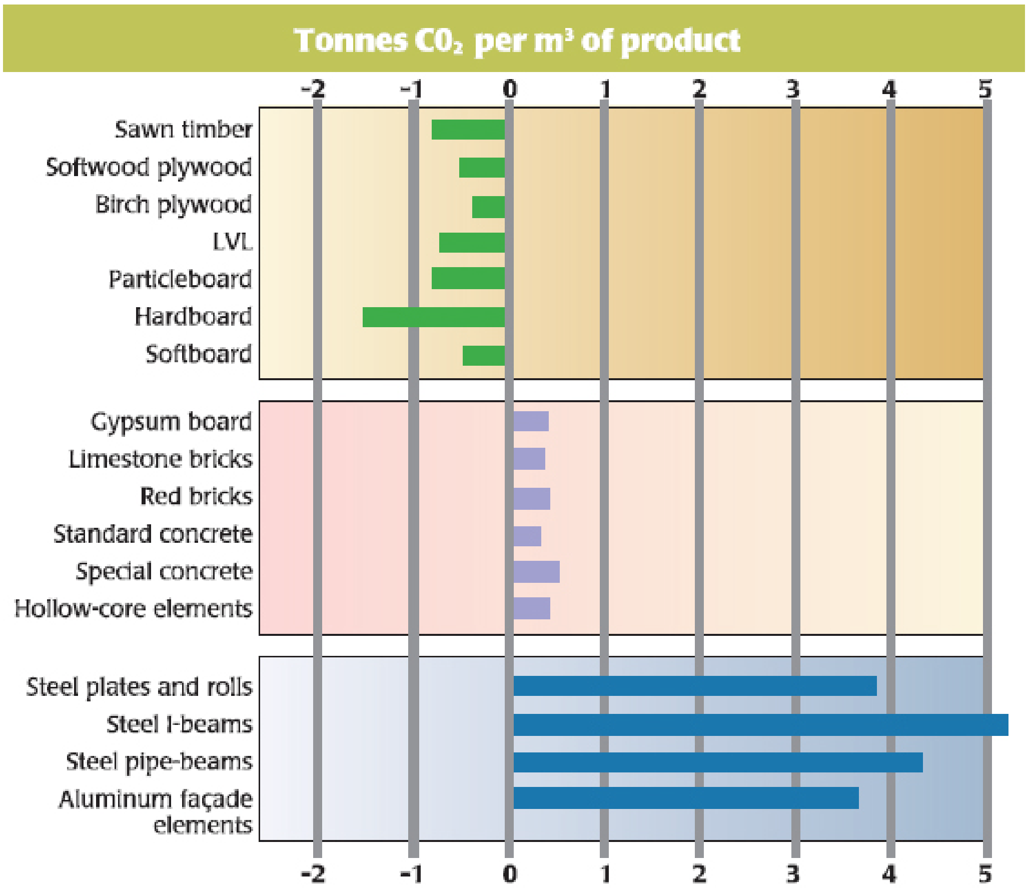


Figure 4.2
Impact on climate change from various building materials

(source: http://www.qualitybuilt.co.uk/pic/graph.jpg)

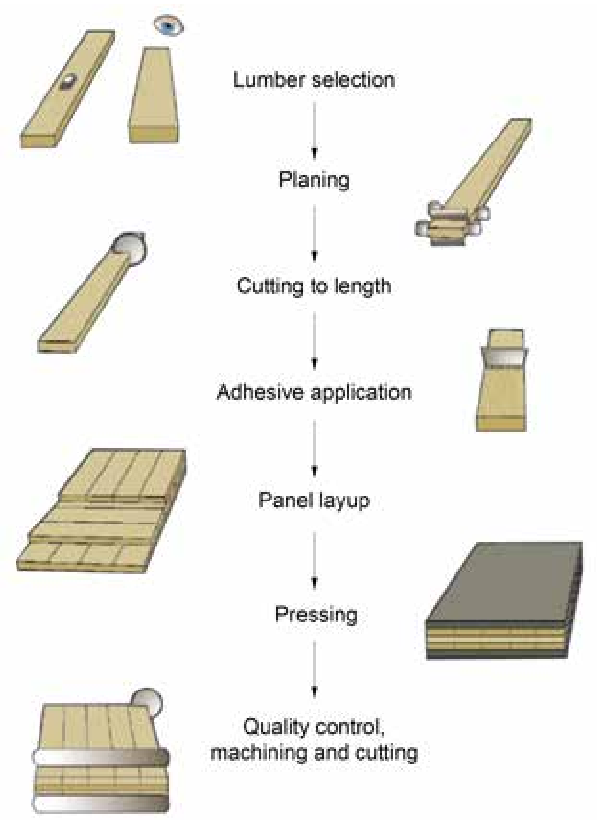
4.3.2 What is Cross Laminated Timber

4.3.2.1Manufacturing

Cross-laminated timber (CLT or XLAM) is produced from layers of wood that are arranged crosswise on top of each other and glued to each other with a pressure of 0.6 N/mm^2 to form large-sized solid wood elements.
The transverse gluing of the boards together with the kiln drying of the lamellae to a timber moisture of 12 ± 2%, limits the swelling and shrinkage of the wood in the plane of the panel.
In addition, the crosswise arrangement of the longitudinal and transverse layers considerably increases the static load-carrying capacity and dimensional stability.
The limited moisture content is also necessary to avoid damage caused by pests, fungi or insects.
The number of layers can vary according to the needs and the different producers. The minimum number to obtain effective mechanical properties is 3 layers, while the maximum produced is generally 9.

Figure 4.3 Manufacturing of CLT panels

(re-adapted source: Lee Hicks article "Montana conference focuses on building green with CLT: Oregon in spotlight as leader in mass timber building", 2017)



Row Materials

The most used wood spices are the conifers, in particular spruce, larch or doulgas.

Layers Assembly

Each layer is composed by 15-30 cm thick boards, which have a width of 80-140 mm. To combine the boards together it is generally used a polyurethanic white glue, but is also possible to use aluminium nails.

Standard Dimensions

General standard dimensions of a CLT panel are a height of around 3 m and a length that can reach up to 16 m. The thickness is normally not greater than 20 cm.

4.3.2.2 Material properties

Dimension stability

The panels are made of solid wood layers, therefore the properties of each layers are the one of solid timber itself, like for glue laminated wood.
On the other hand, the overlapping of perpendicularly oriented layers avoids the orthotropic behaviour typical of solid wood. Moreover, the shrinkage, that for wood is much greater in the longitudinal direction and very low in the transversal one, is compensated. In fact, considering one direction of the panel, the longitudinal fibres that would shrink more are restricted by the behaviour of the perpendicular ones on which they are glued. This results in a material that in both directions has only a reduced shrinkage.
The dimension stability of the material allows the construction of big elements and the possibility to construct dimensionally precise elements.

Environment exposition

The use of the material is restricted to class 1 and 2, where the humidity cannot go below 20%. Service class 1 represents the interior environments and service class 2 consists in external environments but without direct contact with water. In different conditions with the panel exposed to the weather, the durability of the element is compromised.

Fire resistance

The rated value of charring rate of coniferous wood is 0.65 mm/min according to [EN1995-1-2]. This value may be used for the top layer. Due to temperature influences, a softening of the glue line may occur if polyurethane adhesives are used, which may result in the carbon layer coming off in small structures. Later, until a carbon layer of about 25 mm is formed from the nearest layer exposed to fire, the combustion rate is doubled.

Seismic behaviour

Wooden structures are particularly suitable for seismic areas due to the following characteristics:

- Lightweight property that allows the generation of a low seismic force (F= M x a), with a specific weight of approximately 500 kg/m3 and a low weight-to-resistance ratio
- Good traction and compression resistance, in particular for short lasting loads the resistance is higher than for long lasting loads.
- Deformability, in fact the elastic modulus parallel to the fibres is smaller than the one of concrete and therefore the deformability is larger. This leads to lower susceptibility to the seismic action.

Durability

Wood is a material susceptible to degradation. In particular, the humidity and the exposure to the external environment represent a factor of risk.
Considering the external environment, the damaging causes are sun radiation, water and biological agents (insects, fungi, moulds). It is therefore very important to protect the material against these elements.

Thermal properties

The low thermal transmittance of wood λ=0,13 W/mk contributes to the insulation of the building helping to reduce thermal bridges. In addition the material has also a good phase shift that helps to reduce overheating in summer, reducing the cooling consumptions.

4.3.2.3 Building construction with CLT

Some peculiarities of the material for the construction of buildings are:

- Bracing of the building and, at the same time, transfer of vertical loads
- Simple possibility for connections
- No need to stick to a grid
- Construction allows two-dimensional spatial "thinking"
- Horizontal forces (e.g. wind and seismic loads) shall be transferred through covering
- Loads into vertical shear walls and then into the foundations
- Additional reserves through edge clamping of floor elements (biaxial state of floors)

The mechanical behaviour of the panels can be evaluated in different ways:

- Analysing the element with a mono-dimensional calculation to get the stresses inside the different layers according to their mechanical properties. It is required to associate a value of effective inertia to the panel due to the different properties of the perpendicular layers.
- Analysing the element as a plate, distributing the loads in the two directions.
- Analysing the element as a sheet, considering the wall to withstand both the axial forces and the lateral forces (wind, seism). The rigidity of the element is a combination of the properties of the different layers.

4.3.2.4 Carbon Footprint

Trees convert 0.9 tons of carbon dioxide (CO2) which is absorbed from air with 0.5 tons of water and by means of 9,500 MJ of sun energy into 1 cubic meter of biomass (wood) in the course of photosynthesis. Carbon accounts for one half of one cubic meter of wood.

Advantages:

- Timber can take up and release moisture depending on the surrounding atmosphere. This property results in a very comfortable atmosphere in the room.
- Construction components made of cross-laminated timber are cut to size and are not constrained to have standard dimensions. This gives freedom for individual design.
- Buildings made with cross-laminated timber are advantageous, including in earthquake zones, because of their low mass and high strength.
- The high level of prefabrication results in fast building and assembly times, which makes the solid construction components very economical.
- Low thermal conductivity and high thermal protection in summer ensure comfortable living and save energy.

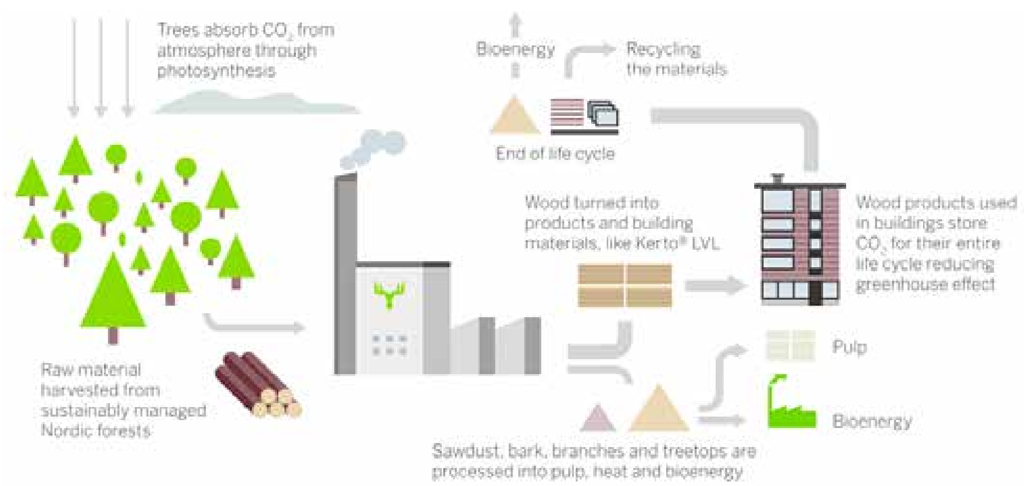


Figure 4.42 Building Carbon Cycle

(source: https://www.metsawood.com/global/news-media/articles/Pages/carbon-storage.aspx)

4.3.2.5 Living in a CLT building: comfort and health

The properties of the material, such as the low thermal transmittance and the thermal mass, create inside the building a high comfort environment both during winter, but also in summer, that is an important requisite for Barcelona climate.

Cross laminated timber is dried to very low timber moisture values and has the capacity to absorb and buffer moisture from the surrounding room air. It therefore plays its part in a healthy room climate.

4.3.3 General Building Structure

The structure of the building is mainly in cross laminated timber (CLT or XLAM), with the exception of some concrete elements.
The concrete part is comprehensive of ground floor plus the walls that support the elevators and the stairs. The foundations are made throw a shallow concrete platform and in some cases, where the first building level is not touching the ground, throw strip foundations where pillars land on.
The xlam walls are connected to the base throw fixing systems such as angle brackets, screws and anchors to avoid the transversal movements of the walls. Moreover, to avoid the rotation of the wall in its plane, hold-downs and perforated plates are provided to absorb the traction force that is generated on the side that wants to lift up.

Note that the concrete basement is fragmented in different parts located at different altitudes above sea levels. This happens due to the particular topography of the place, that is sloped for the presence of the Closerola mountain.

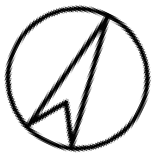
The CLT (Cross Laminated Timber) part consists in slab and wall panels assembled together to create a three-dimensional structure. The panels are responsible for both vertical and horizontal loads.

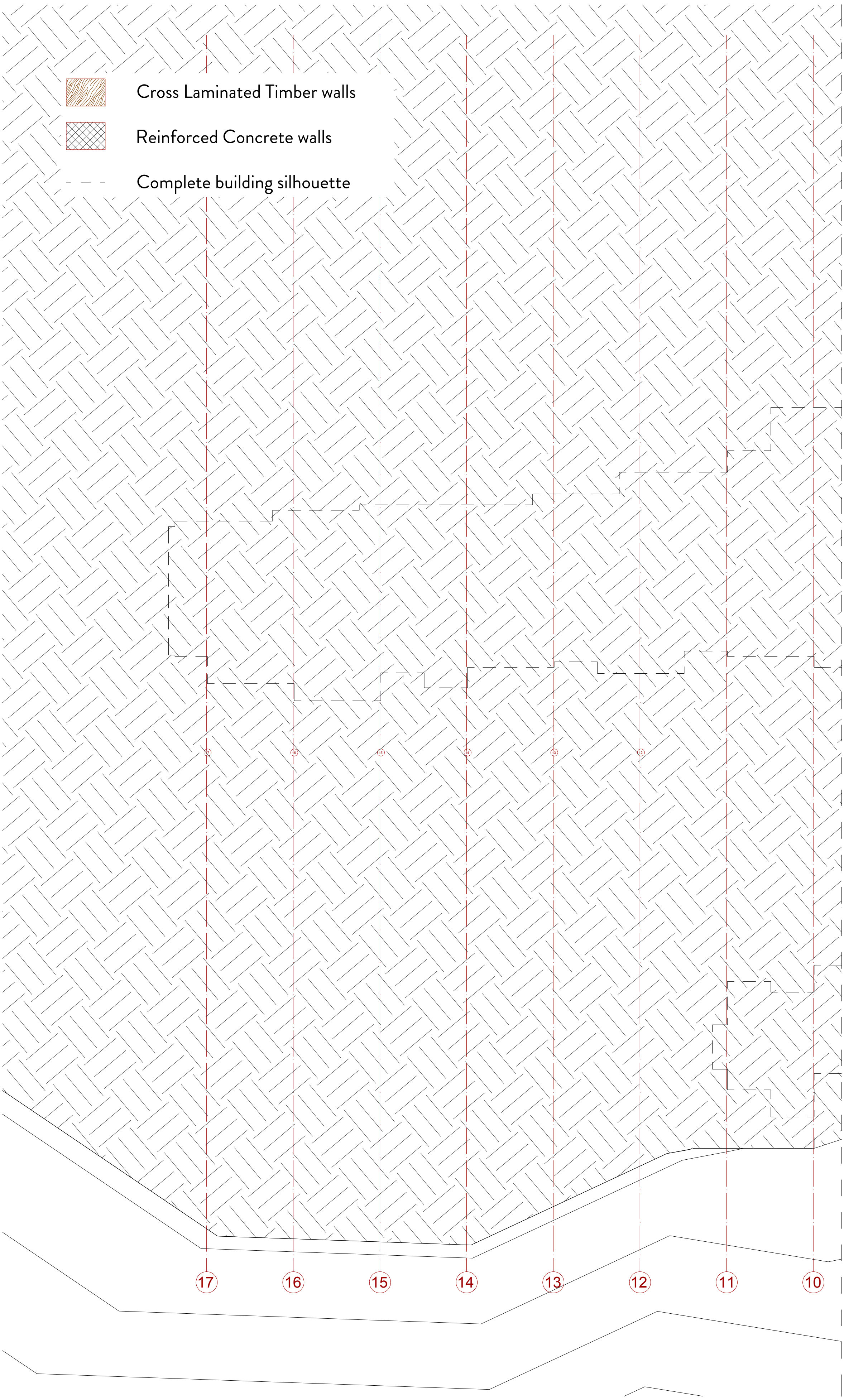
Each apartment unit is composed by two structural modules, both with an x-direction length of 4 meters. An xlam slab covers one module, so it will have one fixed dimension of 4 meters and another one that si around 12-14 m.

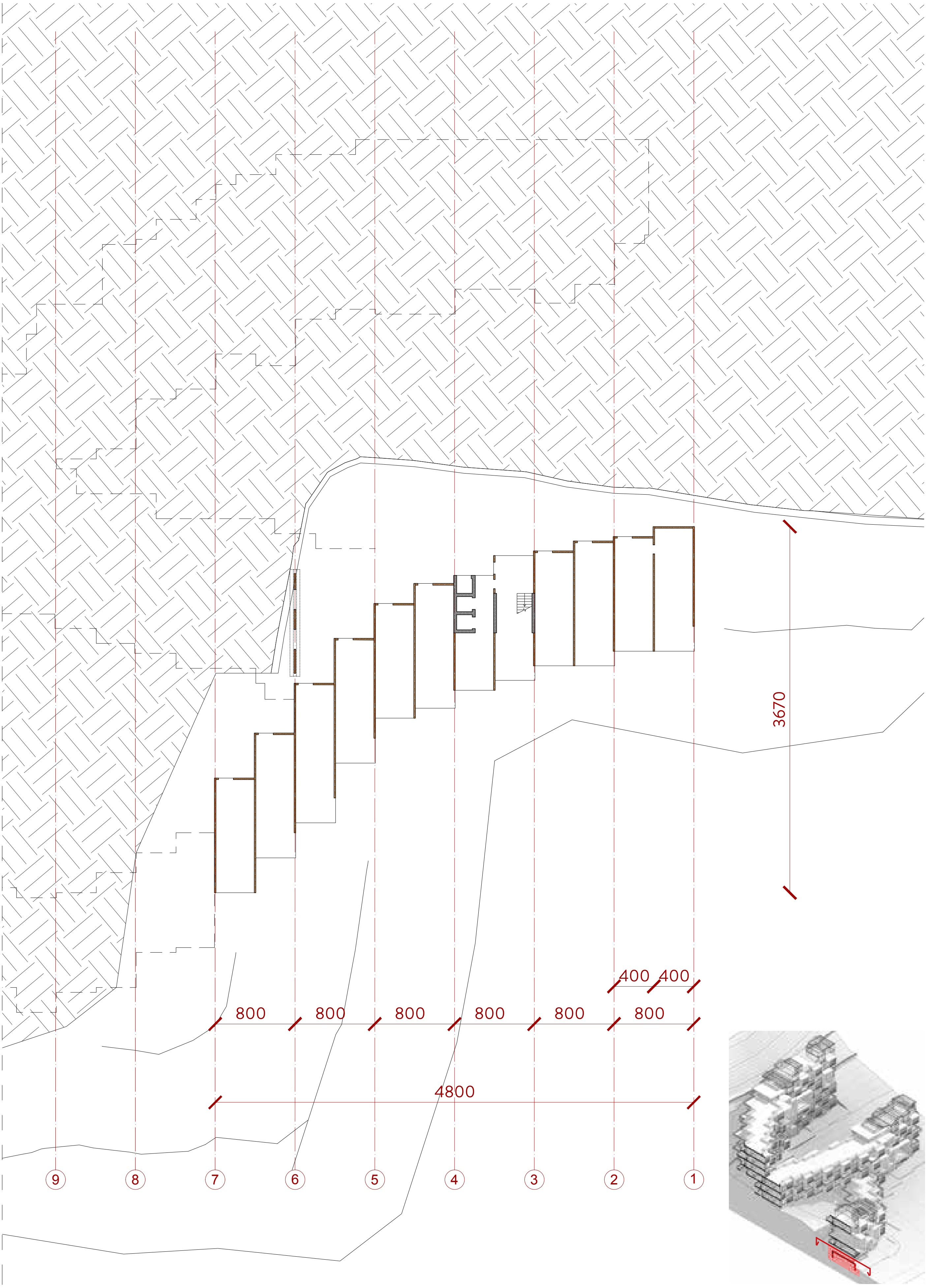
In the next page are reported as example the structural plans of floor 0, 1, 2 and 3 at the scale 1:500, where it's possible to see the general layout of the building. After them are exposed the plans at a bigger scale (1:200) for floors 0, 1 and 2, at this scale are reported with dashed lines also the elements below the slab and the direction of calculation of the slab elements.

Board 4.43
Structural plan of the ground floor

Scale 1:500



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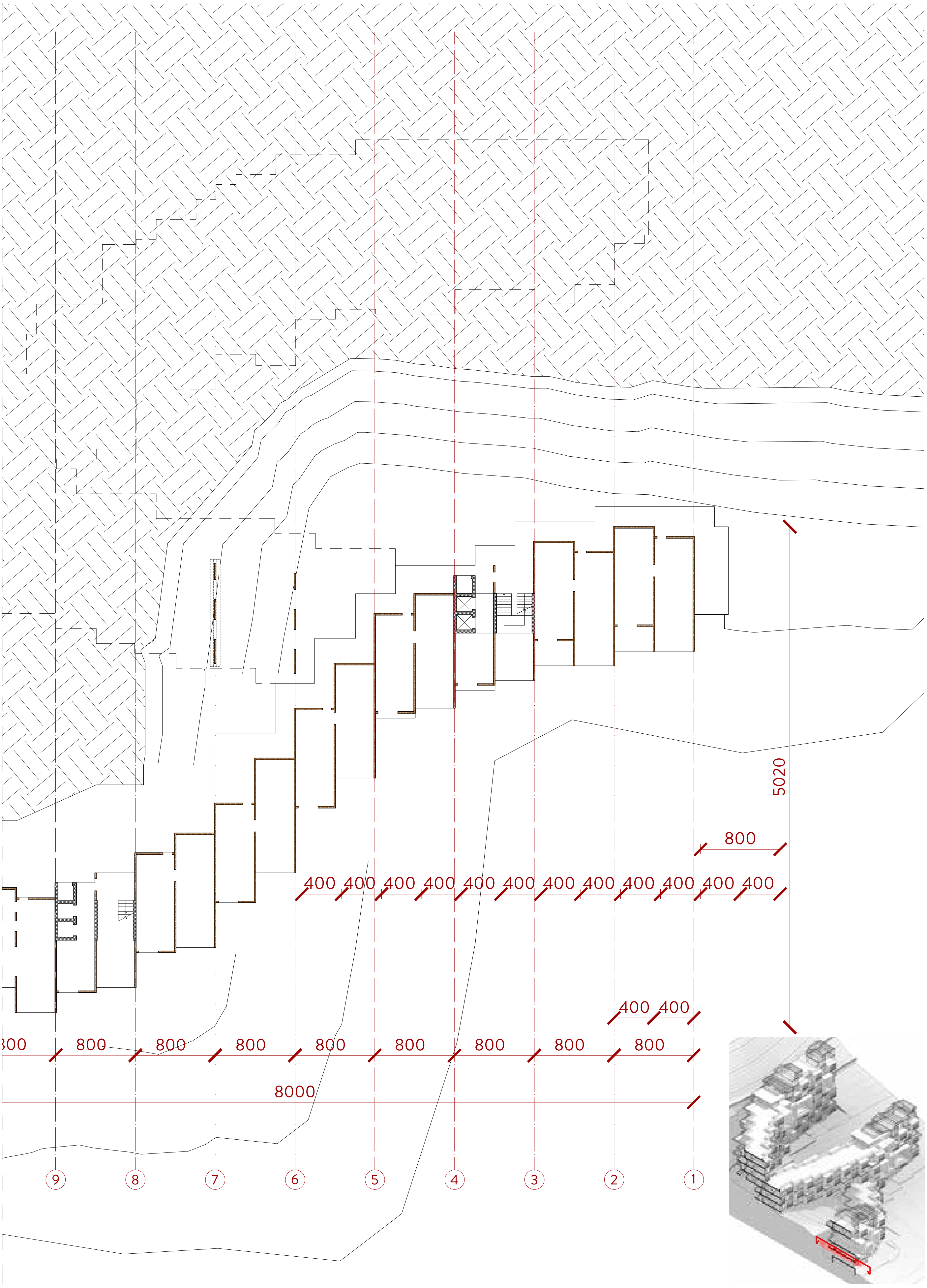
Board 4.44
Structural plan of the first floor

Scale 1:500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800
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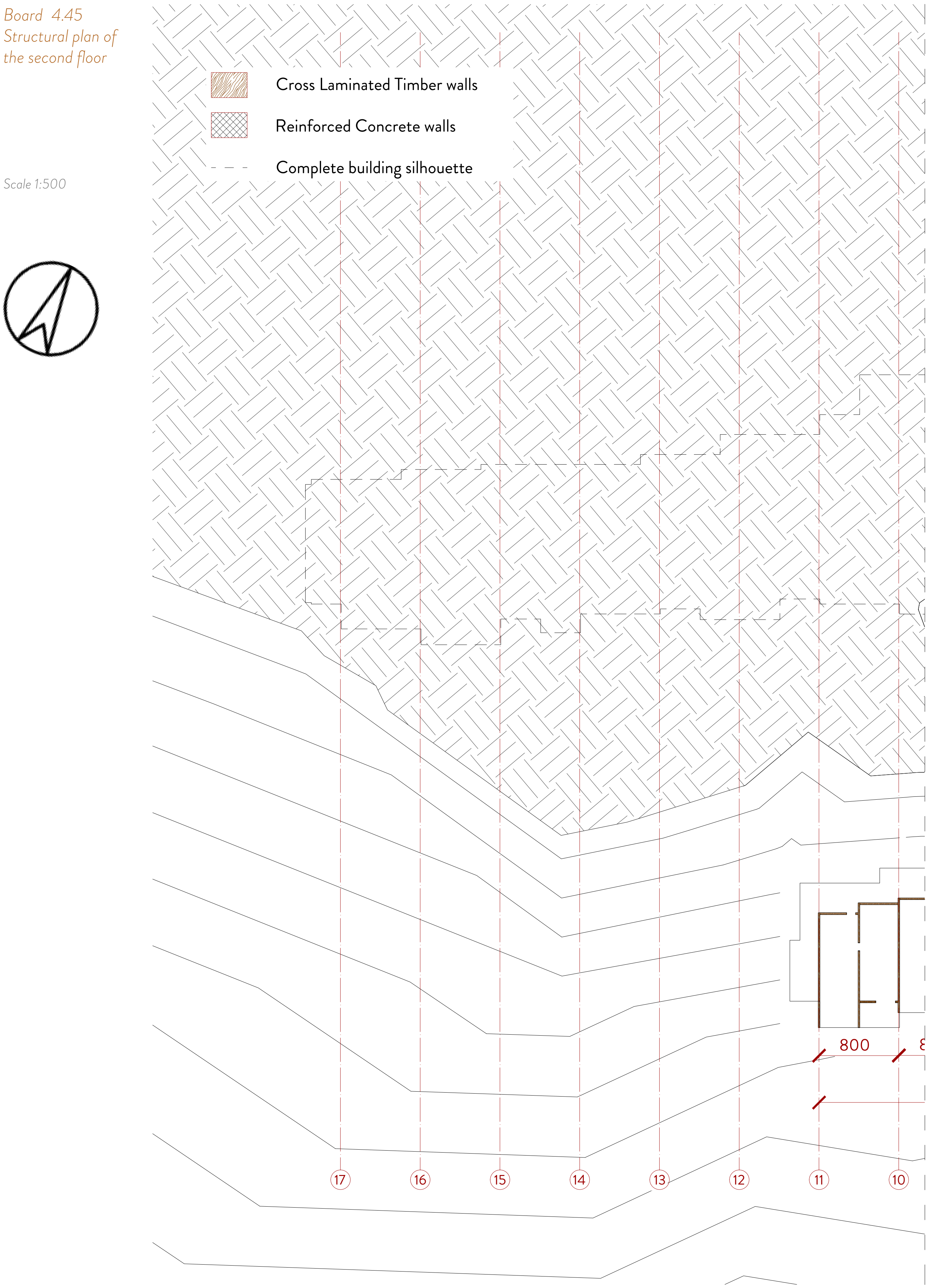
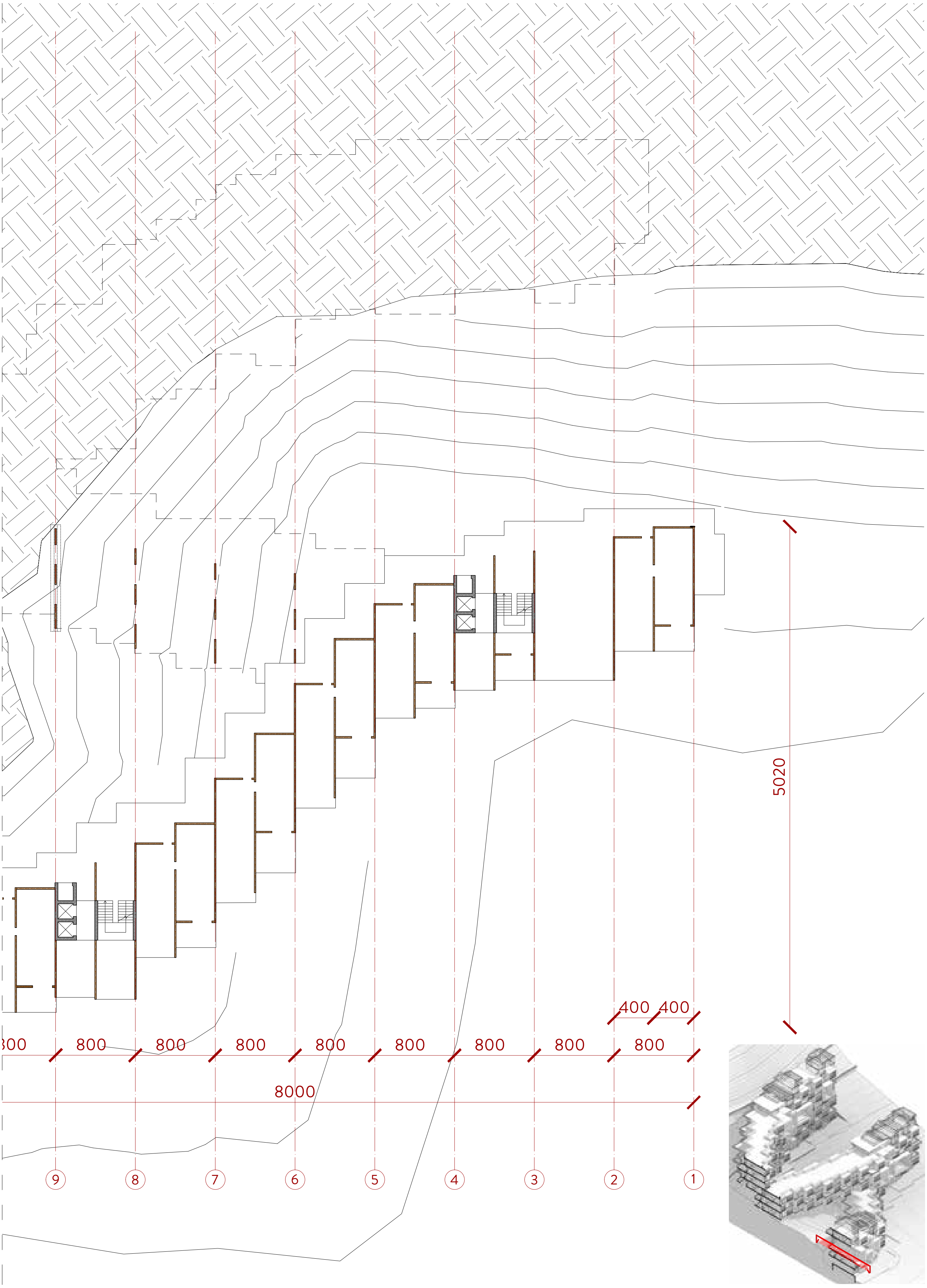
800 800 800 800 800 800 800 800
8000
9 8 7 6 5 4 3 2 1

Board 4.45
Structural plan of the second floor

Scale 1:500

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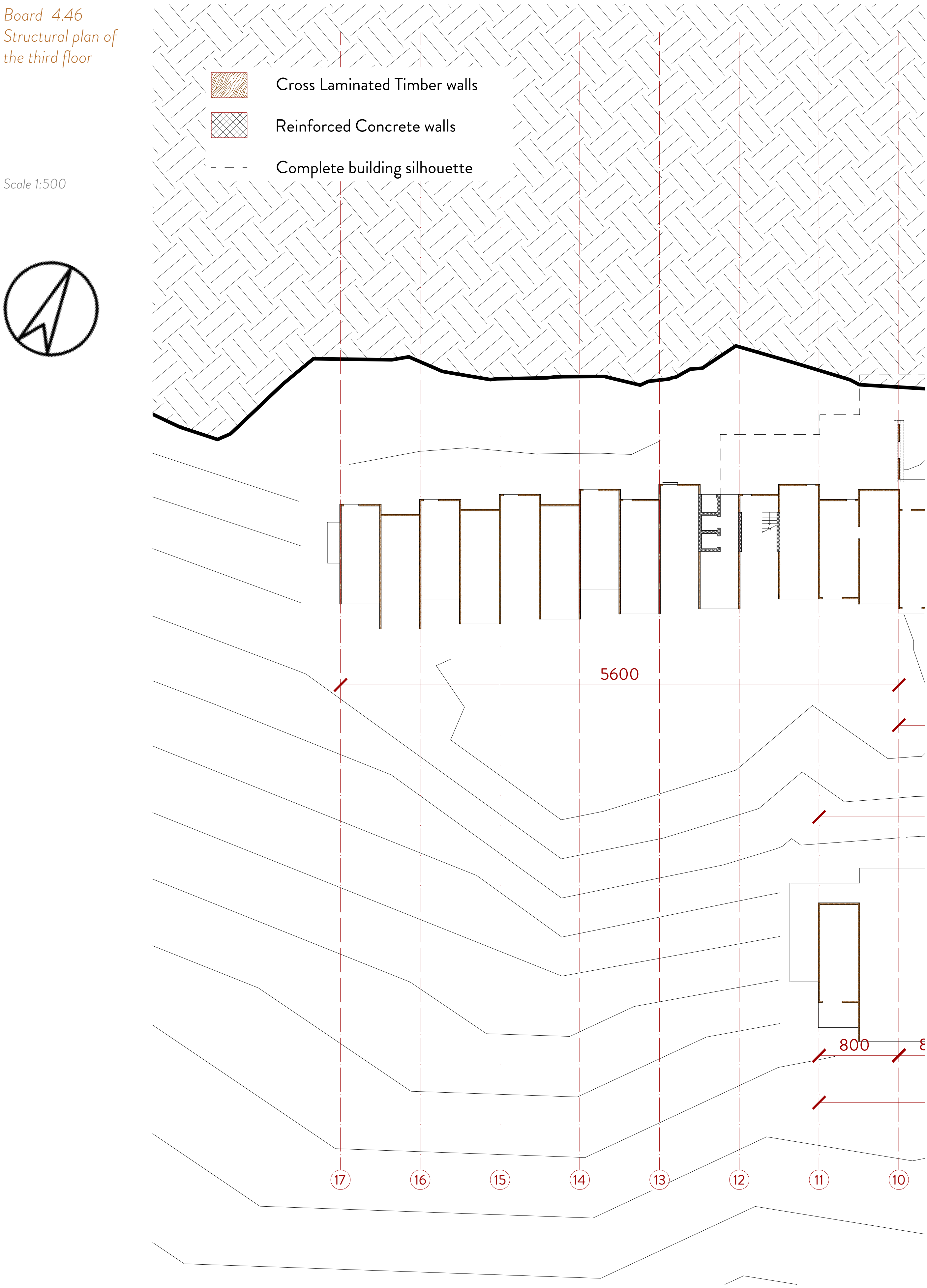
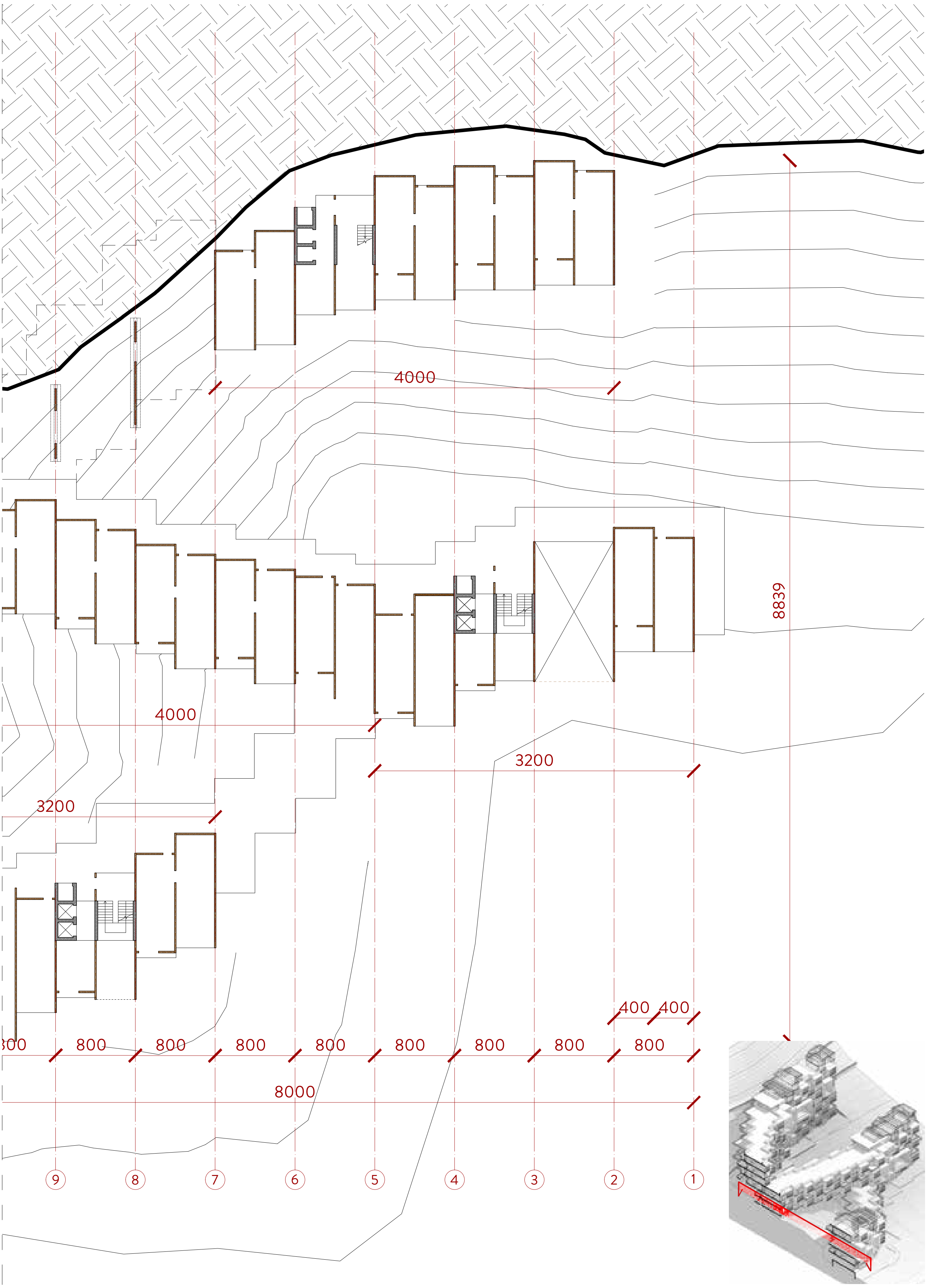
Board 4.46
Structural plan of the third floor

Scale 1:500

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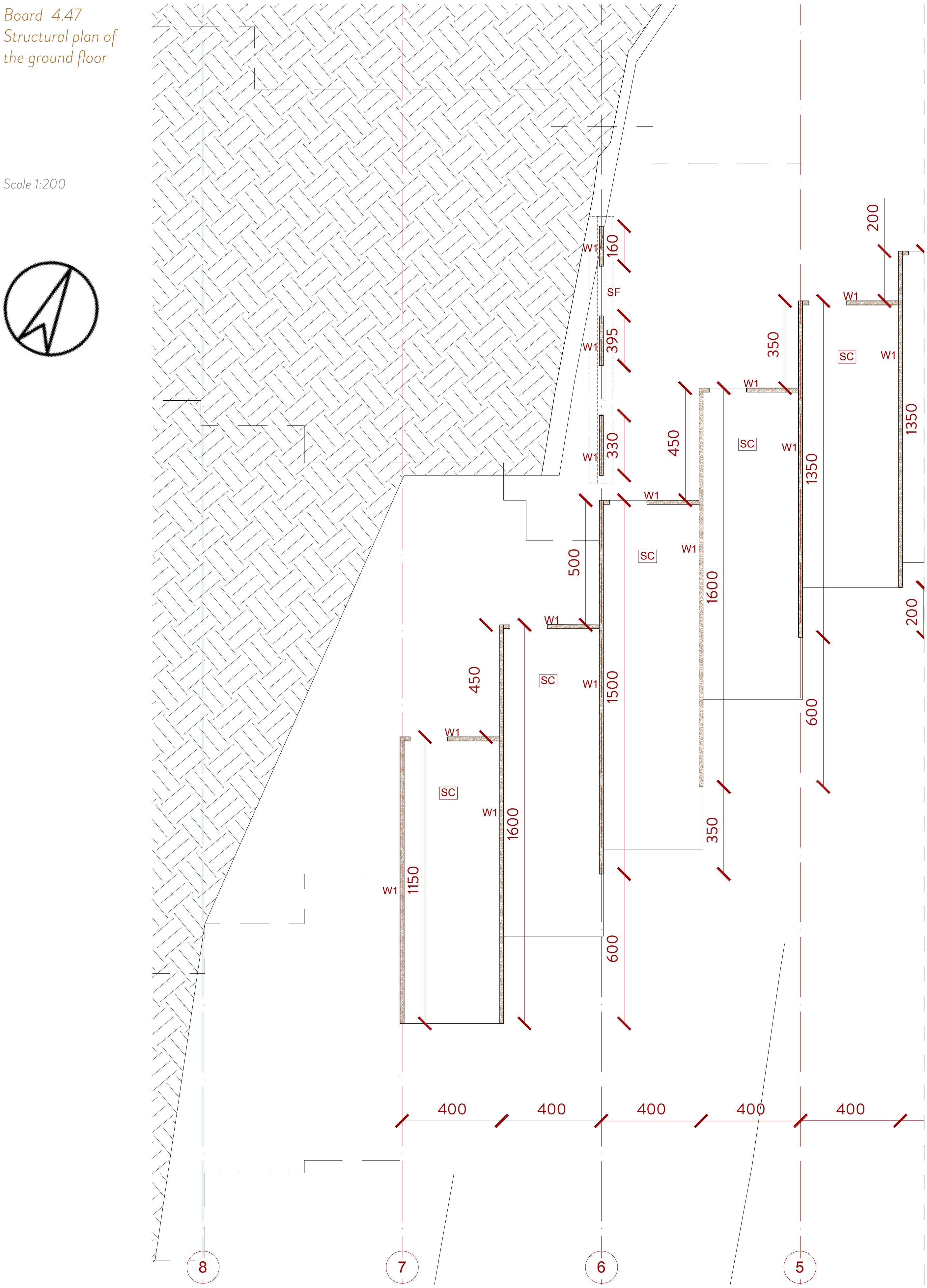
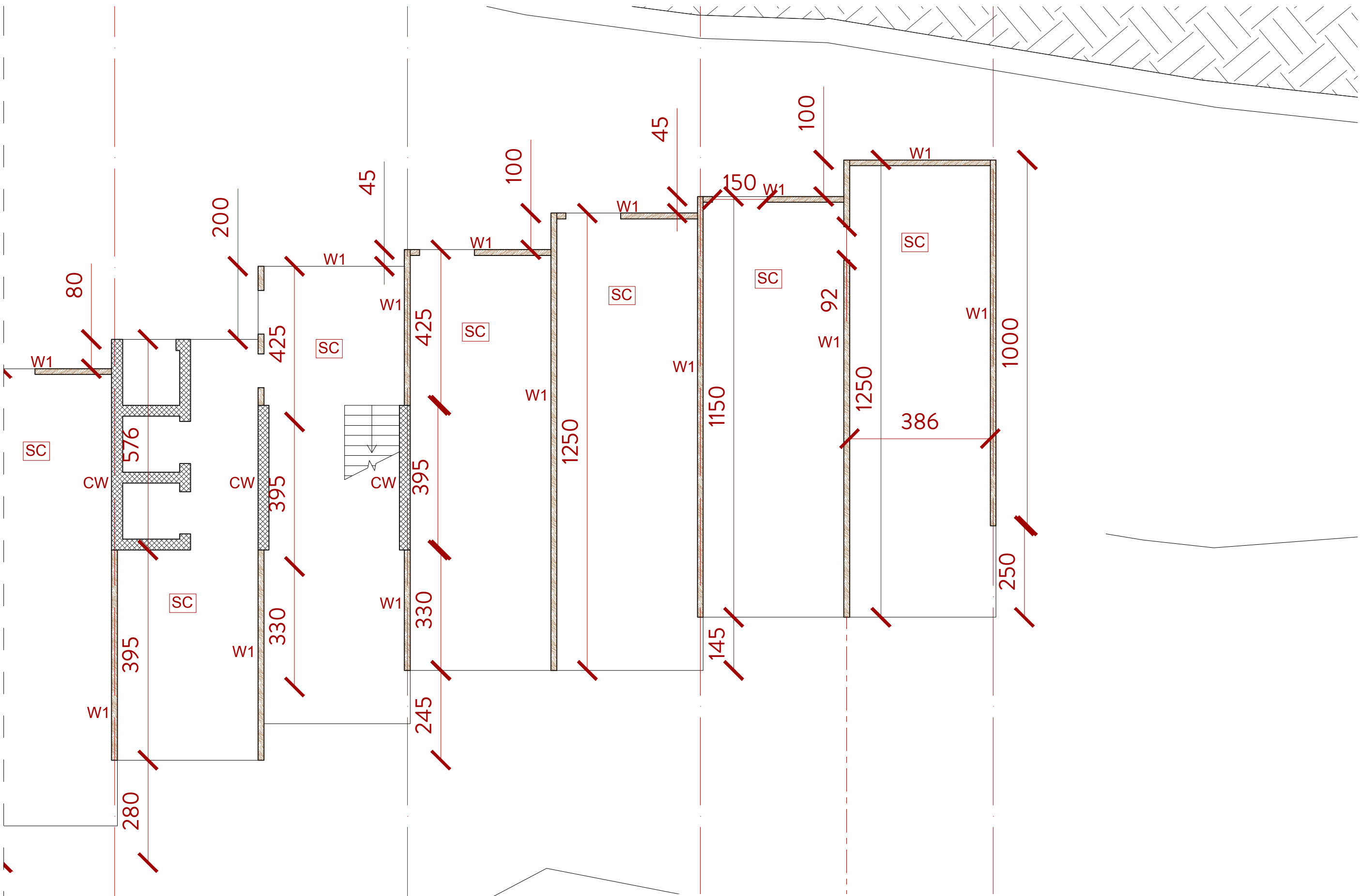
Board 4.47
Structural plan of the ground floor

Scale 1:200





W1 — Cross Laminated Timber wall, 5 layers 40-20-20-20-40 mm, th.=140mm;

CW — Reinforced concrete wall, th.=30cm

S1 — Cross Laminated Timber slab,7 layers: 20-30-20-30-20-30-20, (first layer oriented parallel to x axis), th.170 mm;

S2 — Cross Laminated Timber slab,7 layers: 20-30-20-30-20-30-20, (first layer oriented parallel to y axis), th.170 mm;

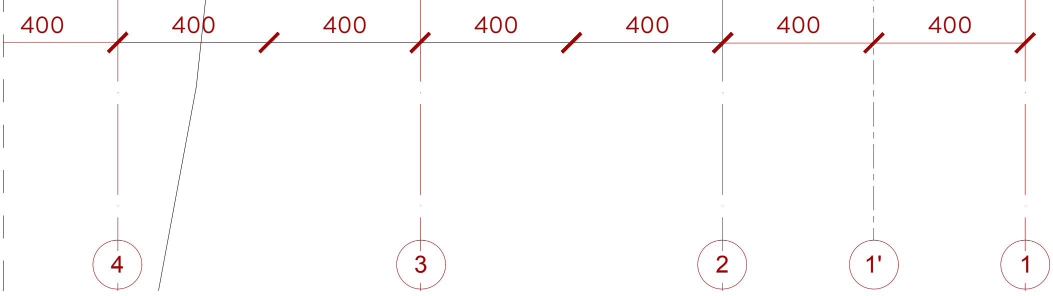
SC — Concrete slab, th.=35cm;

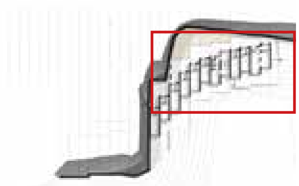
SF — Strip foundation in reinforced concrete;

CLT wall below the slab;

Glued Lamellar wood beam below the slab;

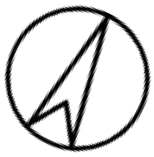
y x — Coordinates.

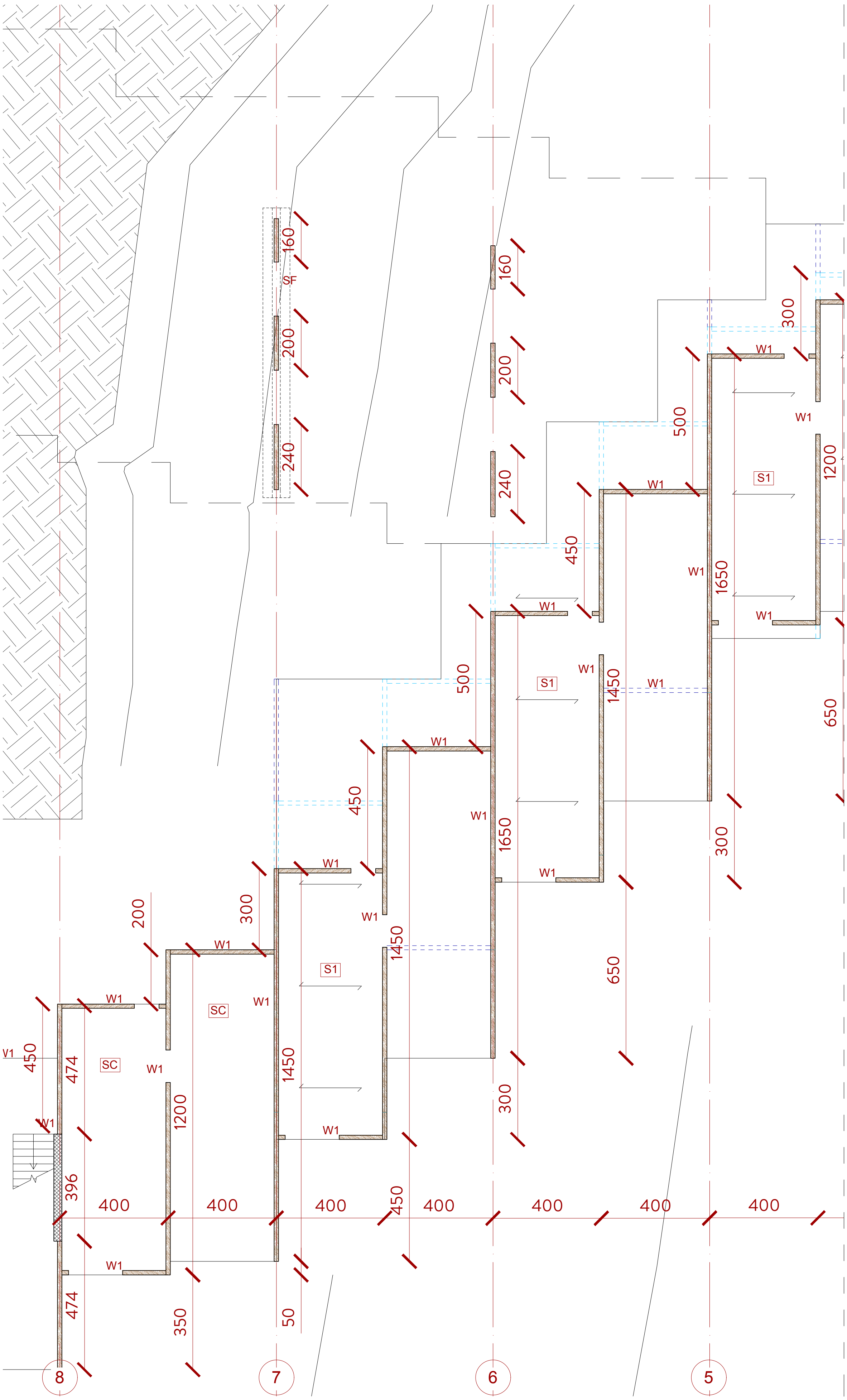


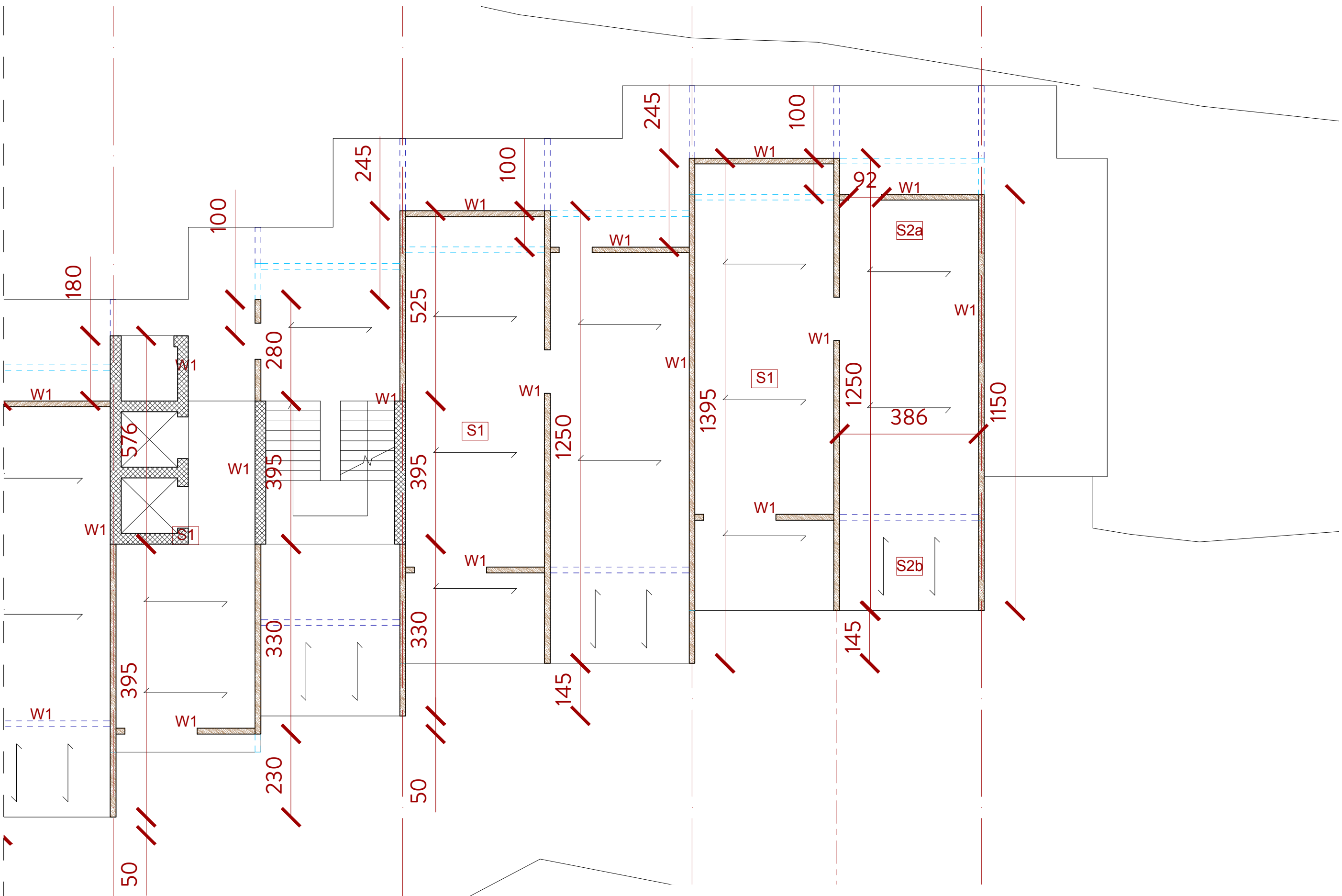


Board 4.48
Structural plan of the first floor

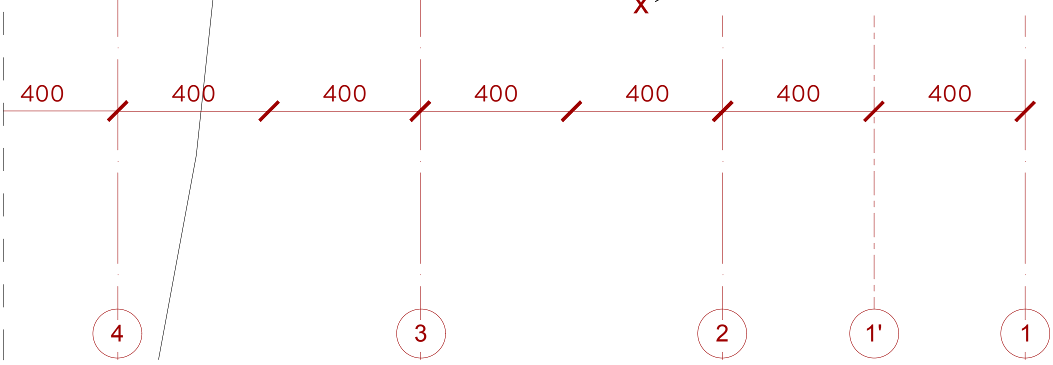
Scale 1:200

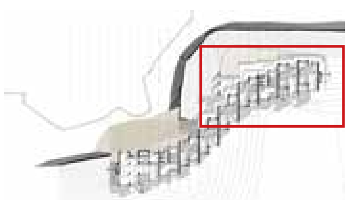






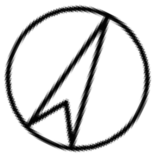
W1	Cross Laminated Timber wall, 5 layers 40-20-20-20-40 mm, th.=140mm;
CW	Reinforced concrete wall, th.=30cm
S1	Cross Laminated Timber slab,7 layers: 20-30-20-30-20-30-20, (first layer oriented parallel to x axis), th.170 mm;
S2	Cross Laminated Timber slab,7 layers: 20-30-20-30-20-30-20, (first layer oriented parallel to y axis), th.170 mm;
SC	Concrete slab, th.=35cm;
SF	Strip foundation in reinforced concrete;
- - - -	CLT wall below the slab;
- - - -	Glued Lamellar wood beam below the slab;
y / x	Coordinates.

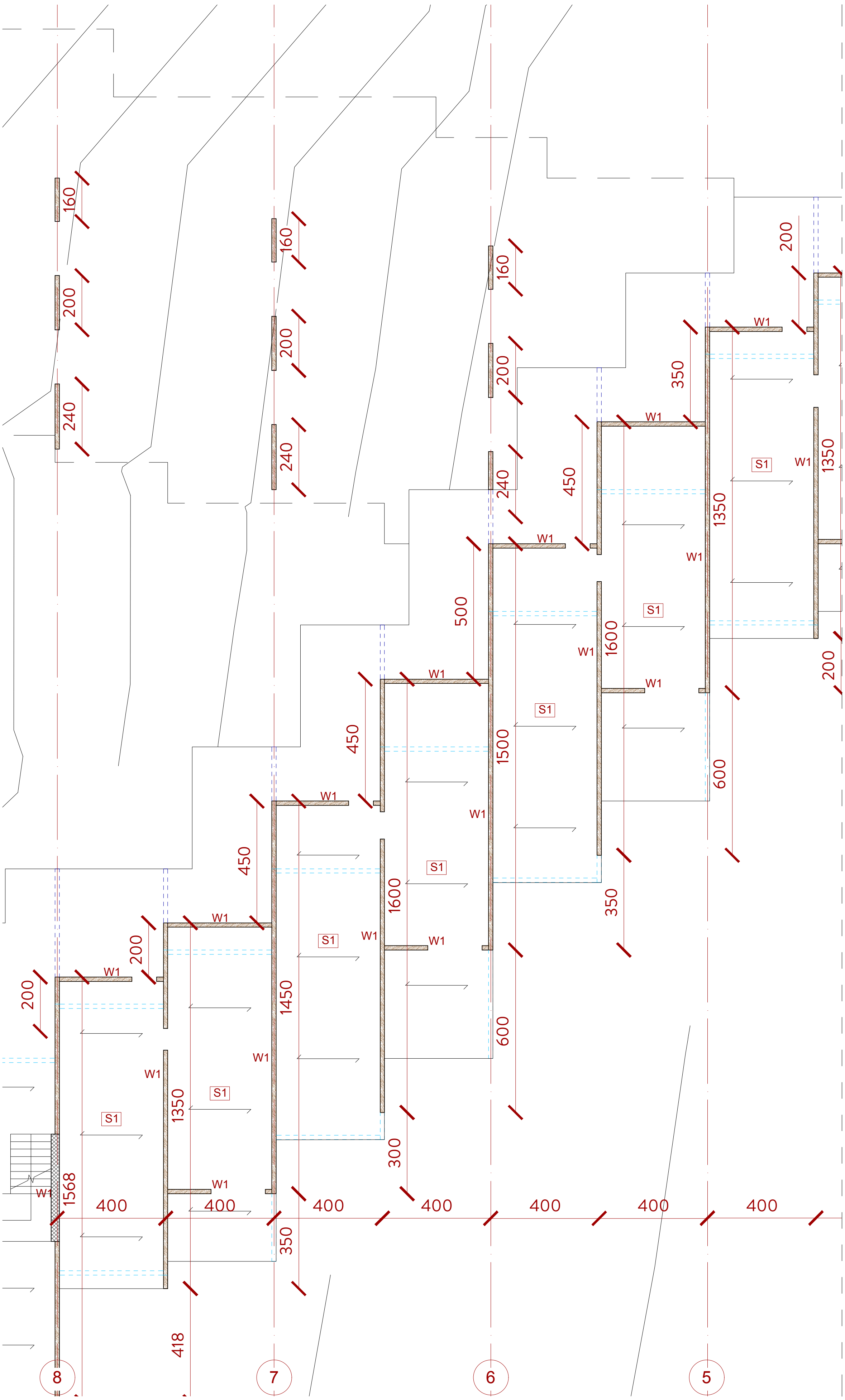


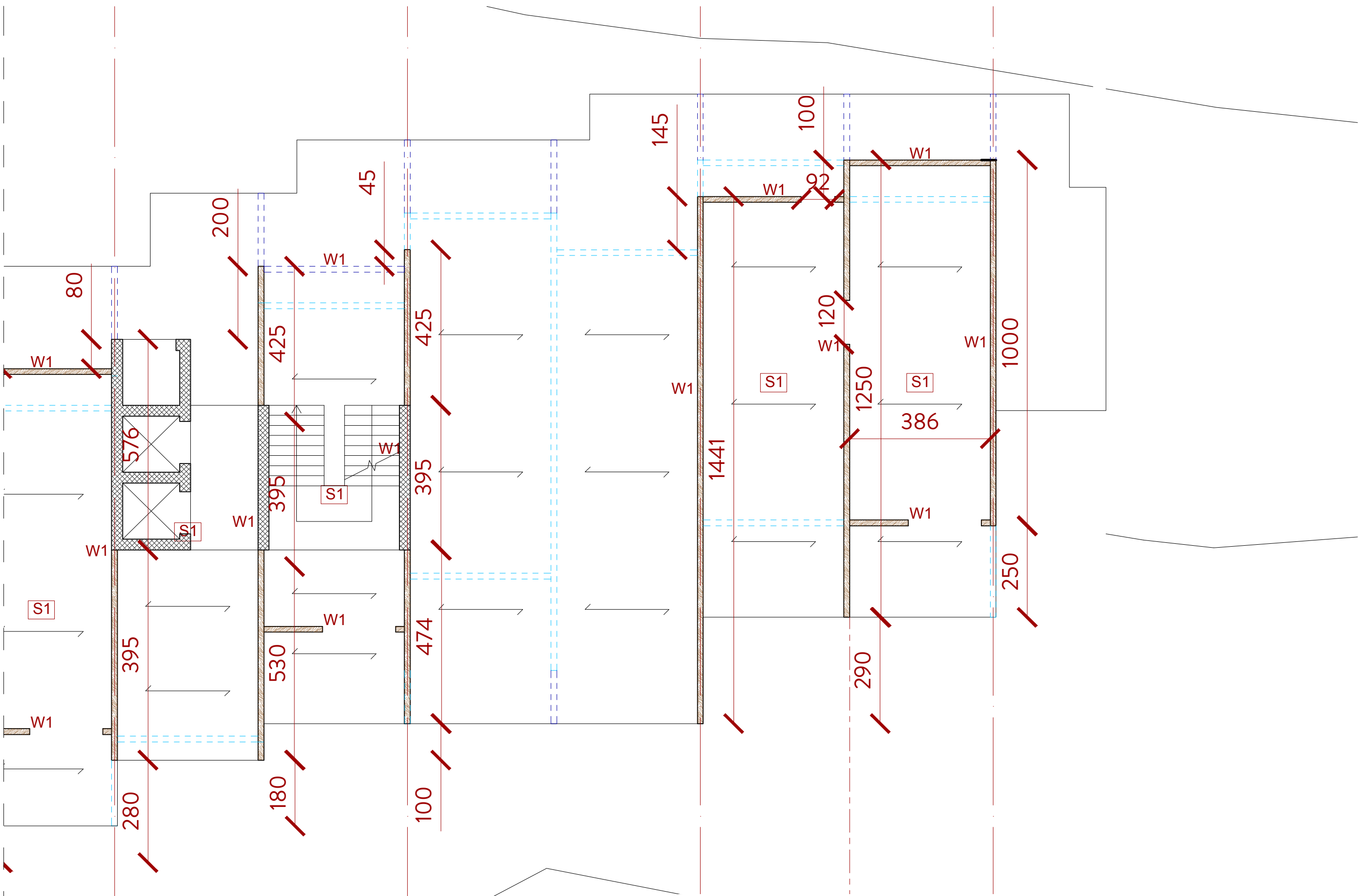


Board 4.49
Structural plan of the second floor

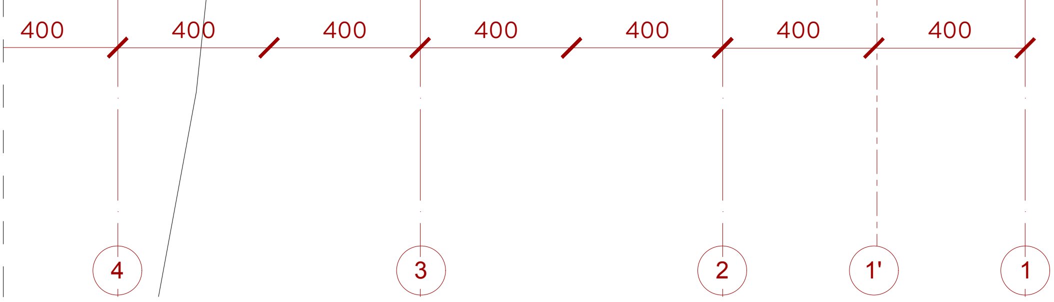
Scale 1:200







W1	Cross Laminated Timber wall, 5 layers 40-20-20-20-40 mm, th.=140mm;
CW	Reinforced concrete wall, th.=30cm
S1	Cross Laminated Timber slab,7 layers: 20-30-20-30-20-30-20, (first layer oriented parallel to x axis), th.170 mm;
S2	Cross Laminated Timber slab,7 layers: 20-30-20-30-20-30-20, (first layer oriented parallel to y axis), th.170 mm;
SC	Concrete slab, th.=35cm;
SF	Strip foundation in reinforced concrete;
------	CLT wall below the slab;
------	Glued Lamellar wood beam below the slab;
y / x	Coordinates.



Now it is explained how the structure is working and the “Flow of loads” in a generic part of the building:

(A) The first elements that are landing on the foundations are CLT wall panels, that are the sopports for the slabs. There are also cantilever beams that support the slab in the “back” part of the building, the one facing Colserola.

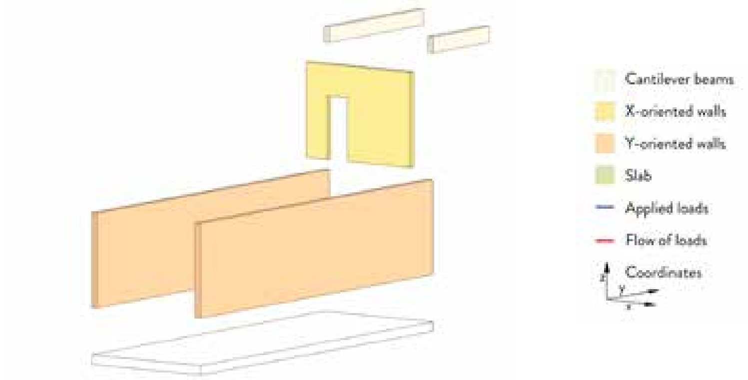


Figure 4.50 Schematic 3D exploded view of the structure (A)

(source: own elaboration)

(B) The slabs are the horizontal elements and they are loaded by different loads (self weight, live load, internal partitions, snow, as reported later). These elements are resting on the vertical walls below them, both the one in x and y direction oriented walls, and on the cantilever beams.

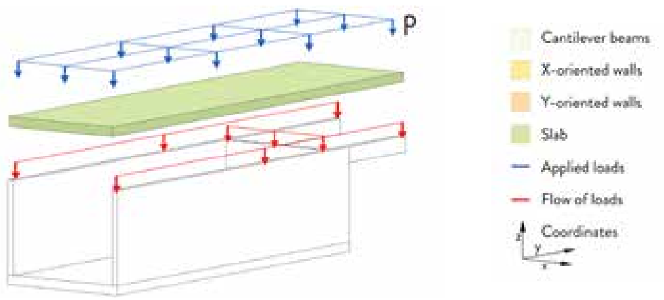


Figure 4.51 Schematic 3D exploded view of the structure (B)

(source: own elaboration)

(C) The vertical elements placed in the y direction are repeated every 4 meters along the x direction and in the z direction they overlap one above the other.
It can be seen that the walls oriented along the x direction do not overlap between floors, so they have to load the y oriented vertical walls to not overload the slabs. So we could say that the x oriented walls act as secondary elements and load the y oriented walls.

In some cases (not represented in the figure) the y oriented wall in one floor can be longer than the y oriented wall standing in the level below it, so it will have a cantilever part, not landing on the vertical y wall below it. This is possible thanks to a behaviour of the panel called “beam-wall”, where the wall acts as a slender beam.

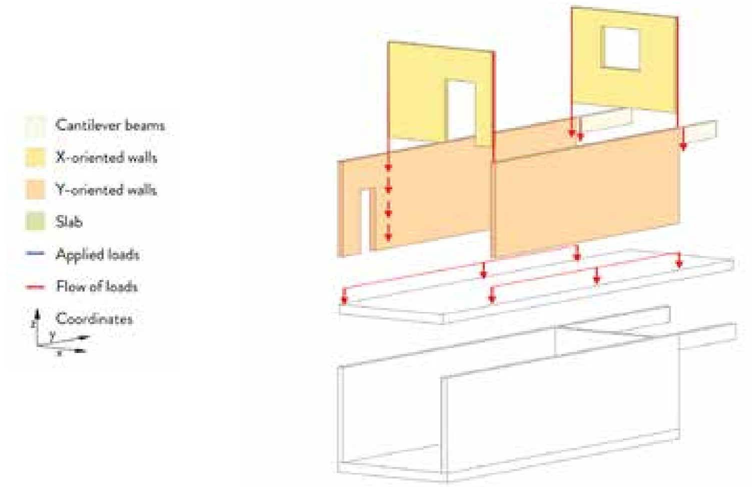


Figure 4.52 Schematic 3D exploded view of the structure (C)

(source: own elaboration)

(D) Another slab is placed above the walls, but in this case the horizontal element has a cantilever part. This may or may not occur, depending on the position of the modules placed on the sides.

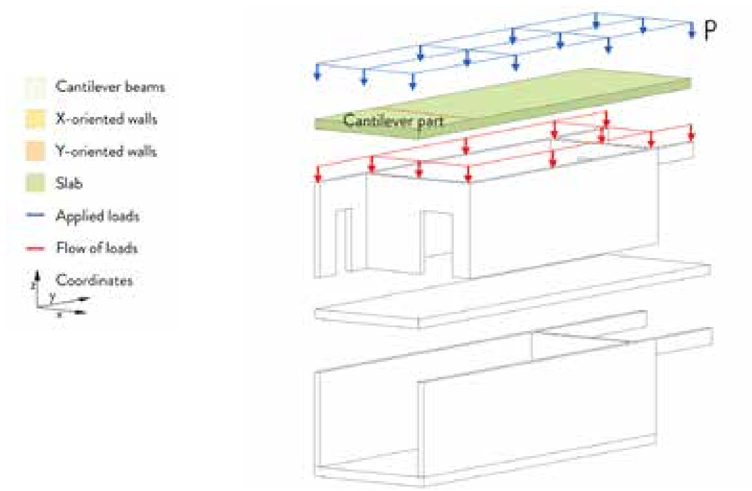


Figure 4.53 Schematic 3D exploded view of the structure (D)

(source: own elaboration)

4.3.4 Loads

4.3.4.1 Variable loads according to the activity

The building is for residential use, therefore, according to the Eurocode, the loads to be applied are the ones for Category A. The imposed load on the slab is 2 kN/m^2, while on the balcony it must be set a load of 4 kN/m^2.

Table 4.4
Categories of use

(source: Table 6.1, EN 1991, 2002)

Category	Specific Use	Example
B	Office areas	
C	Areas where people may congregate (with the exception of areas defined under category A, B, and D[1])	**C1**: Areas with tables, etc. e.g. areas in schools, cafés, restaurants, dining halls, reading rooms, receptions. **C2**: Areas with fixed seats, e.g. areas in churches, theatres or cinemas, conference rooms, lecture halls, assembly halls, waiting rooms, railway waiting rooms. **C3:** Areas without obstacles for moving people, e.g. areas in museums, exhibition rooms, etc. and access areas in public and administration buildings, hotels, hospitals, railway station forecourts. **C4**: Areas with possible physical activities, e.g. dance halls, gymnastic rooms, stages. **C5**: Areas susceptible to large crowds, e.g. in buildings for public events like concert halls, sports halls including stands, terraces and access areas and railway platforms.
D	Shopping areas	**D1:** Areas in general retail shops **D2**: Areas in department stores

[1] Attention is drawn to 6.3.1.1(2), in particular for C4 and C5. See EN 1990 when dynamic effects need to be considered. For Category E, see Table 6.3

NOTE 1 Depending on their anticipated uses, areas likely to be categorised as C2, C3, C4 may be categorised as C5 by decision of the client and/or National annex.

NOTE 2 The National annex may provide sub categories to A, B, C1 to C5, D1 and D2

NOTE 3 See 6.3.2 for storage or industrial activity

Table 6.2 - Imposed loads on floors, balconies and stairs in buildings

Categories of loaded areas	q_k [kN/m²]	Q_k [kN]
Category B	2,0 to 3,0	1,5 to 4,5
Category C		
- C1	2,0 to 3,0	3,0 to 4,0
- C2	3,0 to 4,0	2,5 to 7,0 (4,0)
- C3	3,0 to 5,0	4,0 to 7,0
- C4	4,5 to 5,0	3,5 to 7,0
- C5	5,0 to 7,5	3,5 to 4,5
category D		
- D1	4,0 to 5,0	3,5 to 7,0 (4,0)
- D2	4,0 to 5,0	3,5 to 7,0

Table 4.5 Imposed loads in floors, balconies and stairs in buildings

(source: Table 6.2, EN 1991, 2002)

4.3.4.2 Internal partitions as variable load

The load of the internal partition is the following:

Non-structural Internal Partitions				
Layer	Thickness [m]	Spec weight [kN/m3]	Weight [kN/m2]	Linear weight [kN/m]
Plaster rendering				
Double cement board with vapour barrier	0,028	9	0,248	
Insulation layer: Rock wool	0,08	1,75	0,14	
Double cement board with vapour barrier	0,028	9	0,248	
Plaster rendering				
TOTAL	0,135	19,75	0,635	1,924

Table 4.6 Composition and weight of the non-structural internal partitions

(source: own elaboration)

Eurocode permits to consider an equivalent uniformly distributed load all over the floor, instead of the free action of movable partitions, if the slab can well redistribute the load transversally, as in the case analysed. In this way, it can be structurally accepted a rearrangement of the internal walls in the future.

EN1991, 6.3.1.2 part 8):
Provided that a floor allows a lateral distribution of loads, the self-weight of movable partitions may be taken into account by a uniformly distributed load qk which should be added to the imposed loads of floors obtained from Table 6.2. This defined uniformly distributed load is dependent on the self-weight of the partitions as follows:

- for movable partitions with a self-weight s 1,0 kN/m wall length:
  qk = 0,5 kN/m2;
- for movable partitions with a self-weight > 1 ≤ 2,0 kN/m wall length:
  qk = 0,8 kN/m2;
- for movable partitions with a self-weight> 2 ≤ 3,0 kN/m wall length:
  qk = 1,2 kN/m2;

In this case the value to consider as distributed is 0,8 kN/m2, that will be added to the imposed loads, as prescribed.

4.3.4.3 Permanent loads

The permanent loads are reported in the table below and consist in a structural part and a non-structural one. The first table contains the permanent loads of the internal floor, while in the second table are collected the loads acting on the balcony in the heaviest part, that is the one where vegetation is present.

Table 4.7
Composition and weight of the floor
(source: own elaboration)

Floor stratigraphy			
Layer	Thickness [m]	Spec weight [kN/m3]	Weight [kN/m2]
Laminate flooring	0,08	-	0,073
Gypsum-fibre panel (2x1,25cm)	0,025	-	0
Floor heating system	0,04	0,2	0,008
Granular dry screed	0,06	4	0,24
Polypropilene protective sheet			
Acoustic insulation (anti-footsteps)	0,02	1	0,02
Cross Laminated Timber (CLT)	0,17	5	0,85
Air	0,188	-	
Insulation layer: rock wool	0,085	1,75	0,149
Double cement board with vapour barrier	0,028	9	0,248
Plaster rendering	0,002	15	0,03
TOTAL	0,697		1,617
Total structural			0,85
Total non-structural			0,767

Table 4.8
Composition and weight of the green balcony and green roof
(source: own elaboration)

Green balcony and green roof stratigraphy			
Layer	Thickness [m]	Spec weight [kN/m3]	Weight [kN/m2]
Vegetation			
Soil	0,11	-	0,95
Filtering layer			
Alveolar membrane (rainwater storage)	0,018	-	0,4
Anti-perforation mat	0,05		
Bituminous waterproof layer	0,05	-	0,045
Thermal insulation (slope 1%): wood fibre	0,1	2	0,2
Vapour barrier			
Cross Laminated Timber (CLT)	0,17	5	0,85
Air	0,188	-	
Insulation layer: rock wool	0,085	1,75	0,149
Double cement board with vapour barrier	0,028	9	0,248
TOTAL	0,798		2,841
Total structural			0,85
Total non-structural			1,991

4.3.4.4 Snow load

The calculation of the snow load is performed according to Eurocode 1 part 1.3 and its Annex (EN 1991.1.3, 2003).
According to the expression 5.1 [EN 1991.1.3 5.2 (5.1)] we have:

$$s = \mu_i \cdot C_e \cdot C_t \cdot s_k$$

where

- μ_i is the snow load shape coefficient
- s_k is the characteristic value of snow load on tile ground
- C_e is the exposure coefficient
- C_t is the thermal coefficient

The coefficients required are expressed in the Eurocode throw the following figures and formulas.

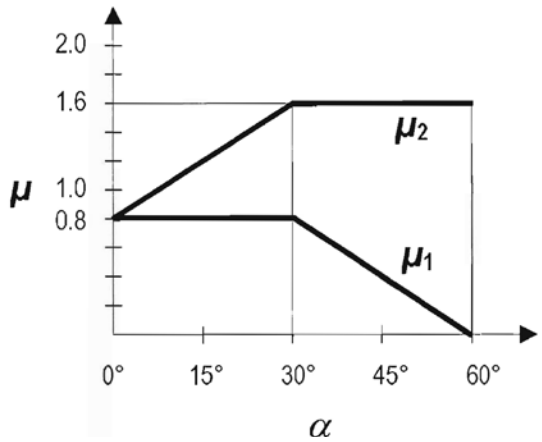


Figure 4.54
Snow loads shape coefficients
(source: figure 5.1, EN 1991-1-3, 2003)

Climatic Region	***Expression***
Iberian Peninsula	$s_k = (0{,}190Z - 0{,}095)\left[1 + \left(\frac{A}{524}\right)^2\right]$

s_k	is the characteristic snow load on the ground [kN/m^2]
A	is the site altitude above Sea Level [m]
Z	is the zone number given on the map.

Figure 4.55
Snow loads in relationship with altitude
(re-adapted source: table C.1, EN 1991-1-3, 2003)

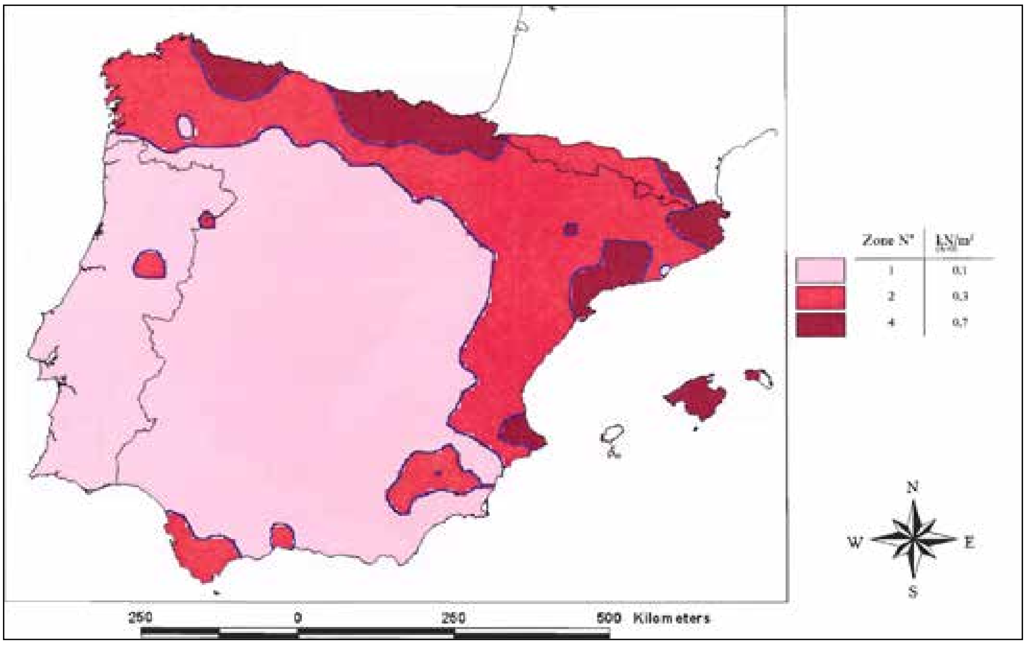


Figure 4.56
Snow loads at sea level for the Iberian Peninsula,
(source: figure C.5, EN 1991-1-3, 2003)

The coefficient C_e depends on the topography typology. In our case we have a normal topography, that means a value of 1.

“Normal topography: areas where there is no significant removal of snow by wind on construction work, because of terrain, other construction works or trees.” [EN 1991.1.3 5.2 Table5.1]

The thermal coefficient is equal to 1 for normal roofs.

So finally it is possible to calculate the snow load:

Table 4.9
Calculation of the snow load

(source: own elaboration)

Snow load			
μi =	0,8		roof inclination = 0° (see figure)
Ce =	1		normal topography
Ct =	1		normal cases
Z = zone number =	2		see figure
A = altitude	180	m	for Canyelles
sk =	0,319	kN/m2	Iberian peninsula (see formula)
s = μi * Ce * Ct * sk =	0,255	kN/m2	

Since we are in a normal snow situation with no exceptional falls and no exceptional drifts, the snow load will be taken into account only for a persistent/transient design situation and not for accidental design situations.
For the same reason the snow load it will be considered as a variable action (Q) and not as accidental action, in accordance to Eurocode 0 paragraph 4.1.1 [EN1990, 2002].

4.3.4.5 Wind load

The wind load calculation it is performed according to Eutocode 1 part 1.4 [EN 1991-1-4, 2005].

First of all it has to be evaluated the basic wind velocity, v_b that is defined by the Eurocode.

Figure 4.57
Basic wind velocity

(source: part 1.4 paragraph 4.2(2), EN 1991-1-4, 2005)

$$v_b = c_{dir} \cdot c_{season} \cdot v_{b,0} \quad (4.1)$$

where:

v_b is the basic wind velocity, defined as a function of wind direction and time of year at 10 m above ground of terrain category II

$v_{b,0}$ is the fundamental value of the basic wind velocity, see (1)P

c_{dir} is the directional factor, see Note 2.

c_{season} is the season factor, see Note 3.

NOTE 1 Where the influence of altitude on the basic wind velocity v_b is not included in the specified fundamental value $v_{b,0}$ the National Annex may give a procedure to take it into account.

NOTE 2 The value of the directional factor, c_{dir}, for various wind directions may be found in the National Annex. The recommended value is 1,0.

NOTE 3 The value of the season factor, c_{season}, may be given in the National Annex. The recommended value is 1,0.

Considering the definition of $v_{b,0}$:
“The fundamental value of the basic wind velocity, $v_{b,0}$, is the characteristic 10 minutes mean wind velocity, irrespective of wind direction and time of year, at 10 m above ground level in open country terrain with low vegetation such as grass and

isolated obstacles with separations of at least 20 obstacle heights.” [EN 1991-1-4 4.2 (1), 2005]

The value of $v_{b,0}$ should be given by the National Annex, but in the case of Spain it is not given there, so the value was taken from the Spanish normative “Documento Basico Seguridad de Estructural: Acciones ne la Edificacion” (DB SE-AE 2007).

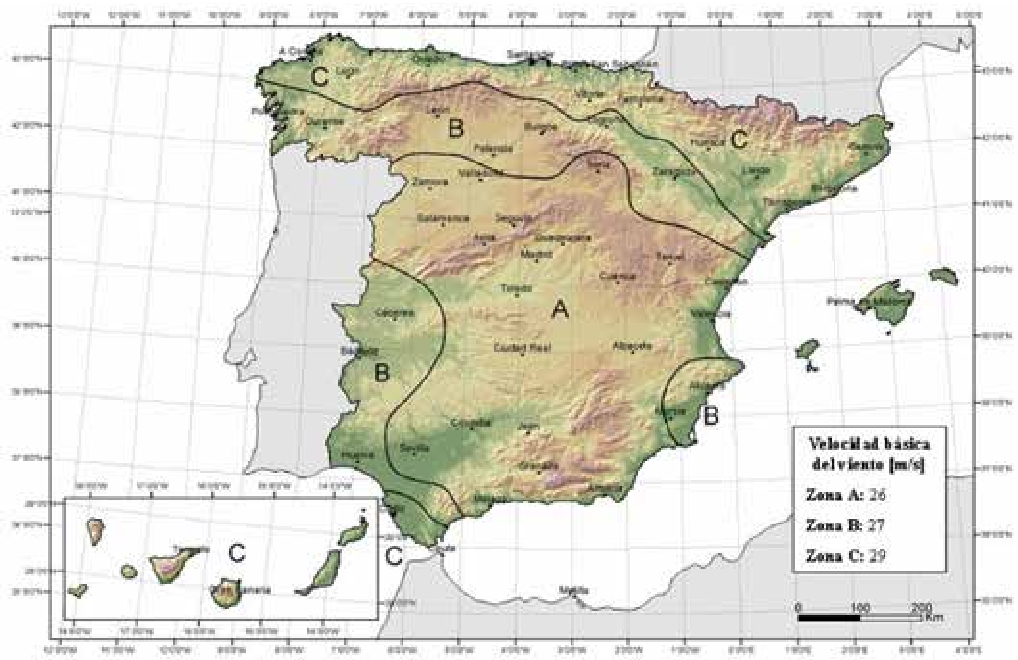


Figure 4.58 Fundamental value of the basic wind velocity

(source: Spanish Documento Basico figure D.1; DB SE-AE 2007)

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So it is calculated v_b:

v_{b0} =	29 m/s	from DB SE-AE 2007
c_{dir} =	1	Recommended value
c_{season} =	1	Recommended value
$v_b = c_{dir} * c_{season} * v_{b0}$ =	29 m/s	

Table 4.10 Calculation of the basic wind velocity

(source: own elaboration)

The terrain category it is necessary to evaluate the mean wind velocity.
In our case we are located in a suburban area of Barcelona, so the category will be the number III in the table.

Terrain category		z_0 m	z_{min} m
0	Sea or coastal area exposed to the open sea	0,003	1
I	Lakes or flat and horizontal area with negligible vegetation and without obstacles	0,01	1
II	Area with low vegetation such as grass and isolated obstacles (trees, buildings) with separations of at least 20 obstacle heights	0,05	2
III	Area with regular cover of vegetation or buildings or with isolated obstacles with separations of maximum 20 obstacle heights (such as villages, suburban terrain, permanent forest)	0,3	5
IV	Area in which at least 15 % of the surface is covered with buildings and their average height exceeds 15 m	1,0	10
NOTE: The terrain categories are illustrated in A.1.			

Table 4.11 Terrain categories and parameters

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(source: Eurocode 1 part 1.4 table 4.1; EN 1991-1-4, 2005)

Then it can be evaluated the mean wind velocity at a height z above the ground, that depends on the roughness and the orography of the terrain and on the basic wind velocity.

Figure 4.59
Mean wind velocity

(source: Eurocode 1 part 1.4 paragraph 4.3.1; EN 1991-1-4, 2005)

$$v_m(z) = c_r(z) \cdot c_o(z) \cdot v_b$$

where:

$c_r(z)$ is the roughness factor, given in 4.3.2

$c_o(z)$ is the orography factor, taken as 1,0 unless otherwise specified in 4.3.3

NOTE 1 Information on c_O may be given in the National Annex. If the orography is accounted for in the basic wind velocity, the recommended value is 1,0.

NOTE 2 Design charts or tables for $v_m(z)$ may be given in the National Annex.

C_o will be taken as 1 and C_r is defined by the code and is a function of z:

Figure 4.60
Roughness factor

(source: Eurocode 1 part 1.4 paragraph 4.3.2; EN 1991-1-4, 2005)

$$c_r(z) = k_r \cdot \ln\left(\frac{z}{z_0}\right) \quad \text{for} \quad z_{min} \leq z \leq z_{max}$$

$$c_r(z) = c_r(z_{min}) \quad \text{for} \quad z \leq z_{min}$$

where:

z_0 is the roughness length

k_r terrain factor depending on the roughness length z_0 calculated using

Figure 4.61
Terrain factor

(source: Eurocode 1 part 1.4 paragraph 4.3.2; EN 1991-1-4, 2005)

$$k_r = 0{,}19 \cdot \left(\frac{z_0}{z_{0,II}}\right)^{0{,}07}$$

where:

$z_{0,II}$ = 0,05 m (terrain category II, Table 4.1)

z_{min} is the minimum height defined in Table 4.1

z_{max} is to be taken as 200 m

Then it is calculated the wind turbulence intensity, taking k_I as 1.

Figure 4.62
Wind turbulence

(source: from Eurocode 1 part 1.4 paragraph 4.4; EN 1991-1-4, 2005)

$$I_v(z) = \frac{\sigma_v}{v_m(z)} = \frac{k_I}{c_o(z) \cdot \ln(z/z_0)} \quad \text{for} \quad z_{min} \leq z \leq z_{max}$$

$$I_v(z) = I_v(z_{min}) \quad \text{for} \quad z < z_{min}$$

where:

k_I is the turbulence factor. The value of k_I may be given in the National Annex. The recommended value for k_I is 1,0.

c_o is the orography factor as described in 4.3.3

z_0 is the roughness length, given in Table 4.1

And finally it's possible to get the peak velocity pressure, that was calculated after q_b and $C_e(z)$.

$$q_p(z) = [1 + 7 \cdot I_v(z)] \cdot \tfrac{1}{2} \cdot \rho \cdot v_m^2(z) = c_e(z) \cdot q_b$$

where:

ρ is the air density, which depends on the altitude, temperature and barometric pressure to be expected in the region during wind storms

$c_e(z)$ is the exposure factor $c_e(z) = \dfrac{q_p(z)}{q_b}$

q_b is the basic velocity pressure $q_b = \tfrac{1}{2} \cdot \rho \cdot v_b^2$

Figure 4.63
Peak velocity pressure
(source: Eurocode 1 part 1.4 paragraph 4.5; EN 1991-1-4, 2005)

The peak velocity pressure was then represented in a diagram to show its value at each different height from the ground (z).

z_0=	0,3		Terrain category: class III
z_{min} =	5		
c_r (z) =	for z<zmin -> cr = cr(zmin)		See formula EC
	for zmin<z<200m -> cr=kr*ln(z/zo)		
c_0 (z) =	1		Recommended value in EC
z_{0II}=	0,05		See table in EC
k_r =0,19(zo/zoII) =	0,215		See formula in EC
k_I =	1		Recommended value in EC
I_v =	for z<zmin -> Iv = Iv(zmin)		See formula EC
	for zmin<z<200m -> cr=kI/[co(z)*ln(z/zo)]		
ρ_{air} =	1,25	kg/m3	Recommended value in EC
q_b =	525,625	N/m2	See formula in EC

Table 4.12
Summary of the data used in the calculation
(source: own elaboration)

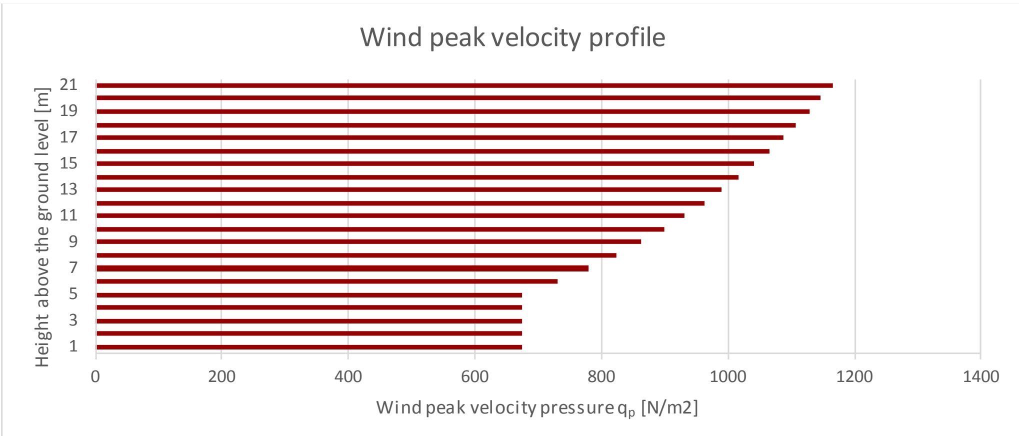


Figure 4.64
Diagram of the wind peak velocity pressure profile
(source: own elaboration)

4.3.5 General Concepts

The building is designed to have a working life of 50 years, according to Eurocode 0.

Table 4.13 Indicative design working life

(source: Eurocode 0 table 2.1; EN 1990, 2002)

Design working life category	Indicative design working life (years)	Examples
1	10	Temporary structures (1)
2	10 to 25	Replaceable structural parts, e.g. gantry girders, bearings
3	15 to 30	Agricultural and similar structures
5	100	Monumental building structures, bridges, and other civil engineering structures
(1) Structures or parts of structures that can be dismantled with a view to being re-used should not be considered as temporary.		

The calculation procedure for a wooden building is explained inside Eurocode 5. Even if the code doesn't contain a specific procedure to follow for an Xlam structure, the general ideas presented for wood were considered in the calculation that was carried out.
In addition to that, Politecnico of Graz has developed a guideline to help Xlam designers, and that was mainly followed in this thesis as a reference.

4.3.5.1Calculation methodology

The model adopted for the calculation of the xlam material was studied and developed by the Politecnico of Graz researchers and it's based on the Timoshenko theories.
The flexural rigidity is evaluated considering only the contribution of the longitudinal layers (that is on the safety side). Regarding the deformations, both the flexural and shear contribution are taken into account.
The method is also characterized by the hypothesis of rigid connections between the layers of the panels.

The so called "gamma method" proposed by the appendix B of the normative EN 1995 could not be applied because the number of layers of the panel is greater than 5.

4.3.5.2 Mechanical properties of CLT

The wood used for the panel is chosen as class C24, and its mechanical properties are the following:

Figure 4.14 Mechanical properties of the CLT considered for the calculation (producer "Cross Timber System")

XLAM properties			
Symbol	Value		Property
$E_{0,mean}$	11500	MPa	Mean elastic modulus parallel to the fibres
$E_{90,mean}$	370	MPa	Mean elastic modulus perpendicular to the fibres
$G_{090,mean}$	690	MPa	Shear modulus parallel to the fibres
$G_{9090,mean}$	50	MPa	Rolling shear modulus perpendicular to the fibres
$f_{m,k}$	24	MPa	Bending strength parallel to the fibres
$f_{t,0,k}$	14	MPa	Tensile strength parallel to the fibres
$f_{t,90,k}$	0,5	MPa	Tensile strength perpendicular to the fibres
$f_{c,0,k}$	21	MPa	Compressive strength parallel to the fibres
$f_{c,90,k}$	2,5	MPa	Compressive strength perpendicular to the fibres
$f_{v,k}$	4	MPa	Shear strength
$f_{r,k}$	1,3	MPa	Rolling shear strength
ρm	500	kg/m3	Mean density

4.3.5.3 Theory and calculation of the material design properties

The service class of the material is defined according to the environment that the wood has to withstand during the working life of the building. According to the Eurocode 5 the 3 service classes for wood are reported in the paragraph 2.3.1.3.

(2)P Service class 1 is characterised by a moisture content in the materials corresponding to a temperature of 20°C and the relative humidity of the surrounding air only exceeding 65 % for a few weeks per year.

NOTE: In service class 1 the average moisture content in most softwoods will not exceed 12 %.

(3)P Service class 2 is characterised by a moisture content in the materials corresponding to a temperature of 20°C and the relative humidity of the surrounding air only exceeding 85 % for a few weeks per year.

NOTE: In service class 2 the average moisture content in most softwoods will not exceed 20 %.

(4)P Service class 3 is characterised by climatic conditions leading to higher moisture contents than in service class 2.

Figure 4.65 Service classes of wood

(source: Eurocode 5 paragraph 2.3.1.3; EN 1995, 2004)

Internal partitions, slabs and external enclosures are all part of the service class 1 because are located inside a heated building without being in contact with the external environment.

The strength properties of the material need to be calculated according to the Eurocode 5 prescription

(1)P The design value X_d of a strength property shall be calculated as:

$$X_d = k_{mod} \frac{X_k}{\gamma_M}$$

where:

X_k is the characteristic value of a strength property;

γ_M is the partial factor for a material property;

k_{mod} is a modification factor taking into account the effect of the duration of load and moisture content.

NOTE 1: Values of k_{mod} are given in 3.1.3.

NOTE 2: The recommended partial factors for material properties (γ_M) are given in Table 2.3. Information on the National choice may be found in the National annex.

Figure 4.66 Design values of material properties

(source: Eurocode 5 paragraph 2.4.1; EN 1995, 2004)

The values of the materials partial factors are defined in the Table of Eurocode 5. In particular for CLT it should be used the factor prescribed for Glue laminated timber that is γ_M =1,25.

Table 4.15
Recommended partial factors γ_M for material properties and resistances

(source: Eurocode 5 table 2.3; EN 1995, 2004)

Fundamental combinations:	
Solid timber	1,3
LVL, plywood, OSB,	1,2
Particleboards	1,3
Fibreboards, hard	1,3
Fibreboards, medium	1,3
Fibreboards, MDF	1,3
Fibreboards, soft	1,3
Connections	1,3
Punched metal plate fasteners	1,25
Accidental combinations	1,0

Also the values of the modification factor k_{mod} are reported inside the Eurocode 5. For every material, the value is prescribed according to the load-duration class and the service class.
In our case it is selected the row of Glue laminated timber and service class 1, that is suitable for elements located inside a heated building.

Table 4.16
Values of k_{mod}

(source: Eurocode 5 extract of table 3.1; EN 1995, 2004)

Material	Standard	Service class	Load-duration class				
			Permanent action	Long term action	Medium term action	Short term action	Instantaneous action
Solid timber	EN 14081-1	1	0,60	0,70	0,80	0,90	1,10
		2	0,60	0,70	0,80	0,90	1,10
		3	0,50	0,55	0,65	0,70	0,90
Glued laminated timber	EN 14080	1	0,60	0,70	0,80	0,90	1,10
		2	0,60	0,70	0,80	0,90	1,10
		3	0,50	0,55	0,65	0,70	0,90

In addition to that Eurocode 5 specifies which load duration should be taken in case of actions that have different durations, as in our case.

Figure 4.67
Load duration selection

(source: Eurocode 5 paragraph 3.1.3; EN 1995, 2004)

(1) The values of the modification factor k_{mod} given in Table 3.1 should be used.

(2) If a load combination consists of actions belonging to different load-duration classes a value of k_{mod} should be chosen which corresponds to the action with the shortest duration, e.g. for a combination of dead load and a short-term load, a value of k_{mod} corresponding to the short-term load should be used.

In our case it has therefore to be considered a medium-term action, that is the duration of the variable loads applied. The resulting value of k_{mod} for service class 1 is 0,8.

Another important coefficient for timber is k_{def}, that takes into account increasing in deformability with the time due to the viscous behaviour together with the humidity of the material. The values of the coefficient are prescribed inside the Eurocode 5 in table 3.2.

Table 4.17
Values of k_{def} for timber and wood-based materials

(source: Eurocode 5 extract of table 3.2; EN 1995, 2004)

Material	Standard	Service class		
		1	2	3
Solid timber	EN 14081-1	0,60	0,80	2,00

When several equally spaced similar members, components or assemblies are laterally connected by a continuous load distribution system, as in the case of a CLT el-

ement under bending, the Eurocode admits the possibility to multiply the member strength property by a system strength factor k_{sys}.
The value of the factor is prescribed in Eurocode 5 and for laminated timber deck it can be evaluated throw the following graph:

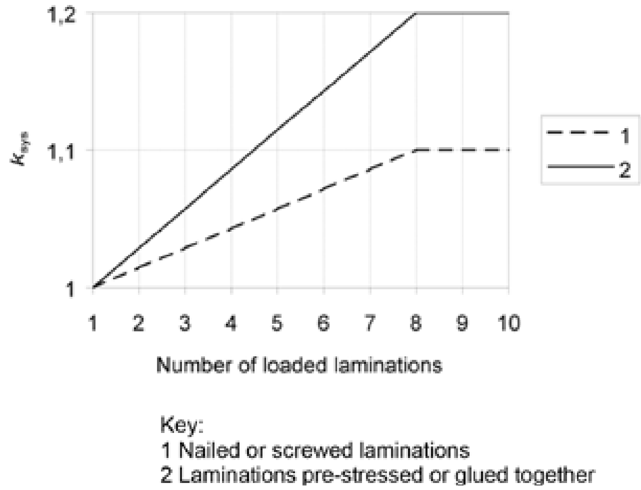


Figure 4.68
Evaluation of k_{sys} for laminated deck plates of glued laminated members

(source: Eurocode 5 fig 6.12; EN 1995, 2004)

The maximum value set by the code is 1,2 for glued laminated members, but according to Promolegno it is generally used a maximum value of 1,1. For safety reasons it is chosen to use a maximum of 1,1.

It is now possible to calculate the design properties of the xlam selected using the coefficients presented above.

The value of the design bending strength parallel to the fibres is:

$$f_{M,XLAM,d} = k_{sys} \frac{k_{\text{mod}} \cdot f_{m,k}}{\gamma_M} = 1,1 \frac{0,8 \cdot 24}{1,25} = 16,9 MPa$$

k_{sys} -> in the case of 7 loaded laminations the value of k_{sys} from the previous table comes out to be greater than the maximum value chosen, so it will be used 1,1.

The value of the design compressive strength perpendicular to the fibres is:

$$f_{c,90,XLAM,d} = \frac{k_{\text{mod}} \cdot f_{c,90,k}}{\gamma_M} = \frac{0,8 \cdot 2,5}{1,25} = 1,6 MPa$$

The value of the design shear strength is:

$$f_{v,XLAM,d} = \frac{k_{\text{mod}} \cdot f_{v,k}}{\gamma_M} = \frac{0,8 \cdot 2,5}{1,25} = 1,6 MPa$$

4.3.5.4 Theory about the properties of the XLAM section

The following properties are a characteristic of each XLAM panel and depend on its global thickness and on its layer combination (number, orientation and thickness)

The net flexural rigidity of the XLAM panel in one direction K_{XLAM} is calculated neglecting the contribution of the layers in the orthogonal direction respect to the calculation one (posing E_{90}=0 due to its low value)
It is considered a CLT stripe of unitary depth b=1m

$$K_{XLAM} = E_{XLAM} I_{XLAM} = \sum E_i \cdot I_i + \sum A_i \cdot a_i^2 \cdot E_i$$

where

- E_i is the elastic modulus of each layer
- I_i is the inertia of each layer
- A_i is the transversal area of each layer
- a_i is the distance of the barycentric axis of each layer to the barycentric axis of the Xlam section

The shear rigidity of the panel can be got from the following expression:

$$S_{XLAM} = (\sum G_i \cdot A_i) \cdot \kappa$$

where

- G_i is the shear modulus of the layer i
- A_i is the transversal area of each layer
- κ is the correction coefficient

The correction coefficient takes into account the non uniformity of the characteristics of the panel along its thickness. It depends on the number of layers, the ratio G_0/G_{90} and the thickness of each layer and can be calculated either throw a mathematical equation or throw tables. There are tables for a panel with layers of the same thickness and with a ratio G_0/G_{90} equal to 10, but it can be proved that the values of $\varkappa$ are between 0,2 and 0,3 also for uneven layers and other standard G values, so for safety reasons it is chosen to use the lowest value: $\varkappa$ =0,2.

4.3.5.5 Static model adopted for the calculation

For simplification, it can be often considered that a CLT panel is subjected to bending and shear in only one direction of the plane. The direction to be considered is the one of the minimum span, to avoid an overestimation of the slab thickness.
In this thesis it was decided to consider a mono-dimensional model for the calculation of the CLT. This implies a simplification of the procedure, but also less accuracy in the result. The assumptions made are always going to the safety side, therefore the result will be more restrictive than an accurate finite element calculation.

4.3.5.6 Partial factors and combination factors

In this paragraph are reported the values of the partial safety factors and combination factors that will be used later in the calculation.

Table 4.18 Partial safety factors of actions

(data source: Eurocode 0 table A1.2; EN 1990, 2002)

Partial safety factors for actions			
	Action	Favourable	Unfavourable
γ_G	Permanent	1	1,35
γ_Q	Variable	0	1,5

Action	ψ_0	ψ_1	ψ_2
Imposed loads in buildings, category (see EN 1991-1-1)			
Category A : domestic, residential areas	0,7	0,5	0,3
Category B : office areas	0,7	0,5	0,3
Category C : congregation areas	0,7	0,7	0,6
Category D : shopping areas	0,7	0,7	0,6
Category E : storage areas	1,0	0,9	0,8
Category F : traffic area, vehicle weight ≤ 30kN	0,7	0,7	0,6
Category G : traffic area, 30kN < vehicle weight ≤ 160kN	0,7	0,5	0,3
Category H : roofs	0	0	0
Snow loads on buildings (see EN 1991-1-3)*			
Finland, Iceland, Norway, Sweden	0,70	0,50	0,20
Remainder of CEN Member States, for sites located at altitude H > 1000 m a.s.l.	0,70	0,50	0,20
Remainder of CEN Member States, for sites located at altitude H ≤ 1000 m a.s.l.	0,50	0,20	0
Wind loads on buildings (see EN 1991-1-4)	0,6	0,2	0
Temperature (non-fire) in buildings (see EN 1991-1-5)	0,6	0,5	0
NOTE The ψ values may be set by the National annex. * For countries not mentioned below, see relevant local conditions.			

Table 4.19 Recommended values of the combination factors Ψ for buildings

(source: Eurocode 0 table A1.1; EN 1990, 2002)

4.3.6 Calculation Scheme

Now the aim is to dimension the main elements of a generic structural module in the building.
First of all it has to be remembered that to create an apartment unit it was chosen to use two CLT elements one next to the other, so each of them will span 4 meters in the x direction.
This choice was made in order to allow a modularity in the building structure slab elements, despite the different shifting between each unit and also between the two modules that create one unit. The dimensions of the slab elements (ca. 4m x 12m) permit also the manufacturing of a unique xlam board and allow the transport of the board to the site by regular track.

It's also important to specify that the following calculation does not pretend to be satisfactory for every part of the building, but should be taken as valid for the majority of the parts of the building, where the standard units are used, excluding therefore specific parts that are not treated in this analysis.

Note also that to create a unit the two slabs required for the floor have a different arrangement of the supporting elements below them, so they have to be treated differently, so they are called slab 1 (S1) and slab 2 (S2).

To dimension the slab it is important first of all to understand on which elements it lies on. In the following drawing are schematized the two types of slab that are present in the building in the most generic way as possible. The elements drawn are the one below the slab and responsible in carrying the slab.

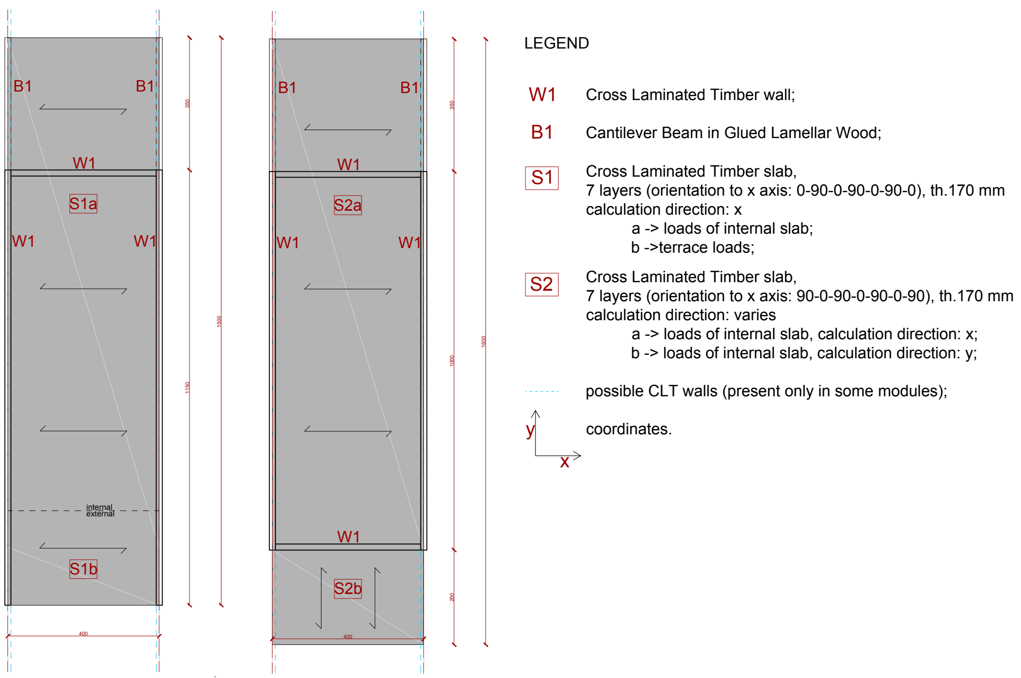


Figure 4.69
Plan of the two slab types present in the building showing the elements on which they are lying on, scale 1:200
(source: own elaboration)

Since the units are always shifted one in respect to the other in different directions (towards the mountain or towards Barcelona) and different quantities, the aim is to dimension the slab for the most critical case.

For slab 1 the presence of longer lateral walls does not influence its supports for the side in Barcelona direction
For the part of slab 1 looking to the mountain the worst case happens when the units or half units on its sides are shifted toward Barcelona, so, to deal with this case,

supporting cantilever beams are placed under the back corridor.

For the part of slab 2 toward Barcelona, the most critical case is the one where on both sides the adjacent half units are shifted in the mountain direction because it implies that there's an overhanging part (not support on the side is present). (Note that in some cases it can happen that the overhang is not existing due to the presence of supporting walls, so the division between S2a and S2b is not necessary and therefore S2 can be treated in the same way as S1 and the same calculation method can be applied!)
On the other hand for the part of slab 2 looking to the mountain the worst case happens when the elements on its sides are shifted toward Barcelona, so supporting cantilever beams are placed under the back corridor (same situation as for slab 1).
These two critical cases for slab 2 can not occur simultaneously but for our calculation it can be considered that no adjacent unit is present on both side of the slab, to create the most critical situation for both the part towards Barcelona and the one towards the mountain.

For the calculation it is also assumed, as explained in a previous paragraph, that the x direction walls will load the y walls and not the slab and that the y walls can act as slender beams when they have a cantilever part.

As indicated in the drawing above, the calculation direction for slab 1 is the x direction and the static scheme will be a simply supported beam.
For slab 2 the minimum span that the panel has to cover is the 4 m span in the x direction, but the cantilever part is oriented in the y direction (in the other direction it would not have any supports). A calculation performed in the y direction would overestimate the thickness of the panel because it would be dimensioned for 12 m span, while in reality the smaller 4 m span would support the slab. For this reason it was decided to split the calculation in two parts: the overhanging part (calculated in the y direction) and the rest of the slab (with the calculation in the x direction, as for slab 1).

4.3.7 Slab Panel: Pre-Dimensioning and Choice

4.3.7.1 Rough pre-dimensioning of the panel

First of all it was chosen to use the same panel for both cases S1 and S2, in order to simplify the construction and have the same slab thickness in all the building parts. Therefore, the panel should be suitable for the two situation and verify both cases.

To estimate the thickness of the slab, pre-dimensioning tables were used. It is selected the thickness suitable for 4 m of span, a permanent non structural load of 1 kN/m^2 and a variable load of 2,8 kN/m^2.

Table 4.20
Pre-dimensioning table for Xlam slabs according to the "Leno" producer
(source: Leno brochure)

<table>
<tr><th rowspan="2">Permanent load g_k</th><th rowspan="2">Variable load q_k</th><th rowspan="2">Category</th><th colspan="6">Single span</th></tr>
<tr><th>3.0m</th><th>3.5m</th><th>4.0m</th><th>4.5m</th><th>5.0m</th><th>5.5m</th></tr>
<tr><td rowspan="6">1.0</td><td>1.5</td><td rowspan="3">A</td><td rowspan="3">90</td><td rowspan="2">100</td><td>120</td><td rowspan="2">140</td><td>150</td><td>170</td></tr>
<tr><td>2.0</td><td>130</td><td>160</td><td rowspan="2">180</td></tr>
<tr><td>2.8</td><td rowspan="2">120</td><td rowspan="2">140</td><td>150</td><td>170</td></tr>
<tr><td>3.0</td><td rowspan="3">C</td><td>100</td><td>160</td><td rowspan="2">180</td><td>190</td></tr>
<tr><td>4.0</td><td rowspan="2">120</td><td>130</td><td>150</td><td>170</td><td>200</td></tr>
<tr><td>5.0</td><td>140</td><td>160</td><td>180</td><td>190</td><td>210</td></tr>
<tr><td rowspan="6">1.5</td><td>1.5</td><td rowspan="3">A</td><td rowspan="2">90</td><td rowspan="3">120</td><td>130</td><td>140</td><td>160</td><td rowspan="2">180</td></tr>
<tr><td>2.0</td><td rowspan="3">140</td><td>150</td><td>170</td></tr>
<tr><td>2.8</td><td rowspan="2">100</td><td rowspan="2">160</td><td rowspan="2">180</td><td rowspan="2">190</td></tr>
<tr><td>3.0</td><td rowspan="3">C</td><td>130</td></tr>
<tr><td>4.0</td><td rowspan="2">120</td><td rowspan="2">140</td><td>150</td><td rowspan="2">180</td><td rowspan="2">190</td><td>200</td></tr>
<tr><td>5.0</td><td>160</td><td>210</td></tr>
<tr><td rowspan="6">2.0</td><td>1.5</td><td rowspan="3">A</td><td rowspan="3">100</td><td rowspan="2">120</td><td rowspan="3">140</td><td>150</td><td>170</td><td>180</td></tr>
<tr><td>2.0</td><td rowspan="2">160</td><td rowspan="3">180</td><td rowspan="2">190</td></tr>
<tr><td>2.8</td><td rowspan="2">130</td></tr>
<tr><td>3.0</td><td rowspan="3">C</td><td rowspan="2">120</td><td>150</td><td>170</td><td>200</td></tr>
<tr><td>4.0</td><td rowspan="2">140</td><td>160</td><td rowspan="2">180</td><td>190</td><td>210</td></tr>
<tr><td>5.0</td><td>130</td><td>170</td><td>200</td><td>220</td></tr>
</table>

According to the table, a thickness of 135 mm would be enough for 2,8 kN/m2 of variable load. Since the pre-dimensioning table is for a simply supported beam, for 2 meters of overhang a larger thickness would be necessary. It is therefore selected a thickness of 170 mm to sustain both the cantilever part and the simply supported part. The panel should however be used also for slab 2, that in the terrace part has a variable load of 4 kN/m^2. According to the table for that load 154 mm are required, so the 170 mm panel is enough.

Another critical point to consider is that in slab 2 the panel should be thick enough to resist in its favourable way the cantilever part and in the opposite direction the 4 meter span. The panel should therefore have a good balance between the layers oriented parallel to the cantilever part and the ones oriented perpendicularly. For these reason it is better to utilise a 7 layers section instead of a 5 layer one.
A suitable solution is the panel proposed by the producer "Cross Timber System" with a total thickness of 170 mm and subdivided in 7 layers with the following thickness expressed in mm: 20-30-20-30-20-30-20. In this way it is guaranteed a good strength also in the "weak" direction, because layers 2, 4 and 6 are thicker than layers 1, 3, 5 and 7.

4.3.7.2 Characteristics of the CLT panel selected

For the longitudinal flexural rigidity the data are reported in the following table and the resulting K_{XLAM_long} is specified below. Considering a unitary depth b=1 m, it is applied the formula explained before:

$$K_{XLAM} = E_{XLAM} I_{XLAM} = \sum E_i \cdot I_i + \sum A_i \cdot a_i^2 \cdot E_i$$

Table 4.21
Longitudinal flexural rigidity
(source: own elaboration)

Longitudinal rigidity Keff_l					
layer	thickness [mm]	a_i from barycentric axis [mm]	inertia Ii [mm^4]	area [mm^2]	E_i [MPa]
1	20	75	33333,333	20000	11500
2	30	50	75000	30000	370
3	20	25	33333,333	20000	11500
4	30	0	75000	30000	370
5	20	25	33333,333	20000	11500
6	30	50	75000	30000	370
7	20	75	33333,333	20000	11500

K_{XLAM_l}	2932116583333,33	N mm^2
	2932,117	kN m^2

In the same way, for the transversal flexural rigidity the data are reported in the following table and the resulting K_{XLAM_trans} is specified below. Note that the result in the transversal direction is much lower than the one in the longitudinal direction.

Transversal rigidity Keff_t					
layer	thickness [mm]	a_i from barycentric axis [mm]	inertia I_i [mm^4]	area [mm^2]	E_i [MPa]
1	20	75	33333,333	20000	370
2	30	50	75000	30000	11500
3	20	25	33333,333	20000	370
4	30	0	75000	30000	11500
5	20	25	33333,333	20000	370
6	30	50	75000	30000	11500
7	20	75	33333,333	20000	370

K_{XLAM_t}	1820136833333,33	N mm^2
	1820,137	kN m^2

Table 4.22 Transversal flexural rigidity

(source: own elaboration)

It can be calculated also the shear rigidity in the longitudinal and transversal direction and the results are reported in the following tables. The expression used is the one seen before:

$$S_{XLAM} = (\sum G_i \cdot A_i) \cdot \kappa$$

Shear rigidity: longitudinal						
layer	thickness [mm]	A=bxt [mm2]	G [N/mm2]	GxA [N]	k	$S_{v,l}$ [kN]
1	20	20000	690	13800000		
2	30	30000	50	1500000		
3	20	20000	690	13800000		
4	30	30000	50	1500000		
5	20	20000	690	13800000		
6	30	30000	50	1500000		
7	20	20000	690	13800000		
				59700000	0,2	11940

Table 4.23 Longitudinal shear rigidity

(source: own elaboration)

Shear rigidity: transversal						
layer	thickness [mm]	A=bxt [mm2]	G [N/mm2]	GxA [N]	k	$S_{v,t}$ [kN]
1	20	20000	50	1000000		
2	30	30000	690	20700000		
3	20	20000	50	1000000		
4	30	30000	690	20700000		
5	20	20000	50	1000000		
6	30	30000	690	20700000		
7	20	20000	50	1000000		
				66100000	0,2	13220

Table 4.24 Transversal shear rigidity

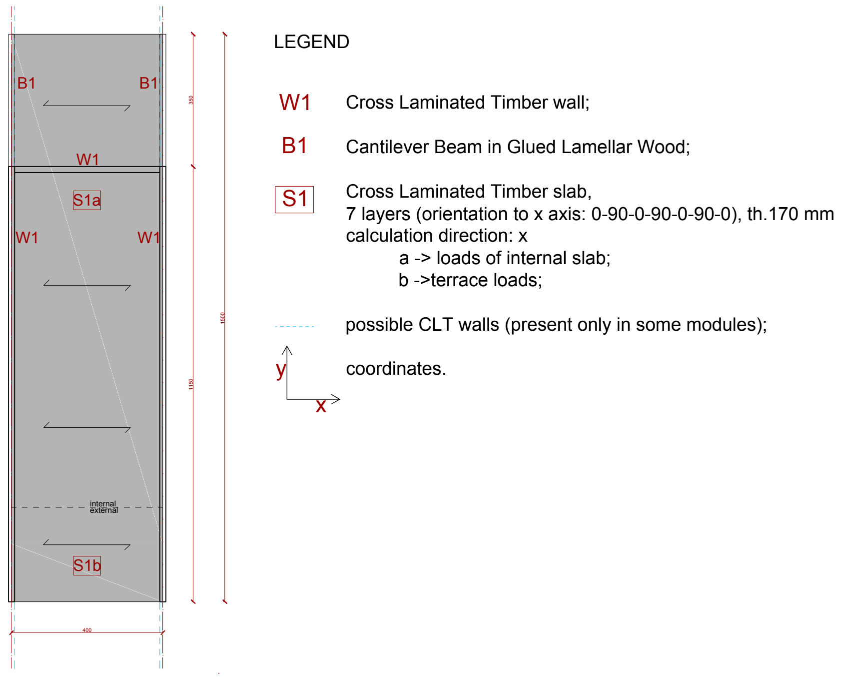
(source: own elaboration)

4.3.8 Verification of slab 1 (sleeping-room & balcony)

Slab 1 is a CLT panel that covers half of a standard apartment floor. Therefore its dimensions are 12m x 4m.
The minimum span that the panel has to cover is the 4 m

Figure 4.70
Plan view of Slab 1 (showing the sustaining element below it), 1:200

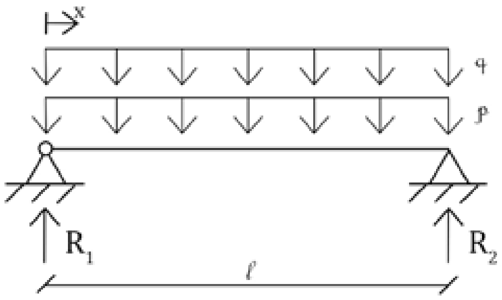
(source: own elaboration)



The static scheme used is a simply supported beam with a span of 4 m (l), that is the minimum span that the panel has to cover. The calculation will be therefore performed along the x axes of the panel, as indicated by the arrows in the figure above. It is considered 1 m of width.

Figure 4.71
Static models adopted for Slab 1

(source: own elaboration)



4.3.8.1 Loads on the panel

The loads applied on the panel are not the same along the x axis, because the first two meters of the slab have the function of a terrace, while the rest is the floor of the apartment.

The part inside the building (case 1A) has the loads reported in the table below:

Table 4.25
Loads on Slab 1 (case A)

(source: own elaboration)

Applied loads on the slab	
Permanent actions	kN/m2
structural weight	0,85
non structural weight	0,767
total floor self weight (G)	1,617
Variable actions	kN/m2
live load + inside partitions (Q1)	2,8

While the terrace part (case1B) has the following loads (considering the case with green terrace)

Applied loads on the slab	
Permanent actions	kN/m2
structural weight	0,85
non structural weight	0,767
total floor self weight (G)	1,617
Variable actions	kN/m2
live load (Q1)	4
snow load (Qs)	0,255
total variable action (Qtot)	4,255

Table 4.26 Loads on Slab 1 (case B)

(source: own elaboration)

4.3.8.2 ULS - Case 1A

According to Eurocode, to get the design values of the actions the loads have to be multiplied by partial factors and after this all the design actions need to be combined in a prescribed way, considering that some actions may happen simultaneously but also that it is very unlikely that all of the loads act at the same time.

Persistent and transient design situations	Permanent actions		Leading variable action	Accompanying variable actions (*)	
	Unfavourable	Favourable		Main (if any)	Others
(Eq. 6.10)	$\gamma_{G,j,sup} G_{k,j,sup}$	$\gamma_{G,j,inf} G_{k,j,inf}$	$\gamma_{Q,1} Q_{k,1}$		$\gamma_{Q,i} \psi_{0,i} Q_{k,i}$

Table 4.27 Design values of actions

(source: Eurocode 0 table A1.2(B); EN 1990, 2002)

Equation 6.10 of Eurocode 0 (see table above) represents the combination of the actions and can be written all together as:

$$\sum_{j\geq 1} \gamma_{G,j} \cdot G_{K,j} + \gamma_{Q,1} \cdot Q_{K,1} + \sum_{i\geq 2} \psi_{0,i} \cdot \gamma_{Q,i} \cdot Q_{K,i}$$

where:

- γ are the partial factors for the actions (see table partial factors)
- G_K are the permanent loads
- Q_K are the variable actions and $Q_{K,1}$ is the leading one
- Ψ is the combination coefficient (see table combination coefficients)

In this case the leading variable action is the live load Q1, that is also the only one acting on the panel. So the characteristic actions will be amplified by means of the partial factors for the actions (that were reported previously in a table) in order to get the amplified loads:

	Charact. action [kN/m]	Partial factor	Design action [kN/m]
G	1,617	1,35	2,183
Q	2,8	1,5	4,2
		Total design load	6,383

Calculation of the reactions at the supports, moment and shear diagrams

Since the static model has only one span, there's only one load distribution to consider, that is the one with all the loads applied.

The first step is the determination of the reactions at the supports throw the equilibrium equations:

$$\sum M = 0 \rightarrow R_1 \cdot l - p \cdot l \cdot \frac{l}{2} = 0 \rightarrow R_1 = \frac{p \cdot l}{2}$$

$$\sum F_{vert} = 0 \rightarrow R_1 + R_2 - p \cdot l = 0 \rightarrow R_2 = p \cdot l - \frac{p \cdot l}{2} = \frac{p \cdot l}{2}$$

It is then possible to calculate the moment diagram, that has a parabolic shape. At the supports we have that the moment is zero, while in the middle there's the maximum value

The shear is linear and it is equal to zero where the moment is maximum, so for x=l/2.

For an x coordinate that runs from left to right and looking left when "cutting" the beam, we have equations to get the internal moment and internal shear in every x:

$$-p \cdot x \cdot \frac{x}{2} + R_1 \cdot x - M_x = 0 \rightarrow M_x = -p \cdot x \cdot \frac{x}{2} + R_1 \cdot x$$

$$-p \cdot x + R_1 - N_x = 0 \rightarrow N_x = -p \cdot x + R_1$$

Table 4.28 Results of the calculation of Slab 1 (case A) for the ULS

(source: own elaboration)

R1=R2=	12,767	kN
M(x=0)=	0	kN m
M(x=l)=	0	kN m
M_{max}(x=l/2)=	12,767	kN m
V(x=0)=	12,767	kN
$x_{zero\ shear}$ =	2	m

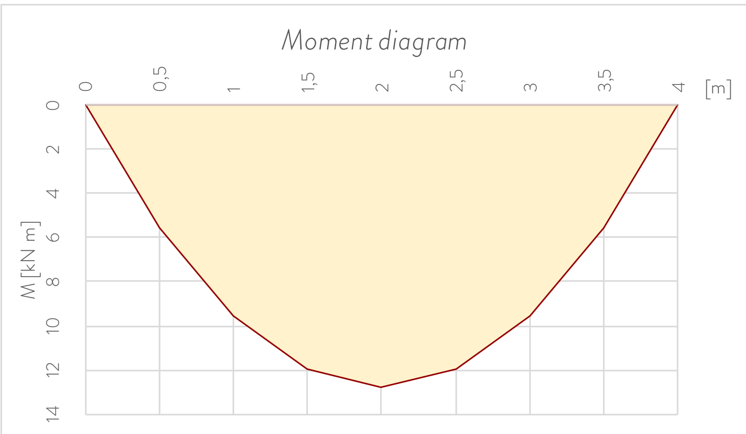


Figure 4.72 Moment diagram of Slab 1 (case A) for the ULS

(source: own elaboration)

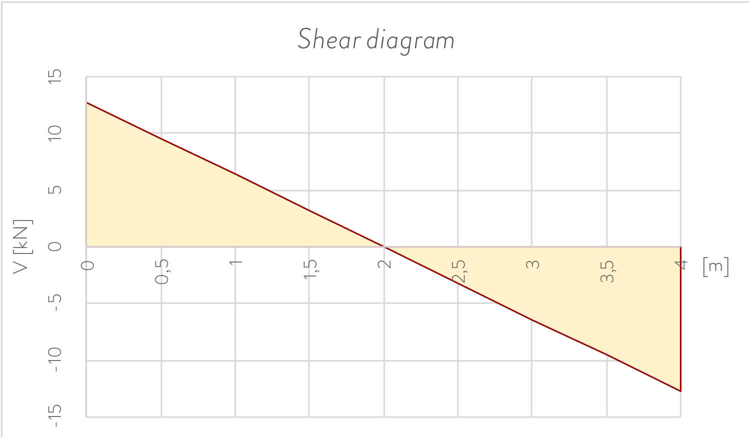


Figure 4.73
Shear diagram of Slab 1 (case A) for the ULS

(source: own elaboration)

Flexural resistance verification

The verification is performed on a CLT 1 m stripe parallel to the calculation direction and, according to Eurocode 5 par. 6.1.6, it should be verified that:

$$\sigma_{m,d} \leq f_{m,d}$$

where:

- $\sigma_{m,d}$ is the design flexural stress
- $f_{m,d}$ is the design flexural resistance

The design flexural stress can be calculated as:

$$\sigma = \frac{M}{K} \cdot a \cdot E_i$$

where:

- M is the bending moment
- K is the flexural rigidity in the direction considered
- a is the distance from the barycentre
- E_i is the elastic modulus of the layer

Since the most stressed fibre is the bottom one, it has to be considered the elastic modulus of the last layer and the distance of the barycentre from the bottom edge of the panel. As a result we have:

$$\sigma_{d,\max} = \frac{M_d}{K} \cdot \frac{h}{2} \cdot E_{0,mean}$$

where:

- M_d is the maximum moment
- h is the total thickness of the panel
- K is the flexural rigidity of the last xlam layer, with the fibres oriented parallel to the calculation direction
- $E_{0,mean}$ is the elastic modulus of the last layer, with the fibres oriented parallel to the calculation direction

So we have that the maximum bending stress is:

$\sigma_{d,max}$	4,256 N/mm2

Comparing the design flexural stress and the design flexural resistance previously calculated we have:

$\sigma_{d,max}$	4,256 MPa
$f_{m,d}$	16,896 MPa

so it is verified that $\sigma_{m,d} \leq f_{m,d}$.

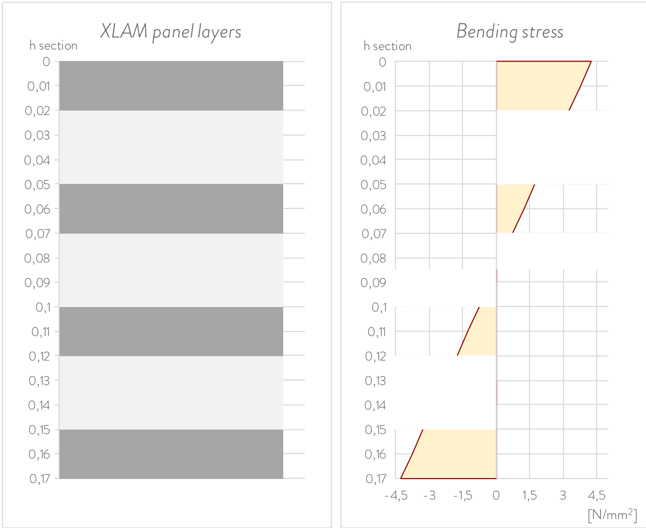


Figure 4.74 Bending stress diagram of Slab 1 (case B) for the ULS

(source: own elaboration)

Shear resistance verification

As for the bending verification, the shear verification is performed according to Eurocode 5, in particular referring to the paragraph 6.1.7 it should be verified that:

$$\tau_{v,d} \leq f_{v,d}$$

where:

- $\tau_{v,d}$ is the design shear stress
- $f_{v,d}$ is the design shear resistance

The layers orthogonal to the calculation direction have however a weaker shear resistance, called rolling shear strength, due to their orientation. It is therefore required for the transversal layers to verify that:

$$\tau_{v,d} \leq f_{vr,d}$$

where:

- $\tau_{v,d}$ is the design shear stress
- $f_{vr,d}$ is the design rolling shear resistance

To determine the shear stress it is not proper to neglect the layers orthogonal oriented to the calculation direction, because they play an important role in transmitting the shear stress between the longitudinal layers.
The shear stress distribution along the panel section is:

$$\tau(a) = \frac{V \cdot S}{I \cdot b} = \frac{V \cdot \int E \cdot a \cdot dA}{K \cdot b}$$

where:

- V is the shear
- a is the distance from the barycentre
- b is the width of the element considered
- I is the moment of inertia
- S is the static moment of the part of the section
- K is the flexural rigidity

So the maximum shear stress in the longitudinal layers evaluated in the barycentric axis is:

$$\tau_{d,\max} = \frac{V_d \cdot \sum(S_m \cdot E_m)}{K \cdot b}$$

where:

V_d	12,767	kN
S_m	2000000	mm3
E_m	11500	MPa
K	2932116583333,33	N mm2
b	1000	mm
$\tau_{d,max}$	0,100	MPa

And the shear profile in the entire section is shown in the figure below:

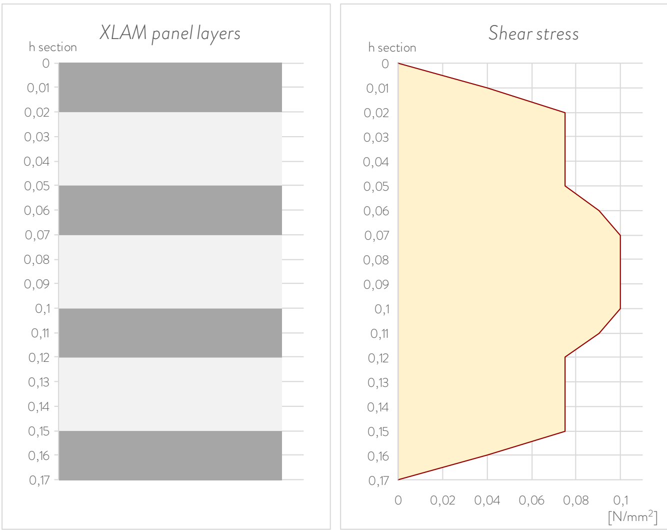


Figure 4.75 Shear stress diagram of Slab 1 (case B) for the ULS

(source: own elaboration)

Note that the maximum shear stress in the longitudinal layers is equal to the maximum shear stress in the transversal layer.

So we have the maximum shear in the longitudinal layer and the maximum in the transversal layer (that for a 7 layers panel are coincident) that have to be compared respectively with the design shear resistance and the design rolling shear resistance.

$\tau_{vd,long}$ [MPa]	$f_{v,d}$ [MPa]
0,100	2,56
$\tau_{vd,trans}$ [MPa]	$f_{vr,d}$ [MPa]
0,100	0,832

The verification is satisfied. $\tau_{v,d} \leq f_{v,d}$ $\tau_{v,d} \leq f_{vr,d}$

4.3.8.3 SLS - Case 1A

According to Eurocode, it has to be verified that the instantaneous and log term deformations of the slab due to the effects of actions and humidity are below the prescribed limits.

The instantaneous deformation should be calculated for the characteristic (rare) combination of actions (Eurocode 5, 2.2.3(2)).
The final deformation should be calculated for the quasi-permanent combination of actions (Eurocode 5, 2.2.3(3)).

The combinations of actions mentioned are defined in Eurocode 0 in the following table:

Table 4.29 Design values of actions for use in the combination of actions for SLS

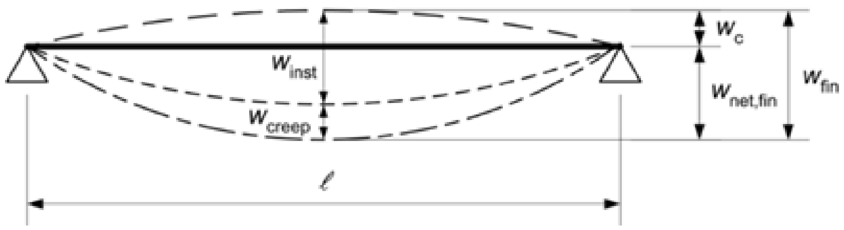
(source: Eurocode 0 table A1.4; EN 1990, 2002)

Combination	Permanent actions G_d		Variable actions Q_d	
	Unfavourable	Favourable	Leading	Others
Characteristic	$G_{k,j,sup}$	$G_{k,j,inf}$	$Q_{k,1}$	$\psi_{0,i}Q_{k,i}$
Frequent	$G_{k,j,sup}$	$G_{k,j,inf}$	$\psi_{1,1}Q_{k,1}$	$\psi_{2,i}Q_{k,i}$
Quasi-permanent	$G_{k,j,sup}$	$G_{k,j,inf}$	$\psi_{2,1}Q_{k,1}$	$\psi_{2,i}Q_{k,i}$

The components of the deflection resulting from a combination of actions are represented in the figure below, taken from Eurocode 5:

Figure 4.76 Components of deflection

(source: Eurocode 5 fig. 7.1; EN1995, 2004)



- w_c is the precamber (if applied);
- w_{inst} is the instantaneous deflection;
- w_{creep} is the creep deflection;
- w_{fin} is the final deflection;
- $w_{net,fin}$ is the net final deflection.

The net deflection can be calculated according to the equation (7.2) of Eurocode 5:

$$w_{net,fin} = w_{inst} + w_{creep} - w_c = w_{fin} - w_c$$

It is important to notice that, due to the material characteristics, the behaviour is elastic only for a short time and later becomes visco-elastic, leading to an increase of deformation with the time even under a constant load. Therefore instantaneous and final deformation are not coincident.

According to Eurocode 5 it is possible to use a simplified procedure for the calculation of u_{fin} when the prescribed assumptions are valid (as for our case):

(5) For structures consisting of members, components and connections with the same creep behaviour and under the assumption of a linear relationship between the actions and the corresponding deformations, as a simplification of 2.2.3(3), the final deformation, u_{fin}, may be taken as:

$$u_{fin} = u_{fin,G} + u_{fin,Q_1} + u_{fin,Q_i} \quad (2.2)$$

where:

$$u_{fin,G} = u_{inst,G}\left(1+k_{def}\right) \quad \text{for a permanent action, } G \quad (2.3)$$

$$u_{fin,Q,1} = u_{inst,Q,1}\left(1+\psi_{2,1}k_{def}\right) \quad \text{for the leading variable action, } Q_1 \quad (2.4)$$

$$u_{fin,Q,i} = u_{inst,Q,i}\left(\psi_{0,i}+\psi_{2,i}k_{def}\right) \quad \text{for accompanying variable actions, } Q_i \ (i > 1) \quad (2.5)$$

$u_{inst,G}$, $u_{inst,Q,1}$, $u_{inst,Q,i}$ are the instantaneous deformations for action *G*, Q_1, Q_i respectively;

$\psi_{2,1}$, $\psi_{2,i}$ are the factors for the quasi-permanent value of variable actions;

$\psi_{0,i}$ are the factors for the combination value of variable actions;

k_{def} is given in table 3.2 for timber and wood-based materials, and in 2.3.2.2 (3) and 2.3.2.2 (4) for connections.

Figure 4.77 Simplified calculation of the final deformation

(source: Eurocode 5 paragraph 2.2.3(5); EN1995, 2004)

The deformation limit values reported in the Eurocede 5 are a function of the span length l and are different for cantilever or simply supported elements:

	w_{inst}	$w_{net,fin}$	w_{fin}
Beam on two supports	ℓ/300 to ℓ/500	ℓ/250 to ℓ/350	ℓ/150 to ℓ/300
Cantilevering beams	ℓ/150 to ℓ/250	ℓ/125 to ℓ/175	ℓ/75 to ℓ/150

Table 4.30 Limiting values for deflections of beams

(source: Eurocode 5 table 7.2; EN1995, 2004)

The instantaneous deformation has therefore to be calculated based on the characteristic combination

$$\sum_{j\geq 1} G_{k,j} + Q_{k,1} + \sum_{i\geq 2} \psi_{0,i} \cdot Q_{k,i}$$

and the different contributions must be summed up

$$u_{inst} = \sum_{j\geq 1} u_{inst,Gj} + \sum_{i\geq 1} u_{inst,Qi}$$

For a generic distributed load p, the deflection of a simply supported beam can be calculated throw the following formula:

$$u_{inst,p} = \frac{5}{348}\frac{p\cdot l^4}{K_{XLAM}} + \frac{1}{8}\frac{p\cdot l^2}{S_{XLAM}}$$

where:

- p is a generic distributed load applied
- l is the span length
- K_{XLAM} is the flexural stiffness of the CLT panel in the direction considered
- S_{XLAM} is the shear stiffness of the CLT panel

The equation for the deformation of a simply supported beam it is then applied to calculate the deformation due to the permanent load G and the variable load Q.

	p [kN/m]	$u_{inst,p}$ [mm]	l/300 [mm]
G	1,617	2,299	
Q	2,8	3,981	
$u_{inst,tot}$		6,281	13,333

Comparing the resulting total instantaneous deformation with the limit value l/300, it can be seen that the calculated u_{inst} is smaller than the limit, so the condition is verified.

The final deformation is calculated using the simplified procedure reported in the Eurocode:

$$u_{\text{fin,G}} = u_{inst,\text{G}}(1 + k_{def})$$

$u_{inst,G}$ [mm]	2,300
k_{def}	0,6
$u_{fin,G}$ [mm]	3,679

$$u_{\text{fin,Q1}} = u_{inst,\text{Q1}}(1 + \psi_{2,1} k_{def})$$

$u_{inst,Q}$ [mm]	3,981
k_{def}	0,6
$\psi_{2,1}$	0,3
$u_{fin,Q1}$ [mm]	4,698

Since there are no other variable actions, the final deformation can now be calculated summing up the two contributions and compared with the limit value.

$$u_{\text{fin}} = u_{\text{fin,G}} + u_{\text{fin,Q1}} + u_{\text{fin,Qi}}$$

	u [mm]	l/250 [mm]
$u_{fin,G}$	3,679	
$u_{fin,Q1}$	4,698	
$u_{fin,tot}$	8,378	16

Also in this case the value of u_{fin} is smaller than the limit value l/250.

4.3.8.4 ULS - Case 1B

This case is almost the same as case 1B but the loads are different and there's the presence also of the snow load to be taken into account.

The combination of actions is always the one prescribed by the Eurocode:

$$\sum_{j \geq 1} \gamma_{G,j} \cdot G_{K,j} + \gamma_{Q,1} \cdot Q_{K,1} + \sum_{i \geq 2} \psi_{0,\text{i}} \cdot \gamma_{Q,i} \cdot Q_{K,\text{i}}$$

The leading variable action is the live load Q1 and the snow load Qs is the secondary action.

So the characteristic actions will be amplified by means of the partial factors and

In this case the leading variable action is the live load Q1 and the snow load Qs is the secondary action. So the characteristic actions will be amplified by means of the partial factors for the actions and reduced with the combination factors, where required, (the factors were reported previously in tables) in order to get the design load:

	Charact. action [kN/m]	γ	Ψ_0	Design action [kN/m]
G	2,841	1,35	-	3,836
Q1	4	1,5	-	6
Qs	0,255	1,5	0,5	0,191
			Total design load	10,027

Calculation of the reactions at the supports, moment and shear diagrams

Since the static model has only one span, there's only one load distribution to consider, that is the one with all the loads applied.

The reactions at the supports are calculated throw the equilibrium equations:

$$\sum M = 0 \rightarrow R_1 \cdot l - p \cdot l \cdot \frac{l}{2} = 0 \rightarrow R_1 = \frac{p \cdot l}{2}$$

$$\sum F_{vert} = 0 \rightarrow R_1 + R_2 - p \cdot l = 0 \rightarrow R_2 = p \cdot l - \frac{p \cdot l}{2} = \frac{p \cdot l}{2}$$

It is then calculated the maximum moment (for x=l/2) and shear (for x=0) and the complete diagrams, as explained before.
The results are exactly the same as case 1A, because the loads are coincident.

R1=R2=	20,054 kN
M(x=0)=	0 kN m
M(x=l)=	0 kN m
M_{max}(x=l/2)=	20,054 kN m
V(x=0)=	20,054 kN
$x_{zero\ shear}$ =	2 m

Table 4.31
Results of the calculation of Slab 1 (case B) for the ULS

(source: own elaboration)

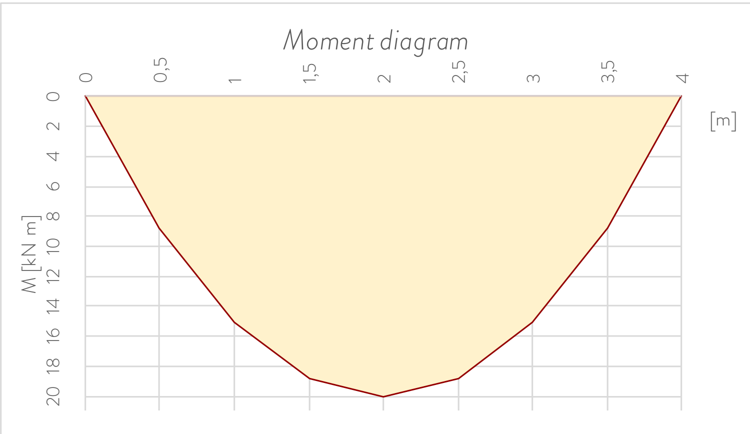
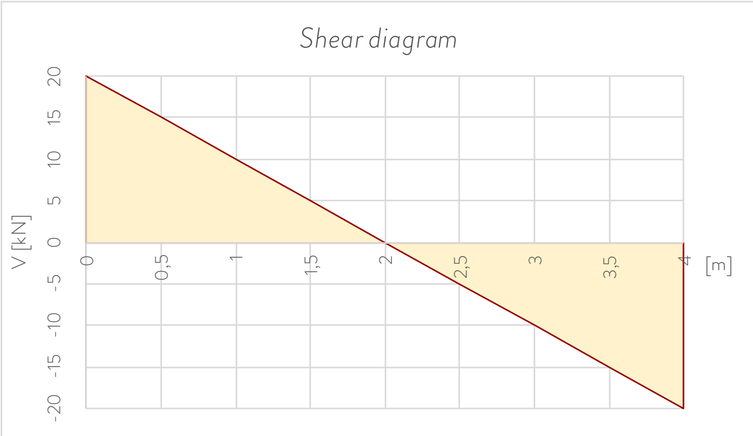


Figure 4.78
Moment diagram of Slab 1 (case B) for the ULS

(source: own elaboration)

Figure 4.79
Shear diagram of Slab 1 (case B) for the ULS

(source: own elaboration)



Flexural resistance verification

Considering a CLT stripe parallel to the calculation direction, it has to be verified that:

$$\sigma_{m,d} \leq f_{m,d}$$

The design flexural stress is calculated with the formula:

$$\sigma = \frac{M}{K} \cdot a \cdot E_i$$

For the most stressed fibre, that is the bottom one, we have:

$$\sigma_{d,\max} = \frac{M_d}{K} \cdot \frac{h}{2} \cdot E_{0,mean}$$

So we have that the maximum bending stress is

$\sigma_{d,max}$	6,685	N/mm2

Comparing the design flexural stress and the design flexural resistance previously calculated we have

$\sigma_{d,max}$	6,685	MPa
$f_{m,d}$	16,896	MPa

so it is verified that $\sigma_{m,d} \leq f_{m,d}$.

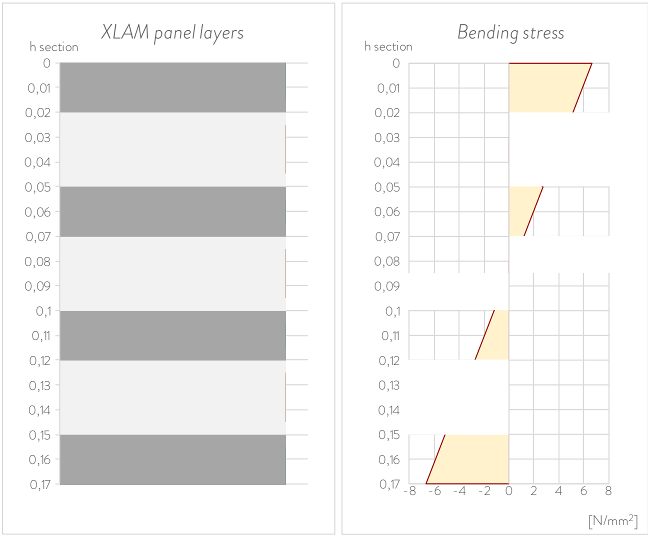


Figure 4.80 Bending stress diagram in the most loaded section (x=l/2) of Slab 1 (case B) for the ULS

(source: own elaboration)

Shear resistance verification

For the shear verification the following two conditions have to be verified (considering both the shear resistance and the rolling shear resistance):

$$\tau_{v,d} \leq f_{v,d}$$

$$\tau_{v,d} \leq f_{vr,d}$$

The shear stress distribution along the panel section is again:

$$\tau(a) = \frac{V \cdot S}{I \cdot b} = \frac{V \cdot \int E \cdot a \cdot dA}{K \cdot b}$$

The maximum stress is calculated throw the formula seen also previously:

$$\tau_{d,\max} = \frac{V_d \cdot \sum (S_m \cdot E_m)}{K \cdot b}$$

So the maximum shear stress in the longitudinal layers, that is also equal to the one in the transversal layers, is evaluated in the barycentric axis of the panel most critical section (x=0):

V_d	12,767	kN
S_m	1612500	mm3
E_m	11500	MPa
$K_{XLAM,l}$	2932116583333,33	N mm2
b	1000	mm
$\tau_{d,long,max}$	0,081	MPa

And the shear profile of the entire section thickness (h) is shown in the figure below:

Figure 4.81
Shear stress diagram in the most loaded section (x=0) of Slab 1 (case B) for the ULS

(source: own elaboration)

Now we have to compare the maximum shear stress in the longitudinal layer and transversal layer, that in this case have the same value, with the design shear resistance and the design rolling shear resistance respectively.

$\tau_{vd,long}$ [MPa]	$f_{v,d}$ [MPa]
0,157	2,56
$\tau_{vd,trans}$ [MPa]	$f_{vr,d}$ [MPa]
0,157	0,832

The verification is satisfied. $\tau_{v,d} \leq f_{v,d}$ $\tau_{v,d} \leq f_{vr,d}$

4.3.8.5 SLS - Case 1B

The instantaneous deformation is calculated also in this case based on the characteristic combination,

$$\sum_{j\geq 1} G_{k,j} + Q_{k,1} + \sum_{i\geq 2} \psi_{0,i} \cdot Q_{k,i}$$

and the different contributions must be summed up:

$$u_{inst} = \sum_{j\geq 1} u_{inst,Gj} + \sum_{i\geq 1} u_{inst,Qi}$$

To calculate the deformation due to the permanent load G and the variable loads Q1 and Qs, it is applied the following formula valid for the deformation of a simply supported beam under a generic distributed load p:

$$u_{inst,p} = \frac{5}{348}\frac{p \cdot l^4}{K_{XLAM}} + \frac{1}{8}\frac{p \cdot l^2}{S_{XLAM}}$$

	p [kN/m]	$u_{inst,p}$ [mm]	l/300 [mm]
G	2,841	4,040	
Q1	4	5,688	
$\Psi \cdot$ Qs	0,5 x 0,255	0,181	
$u_{inst,tot}$		9,909	13,333

Comparing the resulting total instantaneous deformation with the limit value l/300, it can be seen that the calculated u_{inst} is smaller than l/300, so the verification is accepted.

The final deformation is calculated using the simplified procedure reported in the Eurocode and explained previously for case 1A:

$$u_{\text{fin,G}} = u_{inst,\text{G}}(1+k_{def})$$

$u_{inst,G}$ [mm]	3,539
k_{def}	0,6
$u_{fin,G}$ [mm]	5,662

$$u_{\text{fin,Q1}} = u_{inst,\text{Q1}}(1+\psi_{2,1}k_{def})$$

$u_{inst,Q1}$ [mm]	6,127
k_{def}	0,6
$\psi_{2,1}$	0,3
$u_{fin,Q1}$ [mm]	7,230

This time there's also another variable action to be taken into account

$$u_{\text{fin,Qi}} = u_{inst,\text{Q1}}(\psi_{0,i}+\psi_{2,\text{i}}k_{def})$$

$u_{inst,Qs}$ [mm]	6,127
k_{def}	0,6
$\psi_{0,s}$	0,5
$\psi_{2,s}$	0
$u_{fin,Q1}$ [mm]	0,091

The final deformation can now be calculated summing up the three contributions:

$$u_{\text{fin}} = u_{\text{fin,G}} + u_{\text{fin,Q1}} + u_{\text{fin,Qi}}$$

	u [mm]	l/250 [mm]
$u_{fin,G}$	6,464	
$u_{fin,Q1}$	6,712	
$u_{fin,Qs}$	0,091	
$u_{fin,tot}$	13,266	16

Also in this case the value of u_{fin} is smaller than the limit value l/250.

4.3.9 Verification of Slab 2 (living room & kitchen)

The static scheme used are the following:

- Case 2A, x dir: simply supported beam with a span of 4 m
- Case 2B, y dir: cantilever beam with fixed end (full moment connection)

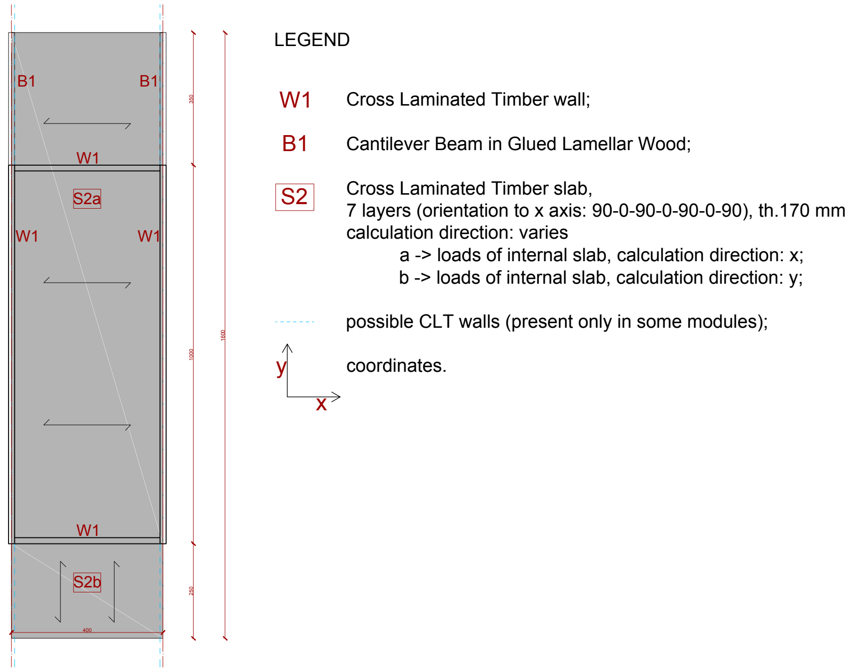


Figure 4.82
Plan view of Slab 2 (showing the sustaining element below it), 1:200

(source: own elaboration)

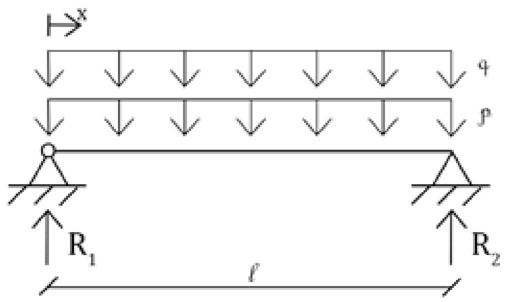


Figure 4.83
Static models adopted for Slab 2 case A

(source: own elaboration)

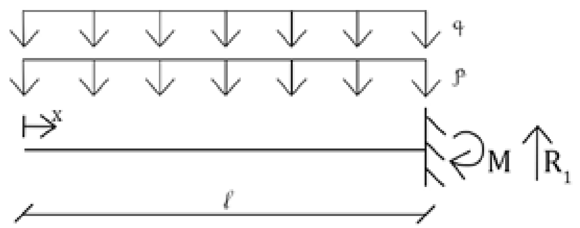


Figure 4.84
Static models adopted for Slab 2 case B

(source: own elaboration)

To merge the two parts it is then necessary to verify if the section at the support that should carry the overhang can stand the moment and shear generated at the fixed end of the cantilever part.

Notice that the slab is continuous between the supported part and the cantilever one, but the verification will be held in different directions. This means that the CLT panel will be oriented in different ways for the two calculations, having in only one case the majority of the layers oriented parallel to the calculation direction (strongest panel direction) and in the other case the opposite.
It is chosen to use the strong direction of the panel to sustain the cantilever part of the slab, so in case 2A the CLT panel will have the first layer transversally oriented to the calculation direction.

4.3.9.1 Loads on the panel

Since the slab is located inside the apartment, the loads applied in Case 2A and Case 2B are the same and they are reported in the following table:

Applied loads on the slab	
Permanent actions	kN/m2
structural weight	0,85
non structural weight	0,767
total floor self weight (G)	1,617
Variable actions	kN/m2
live load + inside partitions (Q1)	2,8

Table 4.32 Loads on Slab 2 (case A and B)

(source: own elaboration)

Note that the loads are the same of slab 1 case A, so the reactions and moment and shear diagrams will be also the same.

4.3.9.2 ULS - Case 2A

This case is similar to case 1A and 1B, but the different orientation of the panel generates some differences in the calculation and in the panel behaviour.

The combination of actions is again described throw the formula:

$$\sum_{j\geq 1} \gamma_{G,j} \cdot G_{K,j} + \gamma_{Q,1} \cdot Q_{K,1} + \sum_{i\geq 2} \psi_{0,i} \cdot \gamma_{Q,i} \cdot Q_{K,i}$$

The leading variable action is the live load Q1, that is also the only one acting on the panel.

Calculation of the reactions at the supports, moment and shear diagrams

Since the static model has only one span, there's only one load distribution to consider, that is the one with all the loads applied.

The reactions at the supports are calculated throw the equilibrium equations:

$$\sum M = 0 \rightarrow R_1 \cdot l - p \cdot l \cdot \frac{l}{2} = 0 \rightarrow R_1 = \frac{p \cdot l}{2}$$

$$\sum F_{vert} = 0 \rightarrow R_1 + R_2 - p \cdot l = 0 \rightarrow R_2 = p \cdot l - \frac{p \cdot l}{2} = \frac{p \cdot l}{2}$$

It is then calculated the maximum moment (for x=l/2) and shear (for x=0) and the complete diagrams, as explained before.
The results are exactly the same as case 1A, because the loads are coincident.

R1=R2=	12,767 kN
M(x=0)=	0 kN m
M(x=l)=	0 kN m
M_{max}(x=l/2)=	12,767 kN m
V(x=0)=	12,767 kN
$x_{zero\ shear}$ =	2 m

Table 4.33 Results of the calculation of Slab 2 (case A) for the ULS

(source: own elaboration)

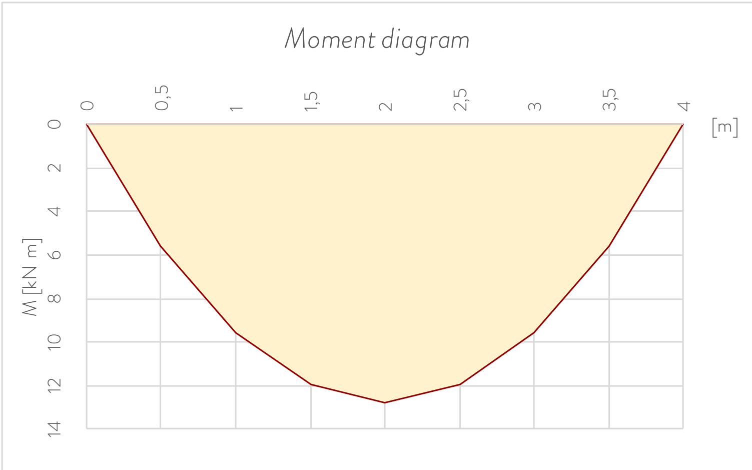


Figure 4.85
Moment diagram of Slab 2 (case A) for the ULS
(source: own elaboration)

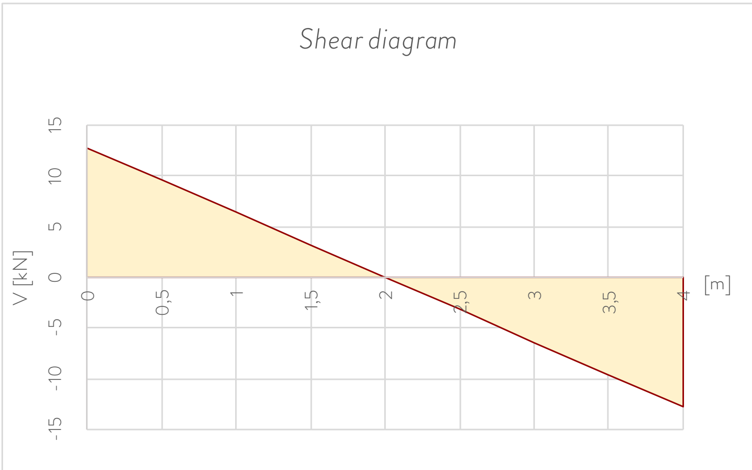


Figure 4.86
Shear diagram of Slab 2 (case A) for the ULS
(source: own elaboration)

Flexural resistance verification

Considering a CLT stripe parallel to the calculation direction, it has to be verified that:

$$\sigma_{m,d} \leq f_{m,d}$$

The design flexural stress is calculated with the formula:

$$\sigma = \frac{M}{K} \cdot a \cdot E_i$$

The most stressed fibre would be the bottom one, but since the bottom layer is a transversal one its contribution will be neglected. So to get σ_{max} it has to be considered the second last layer and for the value of a should be taken the distance from the barycentre to the bottom of the second last layer.

$$\sigma_{d,\max} = \frac{M_d}{K} \cdot (\frac{h}{2} - t_{LastLayer}) \cdot E_{0,mean}$$

where:

- M_d is the maximum moment
- h is the total thickness of the panel
- $t_{LastLayer}$ is the thickness of the bottom layer
- K is the flexural rigidity of the second last xlam layer, with the fibres oriented parallel to the calculation direction
- $E_{0,mean}$ is the elastic modulus of the second last layer, with the fibres oriented parallel to the calculation direction

So we have that the maximum bending stress is

$\sigma_{d,max}$	3,255 N/mm2

Comparing the design flexural stress and the design flexural resistance previously calculated we have

$\sigma_{d,max}$	3,255 MPa
$f_{m,d}$	16,896 MPa

so it is verified that $\sigma_{m,d} \leq f_{m,d}$.

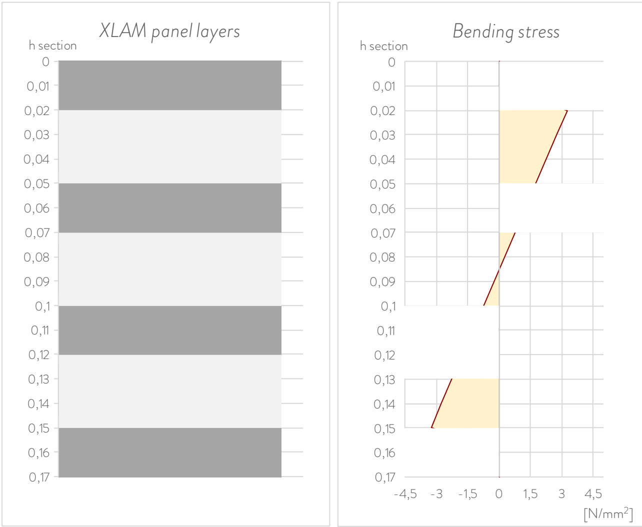


Figure 4.87 Bending stress diagram in the most loaded section (x=l/2) of Slab 2 (case A) for the ULS

(source: own elaboration)

Shear resistance verification

For the shear verification the following two conditions have to be verified (considering both the shear resistance and the rolling shear resistance:

$$\tau_{v,d} \leq f_{v,d}$$

$$\tau_{v,d} \leq f_{vr,d}$$

The shear stress distribution along the panel section is again:

$$\tau(a) = \frac{V \cdot S}{I \cdot b} = \frac{V \cdot \int E \cdot a \cdot dA}{K \cdot b}$$

Il must be noticed that this time the central layer is longitudinal, so we have a different maximum stress for longitudinal and transversal layers, but in both casesit is calculated throw the formula seen also previously:

$$\tau_{d,\max} = \frac{V_d \cdot \sum (S_m \cdot E_m)}{K \cdot b}$$

So the maximum shear stress in the longitudinal layers is evaluated in the barycentric axis of the panel most critical section (x=0):

V_d	12,767	kN
S_m	1612500	mm3
E_m	11500	MPa
$K_{XLAM,l}$	2932116583333,33	N mm2
b	1000	mm
$\tau_{d,long,max}$	0,081	MPa

And the maximum shear stress in the transversal layers is calculated again in the most critical section (x=0), but at a distance from the barycentric axis of half of the central layer (h=0,07 m).

V_d	12,767	kN
S_m	1500000	mm^3
E_m	11500	MPa
$K_{XLAM,l}$	2932116583333,33	N mm^2
b	1000	mm
$\tau_{d,trans,max}$	0,075	MPa

And the shear profile of the entire section thickness (h) is shown in the figure below:

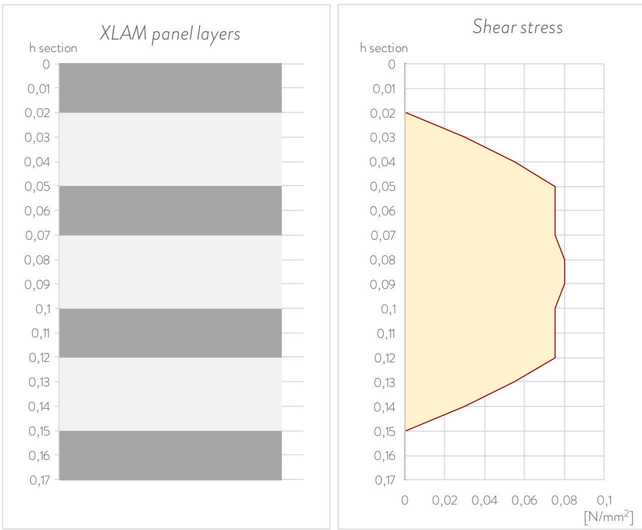


Figure 4.88
Shear stress diagram in the most loaded section (x=0) of Slab 2 (case A) for the ULS

(source: own elaboration)

Now we have to compare the maximum shear stress in the longitudinal layer and transversal layer with the design shear resistance and the design rolling shear resistance respectively.

$\tau_{vd,long}$ [MPa]	$f_{v,d}$ [MPa]
0,081	2,56
$\tau_{vd,trans}$ [MPa]	$f_{vr,d}$ [MPa]
0,075	0,832

The verification is satisfied. $\tau_{v,d} \leq f_{v,d}$ $\tau_{v,d} \leq f_{vr,d}$

4.3.9.3 SLS - Case 2A

The instantaneous deformation is calculated also in this case based on the characteristic combination

$$\sum_{j\geq 1} G_{k,j} + Q_{k,1} + \sum_{i\geq 2} \psi_{0,i} \cdot Q_{k,i}$$

and the different contributions must be summed up

$$u_{inst} = \sum_{j\geq 1} u_{inst,Gj} + \sum_{i\geq 1} u_{inst,Qi}$$

To calculate the deformation due to the permanent load G and the variable load Q, it is applied the following formula valid for the deformation of a simply supported beam under a generic distributed load p:

$$u_{inst,p} = \frac{5}{348} \frac{p \cdot l^4}{K_{XLAM}} + \frac{1}{8} \frac{p \cdot l^2}{S_{XLAM}}$$

	p [kN/m]	$u_{inst,p}$ [mm]	l/300 [mm]
G	1,617	3,539	
Q	2,8	6,127	
$u_{inst,tot}$		9,666	13,333

Comparing the resulting total instantaneous deformation with the limit value l/300, it can be seen that the calculated u_{inst} is smaller than l/300, so the verification is accepted.

The final deformation is calculated using the simplified procedure reported in the Eurocode and explained previously:

$u_{fin,G} = u_{inst,G}(1 + k_{def})$

$u_{inst,G}$ [mm]	3,539
k_{def}	0,6
$u_{fin,G}$ [mm]	5,662

$u_{fin,Q1} = u_{inst,Q1}(1 + \psi_{2,1} k_{def})$

$u_{inst,Q}$ [mm]	6,127
k_{def}	0,6
$\psi_{2,1}$	0,3
$u_{fin,Q1}$ [mm]	7,230

Since there are no other variable actions, the final deformation can now be calculated summing up the two contributions

$u_{fin} = u_{fin,G} + u_{fin,Q1} + u_{fin,Qi}$

	u [mm]	l/250 [mm]
$u_{fin,G}$	5,66	
$u_{fin,Q1}$	7,230	
$u_{fin,tot}$	12,893	16

Also in this case the value of u_{fin} is smaller than the limit value l/250.

4.3.9.4 ULS - Case 2B

The following case is much different from the others seen before, because the static scheme is not any more a simply supported beam, but a cantilever beam (as seen in the figure previously).

The layer disposition is with the top layer oriented in the direction parallel to the calculation, as for case 1A and 1B.

The combination of actions is again described throw the formula:

$$\sum_{j\geq1}\gamma_{G,j}\cdot G_{K,j}+\gamma_{Q,1}\cdot Q_{K,1}+\sum_{i\geq2}\psi_{0,i}\cdot\gamma_{Q,i}\cdot Q_{K,i}$$

The leading variable action is the live load Q1, that is also the only one acting on the panel.

Calculation of the reactions at the supports, moment and shear diagrams

Since the static model has only one span, there's only one load distribution to consider, that is the one with all the loads applied.

The reactions at the supports are calculated throw the equilibrium equations:

$$\sum M=0\rightarrow -p\cdot l\cdot\frac{l}{2}+M_1=0\rightarrow M_1=p\cdot\frac{l^2}{2}$$

$$\sum F_{vert}=0\rightarrow -p\cdot l+R_1=0\rightarrow R_1=p\cdot l$$

It is then possible to calculate the moment diagram, that has a parabolic shape. At the free end (x=0) we have that the moment is zero, while at the fixed end (x=l) there's the maximum value.
The shear is linear and it is equal to zero at the free end (x=0).

For an x coordinate that runs from left to right and looking left when "cutting" the beam, we have equations to get the internal moment and internal shear in every x:

$$-p\cdot x\cdot\frac{x}{2}+M_x=0\rightarrow M_x=p\cdot\frac{x^2}{2}$$

$$-p\cdot x+N_x=0\rightarrow N_x=p\cdot x$$

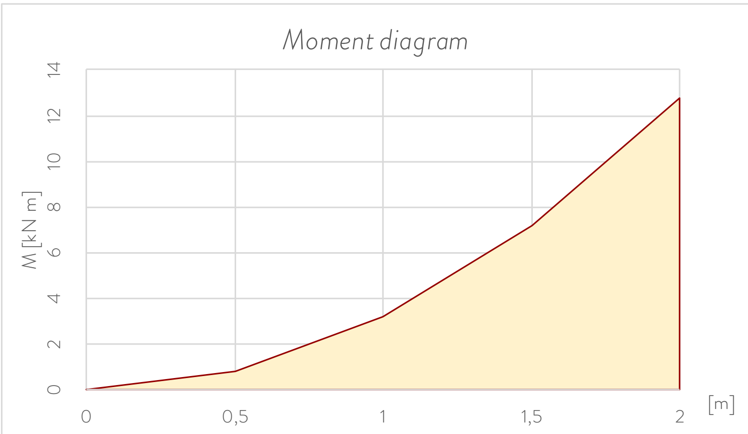
Figure 4.89
Results of the calculation of Slab 2 (case B) for the ULS

(source: own elaboration)

R1=	15,958	kN
M(x=0)=	0	kN m
M_{max}(x=l)=	19,948	kN m
V(x=0)=	15,958	kN
$x_{zero\ shear}$ =	0	m

Figure 4.90
Moment diagram of Slab 2 (case B) for the ULS

(source: own elaboration)



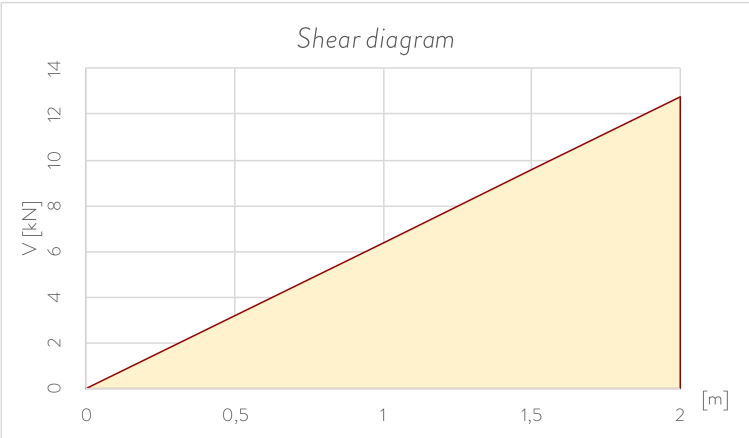


Figure 4.91
Shear diagram of Slab 2 (case B) for the ULS

(source: own elaboration)

Flexural resistance verification

Considering a CLT stripe parallel to the calculation direction, it has to be verified that:

$$\sigma_{m,d} \leq f_{m,d}$$

The design flexural stress is calculated with the formula:

$$\sigma = \frac{M}{K} \cdot a \cdot E_i$$

Since the most stressed fibre is the top one, it has to be considered the elastic modulus of the first layer and the distance of the barycentre from the top edge of the panel. As a result we have:

$$\sigma_{d,\max} = \frac{M_d}{K} \cdot \frac{h}{2} \cdot E_{0,mean}$$

So we have that the maximum bending stress is

$\sigma_{d,max}$	6,650	N/mm2

Comparing the design flexural stress and the design flexural resistance previously calculated we have

$\sigma_{d,max}$	6,650	MPa
$f_{m,d}$	16,896	MPa

so it is verified that $\sigma_{m,d} \leq f_{m,d}$.

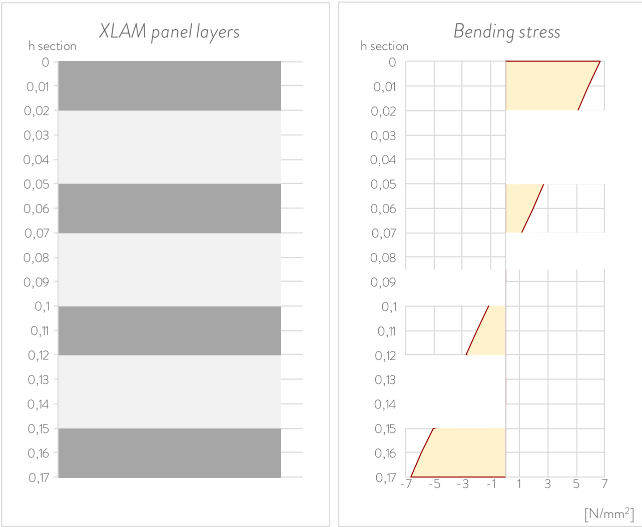


Figure 4.92
Bending stress diagram in the most loaded section (x=l) of Slab 2 case B for the ULS

(source: own elaboration)

Shear resistance verification

For the shear verification the following two conditions have to be verified (considering both the shear resistance and the rolling shear resistance:

$$\tau_{v,d} \leq f_{v,d}$$

$$\tau_{v,d} \leq f_{vr,d}$$

The shear stress distribution along the panel section is again:

$$\tau(a) = \frac{V \cdot S}{I \cdot b} = \frac{V \cdot \int E \cdot a \cdot dA}{K \cdot b}$$

So the maximum shear stress in the longitudinal layers evaluated in the barycentric axis is in the most critical section (x=l):

$$\tau_{d,\max} = \frac{V_d \cdot \sum (S_m \cdot E_m)}{K \cdot b}$$

where:

V_d	15,958	kN
S_m	2000000	mm3
E_m	11500	MPa
$K_{XLAM,l}$	2932116583333,330	N mm2
b	1000	mm
$\tau_{d,long,max}$	0,125	MPa

And the shear profile of the entire section thickness (h) is shown in the figure below:

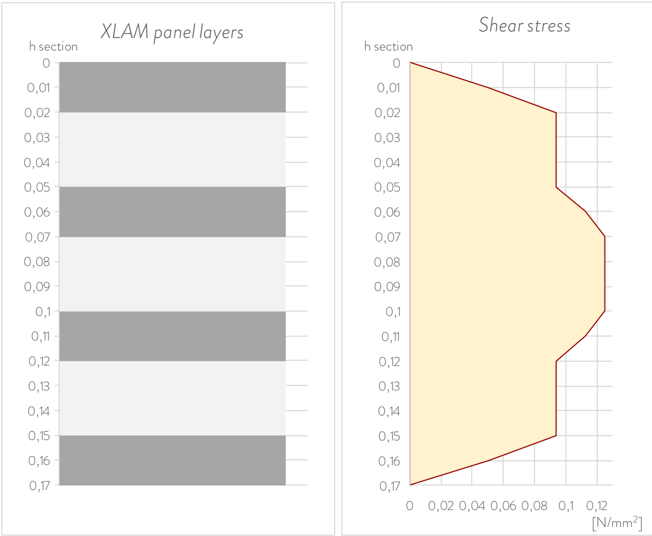


Figure 4.93 Shear stress diagram in the most loaded section (x=l) of Slab 2 case B for the ULS

(source: own elaboration)

Note that the maximum shear stress in the longitudinal layers is equal to the maximum shear stress in the transversal layer.

So we have the maximum shear in the longitudinal layer and the maximum in the transversal layer (that for a 7 layers panel are coincident) that have to be compared respectively with the design shear resistance and the design rolling shear resistance.

$\tau_{vd,long}$ [MPa]	$f_{v,d}$ [MPa]
0,125	2,56
$\tau_{vd,trans}$ [MPa]	$f_{vr,d}$ [MPa]
0,125	0,832

The verification is satisfied. $\tau_{v,d} \leq f_{v,d}$ $\tau_{v,d} \leq f_{vr,d}$

4.3.9.5 SLS - Case 2B

The instantaneous deformation is calculated also in this case based on the characteristic combination

$$\sum_{j\geq 1} G_{k,j} + Q_{k,1} + \sum_{i\geq 2} \psi_{0,i} \cdot Q_{k,i}$$

and the different contributions must be summed up

$$u_{inst} = \sum_{j\geq 1} u_{inst,Gj} + \sum_{i\geq 1} u_{inst,Qi}$$

To calculate the deformation due to the permanent load G and the variable load Q, it is applied the following formula valid for the deformation of a cantilever beam under a generic distributed load p (the symbols are the same used for the simply supported beam deflection):

$$u_{inst,p} = \frac{1}{8}\frac{p \cdot l^4}{K_{XLAM}} + \frac{1}{2}\frac{p \cdot l^2}{S_{XLAM}}$$

	p [kN/m]	$u_{inst,p}$ [mm]	l/150[mm]
G	1,617	3,116	
Q	2,8	5,396	
$u_{inst,tot}$		8,512	16,667

Comparing the resulting total instantaneous deformation with the limit value l/300, it can be seen that the calculated u_{inst} is smaller than l/300, so the verification is accepted.

The final deformation is calculated using the simplified procedure reported in the Eurocode:

$$u_{fin,G} = u_{inst,G}(1+k_{def})$$

$u_{inst,G}$ [mm]	3,116
k_{def}	0,6
$u_{fin,G}$ [mm]	4,986

$$u_{fin,Q1} = u_{inst,Q1}(1+\psi_{2,1}k_{def})$$

$u_{inst,Q}$ [mm]	5,396
k_{def}	0,6
$\psi_{2,1}$	0,3
$u_{fin,Q1}$ [mm]	6,367

Since there are no other variable actions, the final deformation can now be calculated summing up the two contributions

$$u_{fin} = u_{fin,G} + u_{fin,Q1} + u_{fin,Qi}$$

	u [mm]	l/125 [mm]
$u_{fin,G}$	4,986	
$u_{fin,Q1}$	6,367	
$u_{fin,tot}$	11,353	20

Also in this case the value of u_{fin} is smaller than the limit value l/125.

4.3.10 Walls Pre-Dimensioning

The calculation of the wall strength happens to necessitate a specific procedure, due to the presence of openings and also due to the slander beam behaviour in correspondence to the cantilever parts.
As a consequence it is not possible to perform a satisfactory simplification to perform the calculation. It is therefore made only a rough pre-dimensioning of the elements under the hypothesis of a wall without openings and without cantilever parts by means of tables.
The result will be therefore an underestimation of the thickness required and will be then amplified, but in any case more precise calculation are needed for a proper design of the walls.

The most loaded wall is for sure one in the bottom floor and in a point with the greatest number of floors above it, so that will be the one to be pre-dimensioned.

4.3.10.1 Loads on the panel

The maximum numbers of floors one above each other is 7, so the ground floor walls will be loaded by 6 wall elements and 7 times by the floor slabs (it has to be taken the reaction at the support calculated for the slab dimensioning)

	Load [kN/m]	N°
G from 1 slab (support reaction)	4,366575	7
G for 1 floor wall linear weight	4,407438	6
Q from 1 slab (support reaction)	8,4	7

Table 4.34 Loads on the bottom vertical wall

(source: own elaboration)

G_{total}	57,010653
Q_{Total}	58,8

4.3.10.2 Pre-dimensioning using the table

On the left side of the table it's possible to choose the load applied. In our case it is selected a dead weight of 60 kN/m and an imposed load of 60 kN/m.
The wall height is around 3 meters.
The fire class is chosen as R90, because the Spanish normative is very restrictive and requires that fire class.

Table 4.35 Pre-dimensioning table for wall elements in CLT

(source: producer Cross Tymber System)

(w=1.00 kN/m²) Height

Dead weight gk*	Imposed load nk	2,50 m				3,00 m				4,00 m			
		R0	R30	R60	R90	R0	R30	R60	R90	R0	R30	R60	R90
10,00	10,00	60 C3	80 C3	80 C3	120 C3	60 C3	80 C3	100 C5	120 C3	60 C3	80 C3	100 C5	120 C3
	20,00			100 C5						80 C3			140 C5
	30,00										90 C3	120 C5	
	40,00					80 C3			140 C5		100 C3		
	50,00												
	60,00	80 C3					90 C3			90 C3	100 C5		
20,00	10,00	60 C3	80 C3	80 C3	120 C3	60 C3	80 C3	100 C5	120 C3	80 C3	80 C3	100 C5	140 C5
	20,00			100 C5							90 C3	120 C5	
	30,00					80 C3			140 C5		100 C3		
	40,00												
	50,00	80 C3					90 C3			90 C3	100 C5		
	60,00				140 C5			120 C5					
30,00	10,00	60 C3	80 C3	100 C5	120 C3	60 C3	80 C3	100 C5	120 C3	80 C3	90 C3	120 C5	140 C5
	20,00					80 C3					100 C3		
	30,00								140 C5				
	40,00						90 C3			90 C3	100 C5		
	50,00	80 C3			140 C5			120 C5					
	60,00												
40,00	10,00	60 C3	80 C3	100 C5	120 C3	60 C3	80 C3	100 C5	120 C3	80 C3	90 C3	120 C5	140 C5
	20,00					80 C3			140 C5		100 C3		
	30,00						90 C3			90 C3	100 C5		
	40,00	80 C3			140 C5			120 C5					
	50,00												
	60,00		90 C3				100 C3			100 C3	120 C3		
50,00	10,00	60 C3	80 C3	100 C5	120 C3	80 C3	80 C3	100 C5	140 C5	80 C3	100 C3	120 C5	140 C5
	20,00						90 C3			90 C3			
	30,00	80 C3			140 C5			120 C5			100 C5		
	40,00												
	50,00		90 C3				100 C3			100 C3	120 C3		
	60,00			120 C5									
60,00	10,00	60 C3	80 C3	100 C5	120 C3	80 C3	90 C3	100 C5	140 C5	90 C3	100 C3	120 C5	140 C5
	20,00	80 C3			140 C5			120 C5			100 C5		
	30,00												
	40,00		90 C3				100 C3			100 C3	120 C3		
	50,00			120 C5									
	60,00												160 C5

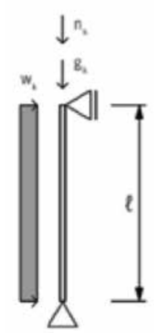
*** In the table the CLT self-weight is already taken into account.**
Service class 1, imposed load category A (ψ0 = 0.7; ψ1 = 0.5; ψ2 = 0.3)

Load-bearing capacity:
a) Verification as a column (compression in accordance with equivalent member method)
b) Shearing stresses

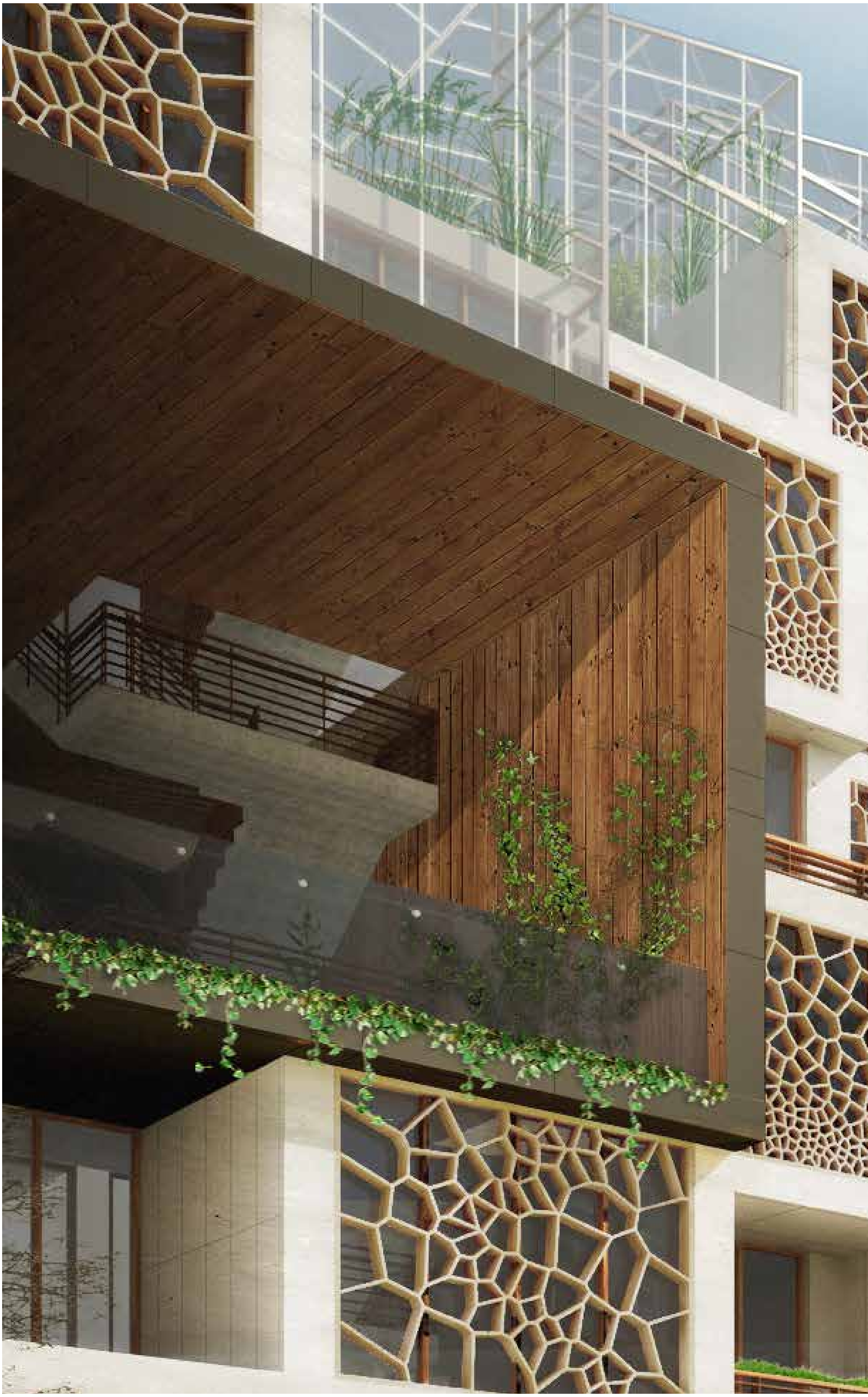
kmod = 0.8

Fire resistance

R0
R30
R60
R90



The result that we get from the table is that a wall of 140 mm is required to support the vertical loads applied.
The panel proposed by the producer Tymber System is therefore a 5 layer panel (40-20-20-20-40 mm) with a total thickness of 140 mm.



4.4 Building technologies

In this chapter the technological aspects of the building will be analysed.

4.4.1 Limit values for the thermal transmittance

4.4.1.1 Climatic Zone

First of all it has to be defined the thermal zone of the location according to the normative present in Spain. Table B.1 of Appendix B of the DB-HE 2013 permits to obtain the climatic zone of an area in function of its province capital and its altitude above see level

Barcelona is in the thermal zone C2 and the site location, that is at 180 m a.s.l., is also in zone C2 because the altitude is less than 250m a.s.l.

4.4.1.2 The Spanish requirements

The Spanish normative prescribes some limit values and some suggested values for the envelope thermal transmittance in the Documento Basico for the energy efficiency [CTE DB-HE, 2013].
The minimum values are reported in the following table. In our case we can see that for Zone C the limits are not very demanding and easily respected, but there are consumption requirements that can not be reached using these values.

Parámetro	Zona climática de invierno					
	α	A	B	C	D	E
Transmitancia térmica de muros y elementos en contacto con el terreno(1) [W/m²·K]	1,35	1,25	1,00	0,75	0,60	0,55
Transmitancia térmica de cubiertas y suelos en contacto con el aire [W/m²·K]	1,20	0,80	0,65	0,50	0,40	0,35
Transmitancia térmica de huecos(2) [W/m²·K]	5,70	5,70	4,20	3,10	2,70	2,50
Permeabilidad al aire de huecos(3) [m³/h·m²]	≤ 50	≤ 50	≤ 50	≤ 27	≤ 27	≤ 27

Figure 4.94 Maximum thermal transmittance for the elements of the building envelope

(source: Documento Basico table 2.3; CTE DB-HE, 2013)

The suggested values of the thermal envelope, reported in appendix E of the norm, are more restrictive and are made in particular for the dimensioning of constructive solutions of residential use.
The use of constructive solutions with characteristic parameters equal to those indicated does not guarantee compliance with the energy consumption requirements (that are set throw a reference building with reference U-values, also given by the code), but should lead to solutions close to it. The values have been obtained considering thermal bridges equivalent to those of the reference building and a building of average compactness.

Figure 4.95 Suggested thermal transmittance for the elements of the building envelope

(source: Documento Basico table E.1; CTE DB-HE, 2013)

	Zona Climática					
Transmitancia del elemento [W/m² K]	**α**	**A**	**B**	**C**	**D**	**E**
U_M	0.94	0.50	0.38	0.29	0.27	0.25
U_S	0.53	0.53	0.46	0.36	0.34	0.31
U_C	0.50	0.47	0.33	0.23	0.22	0.19

U_M: Transmitancia térmica de muros de fachada y cerramientos en contacto con el terreno

U_S: Transmitancia térmica de suelos (forjados en contacto con el aire exterior)

U_C: Transmitancia térmica de cubiertas

For the openings it is reported a transmittance range for each solar capture level and climatic zone, considering a certain percentage of openings relative to the useful surface area. In particular the upper value corresponds to a ratio opening/surface of 10% and the lower level of 15%. The thermal transmittance of the windows and the modified solar factor recommended should be reduced in case of larger ratio of windows area to useful surface.
The description of the solar capture in winter is qualitative. It is high for buildings with unobstructed windows oriented to south, south-east or south-west, and low for orientations north, north-east, north-west, or for any orientation in case there are obstacles that prevent direct radiation on the windows.

Figure 4.96 Suggested thermal transmittance of windows

(source: Documento Basico table E.2; CTE DB-HE, 2013)

Transmitancia térmica de huecos [W/m² K]		**α**	**A**	**B**	**C**	**D**	**E**
Captación solar	**Alta**	5.5 – 5.7	2.6 – 3.5	2.1 – 2.7	1.9 – 2.1	1.8 – 2.1	1.9 – 2.0
	Media	5.1 – 5.7	2.3 – 3.1	1.8 – 2.3	1.6 – 2.0	1.6 – 1.8	1.6 – 1.7
	Baja	4.7 – 5.7	1.8 – 2.6	1.4 – 2.0	1.2 – 1.6	1.2 – 1.4	1.2 – 1.3

4.4.1.3 Nearly Zero Energy Building

The requirements for a nearly zero Energy Building are not set by the normative yet, but there's a document that reports some suggested U values to build a nZEB. The document is called "Quadern Pràctic, Edificis de consum d'energia gairebé zero" and it was published by the Institut Català d'Energia in april 2017.

The recommended transmittances to be able to build a nZEB building come from the results obtained in the energy simulations (described inside the Quadern Pràctic, annex 4), according to parameters depending on building use and climatic zone.

In the following table are collected the values suggested for a nZEB in the document for a building in the climatic zone C, comparing the numbers also with the ones reported in the Documento Basico.

Table 4.36 Comparison of thermal transmittances of Documento Basico [CTE DB-HE, 2013] and Quadern Pràctic 2017

Element	Max value (CTE DB-HE 2013)	Recommended value (CTE DB-HE 2013)	Suggested for nZEB (Quadern Pràctic 2017)
Walls	0,75	0,29	0,16-0,35
Elements in contact with the ground	0,75	0,36	0,16-0,35
Roofs	0,5	0,23	0,16-0,35
Transparent elements	3,1	1,6-2,0	<1,6
All the values reported are in W/m2K			

The U values chosen can be seen in the next paragraphs for each element type. The aim was to have a good performing building, so the thermal transmittances adopted are respecting the Spanish regulations and in the ranges suggested for a nZEB.

4.4.2 General overview

As explained in the structural chapter, the building has a Cross Laminated Timber structure, that is also effective in reducing the thermal bridges in the critical points. In addition, it is important the contribution of the material in the phase shift of walls and roof, that is crucial for the warm climate of Barcelona.

The insulation chosen is mainly in fibre wood, that is a well performing insulation, but it is also an ecological material. In fact it can be reused after the building life time or burned to produce thermal energy.

The facade is covered with a rain screen cladding to improve the performance of the wall both in the winter and the summer season, thanks to the air cavity that reduces the heat flow by conduction and in summer creates a stack effect that cools the wall. The material selected for the rain screen is fibre-cement, that gives to the building a natural aspect and it is also produced with low CO_2 emissions. It is a composite material made with water, cellulose, cement, textile fibres and air combined together to create a high performing strong material that resists well to humidity, fire, moulds and insects.

Concerning building systems, the radiant floor provides heating and cooling, while the air quality is guaranteed throw natural ventilation and mechanical ventilation hidden in the false ceiling present over the corridor and kitchen area of the apartments.

4.4.3 Analysis of the building stratigraphies

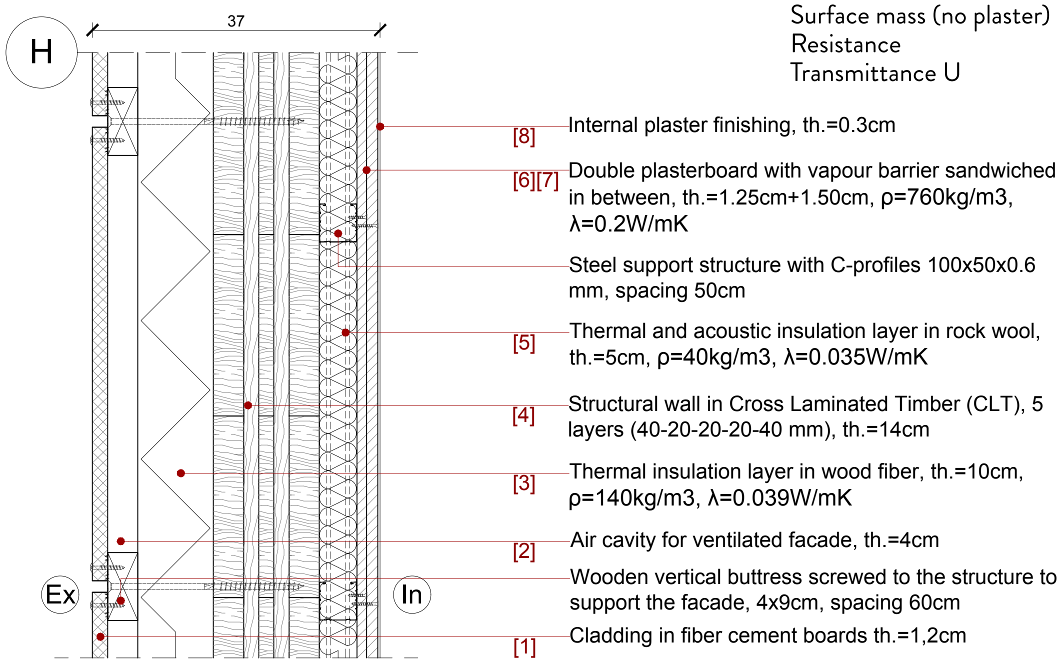
The analysis of the thermal transmittance and periodic thermal transmittance were performed respectively according to the normative UNI EN ISO 6946 and UNI EN ISO 13786, while the condensation risk is verified according to UNI EN ISO 13788.

The elements analysed are characterized by the following identification acronyms:

- V.C. = Vertical Closure
- V.P. = Vertical Partition
- H.C. = Horizontal Closure
- H.P. = Horizontal Partition

4.4.3.1 V.C. 01: External Wall

Total thickness 0,373 m
Surface mass 128,5 kg/m²
Surface mass (no plaster) 124,3 kg/m²
Resistance 5,48 m²K/W
Transmittance U 0,18 W/m²K



Layers

s thickness
ρ density
λ conductivity
c specific heat
μ vap. res. factor
Ms surface mass
R th. resistance

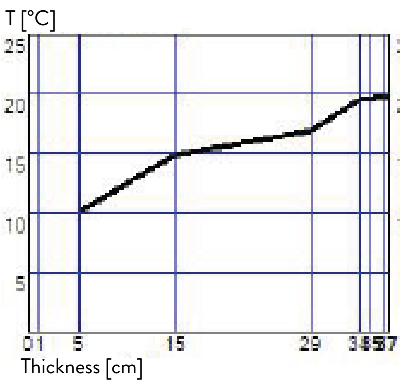
	s [m]	ρ [kg/m³]	λ [W/mK]	c [J/kgK]	μ [-]	M_s [kg/m²]	R [m²K/W]
							0,04
1	0,012	1681,8	0,790	836,8	70,0	20,2	0,02
2	0,040	1,0	0,285	1004,2	1,0	0,0	0,14
3	0,100	140,0	0,039	2100,4	3,0	14,0	2,56
4	0,140	452,6	0,130	1589,9	50,0	63,4	1,08
5	0,050	40,0	0,035	1046,0	1,0	2,0	1,43
6	0,013	900,0	0,210	836,8	8,0	11,3	0,06
7	0,015	900,0	0,210	836,8	8,0	13,5	0,07
8	0,003	1400,0	0,700	836,8	10,0	4,2	0,00
							0,13

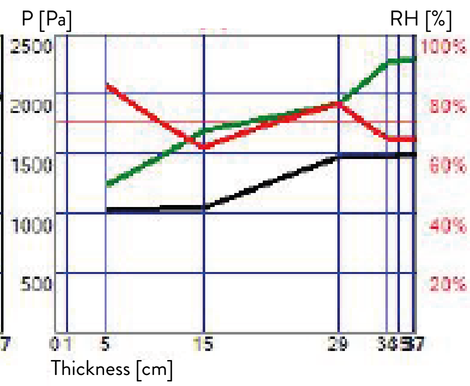
Condensation Verification
(December graphs)

LEFT:
Temperature -----

RIGHT:
$P_{saturation}$ [Pa] -----
$P_{interface}$ [Pa] -----
RH [%] -----

No condensation occurs

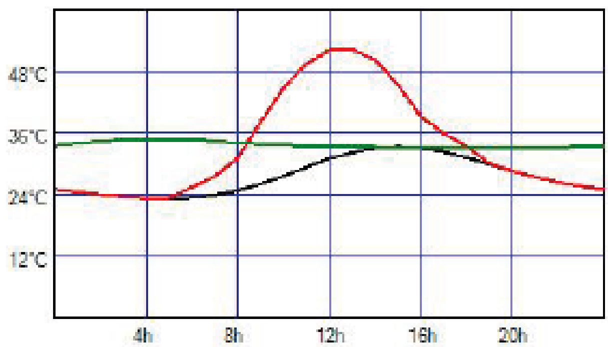




Inertial Verification

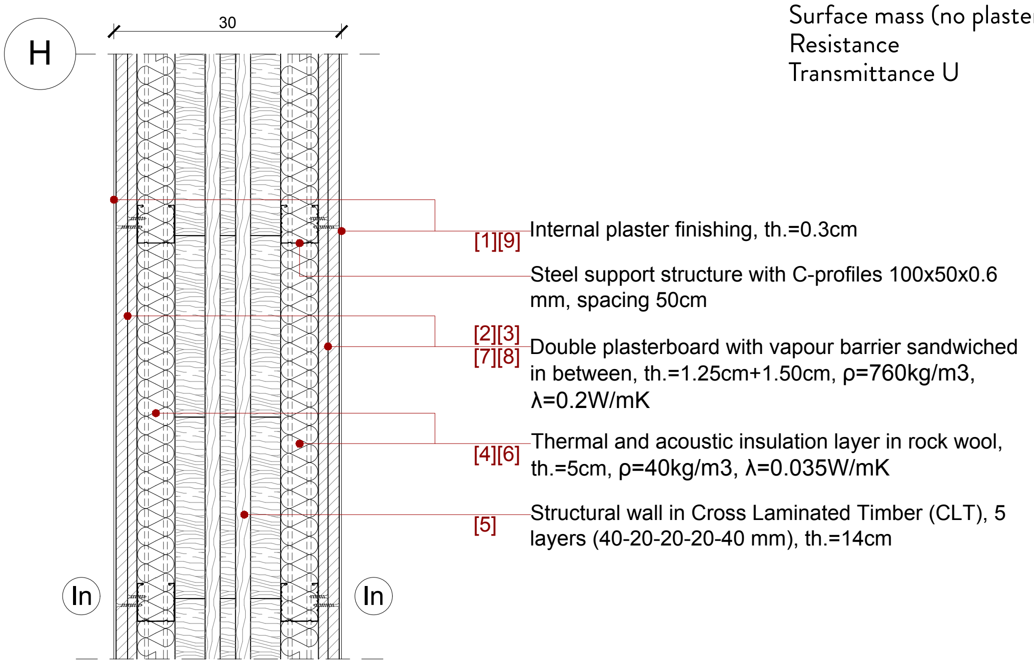
	Winter	Summer
Periodic transmitt. [W/m2K]	0,01	0,01
Attenuation factor [-]	0,06	0,08
Phase shift [-]	15h 21'	15h 30'

T_{AirExt} -----
T_{SupExt} -----
$T_{attenuated}$ -----



4.4.3.2 V.P. 01: Internal Structural Wall

Total thickness	0,331	m
Surface mass	138,4	kg/m²
Surface mass (no plaster)	130,0	kg/m²
Resistance	4,70	m²K/W
Transmittance U	0,21	W/m²K



Layers

s thickness
ρ density
λ conductivity
c specific heat
μ vap. res. factor
Ms surface mass
R th. resistance

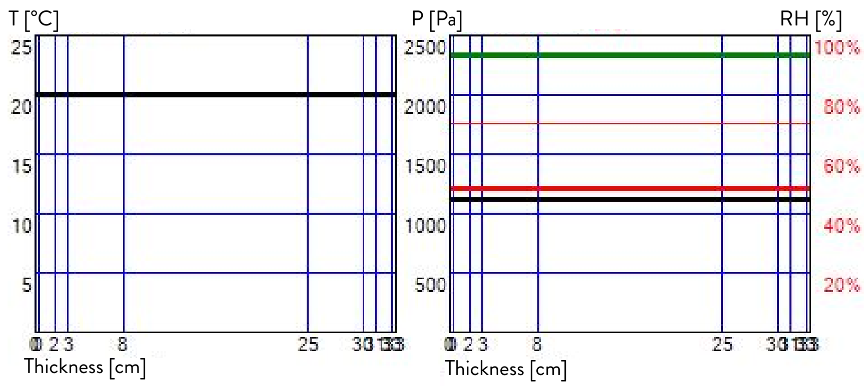
	s [m]	ρ [kg/m³]	λ [W/mK]	c [J/kgK]	μ [-]	M_s [kg/m²]	R [m²K/W]
							0,13
1	0,003	1400,0	0,700	836,8	10,0	4,2	0,00
2	0,015	900,0	0,210	836,8	8,0	13,5	0,07
3	0,013	900,0	0,210	836,8	8,0	11,3	0,06
4	0,050	40,0	0,035	1046,0	1,0	2,0	1,43
5	0,170	450,0	0,130	1589,9	50,0	76,5	1,31
6	0,050	40,0	0,035	1046,0	1,0	2,0	1,43
7	0,013	900,0	0,210	836,8	8,0	11,3	0,06
8	0,015	900,0	0,210	836,8	8,0	13,5	0,07
9	0,003	1400,0	0,700	836,8	10,0	4,2	0,00
							0,13

Condensation Verification
(December graphs)

LEFT:
Temperature -----

RIGHT:
$P_{saturation}$ [Pa] -----
$P_{interface}$ [Pa] -----
RH [%] -----

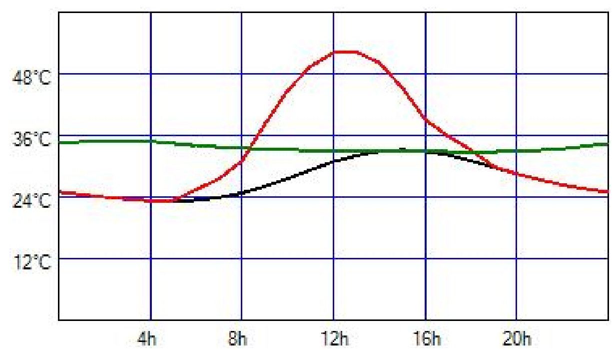
No verification is needed



Inertial Verification

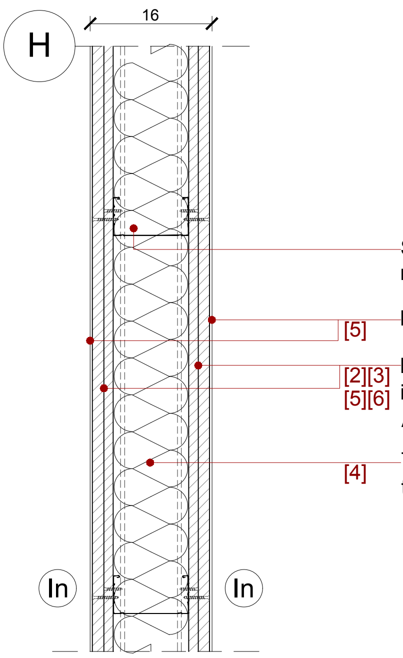
	Winter	Summer
Periodic transmitt. [W/m2K]	0,02	0,02
Attenuation factor [-]	0,07	0,07
Phase shift [-]	13h 50'	13h 47'

T_{AirExt} -----
T_{SupExt} -----
$T_{attenuated}$ -----



4.4.3.3 V.P. 02: Internal Light Wall

Total thickness	0,161	m
Surface mass	61,9	kg/m²
Surface mass (no plaster)	53,5	kg/m²
Resistance	3,39	m²K/W
Transmittance U	0,30	W/m²K



Layers

s thickness
ρ density
λ conductivity
c specific heat
μ vap. res. factor
M_s surface mass
R th. resistance

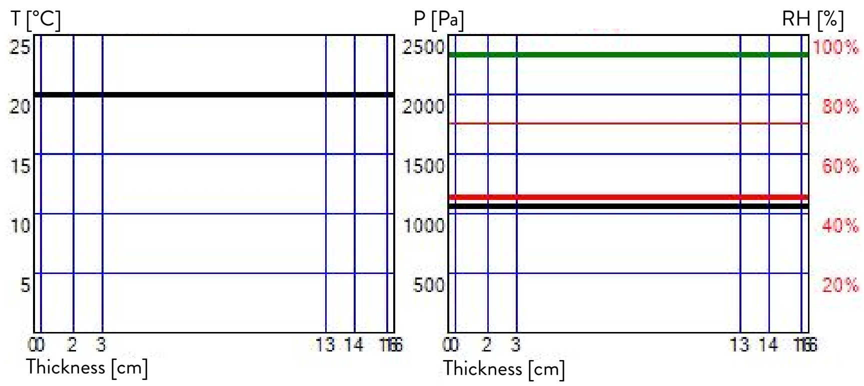
	s [m]	ρ [kg/m³]	λ [W/mK]	c [J/kgK]	μ [-]	M_s [kg/m²]	R [m²K/W]
							0,13
1	0,003	1400,0	0,700	836,8	10,0	4,2	0,00
2	0,015	900,0	0,210	836,8	8,0	13,5	0,07
3	0,013	900,0	0,210	836,8	8,0	11,3	0,06
4	0,100	40,0	0,035	1046,0	1,0	4,0	2,86
5	0,013	900,0	0,210	836,8	8,0	11,3	0,06
6	0,015	900,0	0,210	836,8	8,0	13,5	0,07
7	0,003	1400,0	0,700	836,8	10,0	4,2	0,00
							0,13

Condensation Verification
(December graphs)

LEFT:
Temperature -----

RIGHT:
$P_{saturation}$ [Pa] -----
$P_{interface}$ [Pa] -----
RH [%] -----

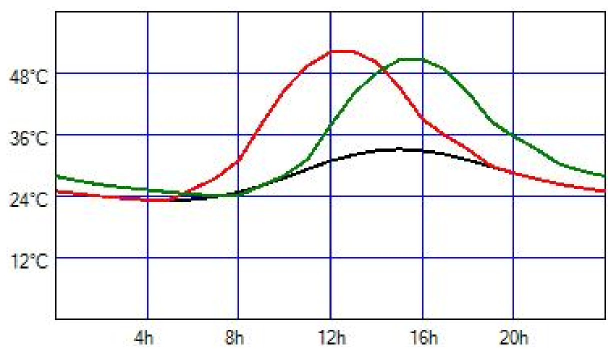
No verification is needed



Inertial Verification

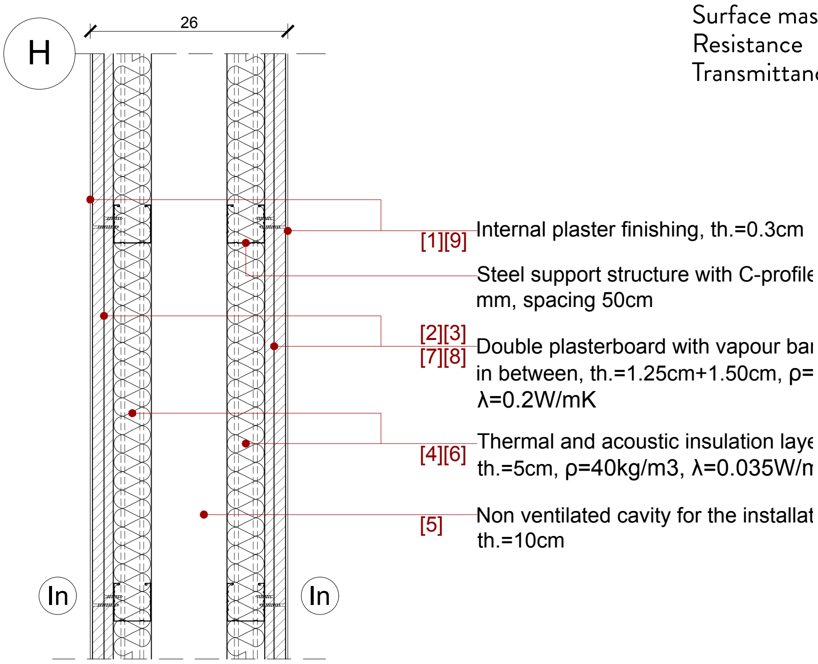
	Winter	Summer
Periodic transmitt. [W/m2K]	0,27	0,27
Attenuation factor [-]	0,91	0,92
Phase shift [-]	3h 5'	3h 2'

T_{AirExt} -----
T_{SupExt} -----
$T_{attenuated}$ -----



4.4.3.4 V.P. 03: Internal Wall for Systems

Total thickness	0,261	m
Surface mass	62,0	kg/m²
Surface mass (no plaster)	53,6	kg/m²
Resistance	3,57	m²K/W
Transmittance U	0,28	W/m²K



Layers

s thickness
ρ density
λ conductivity
c specific heat
μ vap. res. factor
Ms surface mass
R th. resistance

	s [m]	ρ [kg/m³]	λ [W/mK]	c [J/kgK]	μ [-]	M_s [kg/m²]	R [m²K/W]
							0,13
1	0,003	1400,0	0,700	836,8	10,0	4,2	0,00
2	0,015	900,0	0,210	836,8	8,0	13,5	0,07
3	0,013	900,0	0,210	836,8	8,0	11,3	0,06
4	0,050	40,0	0,035	1046,0	1,0	2,0	1,43
5	0,100	1,0	0,546	1004,2	1,0	0,1	0,18
6	0,050	40,0	0,035	1046,0	1,0	2,0	1,43
7	0,013	900,0	0,210	836,8	8,0	11,3	0,06
8	0,015	900,0	0,210	836,8	8,0	13,5	0,07
9	0,003	1400,0	0,700	836,8	10,0	4,2	0,00
							0,13

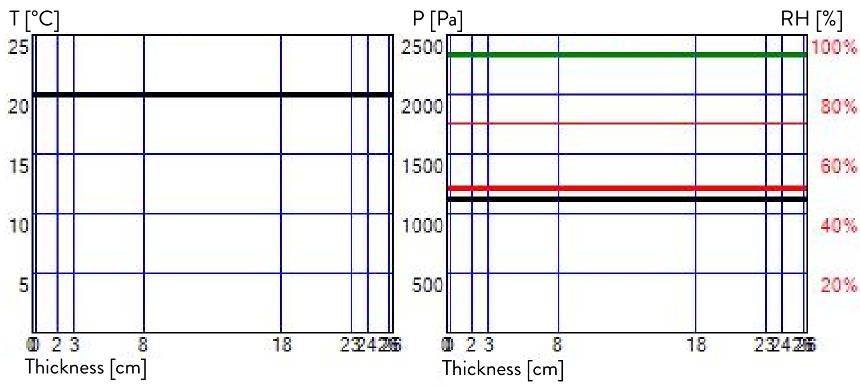
Condensation Verification

(December graphs)

LEFT:
Temperature -----

RIGHT:
$P_{saturation}$ [Pa] -----
$P_{interface}$ [Pa] -----
RH [%] -----

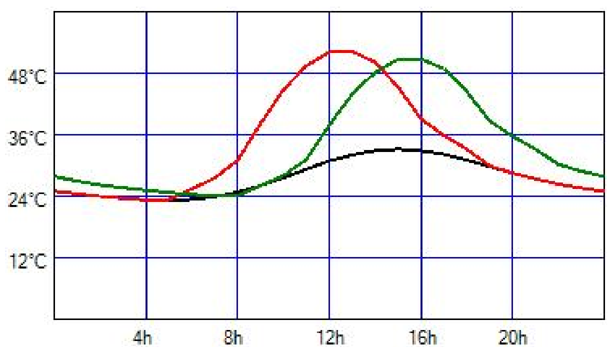
No verification is needed



Inertial Verification

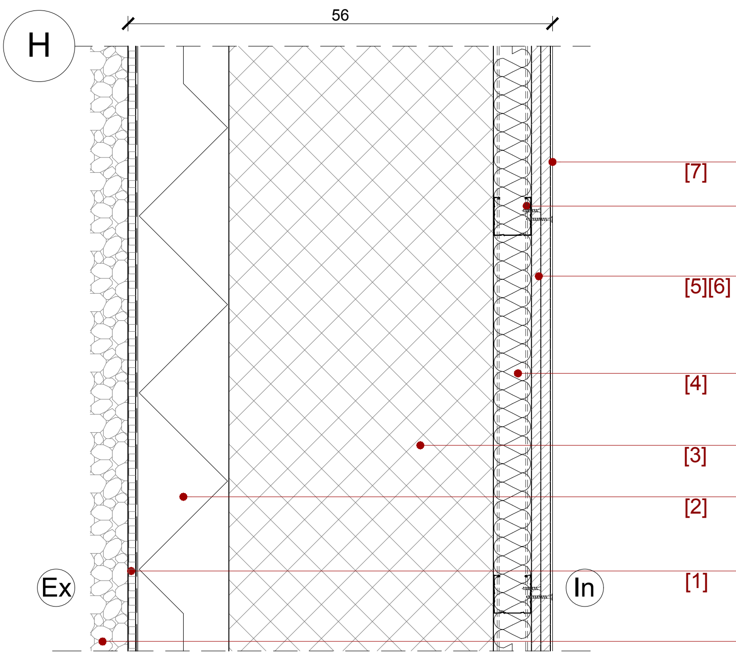
	Winter	Summer
Periodic transmitt. [W/m2K]	0,25	0,26
Attenuation factor [-]	0,91	0,92
Phase shift [-]	3h 7'	3h 3'

T_{AirExt} -----
T_{SupExt} -----
$T_{attenuated}$ -----



4.4.3.5 V.C. 02: Retaining Wall

Total thickness	0,533	m
Surface mass	877,2	kg/m²
Surface mass (no plaster)	873,0	kg/m²
Resistance	4,38	m²K/W
Transmittance U	0,23	W/m²K



Internal plaster finishing, th.=0.3cm

Steel support structure with C-profiles 100x50x0.6 mm, spacing 50cm

Double plasterboard with vapour barrier sandwiched in between, th.=1.25cm+1.50cm, ρ=760kg/m3, λ=0.2W/mK

Thermal and acoustic insulation layer in rock wool, th.=5cm, ρ=40kg/m3, λ=0.035W/mK

Structural wall in reinforced concrete, th.=35cm

Thermal insulation layer in polystyrene EPS, th.=10cm, ρ=30kg/m3, λ=0.04W/mK

Alveolar protecting membrane with bituminous water proof layer

Draining gravel

Layers

s thickness
ρ density
λ conductivity
c specific heat
μ vap. res. factor
Ms surface mass
R th. resistance

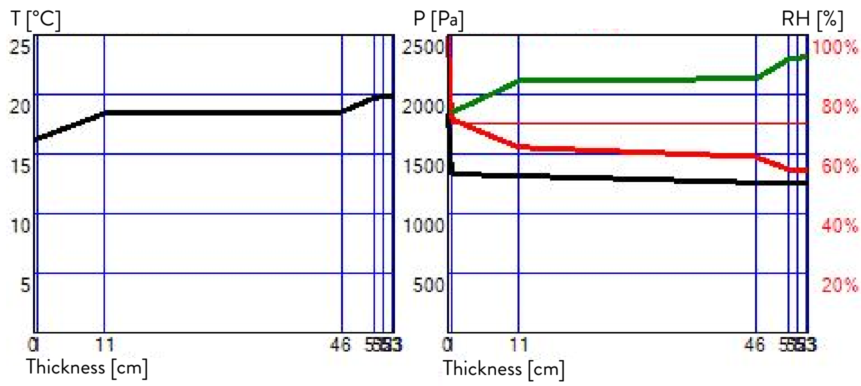
	s [m]	ρ [kg/m³]	λ [W/mK]	c [J/kgK]	μ [-]	M_s [kg/m²]	R [m²K/W]
							0,04
1	0,005	1100,0	0,230	1000,0	50000,0	5,5	0,02
2	0,100	30,0	0,040	1464,4	60,0	3,0	2,50
3	0,350	2400,0	2,500	1000,0	80,0	840,0	0,14
4	0,050	40,0	0,035	1046,0	1,0	2,0	1,43
5	0,013	900,0	0,210	836,8	8,0	11,3	0,06
6	0,013	900,0	0,210	836,8	8,0	11,3	0,06
7	0,003	1400,0	0,700	836,8	10,0	4,2	0,00
							0,13

Condensation Verification
(December graphs)

LEFT:
Temperature -----

RIGHT:
$P_{saturation}$ [Pa] -----
$P_{interface}$ [Pa] -----
RH [%] -----

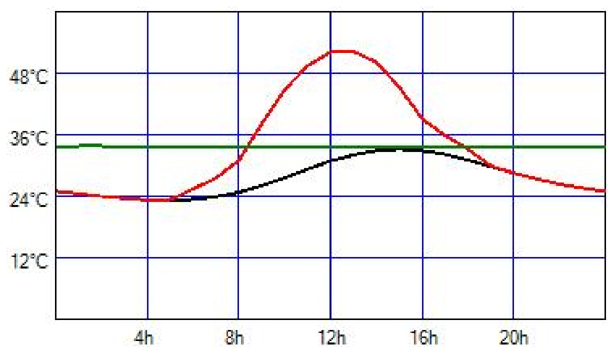
No condensation occurs



Inertial Verification

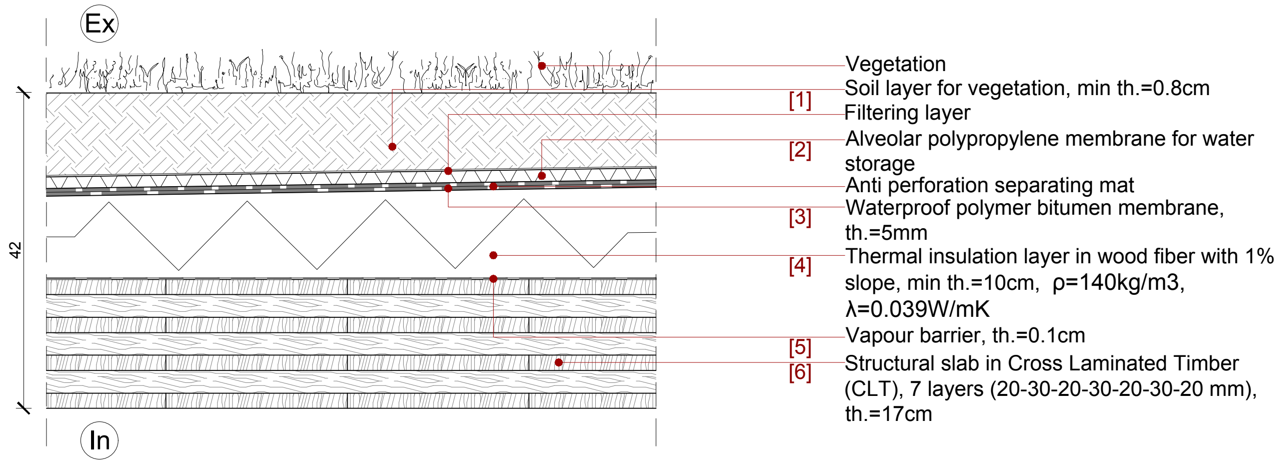
	Winter	Summer
Periodic transmitt. [W/m2K]	0,00	0,00
Attenuation factor [-]	0,01	0,01
Phase shift [-]	12h 32'	12h 34'

T_{AirExt} -----
T_{SupExt} -----
$T_{attenuated}$ -----



4.4.3.6 H.C. 01: Green Roof

Total thickness	0,377	m
Surface mass	217,9	kg/m²
Surface mass (no plaster)	217,9	kg/m²
Resistance	4,11	m²K/W
Transmittance U	0,24	W/m²K



Layers

s thickness
ρ density
λ conductivity
c specific heat
μ vap. res. factor
Ms surface mass
R th. resistance

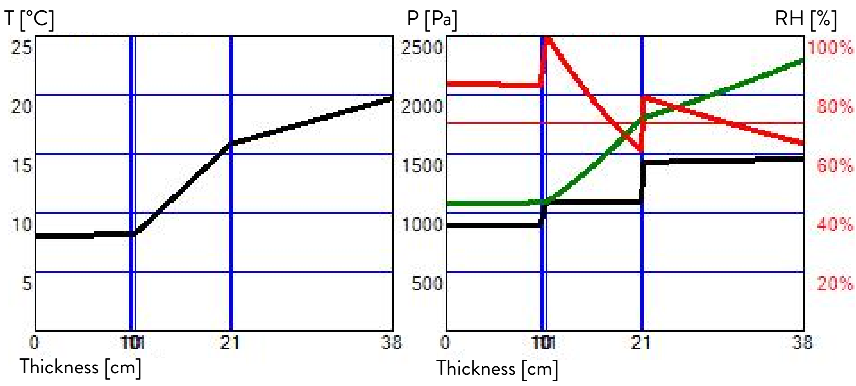
	s [m]	ρ [kg/m³]	λ [W/mK]	c [J/kgK]	μ [-]	M_s [kg/m²]	R [m²K/W]
							0,04
1	0,100	1200,0	1,500	1669,4	50,0	120,0	0,07
2	0,001	950,0	0,350	2092,0	100000,0	1,0	0,00
3	0,005	1100,0	0,230	1000,0	50000,0	5,5	0,02
4	0,100	140,0	0,039	2100,4	3,0	14,0	2,56
5	0,001	950,0	0,350	2092,0	100000,0	1,0	0,00
6	0,170	450,0	0,130	1589,9	50,0	76,5	1,31
							0,10

Condensation Verification
(December graphs)

LEFT:
Temperature -----

RIGHT:
$P_{saturation}$ [Pa] -----
$P_{interface}$ [Pa] -----
RH [%] -----

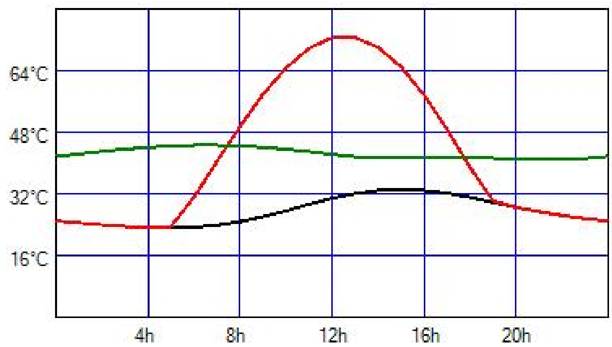
Condensation occurs, but it evaporates in summer



Inertial Verification

		Winter	Summer
Periodic transmitt.	[W/m2K]	0,02	0,02
Attenuation factor	[-]	0,10	0,07
Phase shift	[-]	16h 50'	17h 53'

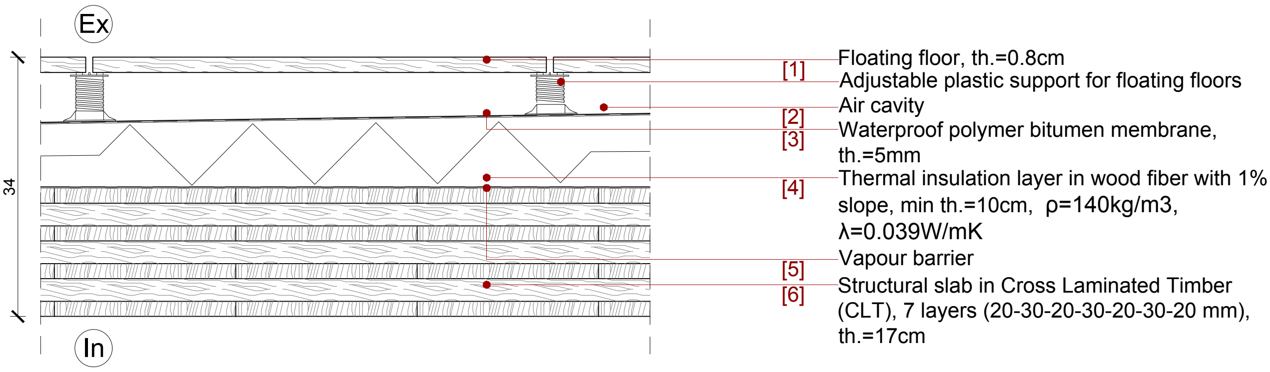
T_{AirExt} -----
T_{SupExt} -----
$T_{attenuated}$ -----



4.4.3.7 H.C. 02: Terrace Floor

Total thickness	0,352	m
Surface mass	92,6	kg/m²
Surface mass (no plaster)	92,6	kg/m²
Resistance	4,02	m²K/W
Transmittance U	0,25	W/m²K

a



Layers

s thickness
ρ density
λ conductivity
c specific heat
μ vap. res. factor
Ms surface mass
R th. resistance

	s [m]	ρ [kg/m³]	λ [W/mK]	c [J/kgK]	μ [-]	M_s [kg/m²]	R [m²K/W]
							0,04
1	0,020	550,0	0,150	2719,6	60,0	11,0	0,13
2	0,060	1,0	0,578	1004,2	1,0	0,1	0,10
3	0,001	1100,0	0,230	1000,0	50000,0	1,1	0,00
4	0,100	30,0	0,040	1464,4	60,0	3,0	2,50
5	0,001	910,0	0,220	1799,1	10000,0	0,9	0,00
6	0,170	450,0	0,130	1589,9	50,0	76,5	1,31
							0,10

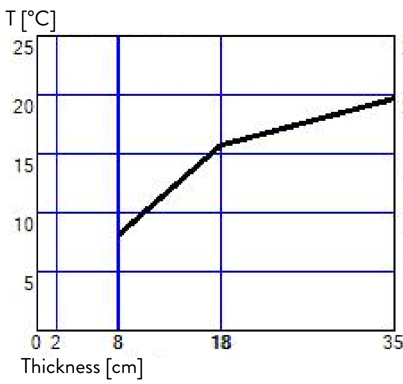
Condensation Verification

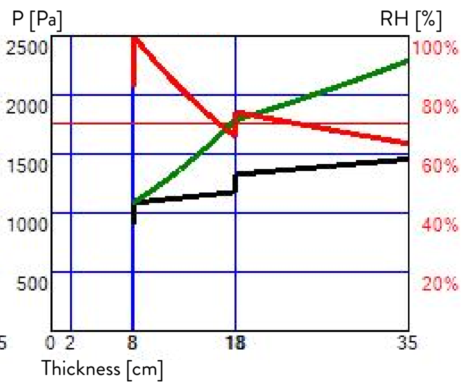
(December graphs)

LEFT:
Temperature -----

RIGHT:
$P_{saturation}$ [Pa] -----
$P_{interface}$ [Pa] -----
RH [%] -----

Condensation occurs, but it evaporates in summer





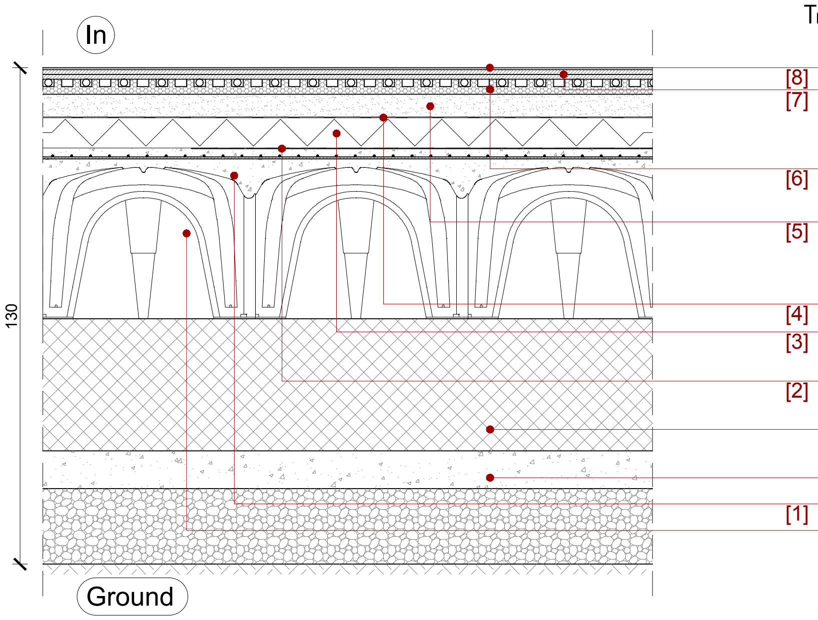
Inertial Verification

	Winter	Summer
Periodic transmitt. [W/m2K]	0,05	0,04
Attenuation factor [-]	0,18	0,16
Phase shift [-]	11h 12'	11h 46'

T_{AirExt} -----
T_{SupExt} -----
$T_{attenuated}$ -----

4.4.3.8 H.C. 03: Floor to ground with aerated space

Total thickness	0,309	m
Surface mass	203,2	kg/m²
Surface mass (no plaster)	203,2	kg/m²
Resistance	5,14	m²K/W
Transmittance U	0,19	W/m²K



Laminate flooring, th.=0.8cm
Double gypsum flooring panel to support the floor, th.=1.25cm+1.25cm, ρ=1100kg/m3, λ=0.38W/mK
Radiant floor heating system, th.=4cm, ρ=20kg/m3, λ=0.04W/mK
Granular dry screed for systems on polyethylene containing layer, th.=6cm, ρ=400kg/m3, λ=0.09W/mK
Vapour barrier
Thermal insulation layer in wood fiber, th.=10cm, ρ=140kg/m3, λ=0.039W/mK
Waterproof polymer bitumen membrane, th.=5mm
Structural slab in reinforced concrete, th.=35cm
Weak mix concrete layer, th.=10cm
Cast concrete with reinforcing net ϕ=4mm
Aerated flooring system in recycled plastic, h=40cm

Layers

s thickness
ρ density
λ conductivity
c specific heat
μ vap. res. factor
Ms surface mass
R th. resistance

	s [m]	ρ [kg/m³]	λ [W/mK]	c [J/kgK]	μ [-]	M_s [kg/m²]	R [m²K/W]
							0,17
1	0,050	2300,0	2,300	1000,0	80,0	115,0	0,02
2	0,005	1200,0	0,170	920,5	20000,0	6,0	0,03
3	0,100	140,0	0,039	2100,4	3,0	14,0	2,56
4	0,001	950,0	0,350	2092,0	100000,0	1,0	0,00
5	0,060	440,0	0,114	920,5	2,0	26,4	0,53
6	0,060	20,0	0,040	1255,2	60,0	1,2	1,50
7	0,025	1040,0	0,210	836,8	10,0	26,0	0,12
8	0,008	1700,0	0,250	1401,6	10000,0	13,6	0,03
							0,17

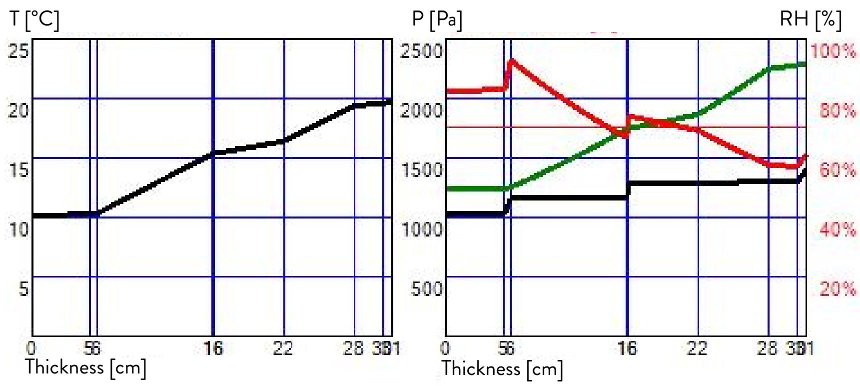
Condensation Verification

(December graphs)

LEFT:
Temperature -----

RIGHT:
$P_{saturation}$ [Pa] -----
$P_{interface}$ [Pa] -----
RH [%] -----

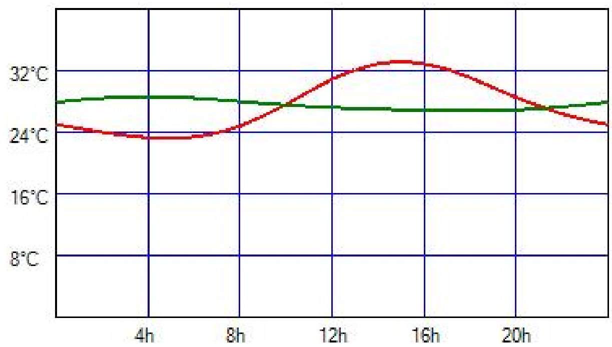
Condensation occurs, but it evaporates in summer



Inertial Verification

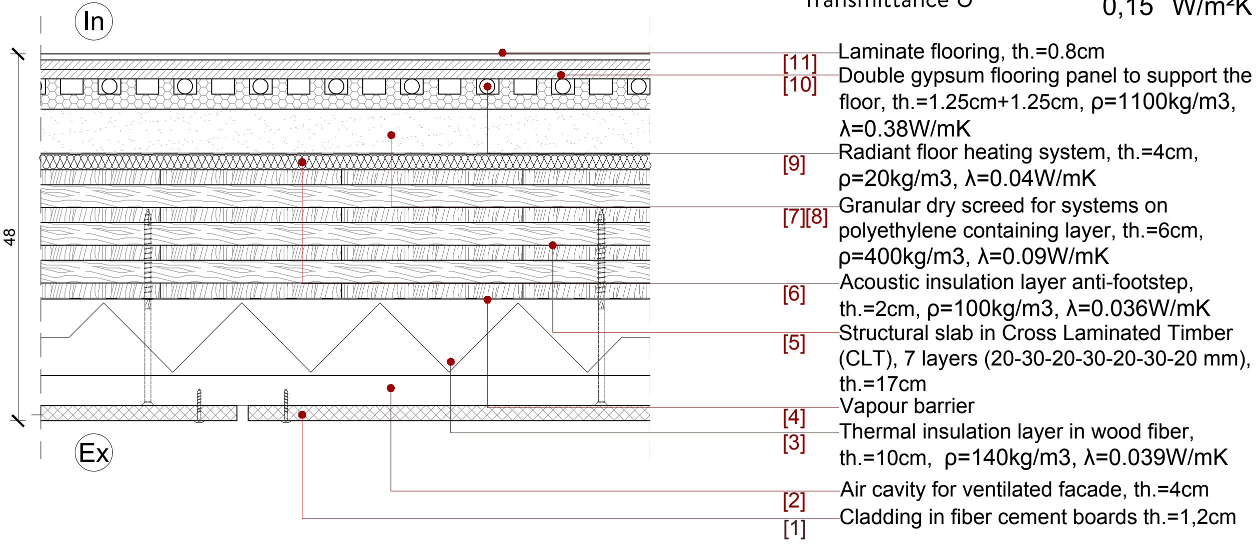
	Winter	Summer
Periodic transmitt. [W/m2K]	0,02	0,04
Attenuation factor [-]	0,12	0,19
Phase shift [-]	14h 51'	13h 18'

T_{AirExt} -----
T_{SupExt} -----
$T_{attenuated}$ -----



4.4.3.9 H.C. 04: Floor exposed to external air

Total thickness	0,475	m
Surface mass	179,7	kg/m²
Surface mass (no plaster)	179,7	kg/m²
Resistance	6,48	m²K/W
Transmittance U	0,15	W/m²K



Layers

s thickness
ρ density
λ conductivity
c specific heat
μ vap. res. factor
M_s surface mass
R th. resistance

	s [m]	ρ [kg/m³]	λ [W/mK]	c [J/kgK]	μ [-]	M_s [kg/m²]	R [m²K/W]
							0,04
1	0,012	1681,8	0,790	836,8	70,0	20,2	0,02
2	0,040	1,0	0,213	1004,2	1,0	0,0	0,19
3	0,100	140,0	0,039	2100,4	3,0	14,0	2,56
4	0,000	910,0	0,220	1799,1	10000,0	0,1	0,00
5	0,170	450,0	0,130	1589,9	50,0	76,5	1,31
6	0,020	100,0	0,035	1029,3	1,0	2,0	0,57
7	0,000	950,0	0,350	2092,0	100000,0	0,1	0,00
8	0,060	440,0	0,114	920,5	2,0	26,4	0,53
9	0,040	20,0	0,040	1255,2	60,0	0,8	1,00
10	0,025	1040,0	0,210	836,8	10,0	26,0	0,12
11	0,008	1700,0	0,250	1401,6	10000,0	13,6	0,03
							0,17

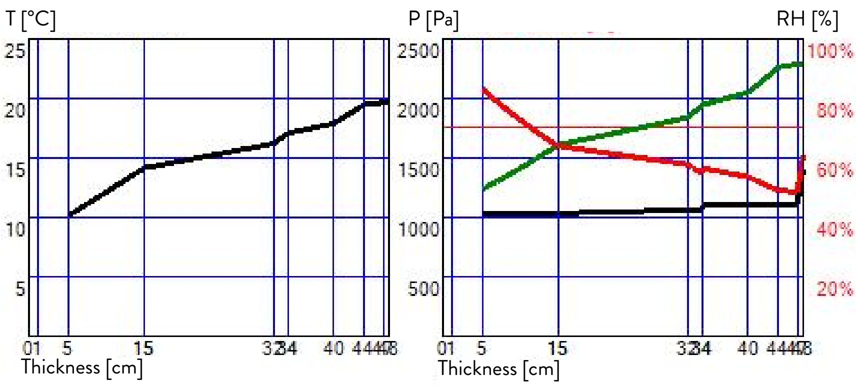
Condensation Verification

(December graphs)

LEFT:
Temperature -----

RIGHT:
$P_{saturation}$ [Pa] -----
$P_{interface}$ [Pa] -----
RH [%] -----

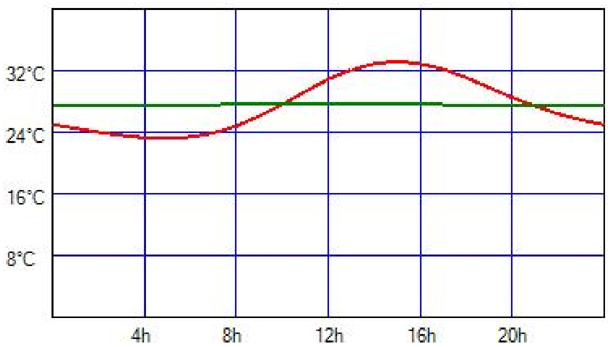
No condensation occurs



Inertial Verification

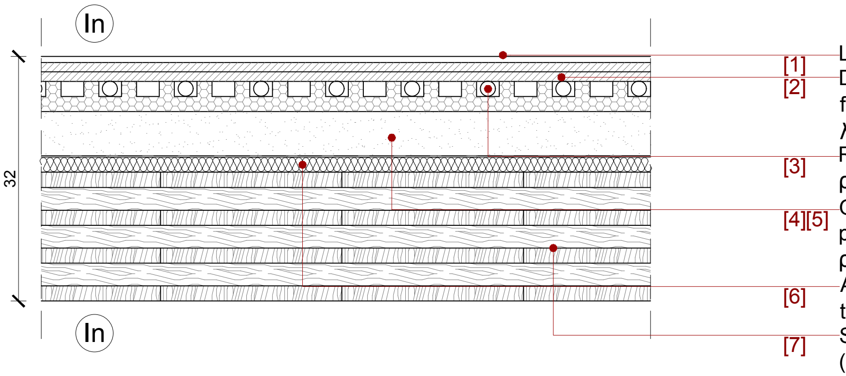
	Winter	Summer
Periodic transmitt. [W/m2K]	0,00	0,00
Attenuation factor [-]	0,02	0,02
Phase shift [-]	21h 26'	20h 52'

T_{AirExt} -----
T_{SupExt} -----
$T_{attenuated}$ -----



4.4.3.10 H.P. 01: Internal Floor

Total thickness	0,343	m
Surface mass	145,8	kg/m²
Surface mass (no plaster)	145,8	kg/m²
Resistance	4,33	m²K/W
Transmittance U	0,23	W/m²K



[1] Laminate flooring, th.=0.8cm

[2] Double gypsum flooring panel to support the floor, th.=1.25cm+1.25cm, ρ=1100kg/m3, λ=0.38W/mK

[3] Radiant floor heating system, th.=4cm, ρ=20kg/m3, λ=0.04W/mK

[4][5] Granular dry screed for systems on polyethylene containing layer, th.=6cm, ρ=400kg/m3, λ=0.09W/mK

[6] Acoustic insulation layer anti-footstep, th.=2cm, ρ=100kg/m3, λ=0.036W/mK

[7] Structural slab in Cross Laminated Timber (CLT), 7 layers (20-30-20-30-20-30-20 mm), th.=17cm

Layers

s thickness
ρ density
λ conductivity
c specific heat
μ vap. res. factor
Ms surface mass
R th. resistance

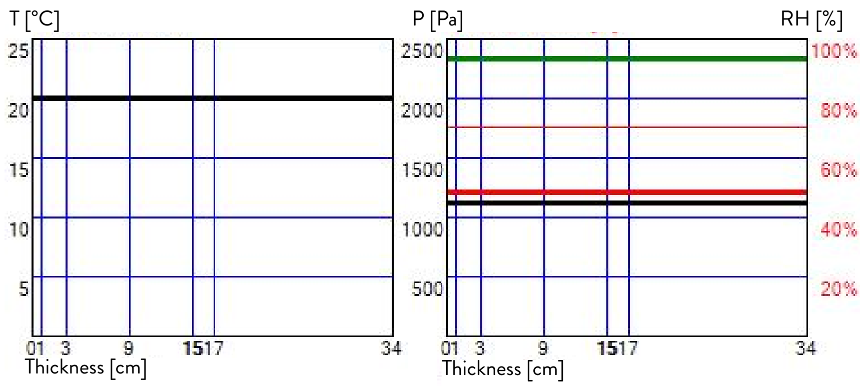
	s [m]	ρ [kg/m³]	λ [W/mK]	c [J/kgK]	μ [-]	M_s [kg/m²]	R [m²K/W]
							0,17
1	0,008	1700,0	0,250	1401,6	10000,0	13,6	0,03
2	0,025	1040,0	0,210	836,8	10,0	26,0	0,12
3	0,060	20,0	0,040	1255,2	60,0	1,2	1,50
4	0,060	440,0	0,114	920,5	2,0	26,4	0,53
5	0,000	950,0	0,350	2092,0	100000,0	0,1	0,00
6	0,020	100,0	0,035	1029,3	1,0	2,0	0,57
7	0,170	450,0	0,130	1589,9	50,0	76,5	1,31
							0,10

Condensation Verification
(December graphs)

LEFT:
Temperature -----

RIGHT:
$P_{saturation}$ [Pa] -----
$P_{interface}$ [Pa] -----
RH [%] -----

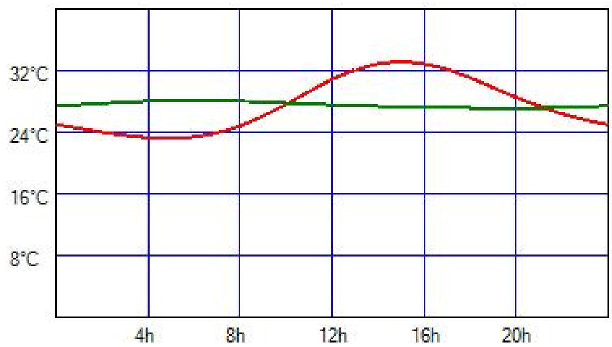
No verification required



Inertial Verification

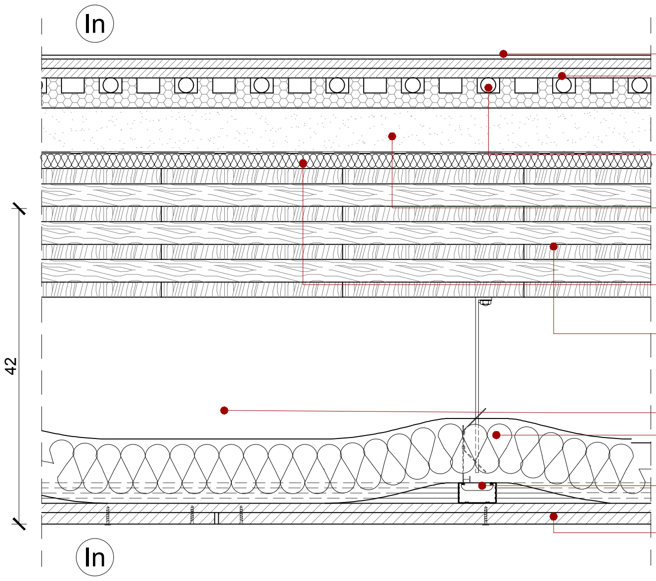
		Winter	Summer
Periodic transmitt.	[W/m2K]	0,02	0,02
Attenuation factor	[-]	0,10	0,10
Phase shift	[-]	15h 23'	15h 2'

T_{AirExt} -----
T_{SupExt} -----
$T_{attenuated}$ -----



4.4.3.11 H.P. 02: Internal Floor with False Ceiling

Total thickness	0,726	m
Surface mass	174,0	kg/m
Surface mass (no plaster)	174,0	kg/m
Resistance	6,98	m²K/
Transmittance U	0,14	W/m



[1] Laminate flooring, th.=0.8cm
[2] Double gypsum flooring panel to support th floor, th.=1.25cm+1.25cm, ρ=1100kg/m3, λ=0.38W/mK
[3] Radiant floor heating system, th.=4cm, ρ=20kg/m3, λ=0.04W/mK
[4][5] Granular dry screed for systems on polyethylene containing layer, th.=6cm, ρ=400kg/m3, λ=0.09W/mK
[6] Acoustic insulation layer anti-footstep, th.=2cm, ρ=100kg/m3, λ=0.036W/mK
[7] Structural slab in Cross Laminated Timber (CLT), 7 layers (20-30-20-30-20-30-20 mm th.=17cm
[8] Cavity for the installation of systems, th.=27
[9] Roll of thermal and acoustic insulation in ro wool, th.=8cm, ρ=40kg/m3, λ=0.035W/m False ceiling supporting structure with hang steel profiles th.=0.8mm
[10][11] Double plasterboard with vapour barrier sandwiched in between, th.=1.25cm+1.50c ρ=760kg/m3, λ=0.2W/mK

Layers

s thickness
ρ density
λ conductivity
c specific heat
μ vap. res. factor
Ms surface mass
R th. resistance

	s [m]	ρ [kg/m³]	λ [W/mK]	c [J/kgK]	μ [-]	M_s [kg/m²]	R [m²K/W
							0,
1	0,008	1700,0	0,250	1401,6	10000,0	13,6	0,0
2	0,025	1040,0	0,210	836,8	10,0	26,0	0,
3	0,060	20,0	0,040	1255,2	60,0	1,2	1,
4	0,060	440,0	0,114	920,5	2,0	26,4	0,
5	0,000	950,0	0,350	2092,0	100000,0	0,1	0,0
6	0,020	100,0	0,035	1029,3	1,0	2,0	0,
7	0,170	450,0	0,130	1589,9	50,0	76,5	1,
8	0,275	1,0	1,182	1004,2	1,0	0,3	0,
9	0,080	40,0	0,035	1046,0	1,0	3,2	2,
10	0,013	900,0	0,210	836,8	8,0	11,3	0,0
11	0,015	900,0	0,210	836,8	8,0	13,5	0,0
							0,

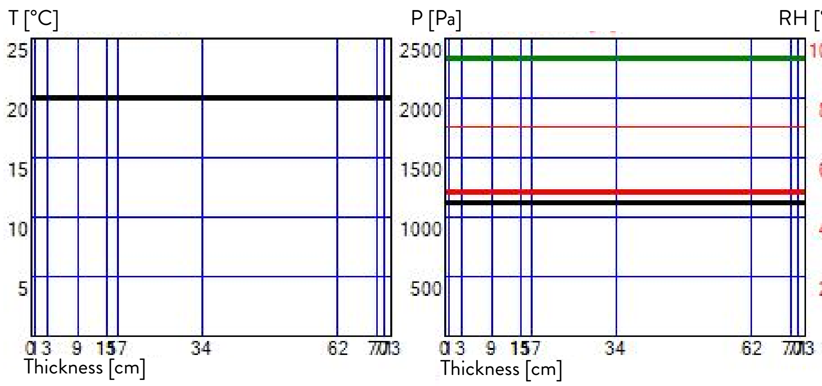
Condensation Verification

(December graphs)

LEFT:
Temperature -----

RIGHT:
$P_{saturation}$ [Pa] -----
$P_{interface}$ [Pa] -----
RH [%] -----

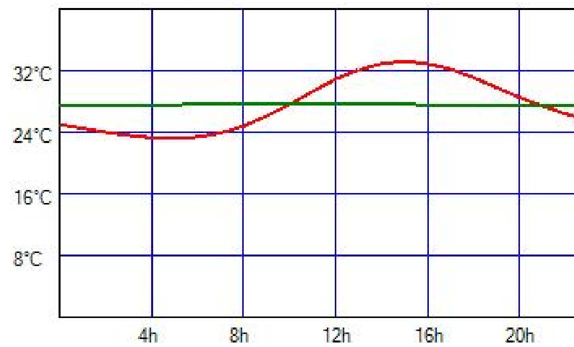
No verification required



Inertial Verification

	Winter	Summer
Periodic transmitt. [W/m2K]	0,00	0,00
Attenuation factor [-]	0,02	0,03
Phase shift [-]	18h 52'	18h 32'

T_{AirExt} -----
T_{SupExt} -----
$T_{attenuated}$ -----



4.4.4 Technical drawings: Blow ups and details

In the next page are reported the technological drawings. The details shown are the ones that are the most common in the building and repeated in every unit in more or less the same way.

It will be shown first some sections and blow ups at the scale 1:20 and after them are proposed the details in a scale 1:10.

It can be noticed how the building is created overlapping modules and shifting them both in plan and in elevation.
The terraces in the back are realized continuing the wooden slab, so to avoid thermal bridges it was chosen to cover completely the slab with insulation. In this way it was possible to have a continuous insulation layer.

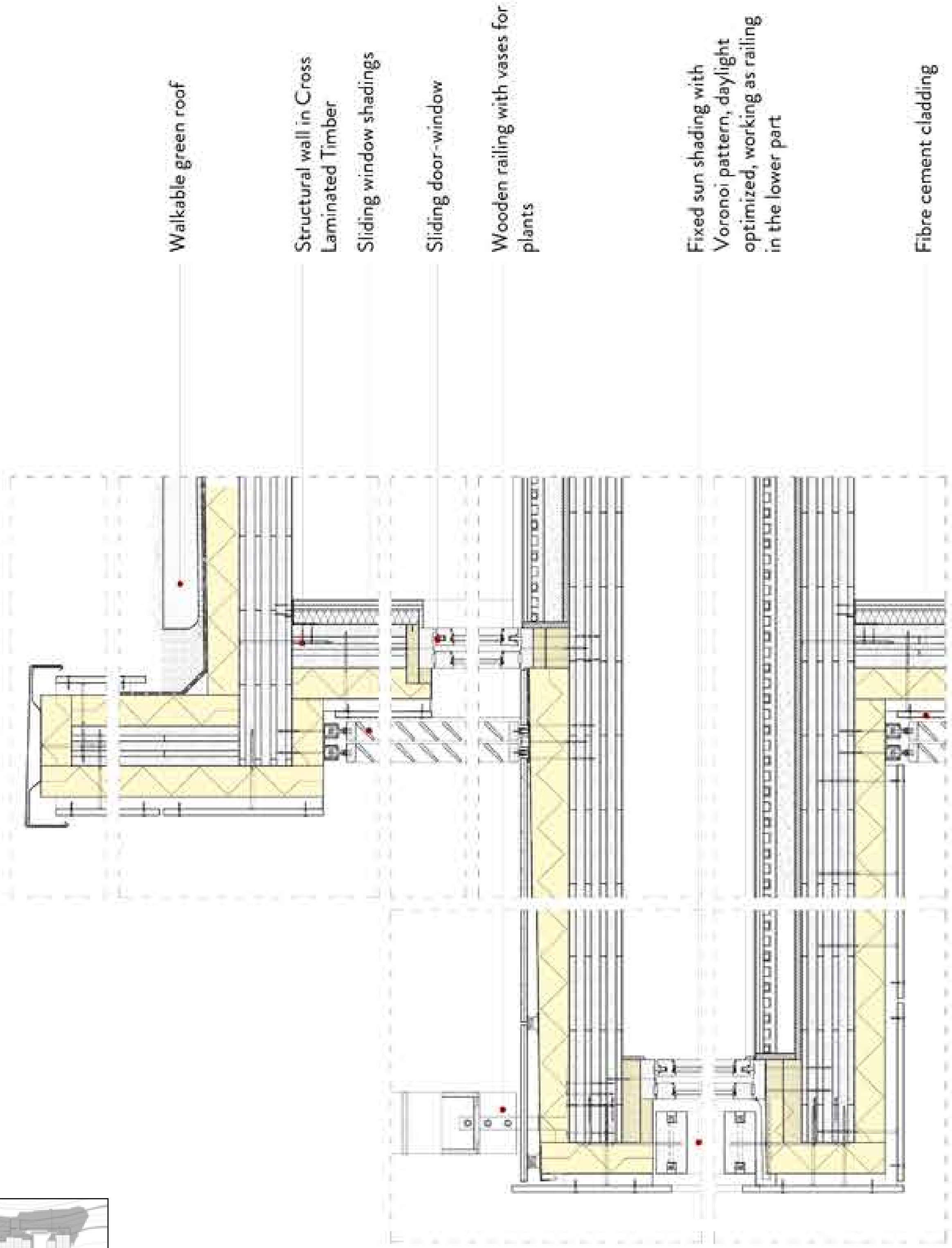
The windows are mainly sliding, so the internal space is not reduced by them when are open. The only vasistas window is the one over the door, that is made in order to allow the cross ventilation inside the apartments.

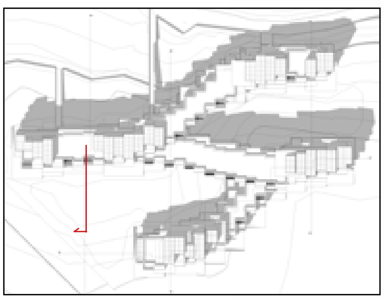
Particular attention was also given to the cladding, that covers all the gutters and brackets, to have clearer and nicer elevations.

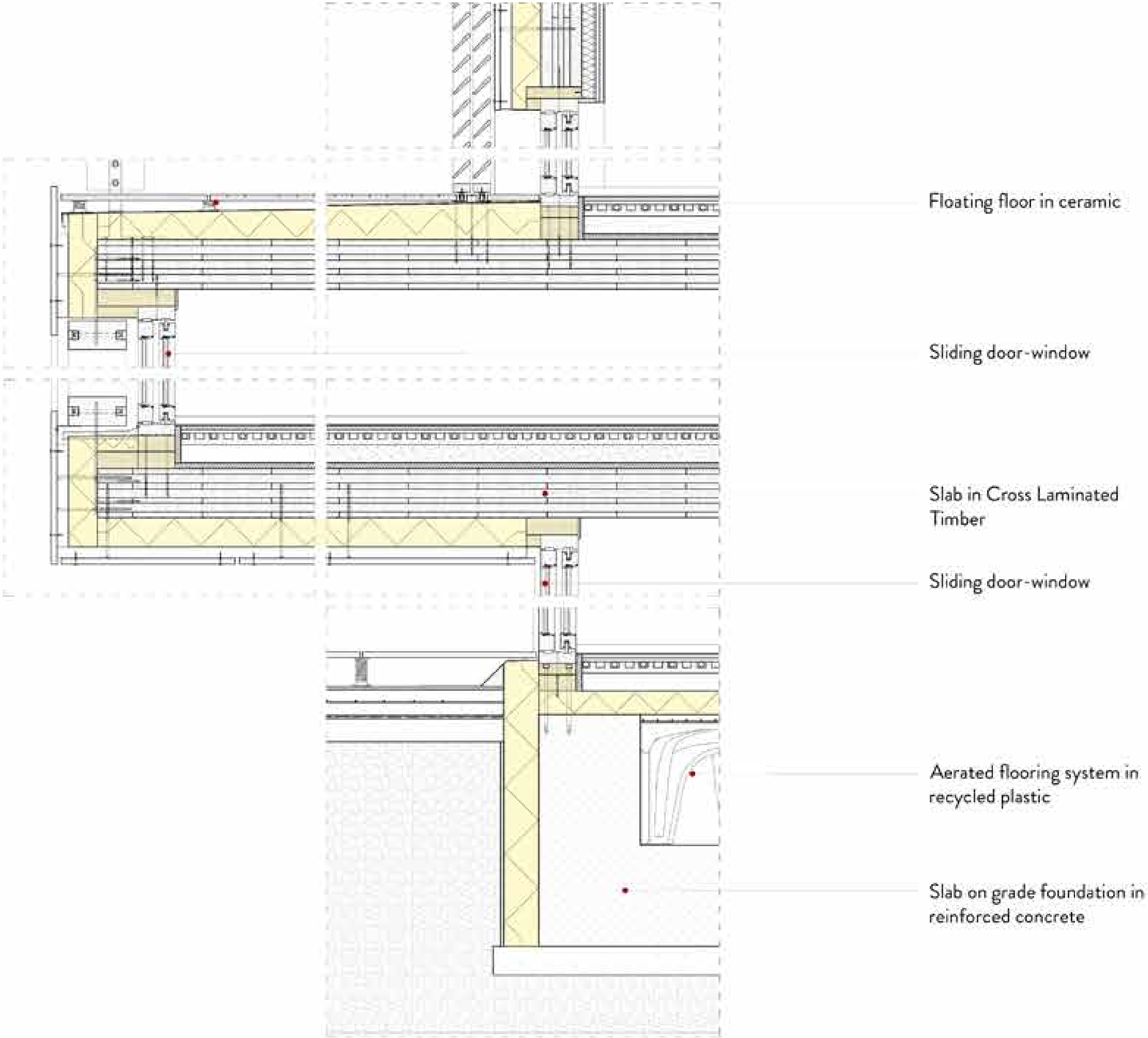
In the south-east elevation is visible the fixed wooden shading with Voronoi pattern that is optimized for the daylight during the day, and the terraces, that characterise the facade.
On the other side of the building are present external corridors, that are also used as common cultivation areas in the larger parts.

Board 4.12
Technological section towards Barcelona (S-E)

Scale 1:20

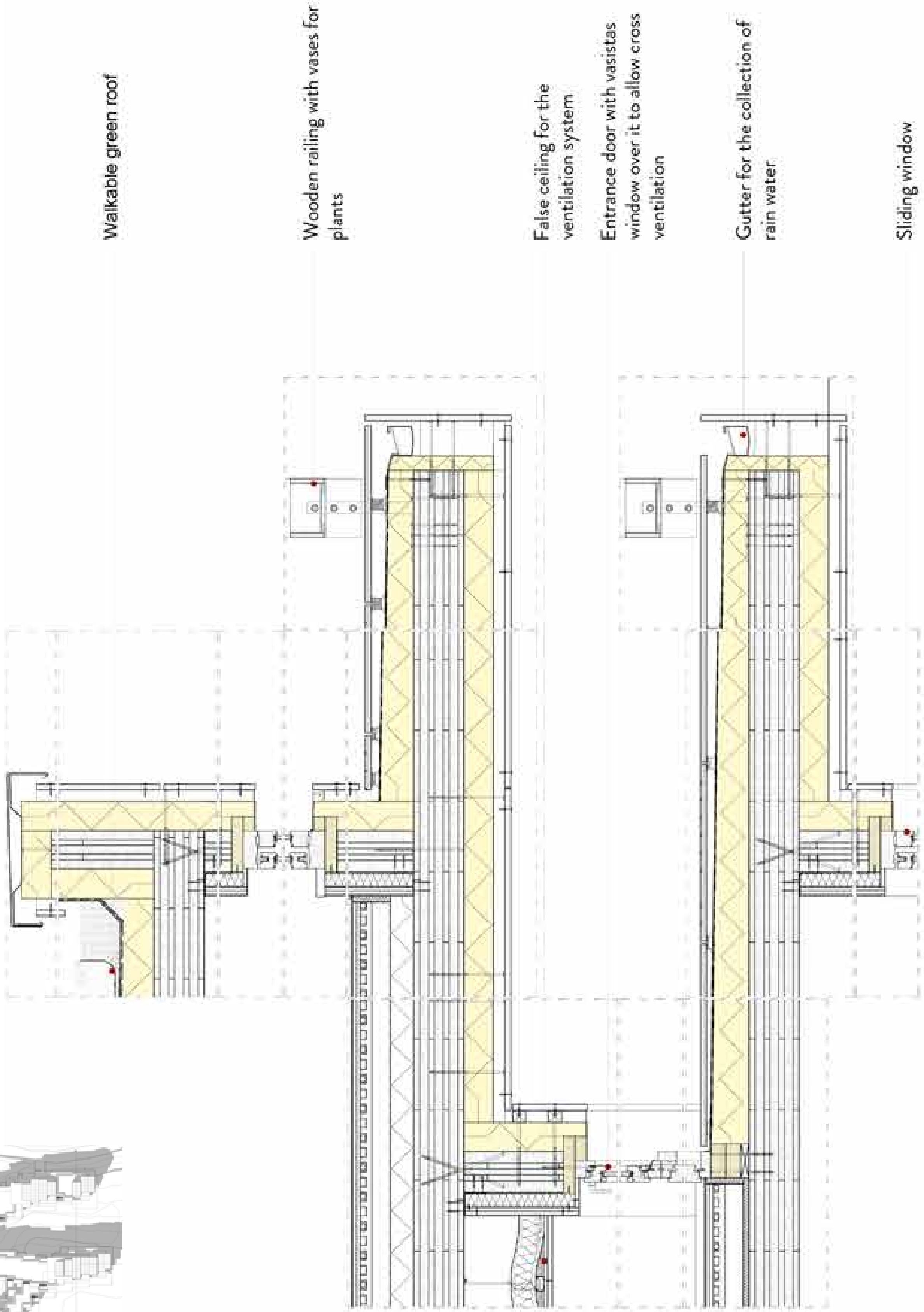


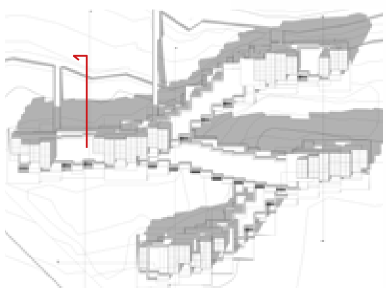


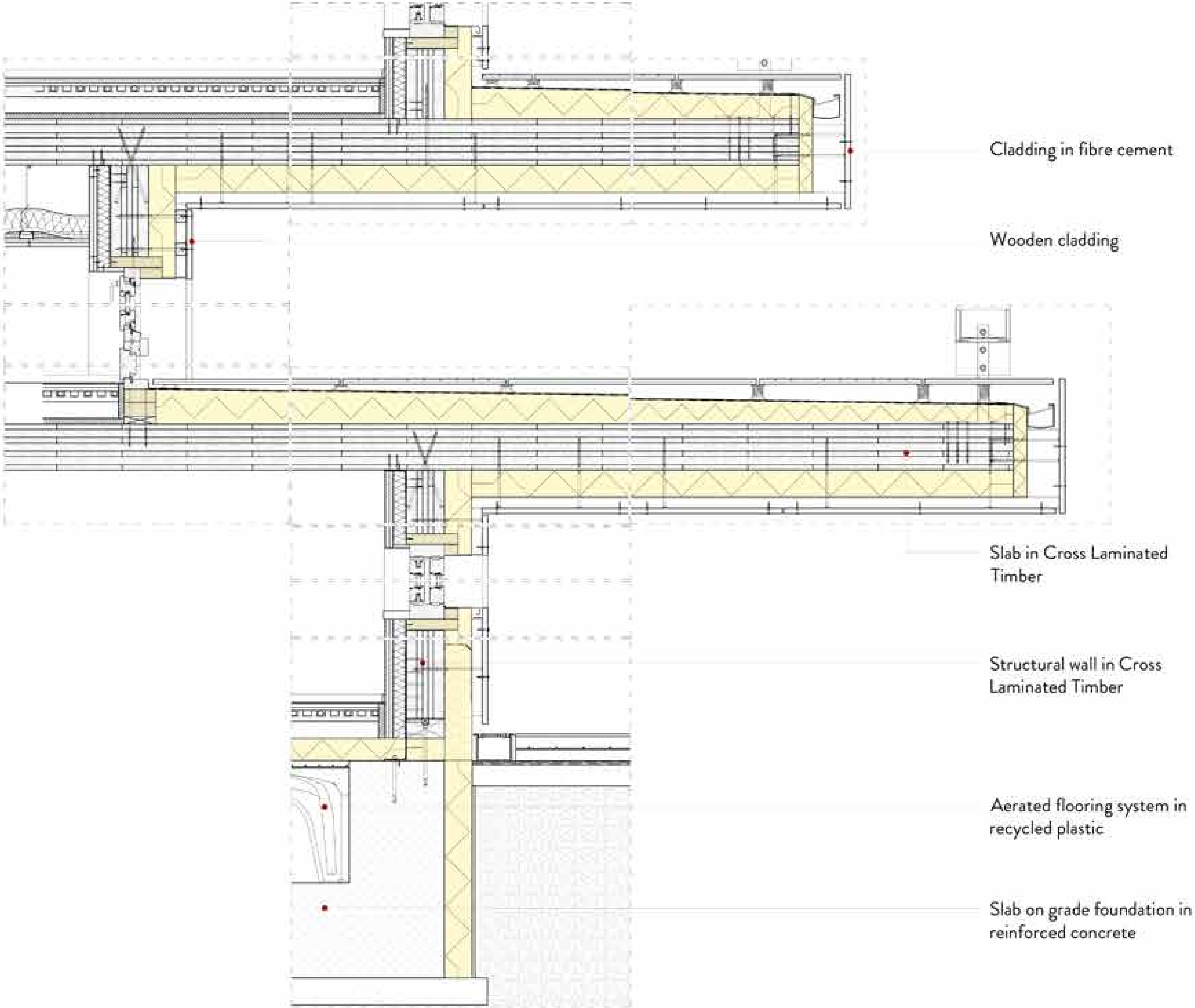

Floating floor in ceramic
Sliding door-window
Slab in Cross Laminated Timber
Sliding door-window
Aerated flooring system in recycled plastic
Slab on grade foundation in reinforced concrete

Board 4.13
Technological section towards Closerola (N-W)

Scale 1:20

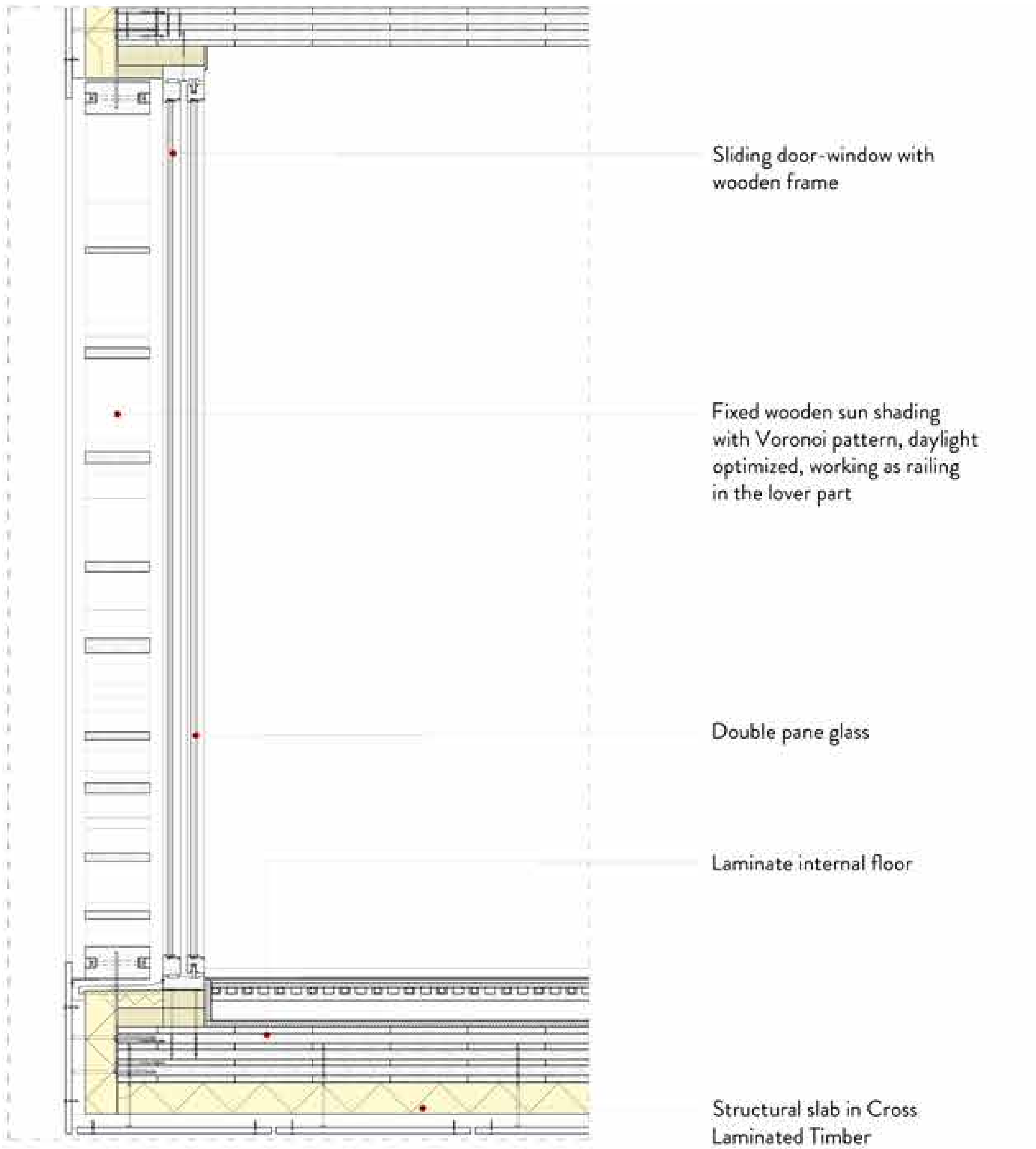


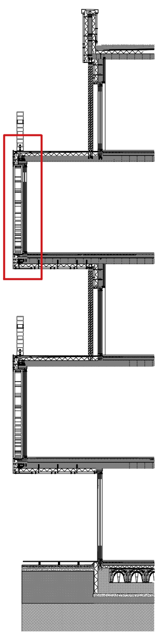



Cladding in fibre cement
Wooden cladding
Slab in Cross Laminated Timber
Structural wall in Cross Laminated Timber
Aerated flooring system in recycled plastic
Slab on grade foundation in reinforced concrete

Board 4.14
Blow up S-E facade, part with Voronoi screen

Scale 1:20





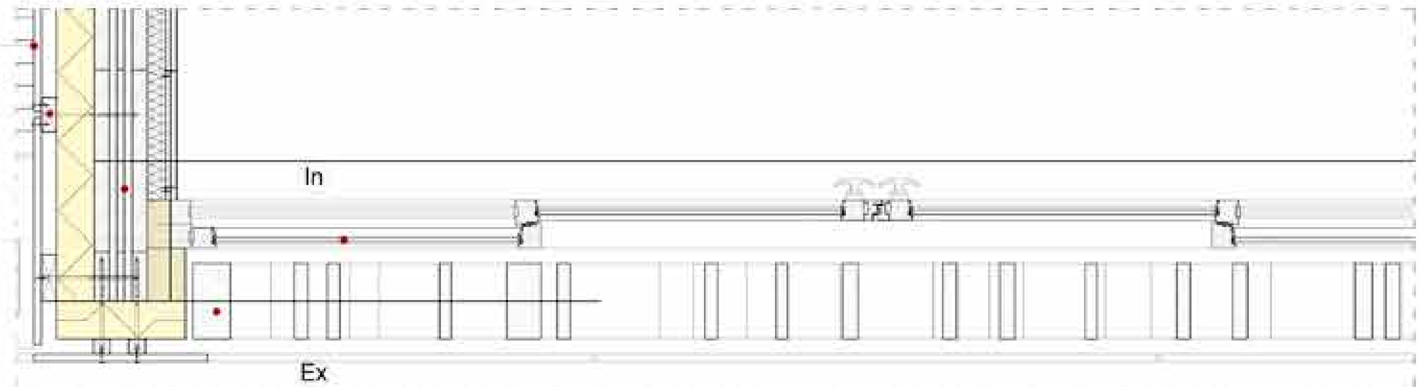
Fibre cement cladding

Wooden batten to support the facade

Structural wall in CLT

Sliding door-window

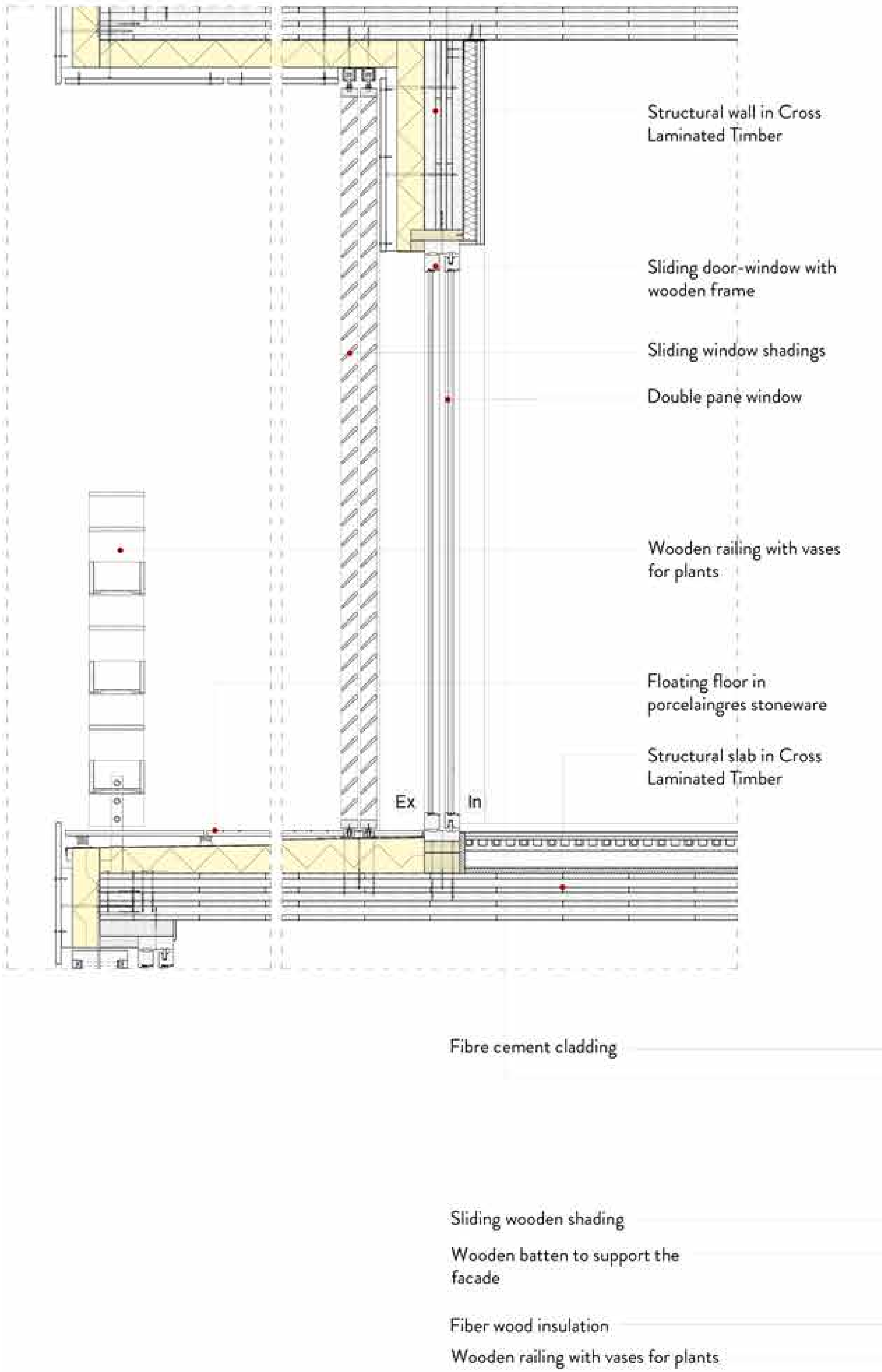
Fixed shading with Voronoi pattern

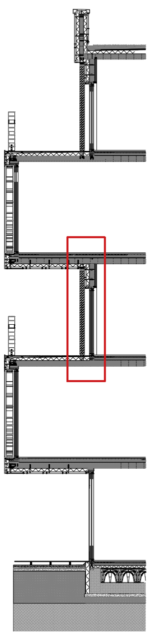


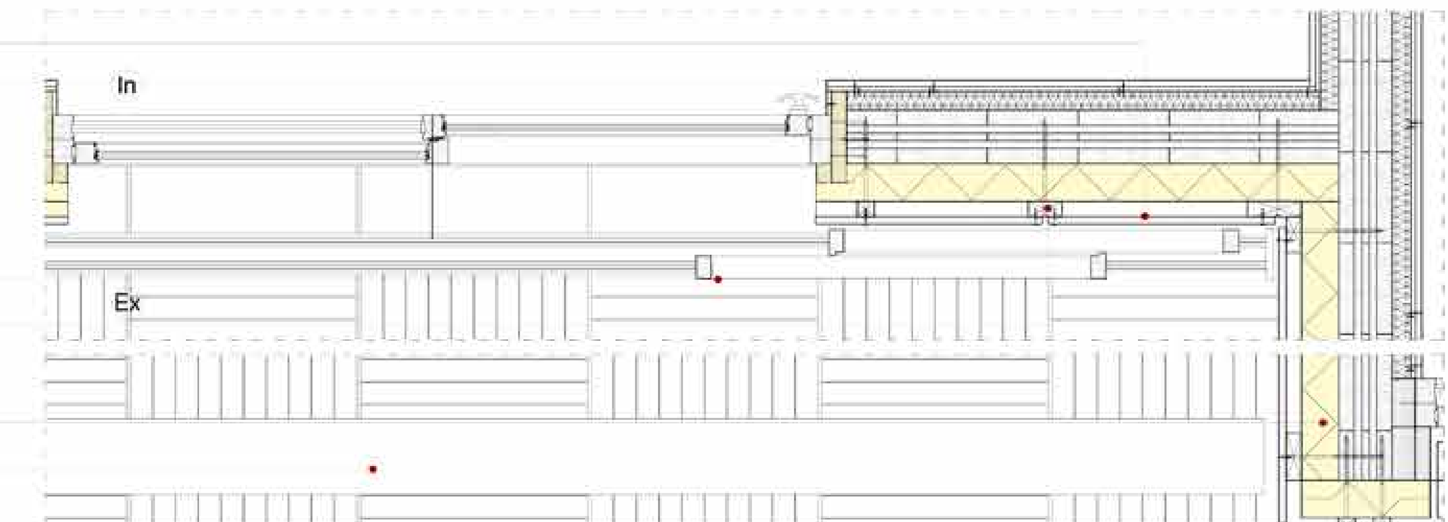
In
Ex

Board 4.15
Blow up S-E facade, part with terrace

Scale 1:20

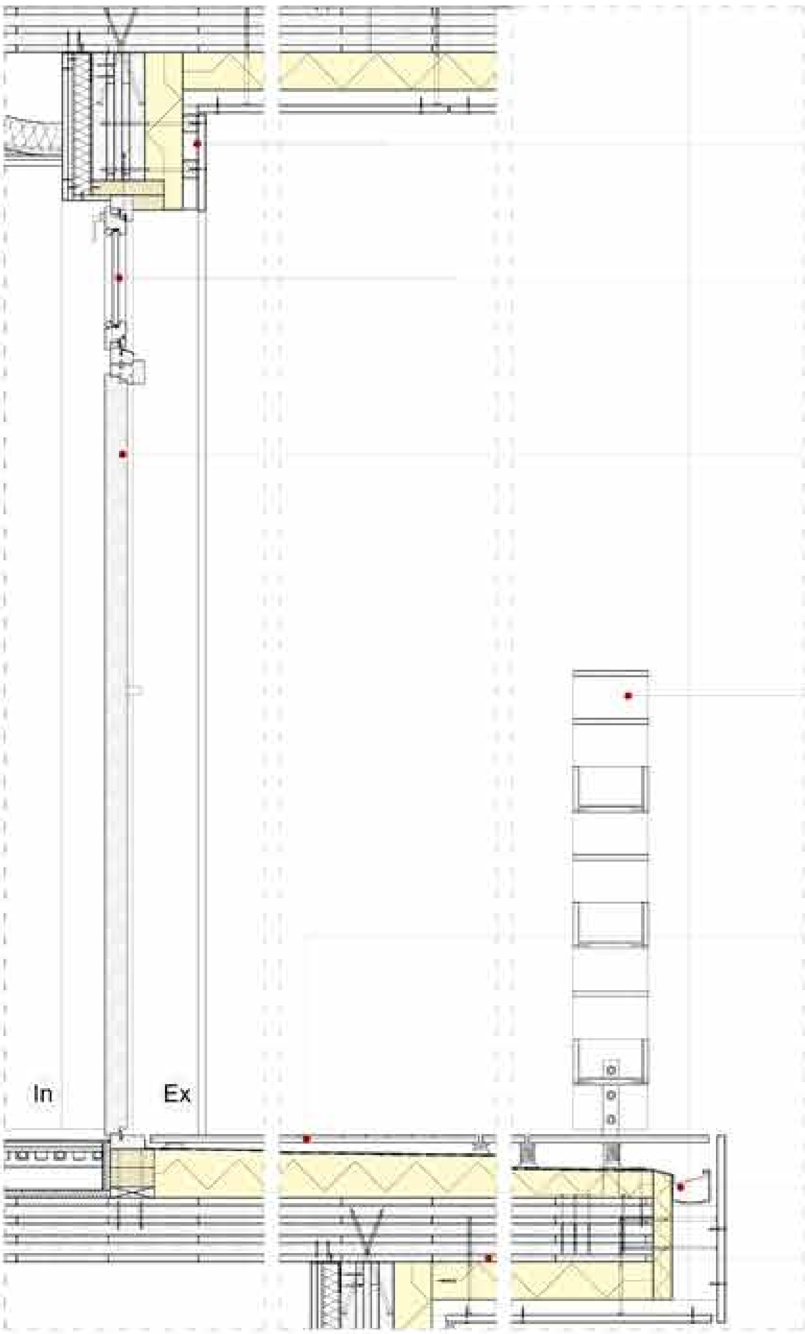





In
Ex

Board 4.16
Blow up N-W facade, part with door and window

Scale 1:20



Wooden cladding

Vasistas window to allow cross ventilation

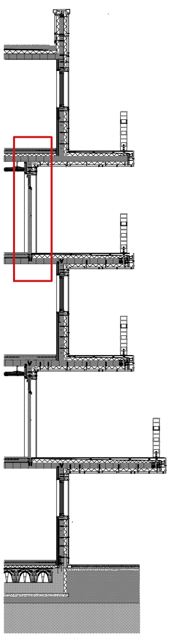
Wooden entrance door

Wooden railing with vases for plants

Floating floor in porcelaingres stoneware

Gutter for the collection of rain water

Structural slab in Cross Laminated Timber



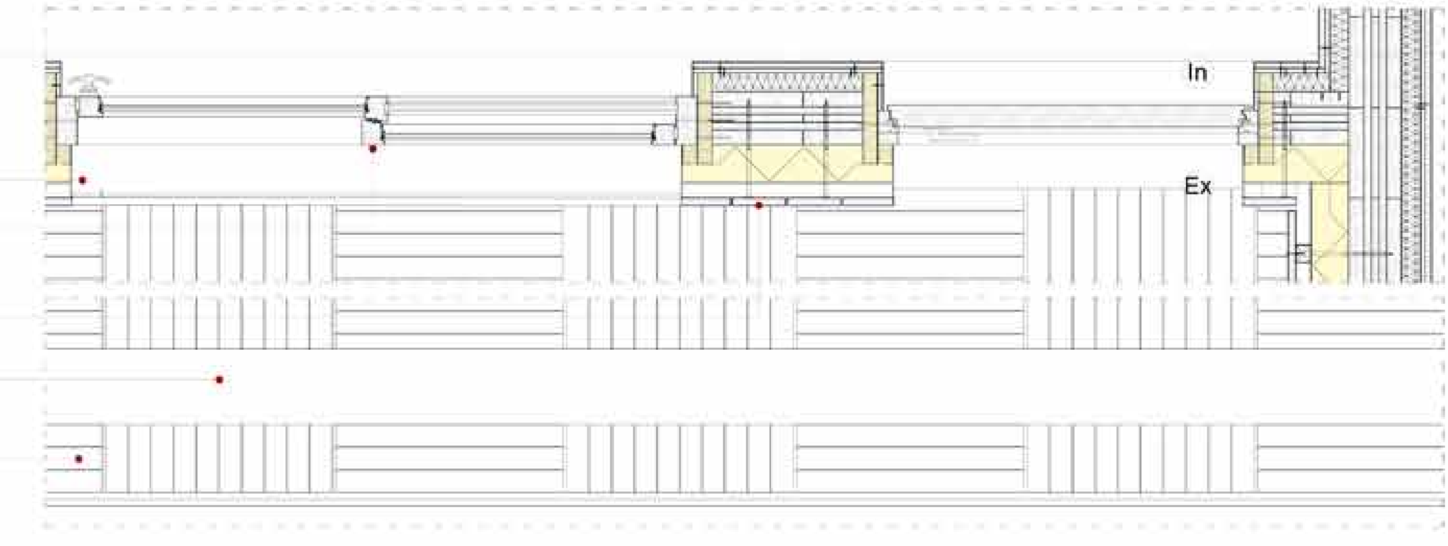
Fibre cement cladding

Sliding double pane window

Wooden cladding

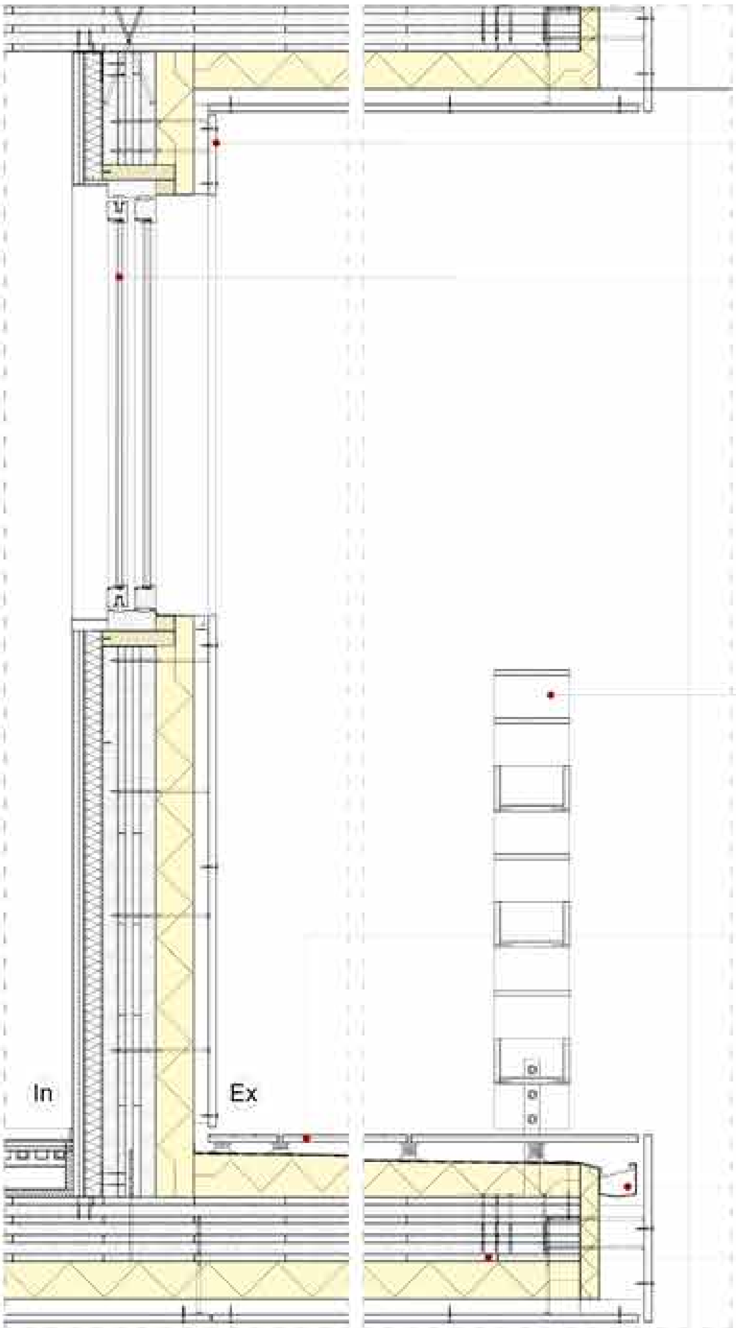
Wooden railing with vases for plants

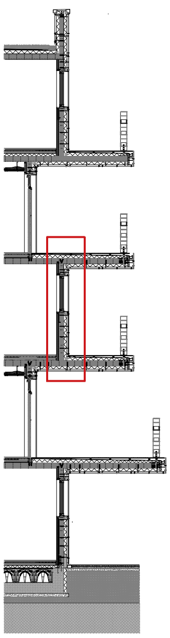
Floating floor in porcelaingres stoneware


In
Ex

Board 4.17
Blow up N-W facade, part with window

Scale 1:20





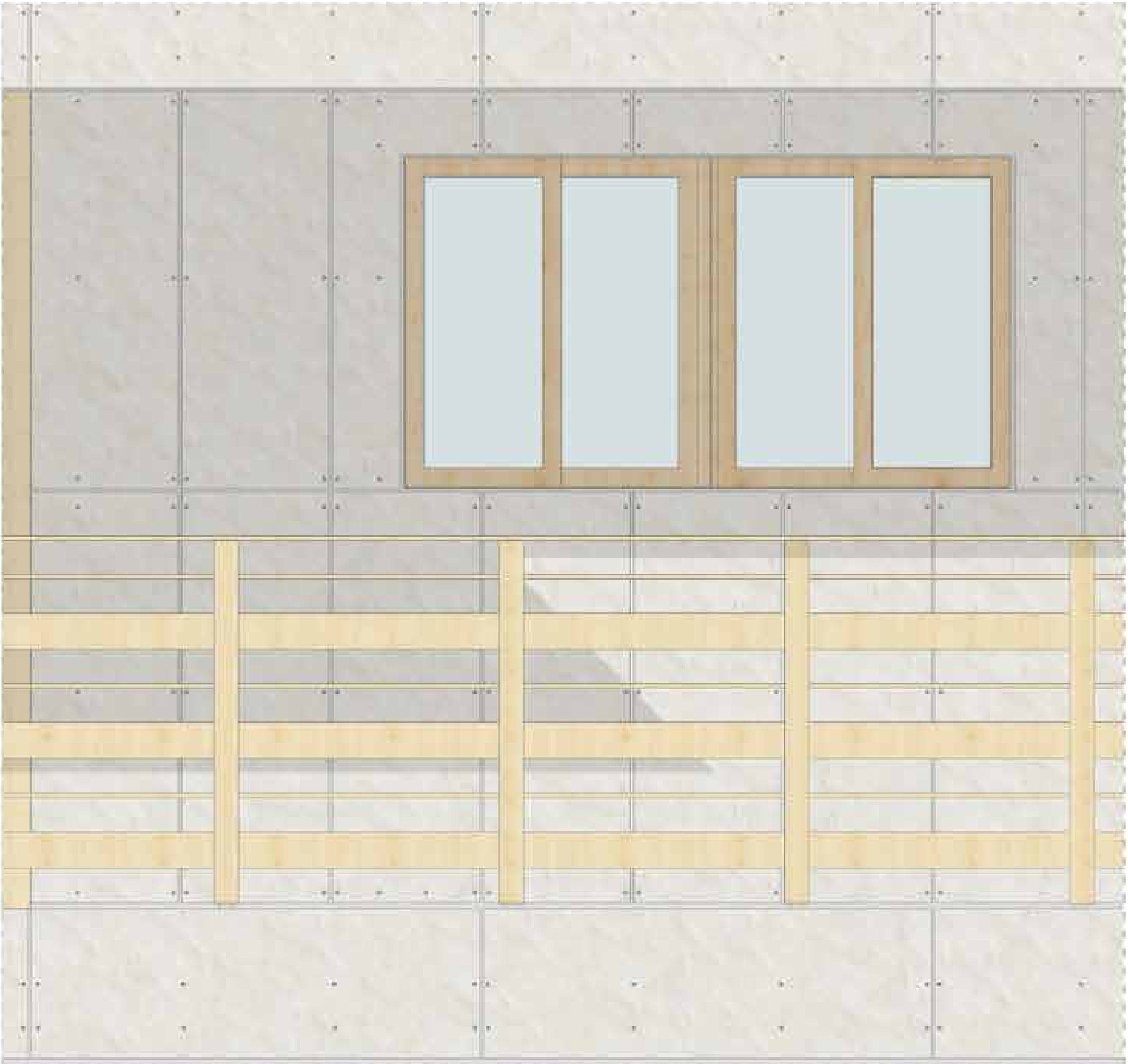
Wooden batten to support the facade

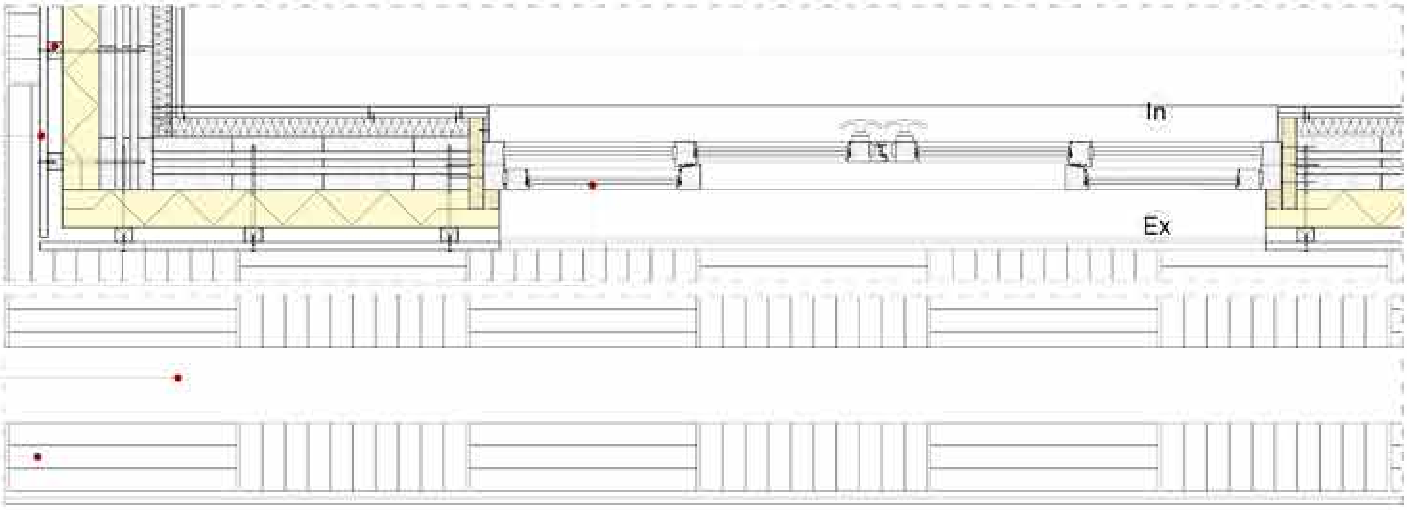
Fibre cement cladding

Sliding double pane window

Wooden railing with vases for plants

Floating floor in porcelaingres stoneware

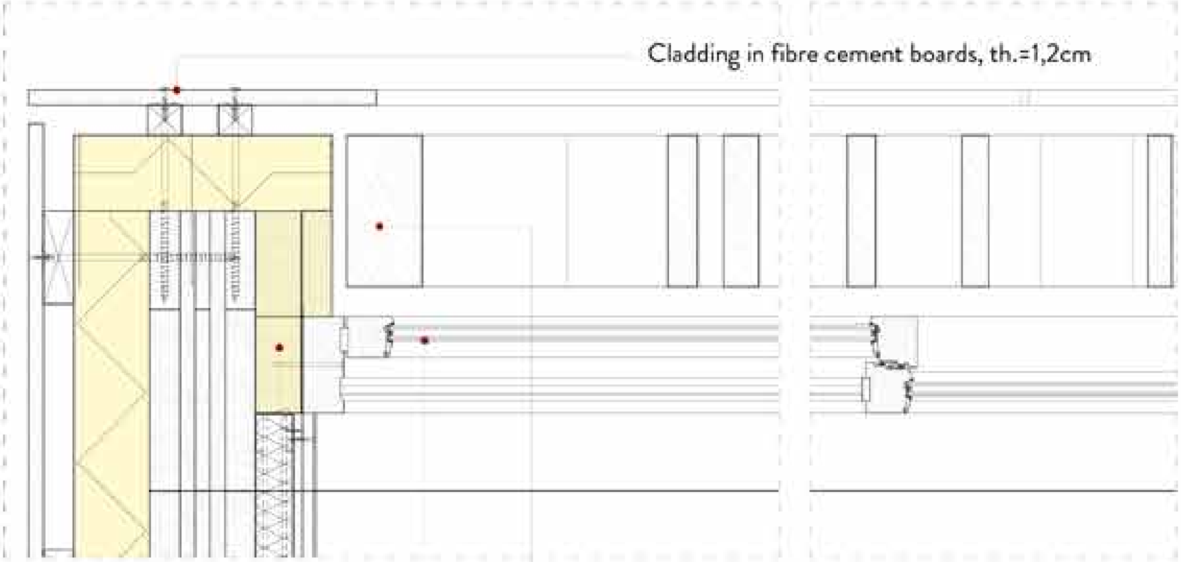



In
Ex

Board 4.18
Horizontal section of half unit (module with Voronoi screen and door)

Scale 1:10

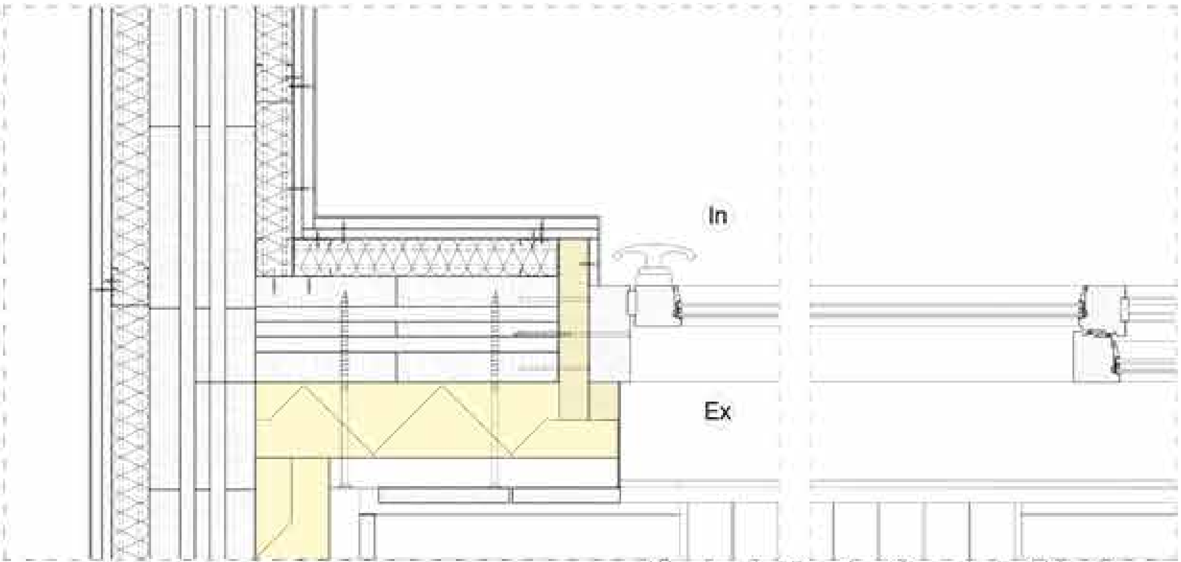
Cladding in fibre cement boards, th.=1,2cm



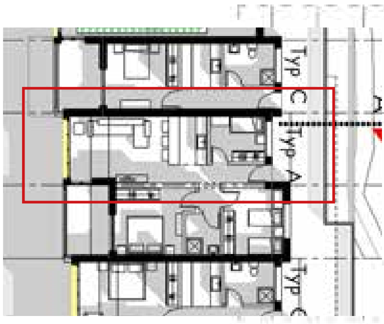
Fixed wooden sun shading with Voronoi pattern, daylight optimized, working as railing in the lower part, width=20cm, th.=3cm

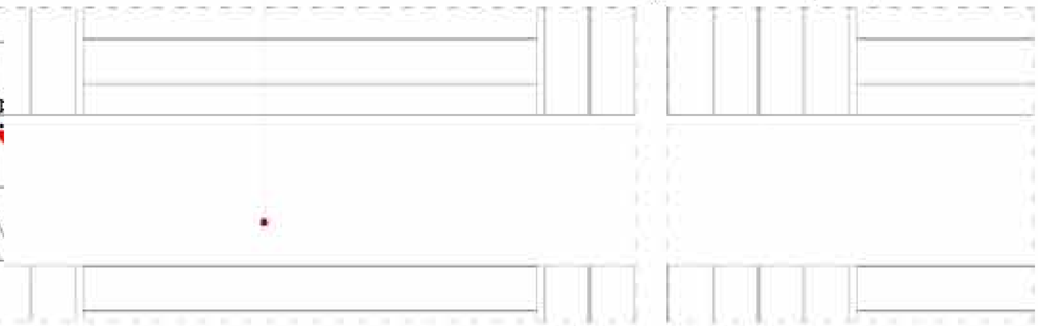
Door window with wooden frame and sliding opening

Thermal insulating block system in extruded polystyrene (XPS) covered with a fiber cement layer, th.=4cm, ρ=35kg/m3, λ=0.030W/mK

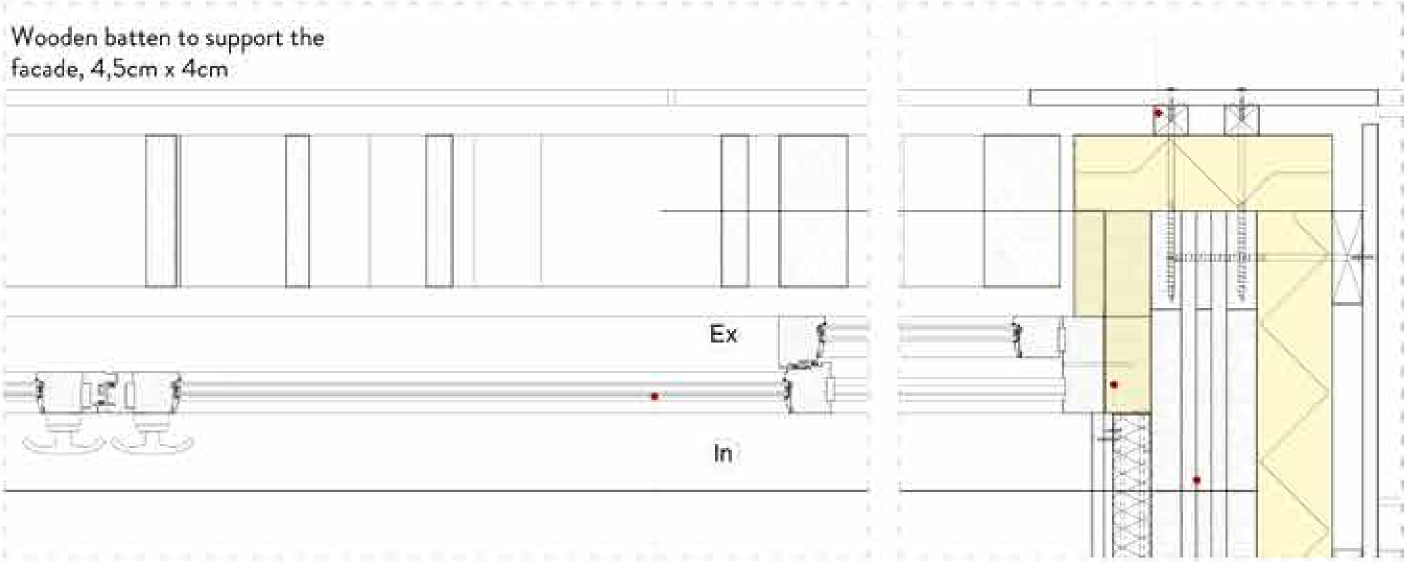


Wooden cladding, th.=1,2cm, plank width=12cm
Wooden railing with vases for plants, width=20cm





Wooden batten to support the facade, 4,5cm x 4cm



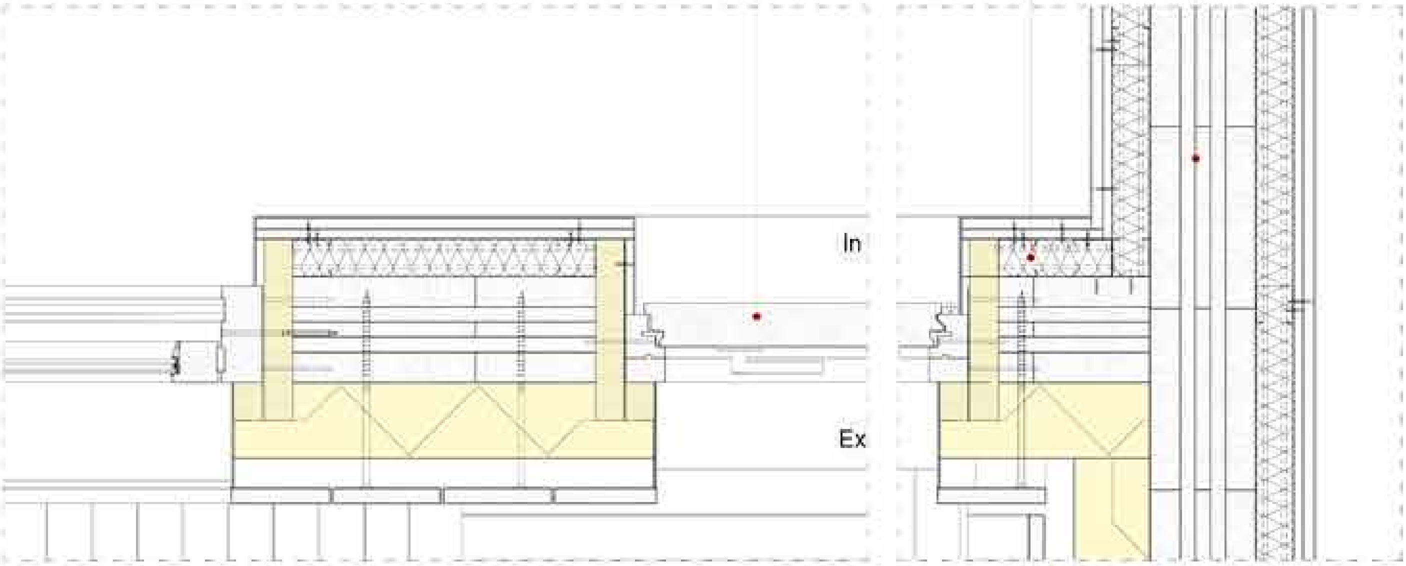
Double pane glass

Thermal insulating block system in extruded polystyrene (XPS) covered with a fiber cement layer, th.=4cm, ρ=35kg/m3, λ=0.030W/mK

Structural wall in Cross Laminated Timber (CLT), 5 layers (40-20-20-20-40 mm), th.=14cm

Thermal and acoustic insulation layer in rock wool, th.=5cm, ρ=40kg/m3, λ=0.035W/mK

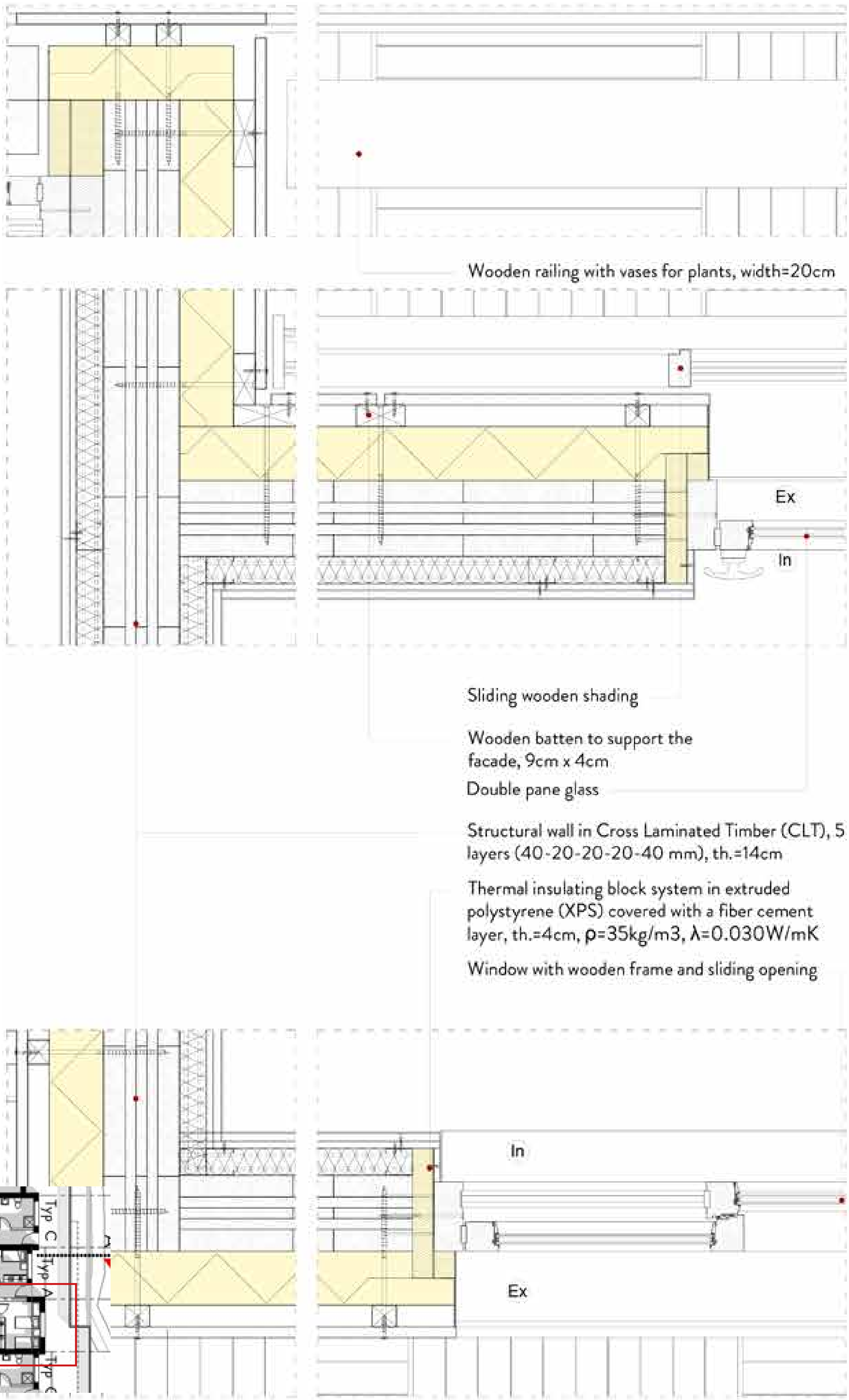
Wooden entrance door



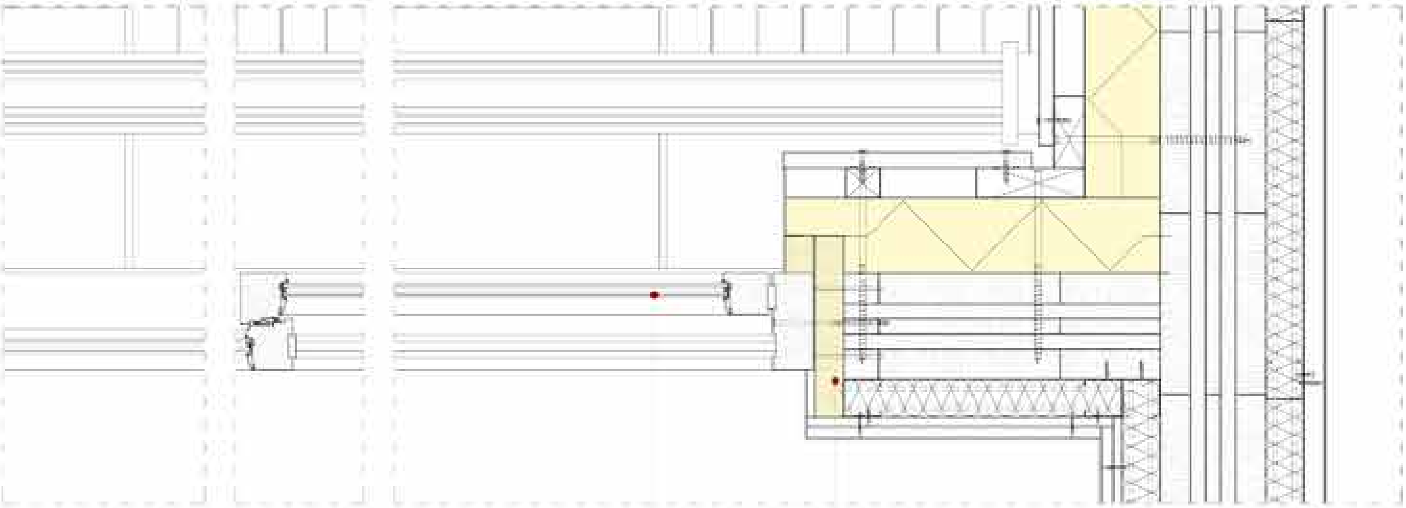
Floating floor in porcelaingres stoneware, dim. 60cm x 60cm, th.=2cm

Board 4.19
Horizontal section of half unit (module with terrace and windowr)

Scale 1:10



Floating floor in porcelaingres stoneware, dim. 60cm x 60cm, th.=2cm



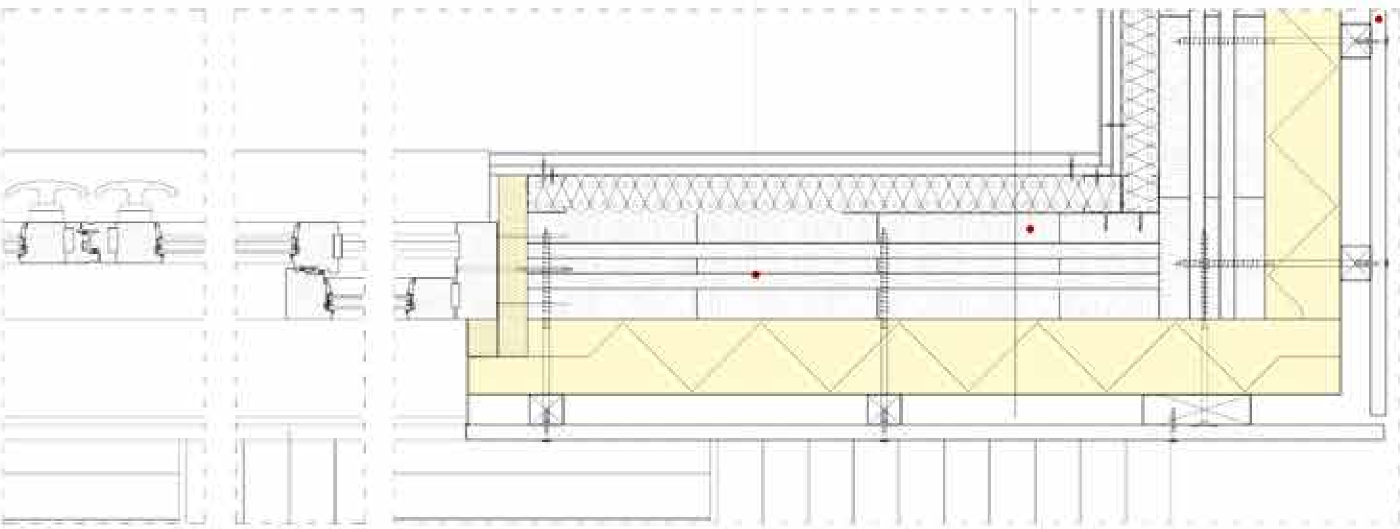
Door window with wooden frame and sliding opening

Thermal insulating block system in extruded polystyrene (XPS) covered with a fiber cement layer, th.=4cm, ρ=35kg/m3, λ=0.030W/mK

Cladding in fibre cement boards, th.=1,2cm

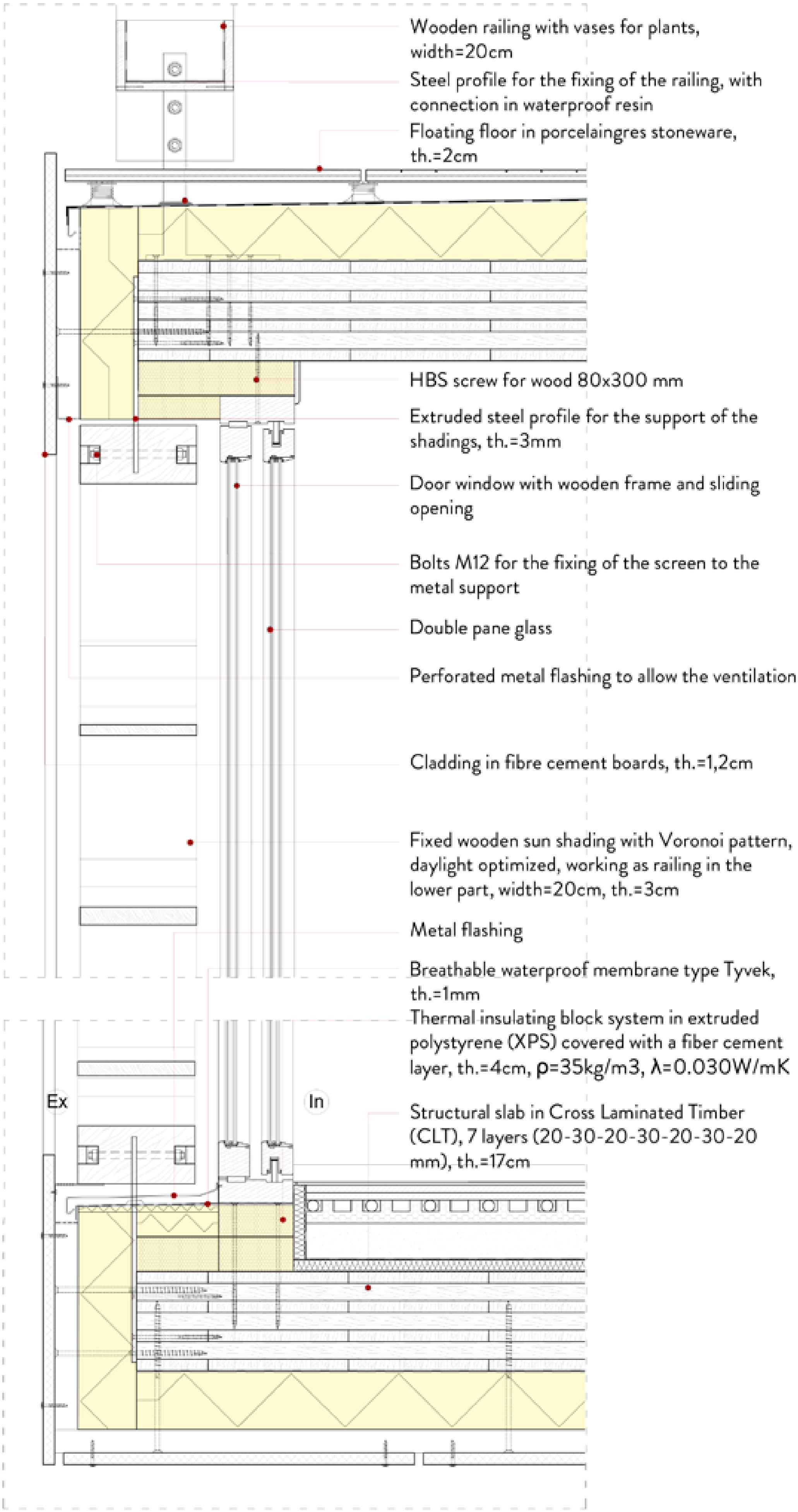
Thermal and acoustic insulation layer in rock wool, th.=5cm, ρ=40kg/m3, λ=0.035W/mK

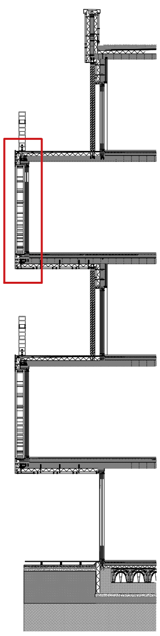
Wooden entrance door



Board 4.20
Vertical node of the S-E facade, part with Voronoi screen

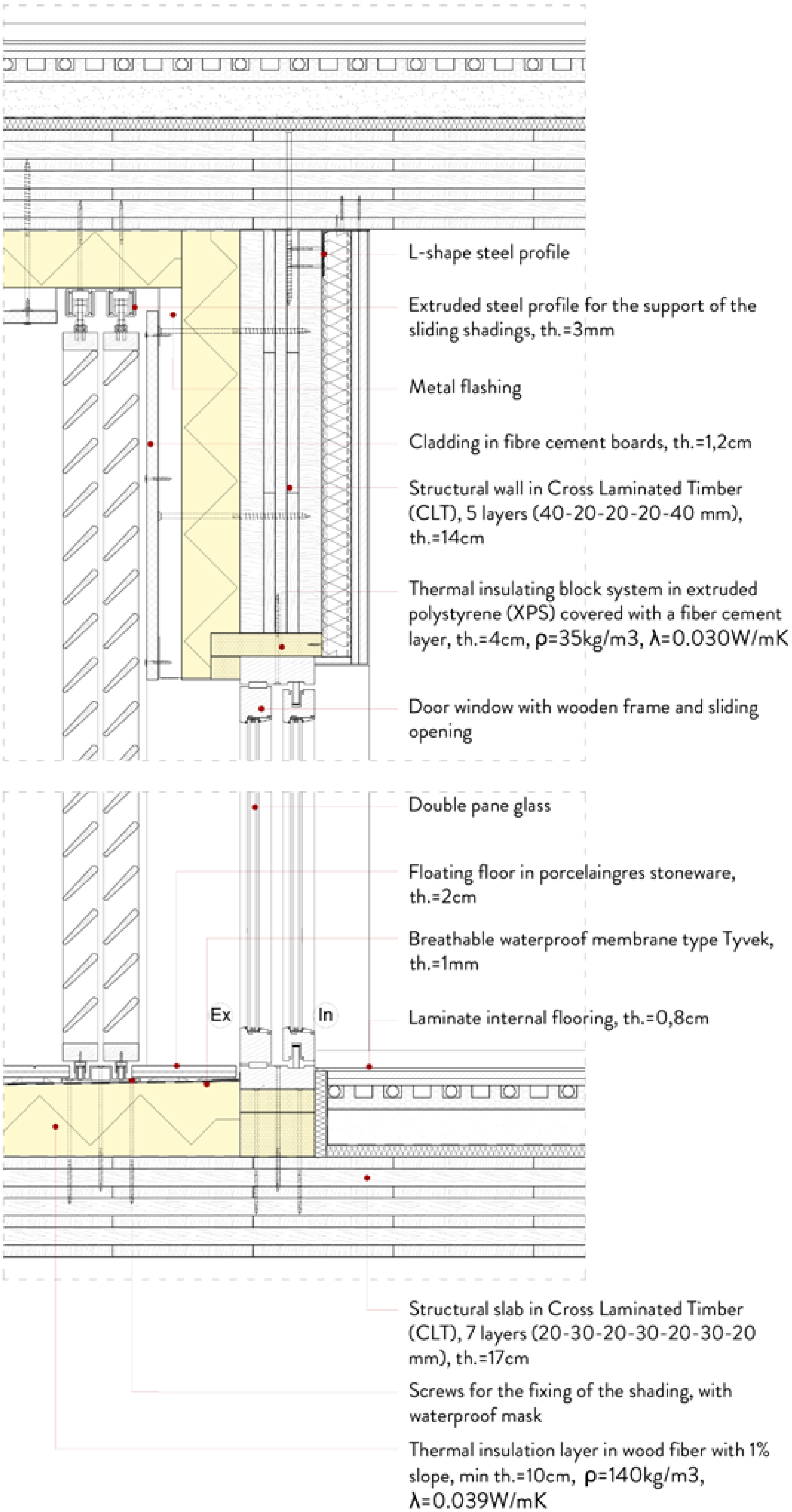
Scale 1:10

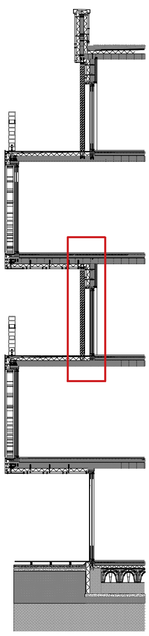




Board 4.21
Vertical node of the S-E facade, part with terrace

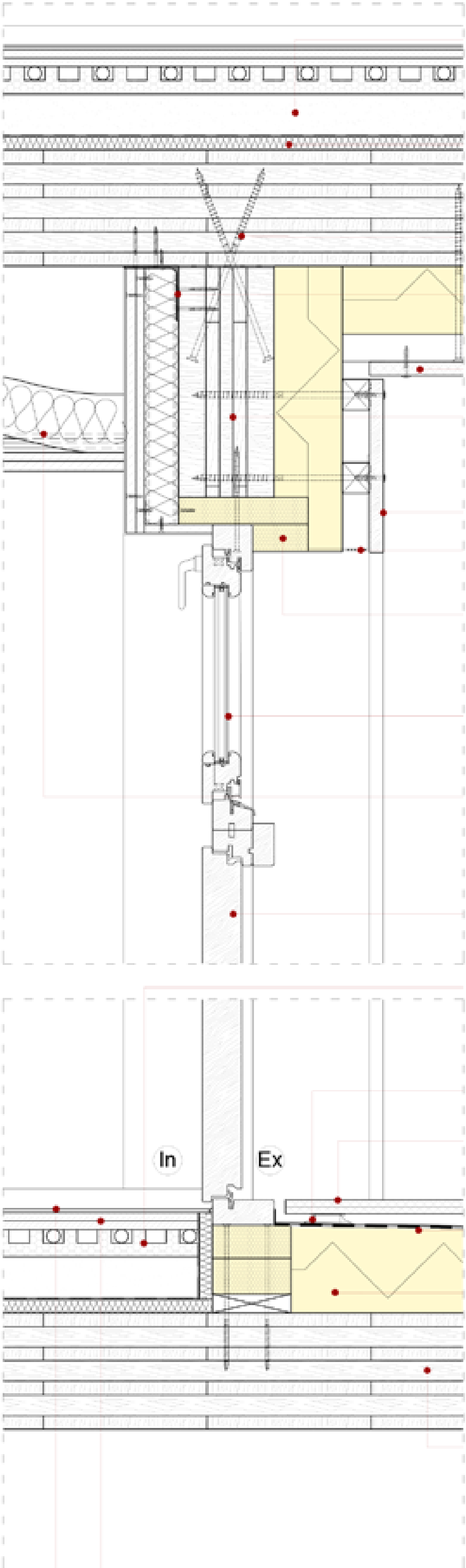
Scale 1:10





Board 4.22
Vertical node of the N-W facade, part with dood

Scale 1:10



Granular dry screed for systems on polyethylene containing layer, th.=6cm, ρ=400kg/m3, λ=0.09W/mK

Acoustic insulation layer anti-footstep, th.=2cm, ρ=100kg/m3, λ=0.036W/mK

HBS screw for wood 80x300 mm

L-shape steel profile

Cladding in fibre cement boards, th.=1,2cm

Structural wall in Cross Laminated Timber (CLT), 5 layers (40-20-20-20-40 mm), th.=14cm

Wooden cladding, th.=1,2cm, plank width=12cm

Perforated metal flashing

Thermal insulating block system in extruded polystyrene (XPS) covered with a fiber cement layer, th.=4cm, ρ=35kg/m3, λ=0.030W/mK

Window with wooden frame with vasistas opening to allow the cross ventilation

False ceiling with cavity for systems, insulating layer and double pasterboard with sandwiched vapour barrier

Wooden entrance door

Radiant floor heating system, th.=4cm, ρ=20kg/m3, λ=0.04W/mK

Adjustable plastic support for floating floors

Floating floor in porcelaingres stoneware, th.=2cm

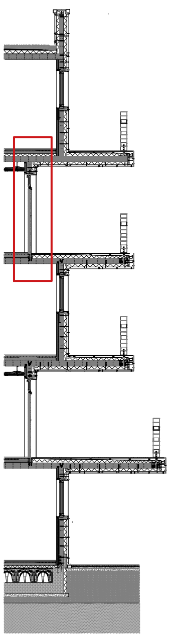
Waterproof polymer bitumen membrane, th.=5mm

Thermal insulation layer in wood fiber with 1% slope, min th.=10cm, ρ=140kg/m3, λ=0.039W/mK

Structural slab in Cross Laminated Timber (CLT), 7 layers (20-30-20-30-20-30-20 mm), th.=17cm

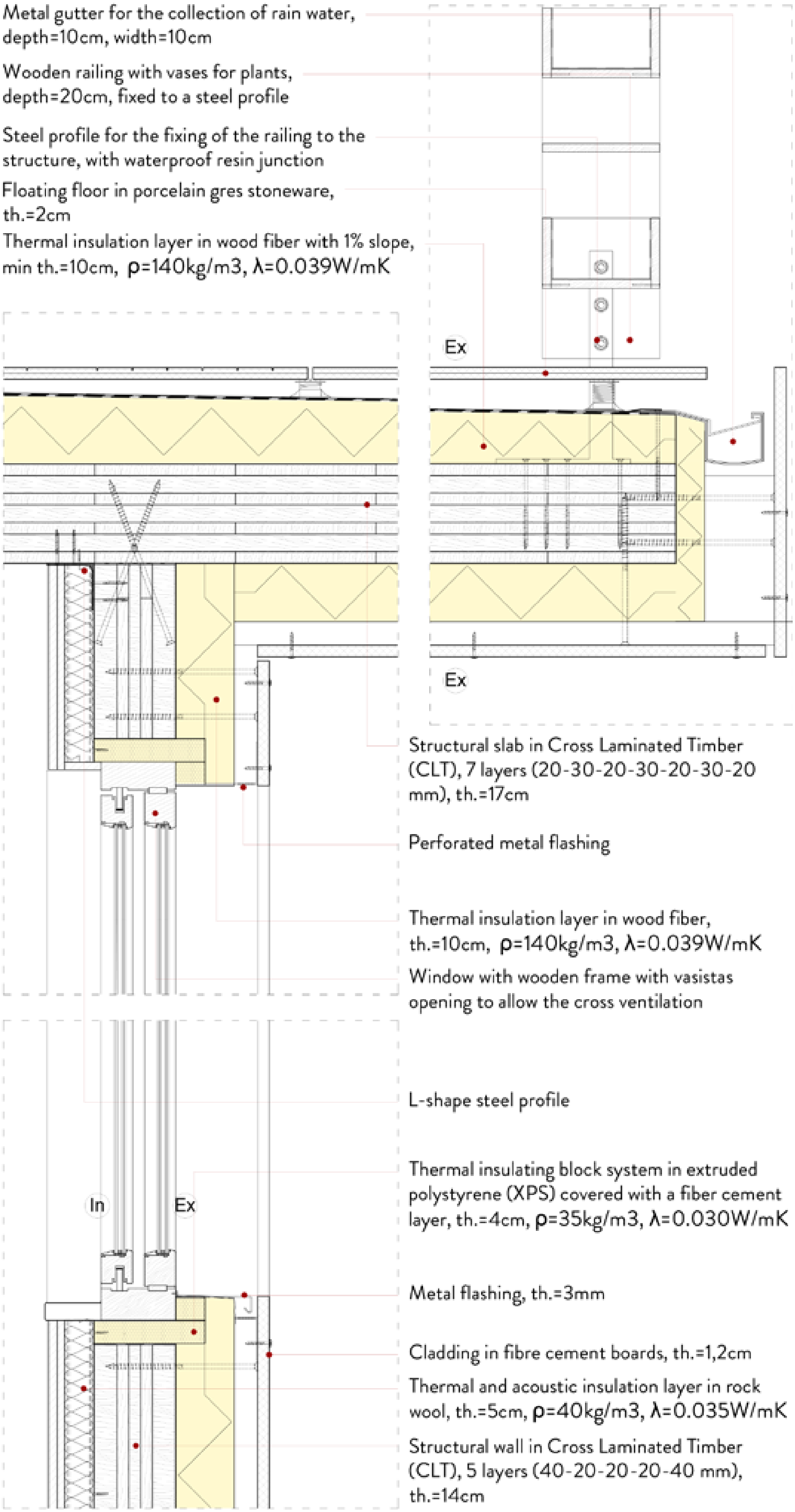
Double gypsum flooring panel to support the floor, th.=1.25cm+1.25cm, ρ=1100kg/m3, λ=0.38W/mK

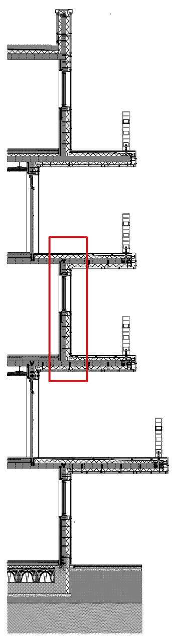
Laminate flooring, th.=0.8cm



Board 4.23
Vertical node of the N-W facade, part with window

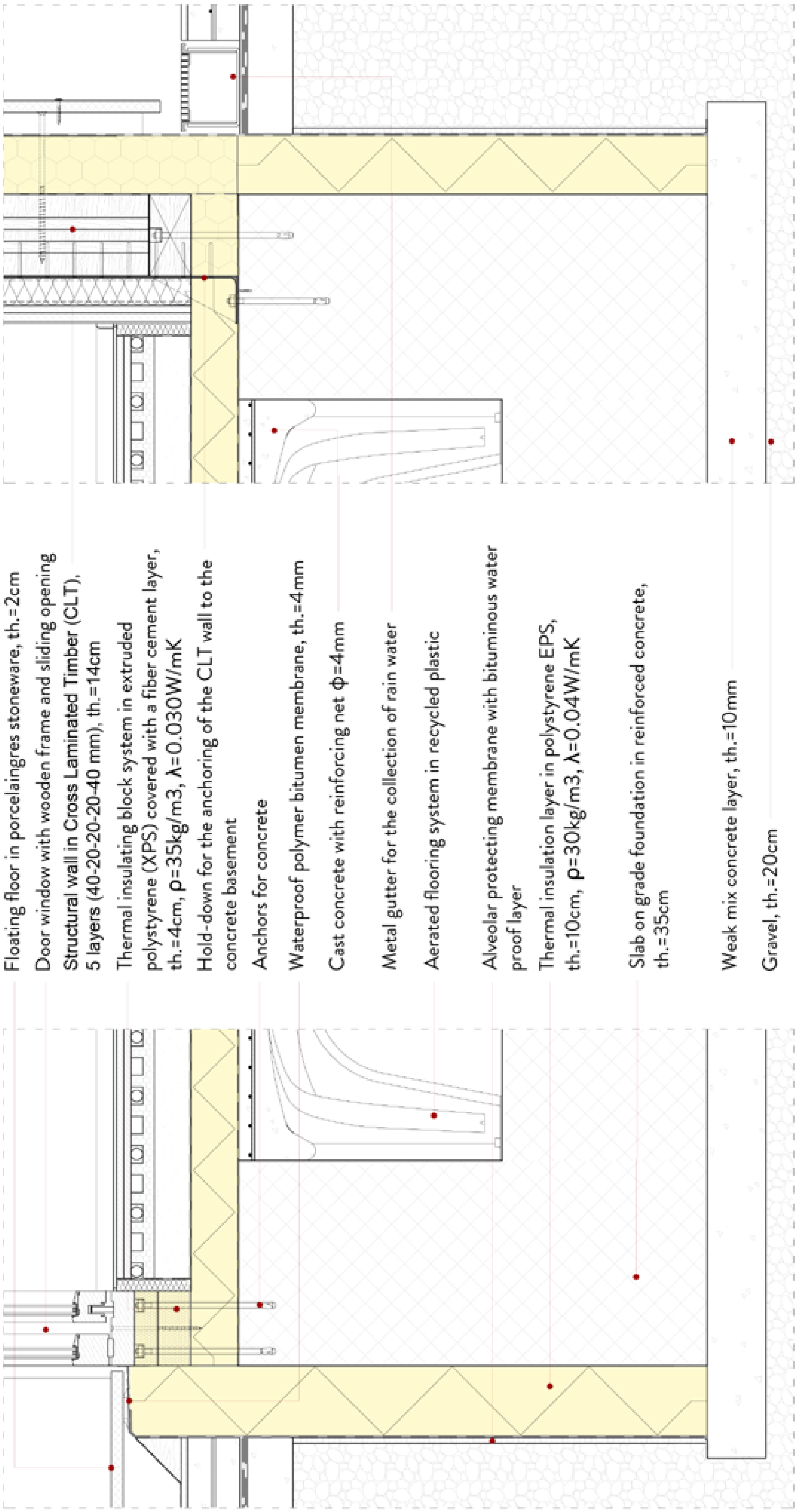
Scale 1:10

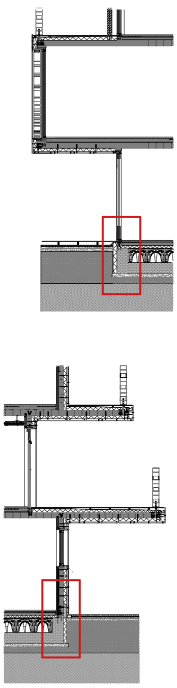




Board 4.24
Vertical node of the foundations

Scale 1:10





4.5 Building energy

The energy analysis of the final building design was made throw the software Sefaira, that allows a preliminary calculation of the energy use of buildings and offers the possibility to compare different strategies according to the changes in consumptions. It is therefore useful to see the improvements in the building performance with the variation of parameters such as walls U-value, Solar Heat Gain Coefficient of windows and also with the addition of passive strategies.

4.5.1 Object of the analysis

It was chosen to analyse only 18 modules out of the entire number (...), because otherwise the model would have been too large and heavy for the software.
The 18 modules selected were chosen considering that in the entire building we have modules that do not have the same number of surfaces exposed to the external air. In particular, we have the following cases with respective percentages:

- 16% With the floor in contact with the ground
- 52% With one surface exposed to external air (in addition to the Barcelona (S-E) and Colserola (N-W) façades that are exposed to the external for all the modules)
- 2% with two surfaces exposed to external air (in addition to the Barcelona (S-E) and Colserola (N-W) façades that are exposed to the external for all the modules)

So the same proportions were kept in the building part that was considered for the analysis.

Figure 4.97 Highlighting of the modules considered for the energy calculation

The 18 modules consist of a gross floor area of around 787 m2 and a gross volume of 2440 m3.

4.5.2 Modelling and setting

The first step was to model the building, creating a model at the same time simple, but enough detailed to get reliable results.
The selected part was modelled considering external walls, internal walls, glazings, roofs and floors, while all the rest was simplified and tagged as shading. The window Voronoi screen was simplified as a grid pattern and of course considered as shading

for Sefaira.
The model created was then uploaded to the Sefaira Web Application for the analysis.

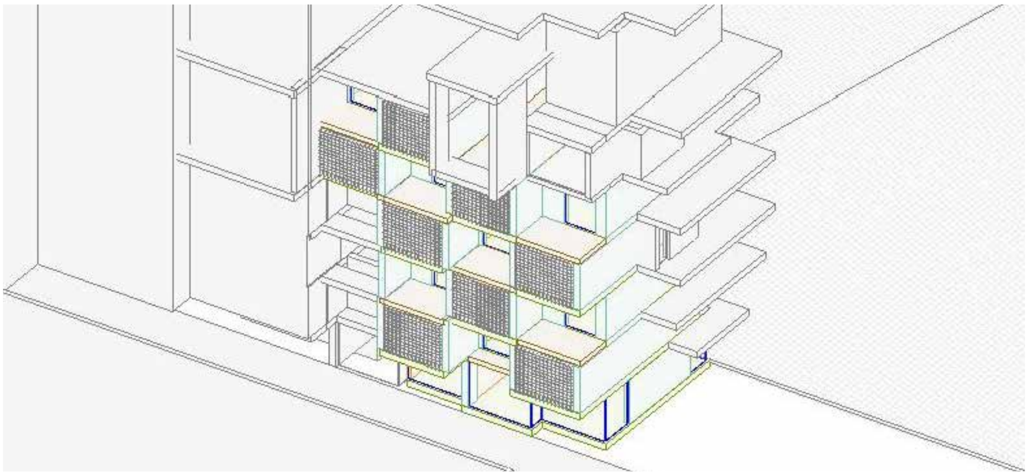


Figure 4.98 Simplified model in the Sefaira plugin fro Revit

The settings of the schedules and thermal loads were made also referring to the Spanish normative [Annex C of CTE DB-HE, 2013]. And the values selected are reported in the following tables.

Table 4.37 Loads settings

Parameter	Value
Occupant density	20 m^2/person
Equipment Power Density	2 W/m^2
Lighting Power density	3 W/m^2
Outside air rate per person	10 l/s

Table 4.38 HVAC settings

Parameter	Value
Heating set point	20 °C
Cooling set point	26 °C

The starting baseline for the envelope values is based on the suggested thermal transmittances reported in Appendix E of the Documento Basico table E.1 [CTE DB-HE, 2013] together with reasonable assumptions, in order to start from the characteristics of a generic residential building with local standard performances.

Table 4.39 Envelope baseline settings

Parameter	Value
U wall [W/m^2K]	0.29
U roof [W/m^2K]	0.23
U floor [W/m^2K]	0.36
U windows [W/m^2K]	2
Solar Hear Gain Coefficient	0.5
Infiltration rate [l/s m]	2

The values of the enveloped where then improved with the characteristics that were selected in the project and also other passive and active strategies were adopted. In the end it was analysed the energy performance of the building comparing it to the performance obtained with the initial baseline.

The characteristics of the final envelope are:

Parameter	Value
U wall [W/m²K]	0.18
U roof [W/m²K]	0.23
U floor [W/m²K]	0.19
U windows [W/m²K]	1.3
Solar Hear Gain Coefficient	0.5
Infiltration rate [l/s m]	1

Table 4.40 Envelope final settings

After the improvements regarding the envelope it was set the natural ventilation, considering the openable elements present in the building, and in the end the PV panels were added.
It has to be considered that not all the adopted strategies were inserted in the calculation, because of the limits of the software. In particular it was not possible to compute the effect of water solar panels, and heat pumps.

4.5.3 Results' analysis

4.5.3.1 Passive strategies: "reducing before producing"

First of all it was analysed the effect of improvements in the building envelope and the changes in energy consumptions that they implied.
It can be seen that they have a big impact in reducing the heating consumptions, but they also increase slightly the cooling consumptions. When it is added the natural cross ventilation, the cooling energy gets reduced by more than 80%. Also the HVAC consumption decreases with the addition of the passive strategies.

	HVAC En/m2		CoolingEn/m2/y		HeatingEn/m2/y		EUI	
	kWh/m² per year	red%	kWh/m² per year	red%	kWh/m2 per year	red %	kWh/m2 per year	red%
Basecase	44,53		5,52		27,81		60,22	
S1_Uwall=0.18W/m²K	43,25	-2,9%	5,5	-0,4%	26,6	-4,4%	58,95	-2,1%
S2_Uwindow=1.3W/m²K	40,78	-8,4%	5,52	0,0%	24,23	-12,9%	56,48	-6,2%
S3_Ufloor=0.19W/m²K	44,05	-1,1%	5,58	1,1%	27,25	-2,0%	59,75	-0,8%
S4_Infiltration=1l/sm	38,86	-12,7%	5,58	1,1%	22,29	-19,8%	54,56	-9,4%
ImprovedEnvelope	29,54	-33,7%	5,8	5,1%	13,08	-53,0%	45,24	-24,9%
S5_NatVent	27,85	-37,5%	0,87	-84,2%	22,92	-17,6%	43,55	-27,7%
Envelope+NatVent	16,2	-63,6%	0,88	-84,1%	12,08	-56,6%	***28,76***	**-52,2%**

Table 4.41 Implementation of passive strategies

The following graph shows in particular the effects of the strategies on the cooling and heating consumptions. The envelope improvements are very effective in reducing the heating energy, while the natural ventilation helps reducing the cooling consumptions.

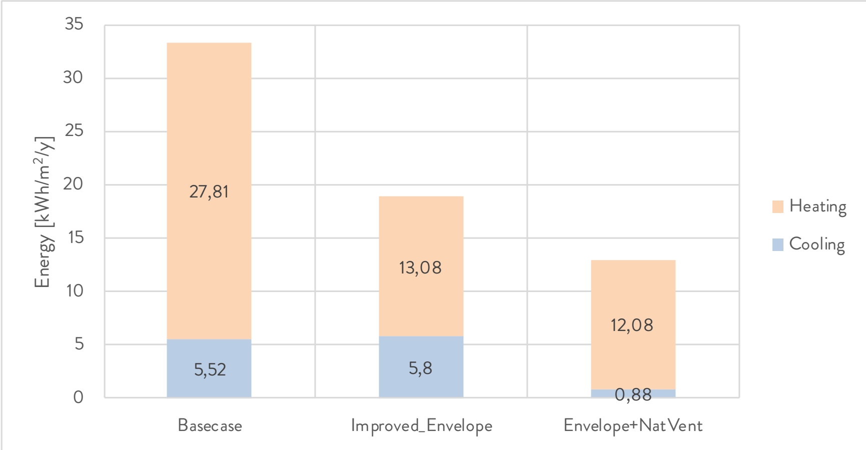


Figure 4.99 Comparison of the annual energy consumptions per unit area for heating and cooling

Looking at the graph of the energy use intensity (EUI), that is the total consumption per unit area, it's visible the reduction given by the envelope strategies from the base case (-25%) and the decrement reached with all the passive strategies together (-52%).

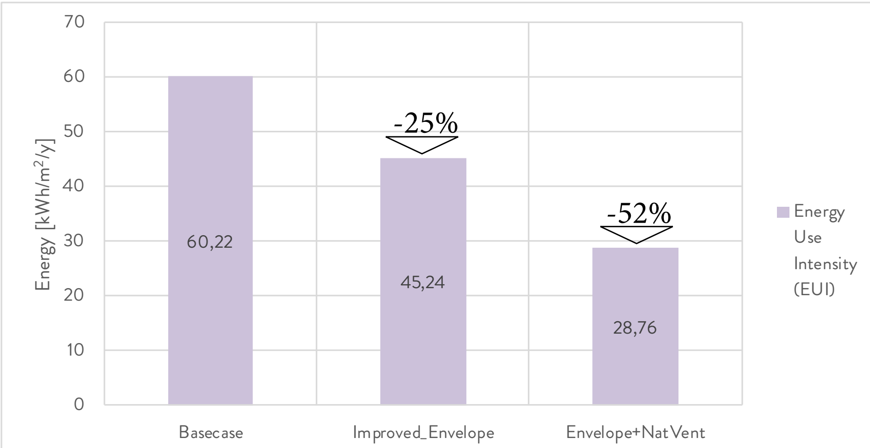


Figure 4.100 Comparison of the total annual energy consumptions per unit area

By means of passive strategies it was possible to reach a total consumption of around 29 kWh/m^2/yr and a CO_2 emission of 14 kg/m2.

4.5.3.2 Addition of active strategies

Concerning active strategies, it was chosen to implement in the building the use of solar panels for the production of domestic hot water (DHW), photovoltaic panels and heat pumps.
It has also the be remembered that the site has a biomass plant that supplies thermal and electric energy to the site and therefore also used in the building and should cover almost the total thermal energy demand of the housing complex with a renewable source. This part of renewable energy can not be calculate by the software, and the same occurs for the solar panels and heat pumps.

So to sum up we have the following RES on which the building will count on:

- Biomass co-generation heat and power district plant
- Heat pumps
- Water solar panels
- PV panels

According to section 5 of the Documento Basico [CTE DB-HE, 2013], there's a minimum electric power that has to be produced on a new building throw photovoltaic panels or other renewable sources. However the requirement is valid only for some building uses that do not consider the residential one. Concerning the commercial use, the power requirement occurs only if the activity covers more than 5000 m^2, which is not our case.

If we consider the "Decreto Legislativo 3 marzo 2011 n. 28 Allegato 3" of the Italian normative, we would have a minimum PV power expressed in kW given by the formula: P = (1/K) S
where

- S is the building footprint: 2930 m^2 for our building
- K is a coefficient: 50 m^2/kW for new buildings

This would lead to P= 2930/50 = 58,6 kW
Considering good performing PV panels with 18% efficiency, they need around 5,1 m^2 for 1 kW. Therefore would be required around 300 m^2 of PV panels.
This quantity would not cover the 50% of the heating cooling and DHW energy of the building, that is another Italian requirement, but this is not the only renewable energy source adopted in the building.

The building roof has a usable area of around 2112 m^2, and the main part of it should be used as cultivation area, as explained in previous chapters. It can be therefore reasonable to cover with PV panels an area of 500 m^2.
Remembering that the energy analysis was performed only on a part of the building, we can consider in proportion to set in the analysed part around 33 m^2 of the total PV area.

In the following graph we can see the building consumptions month by month and the part that can be covered by the PV panels (not by other active strategies).

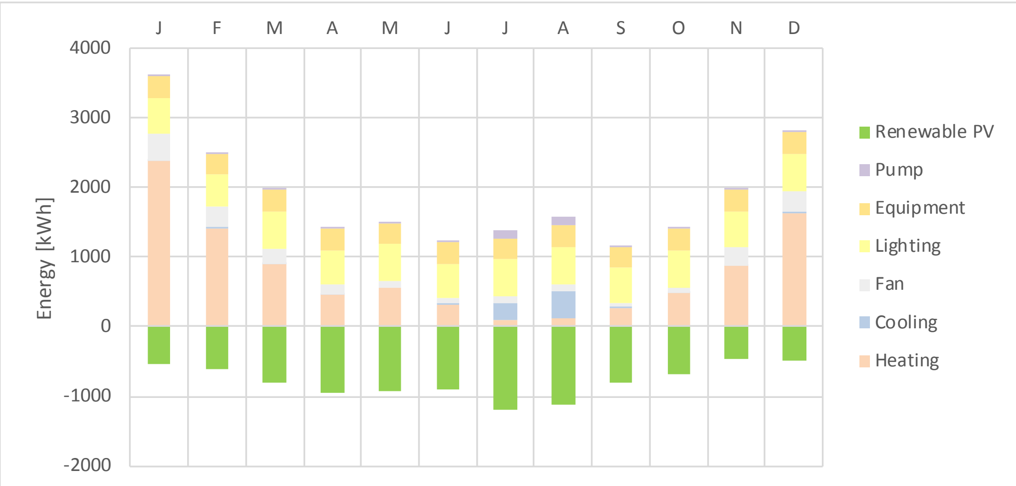
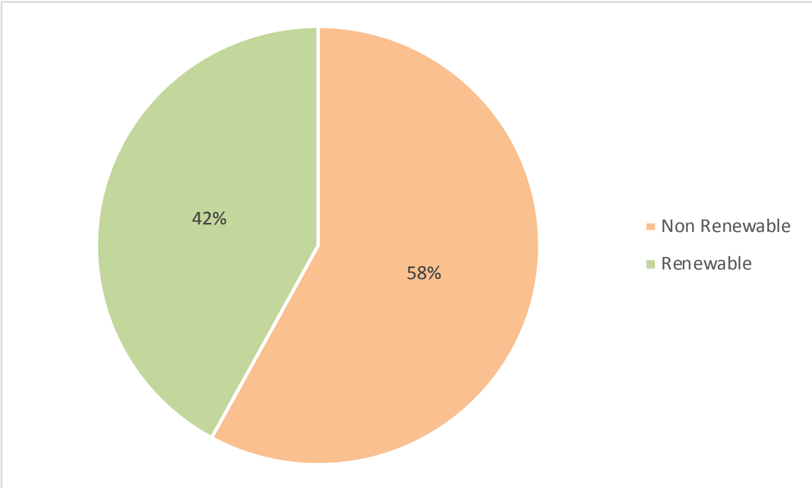


Figure 4.101 Monthly energy consumption per use and PV energy

If we look at the PV contribute in the entire year, we can see that with the addition of the panels we have a renewable energy production that covers 42% of the consumptions.

Figure 4.102 Renewable and non-renewble energy fraction in the entire year with PV

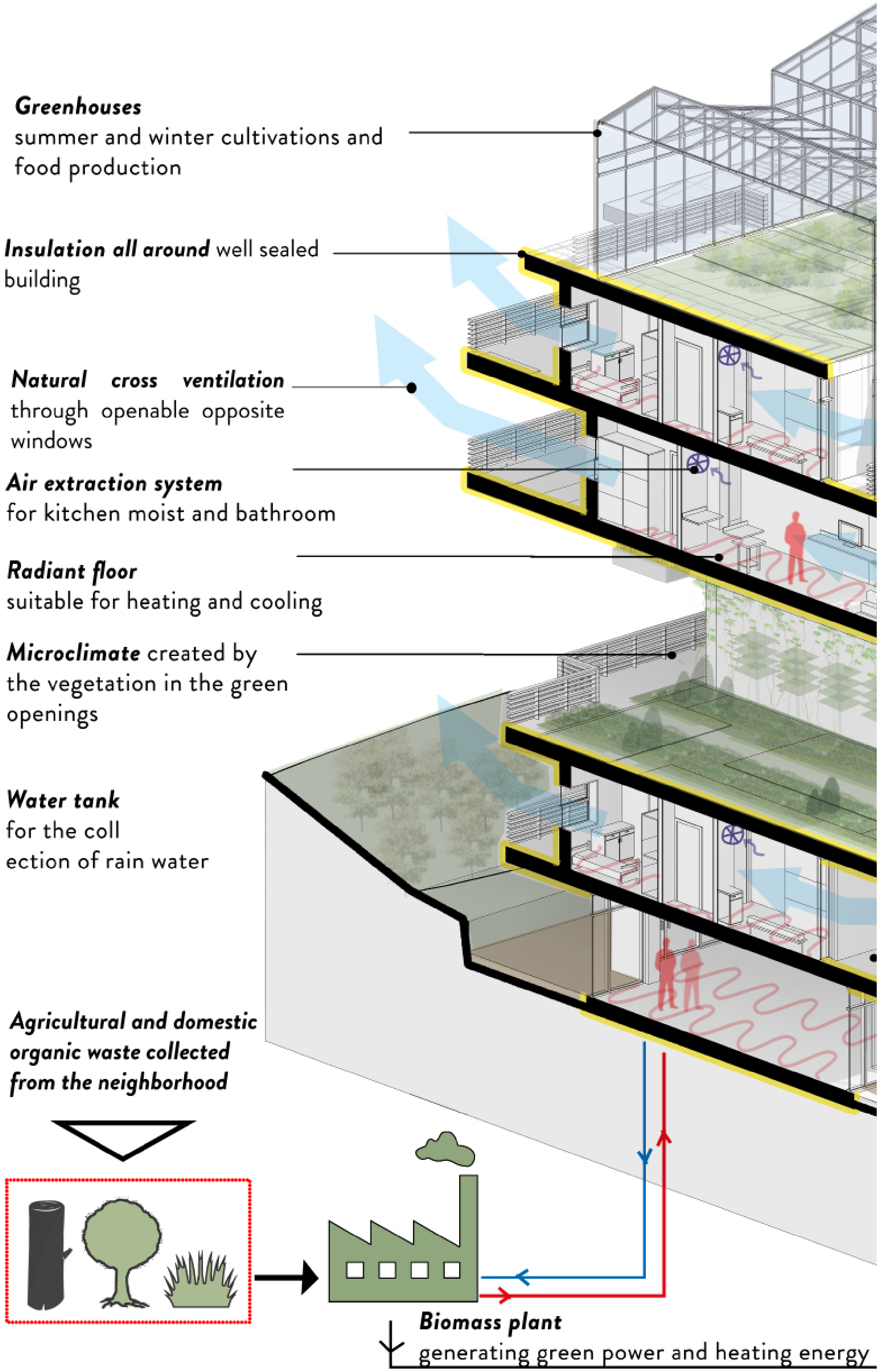


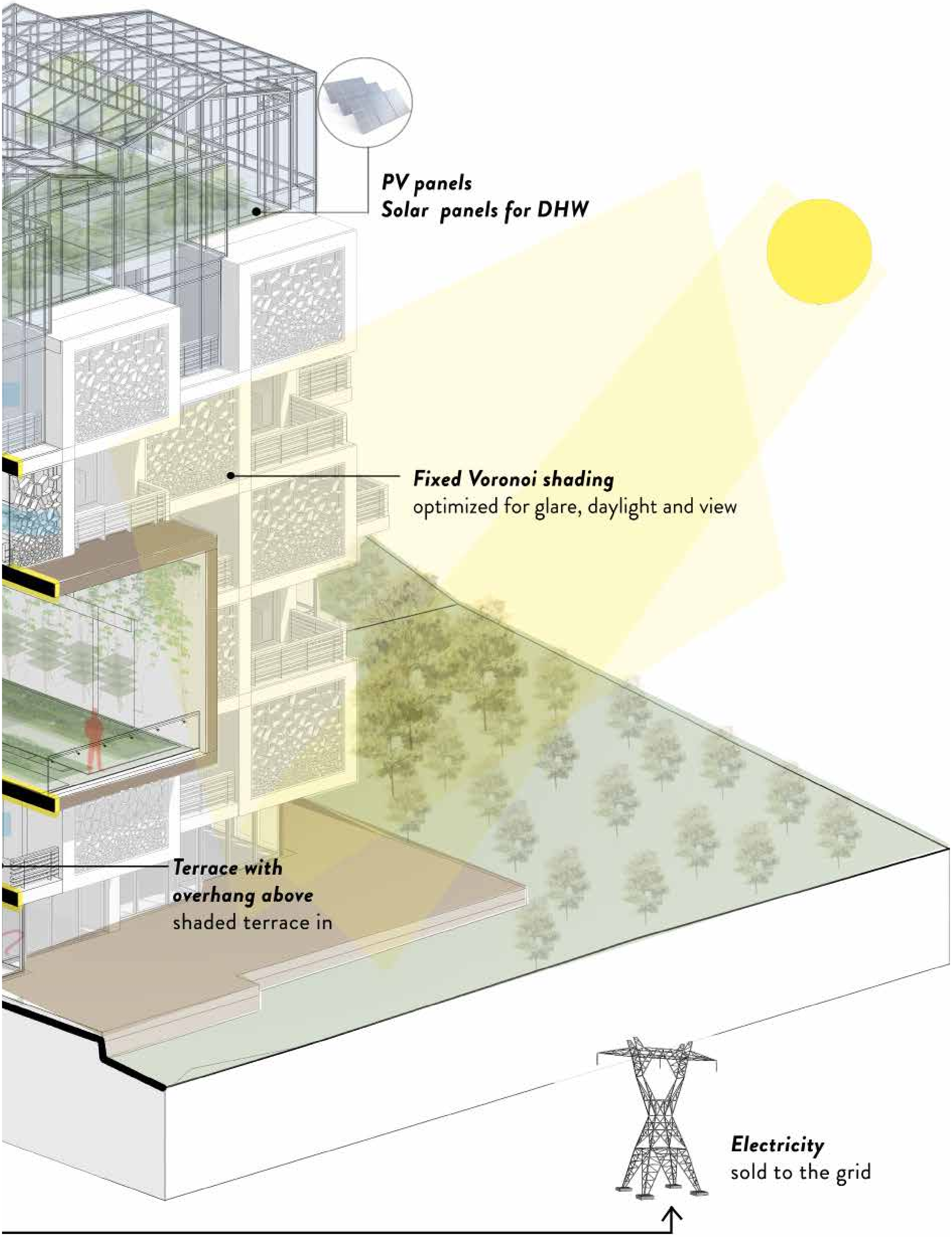
However it has to be kept in mind that the analyses building is not counting only on PV panels as renewable sources, so the total amount of renewable energy is much higher, in particular if we consider the contribute of the biomass plant.

4.5.4 Schematic design

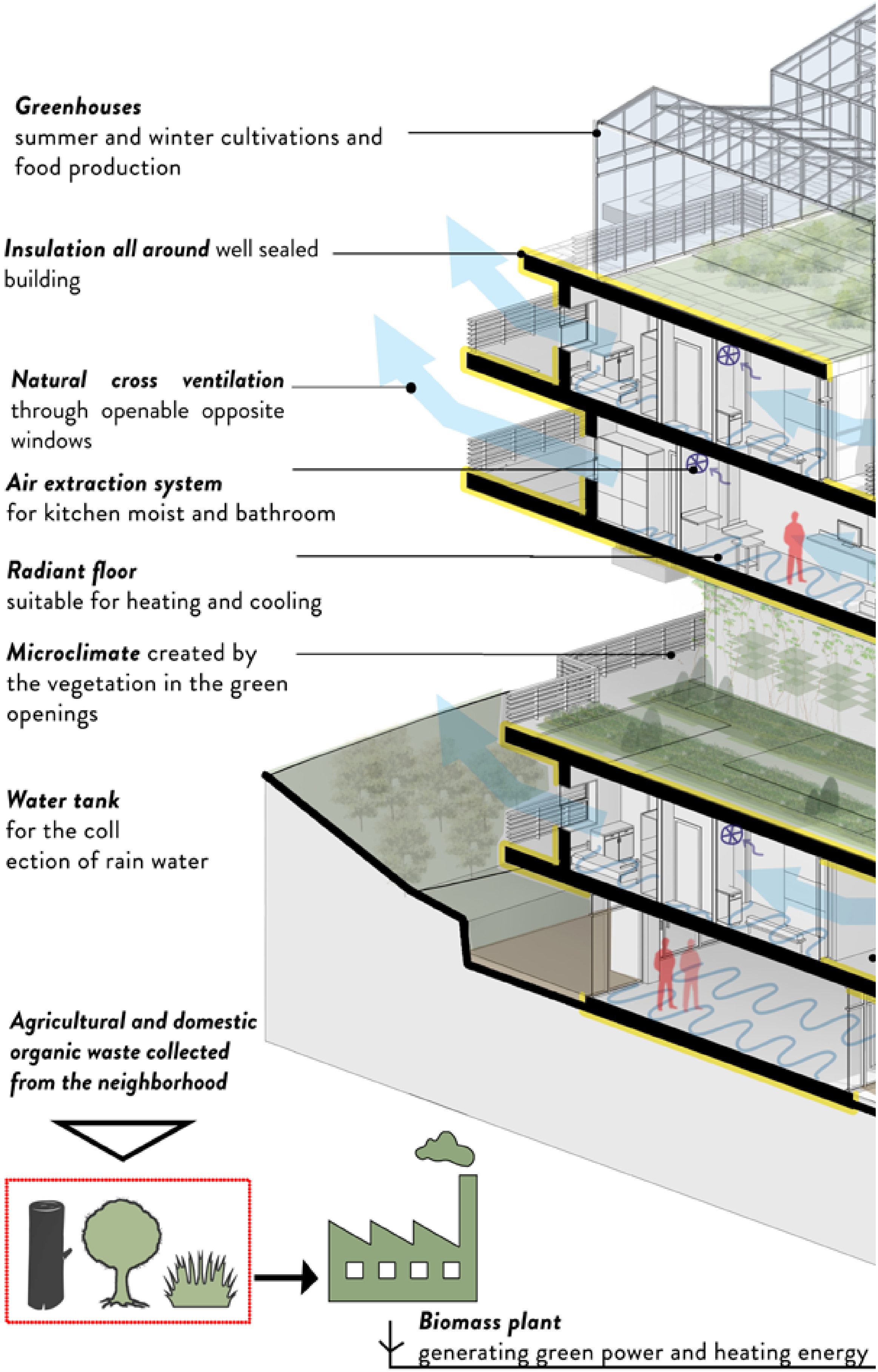
In the following pages are reported the schematic designs, that represent the behaviour of the building in the winter and summer season.
The strategies mentioned before and all the other strategies implemented in the building are reported in the drawings, to give a general idea of the building performance.

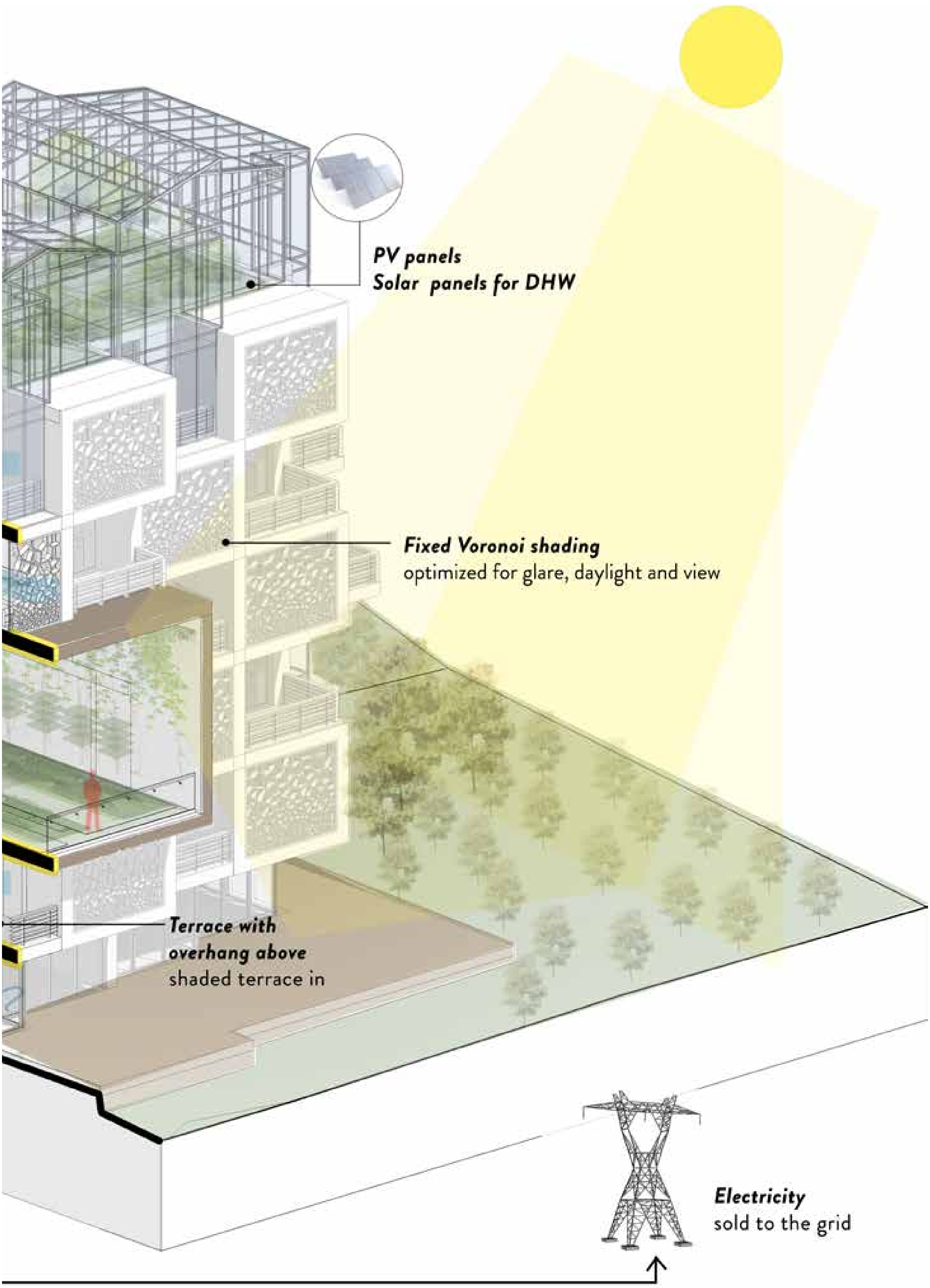
Board 4.25
Schematic design
winter season




PV panels
Solar panels for DHW
Fixed Voronoi shading
optimized for glare, daylight and view
Terrace with
overhang above
shaded terrace in
Electricity
sold to the grid

Board 4.26
Schematic design
winter season




PV panels
Solar panels for DHW
Fixed Voronoi shading
optimized for glare, daylight and view
Terrace with
overhang above
shaded terrace in
Electricity
sold to the grid

4.6 Optimization of Facade Design for Daylighting and View-to-Outside

Shading devices affecting the ability of the users to use the spaces, as it has a direct impact on offering adequate daylight and avoiding glare probability. On the other hand, In the indoor spaces that overlook exceptional scenery and views has a critical requirement, as the shading could obstruct the view to the outdoors. Otherwise poorly designed shading devices can result in high solar penetration and glare probability, and affecting the ability of the users to enjoy the outdoor view. At that part of this chapter, the effect of adding different shading devices and configurations to a south façade for the typical living room space in the project had been analszed, by a parametric model of five types of shading devices was analysed for the daylighting, glare and view performance. To trade-off between the objectives and the cases to achieve satisfactory performance in all three criteria were presented. That's aims to ensure the integration between architecture design for the façade shape, energy efficiency and the requirements for user comfort.

As the project's goal was to design a social house building located in Canyelles area, in the threshold point between Barcelona city and the mountain of, in Les Roquetes neighbourhood, between Canyelles and Nou Barri parcels, north of Barcelona. The building's site with an unobstructed panoramic view of the mountain from the north direction, and the Barcelona city toward the Parc de la Guineueta, due to the privilege of the site altitude. The building form reconfigured to maximize the number of units could get the connection between the northern and southern view.

The Living room space, and the open bar kitchen – as it used the most the day time - with an area 4m x 6m, oriented toward to Parc de la Guineueta, in south direction, as the most building façade exposed for direct sun light with the highest sun altitude 70° in summer, and 25° in winter.

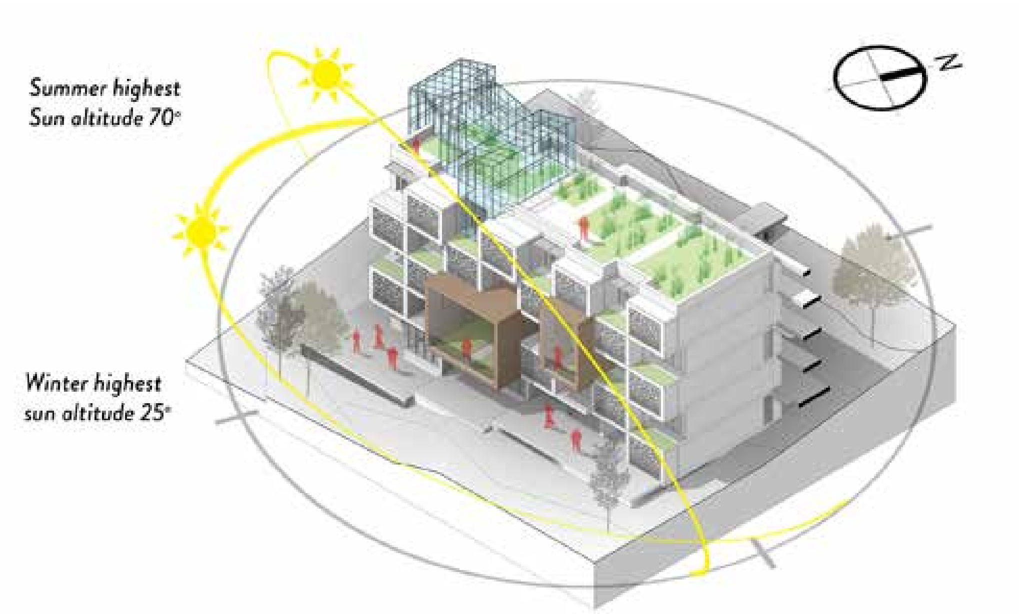


Figure 4.103 Project Location and Building configurations in the site. The diagram shows the orientation of the repetitive building module with the sun altitude

Therefore, the biggest challenge facing the proposed project was to keep the view from inside to outside with minimum obstruction in the two directions - specially the south- while providing sufficient daylighting and minimal glare.

Figure 4.104 Photos of the view from beside the project site. Image (A, B), toward the south direction. (C) toward North

The Living room space has a rectangular shape with the short side – 4.00 m - to south as the south façade is subjected to high exposure for most of the day, throughout the year. The apartments unit are attached side by side in the long side, so east and west facades hasn't impact on the daylighting performance.

The city of Barcelona has a humid subtropical climate, with hot and humid summer and cold winter. The highest sun altitude in winter is of 25°, while in summer 70°. Moreover, the solar radiation can rise to 1700 kWh/m2 per year. The temperature rarely goes far below 10° Celsius, the winter conditions nonetheless require non-negligible heating systems for the comfort. On the other hand, in summer, the high humidity and temperatures (often rising over 26° Celsius from June to August) require an equally important cooling load. As the air flow rate through the year is not adequate to provide natural ventilation, special attention for cooling and heating loads is necessary. Conventional design methods of passive techniques such as shading devices like horizontal shades, venetian blinds and screens were historically used especially in south facades to reduce the sun exposure, provide adequate daylight and to reduce the glare probability. The concerns in using this kind of shading device are that it doesn't implicate the view factor to outside as a driving force for the design. Therefore, a trade-off between the different measures must be reached to achieve a visual comfort and preserve the view of the surrounding landscape. And that part discusses the relation between the two parameters (daylight and view) by applying daylighting and glare analysis as well as view assessment of different shading devices.

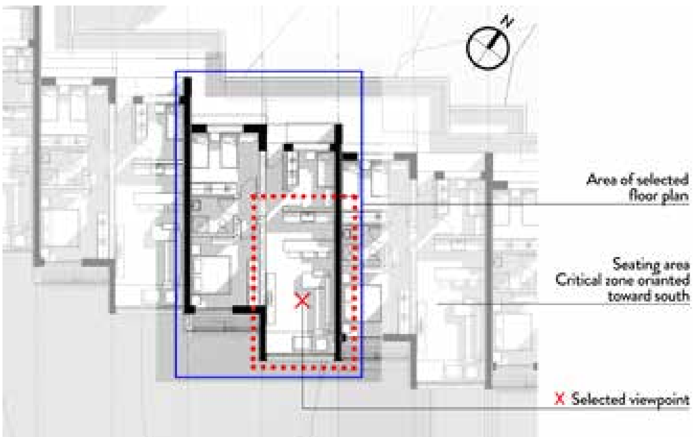


Figure 4.105 The apartment floor plan. As shown the "critical" area of investigation – the living room - with applied intermediated points of examination

4.6.1 Previous works

Shading devices were historically used to reduce the negative effects of direct sunlight and solar radiation inside buildings during cooling period and to permit heat gains during heating (Platzer, WJ.,2001). The impact of using traditional shading devices such as horizontal louvers and solar screens on daylighting, energy use and thermal comfort was studied by several
researchers in different locations and climates. Yoo S, et al., (2011) investigated the usage of fixed shading devices on decreasing the thermal loads in addition to increasing the visual comfort and decreasing the glare, and, it was found inevitable to use it on the south facades, especially in Mediterranean climates. In a similar approach, Datta G. (2001) studied the thermal performance of a building with external fixed horizontal louver with variable slat lengths and tilts. LIGHTSCAPE software and PHOENICS Computational CFD package for natural ventilation were used by Hien and Istiadji (2003) to study the effects of 6 different shading device types on thermal comfort in a residential building in Singapore. Hammad and Abuhijleh (2010) analyzed the energy consumption of external dynamic louvers integrated to office building's facade in Abu Dhabi. The impact of using different shapes of solar screens on daylighting and energy performance in hot arid climate was investigated by Sherif et al. (2012). Parametric and generative design tools allowed the creation of shading devices with more geometrical complexity. El Ahmar et al., (2015) used a double skin facades inspired from nature to design a porous and folded façade for reducing cooling loads while maintaining daylight needs of office buildings in hot climatic regions. The possibilities of different arrangements of folded modules had been also examined to create environmental efficient kinetic morphed skins, to achieve different Kinetic origami-based shading screens categorized parametrically to provide suitable daylighting (El Ghazi et al. 2014).Kirimtat et.al, (2016) conducted a review of previous research work that utilized simulation modeling to analyze the impact of shading devices. More than a hundred papers were analyzed and organized by simulation type. Different types of simulation analyses were studied including the overall energy performance, daylighting, natural ventilation, indoor thermal and visual comfort among many others. However, it can be noted that only a few studies considered the view as one of the main objectives of shading devices design (Tzempelikos A. (2008), Kim & Kim (2010), Sherif et al. (2016)). (Wageh et al.2017) asserted that previous literature on a case study in Lecco, Lombardy in Italy to reach an optimization of facade design for a shading device element in a workshop space for the daylighting and view to outside.
View to the outside is more than often left out during design, despite the undoubted importance of view and effects on users (Leather et al., 1998; Heschong Mahone Group, 2003), Hellinga and Hordijk (2014) attributes this to the reasons that research on daylighting and view quality belongs to different research discipline and secondly, there is usually very limited time and budget for architects and engineers to work on daylighting and view. Hellinga and Hordijk also found that users prefer distant and nature views and views that contain water. In design cases were view is an essential concern, such as spaces overlooking important landmarks or natural features, such as the case presented in that part, view to the outside
cannot be neglected. This part, therefore, tries to answer the question of How to design a shading system that ensures excellent daylight performance with minimum sacrifice of the view? In the design, utilizing computational and parametric tools to evaluate and optimize the shading systems for daylight and view quality.

Figure 4.106 Main designed shading system selected. A.Vertical louvres. B.Horizontal louvres. C.Egg-crate. D.Voronoi cells. For each, the most effective variables were identified. represented in "modular size", "shading angle" and "shading thickness"

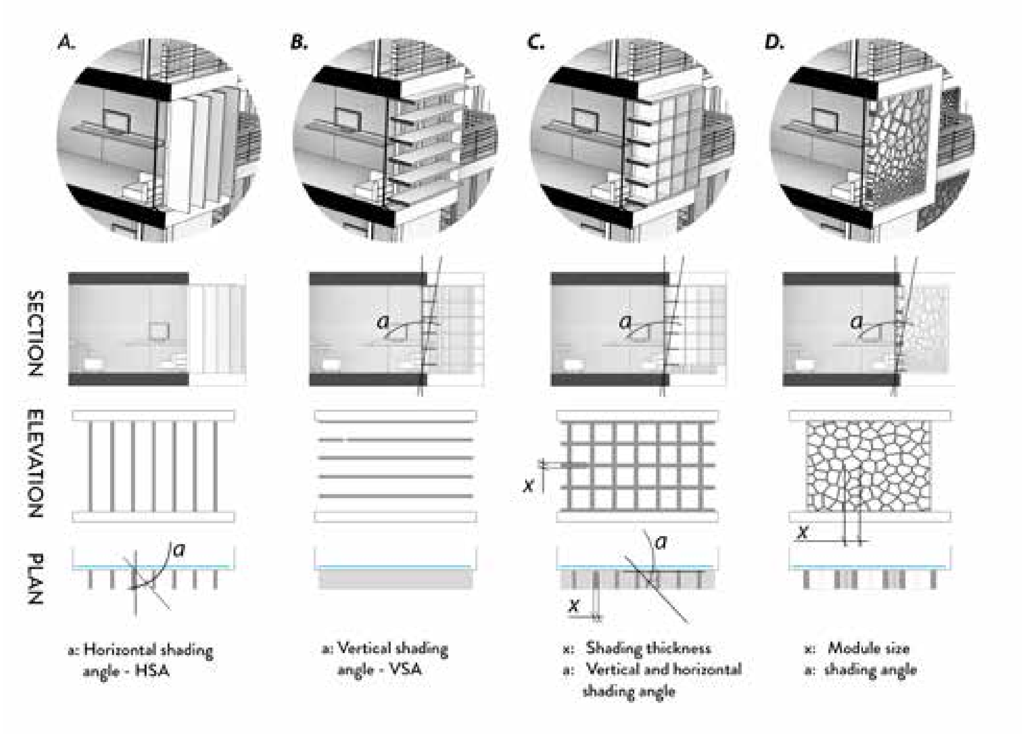


Table 4.42 The studied shading devices and its parameters

Shading type	Parameters	Range
Horizontal shading	Vertical Shading Angel (VSA)	20° to 50° with a step of 5°
Vertical shading	Horizontal Shading Angel (HSA)	20° to 50° with a step of 5°
Eggcrate	Vertical Shading Angel (VSA) Thickness	20° to 50° with a step of 5° 10 cm
Voronoi Cells	Vertical Shading Angel (VSA) Thickness	20° to 50° with a step of 5° 10 cm

4.6.2 Methodology

Parametric modelling

A parametric model for the residential building was created using the Building Information Modelling software Revit. To have a greater control on the design parameters, the model was then exported to, and modified by, a visual programming language for parametric design Grasshopper. The investigated space, which is considered as a typical space, had the dimensions of 4.0 m x 6.0m with 3.0m ceiling height. Different types of shading devices were investigated for the daylighting performance, glare probability and view to outdoors. The performances of four shading devices were examined: horizontal shadings, vertical shadings, egg crate, and Voronoi cells structure. For each of these shading devices, the impact of changing the vertical (or horizontal) shading angle was studied. The impact of changing the eggcrate and Voronoi cells spacing was also considered. Figure 4.104 shows an illustration of the four shading devices and their design parameters.
7 different cases for each shading were studied. Overall 28 shading designs were examined. The ranges of the shading devices parameters that were examined are shown in Table 4.42.

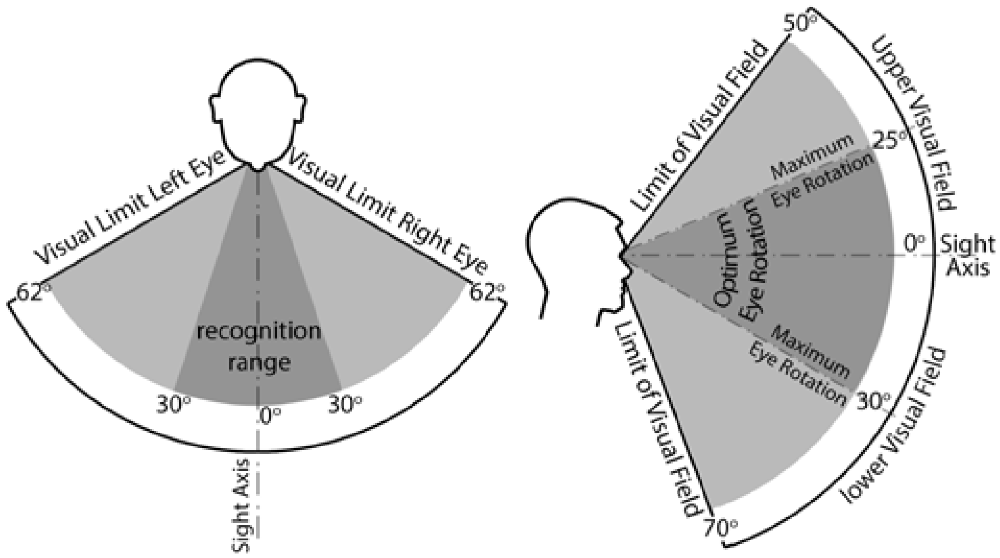


Figure 4.107 Diagram of the human cone of vision. showing the limit of the visual field and the area of recognition, in two directions, horizontally and vertically

Simulation methodology

Daylighting analysis was carried out using DIVA for Rhino, which is used as an interface to Radiance and Daysim simulation engines. The criteria used for evaluating the daylighting performance was the daylight availability which was found more suitable to the studied case. The DAv divides the measuring nodes according to three criteria daylit for points that receives illuminance between 300-3000 lux for 50% of the time, over lit for points that receives >3000 lux for at least 10% of the time and partially daylit for points that has illuminance values<300 lux for more than 50% of the time. The aim is, therefore, is to increase the daylit area of the space. The analysis grid had a desk-level height of 0.80 m and spacing of 0.60 m. (see Figure 5)

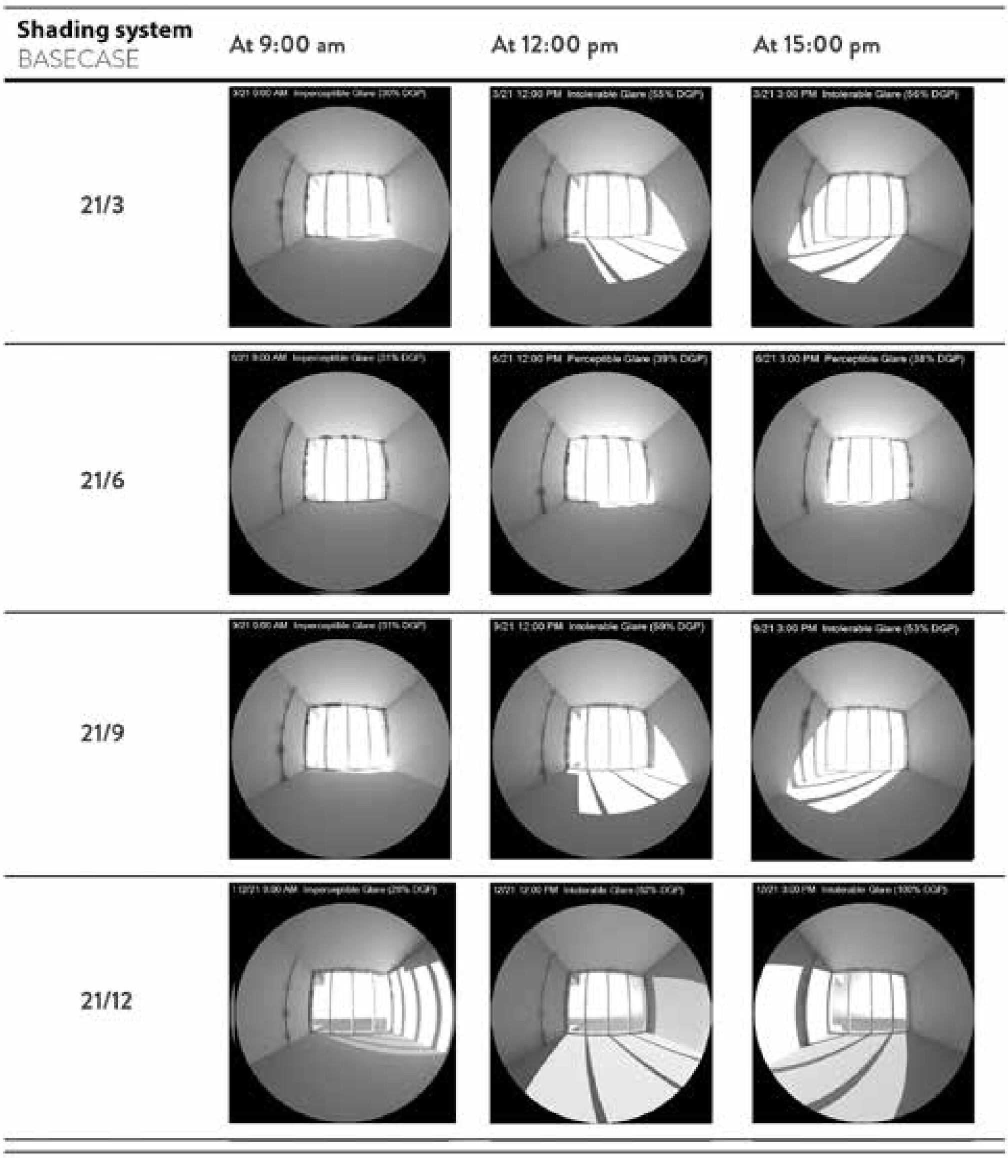
Glare and view analysis were conducted for a selective viewpoint that represents a seated person (height = 1.2m), 2.0 m from the facade and facing the window. For Glare analysis Evaglare was used to measure the discomfort using the Daylight Glare Probability (DGP) index. the GDP was analyzed at 9:00, 12:00 and 15:00 on the solstice and equinox dates to cover the different sun positions. In the DGP index, glare is divided into four categories: intolerable glare (DGP > 45%), disturbing glare (45% > DGPP 40%), perceptible glare (40% > DGPP 35%), and imperceptible glare (DGP < 35%). In this study, each category was given a score number with imperceptible glare having the highest score (3 pts) and intolerable glare the least (0 pts). the Accumulative Glare Percentage (AGP) is then calculated to compare the performance of different shading designs, where the highest possible value (100%) means that only imperceptible glare occurs at all times and the least (0%) indicates that an intolerable glare can be witnessed at all times. For the view analysis, a view factor was calculated using 3D isovist. An isovist field is defined as ".. the set of all points visible from a given vantage point in space and with respect to an environment." (Benedikt, M. L.1979) . In this study, the vantage point is the same one defined for the glare analysis. A 3D isovist was created for the focal area of the viewer's field of view (see Figure 4.105). The ratio between the number points seen from the vantage point in each case to that without a shading device is calculated to compare between the different shading devices. The results from the three analysis criteria, daylighting performance (DAv), Glare (AGP), and View Factor are compared to arrive at shading devices with a satisfactory performance. Acceptable values for the three criteria were assumed to be 75%, 50% and 50% for the daylight availability, accumulated glare percentage, and view factor respectively.

4.6.3 Results

Basecase

The unshaded facade was assumed as the base case in this study to evaluate the effect of each shading device on the daylighting, glare and view performance. The base case had a significantly low daylighting and glare performance due to the area of unshaded glazing in south façades. Even the useful daylight index exceeding 2000 lux Due to the penetration of sunrays from south, the daylight availability reached only 13%, with 33% a daylit area, while the overlit area occupied almost third of the space. The accumulative glare score was found to be low with a value of 44% as an intolerable glare was witnessed in most of the cases except for the morning hours. however, even at that time, a perceptible or disturbing glare was witnessed. and sun penetration would surely affect the possibility of enjoying the view.

Figure 4.108 Glare performance at 9:00 to 15:00 on 21 March, June, September and December for the base case



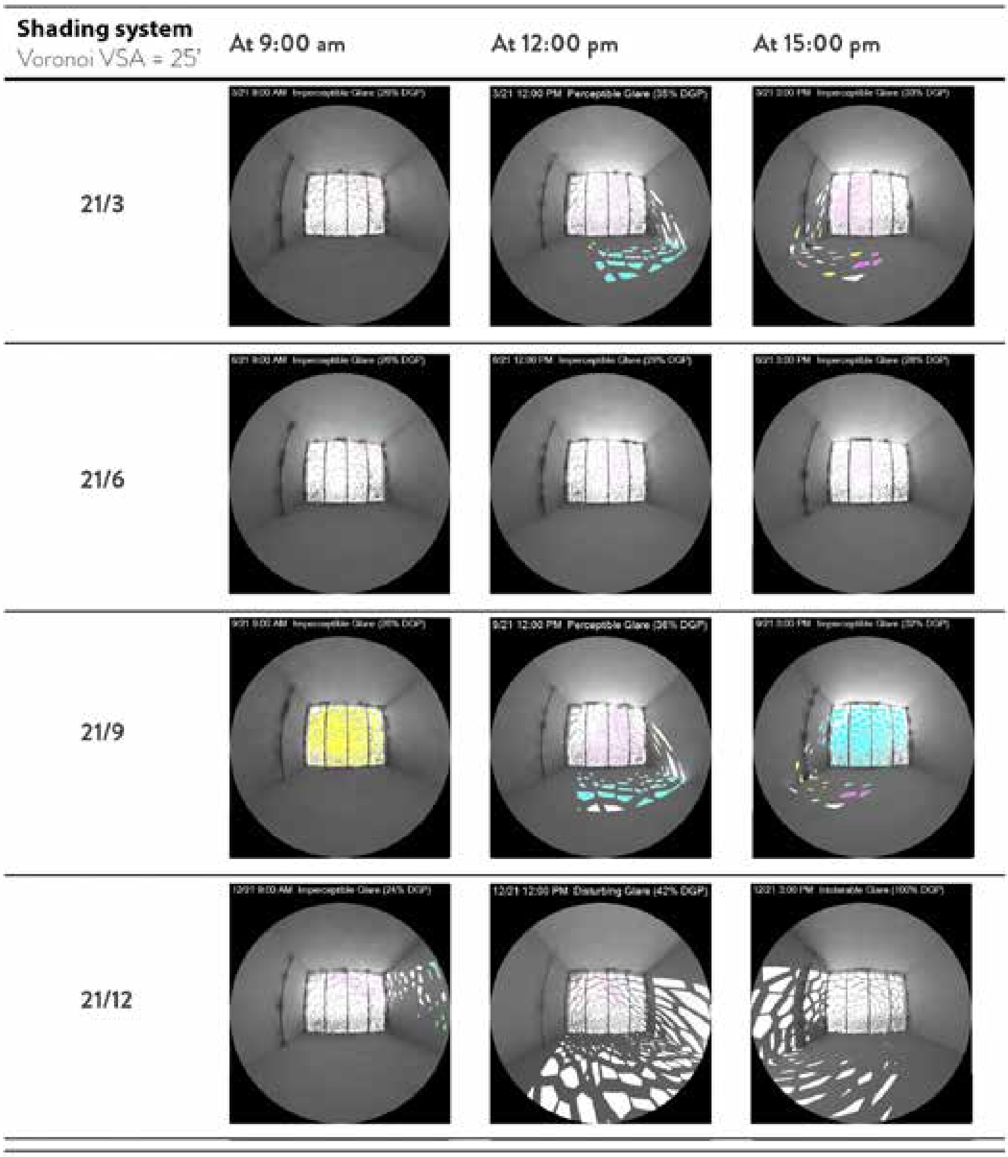


Figure 4.109 Glare performance at 9:00 to 15:00 on 21 March, June, September and December for the Voronoi Cells with VSA = 25°

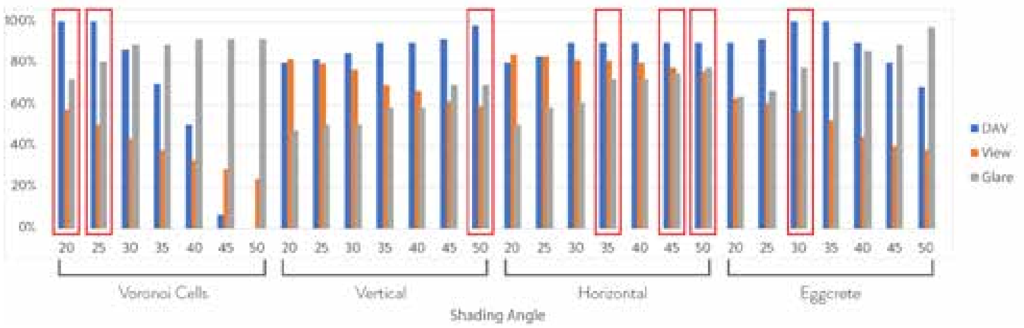


Figure 4.110 Daylighting, glare, and view performances for Voronoi Cells, Vertical, Horizontal, and Egg crate. The cases with satisfactory performances are highlighted.

Horizontal shadings

The horizontal shading devices enhanced the daylighting performance greatly were most of the cases had over 90% daylit area percentage, in comparison to just 33% in the base case. The glare analysis, however, showed a perceptible and disturbing glare occurrence and two cases achieved an AGP higher than 50%. The impact on the view was, however, better than anticipated with only between 20% to 25% of the view obstructed. Cases with larger extrusions (higher shading angles) had a better daylighting and glare performance while cases with smaller extrusions had a better view factor. (see Figure 4.104).

Vertical shadings

Vertical shadings provided acceptable daylighting performance. The daylit area percentages ranged between 50% with a Horizontal shading angle = 20°, and 70% with HAS=50°. Glare analysis also showed between a disturbing and perceptible glare occurrence all year round with a maximum accumulative score percentage of 50%. Nevertheless, the view factor was also found acceptable in all the cases with a maximum view factor of 80% and a minimum of 50%.

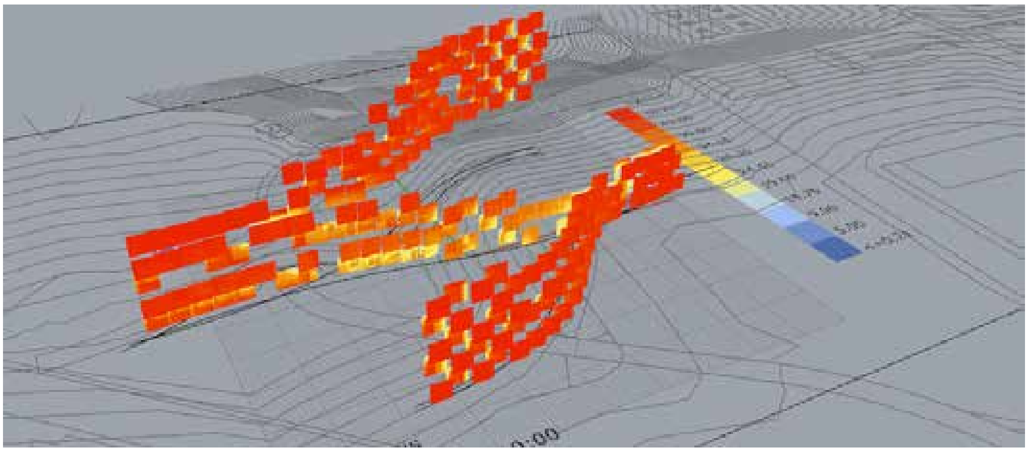
Eggcrate

Seven cases of eggcrate shadings were analysed. Almost all the cases achieved over 70% daylit area. The eggcrate reduced the chance of glare probability occurrence significantly. Most of the cases had an imperceptible accumulative glare percentage and in few cases the AGP reached more than 10%. This, however, came in the expanse of the view performance. With the eggcrate cells causing a significant obstruction to the view, the view factor was found to be unacceptable in most of the cases. Only cases with very small shading angle acceptable view factor. There were cases achieved an acceptable performance in all the three criteria like the one with 30° shading angle.

Voronoi cells

As the Voronoi cells the most critical case of this simulation, as it was proposed as an inspirational proposal from Barcelona heritage pattern. This unique shading solution succeeded in achieving notable improvements daylit area as it reaches more than 80%. Daylighting performance achieved more than 75% daylit area in two cases and another two cases having a 100% daylit area percentage with appropriate useful daylight index. Glare probability also improved as almost all of the cases had an acceptable performance and AGP reaching 90% in few cases. While not all the cases had a satisfactory view performance, in many cases the view factor had an acceptable value and reached a maximum of 60%. In two cases, the daylighting, glare and view were found to have acceptable and significantly improved performances. One notable case was with 05° shading angles, where daylit area percentage reached 100%, AGP of 70% and view factor of 60%. That configurations achieved an acceptable performance in all the three criteria.

Figure 4.111 Annual solar radiation for the souther facade showing the differences in solar exposure according to the location of each unit



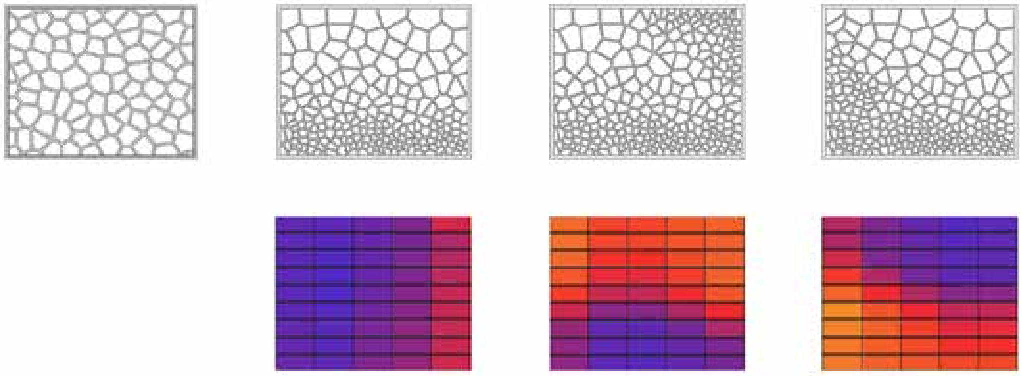


Figure 4.112 Flexible Voronoi cells to be adapted for the different solar exposures

4.6.4 Conclusions

This part presented and discussed a design approach for designing building facades that overlook exceptional scenery and views, which requires special care not to obstruct the view to the outdoors. Nevertheless, poor shading design can usually result in high solar penetration and glare probability affecting the ability of the users to enjoy the outdoor view. In this study, 28 different configurations of four shading types were investigated. Overall, 11 different configurations from 4 types of the shading devices achieved a satisfactory performance for daylighting, view and glare. The Voronoi cells offered two of the best performance, beside horizontal louvers and vertical two. Using one of cases of Voronoi cells supports the design feature and can reach the visual comfort requirements for building user.

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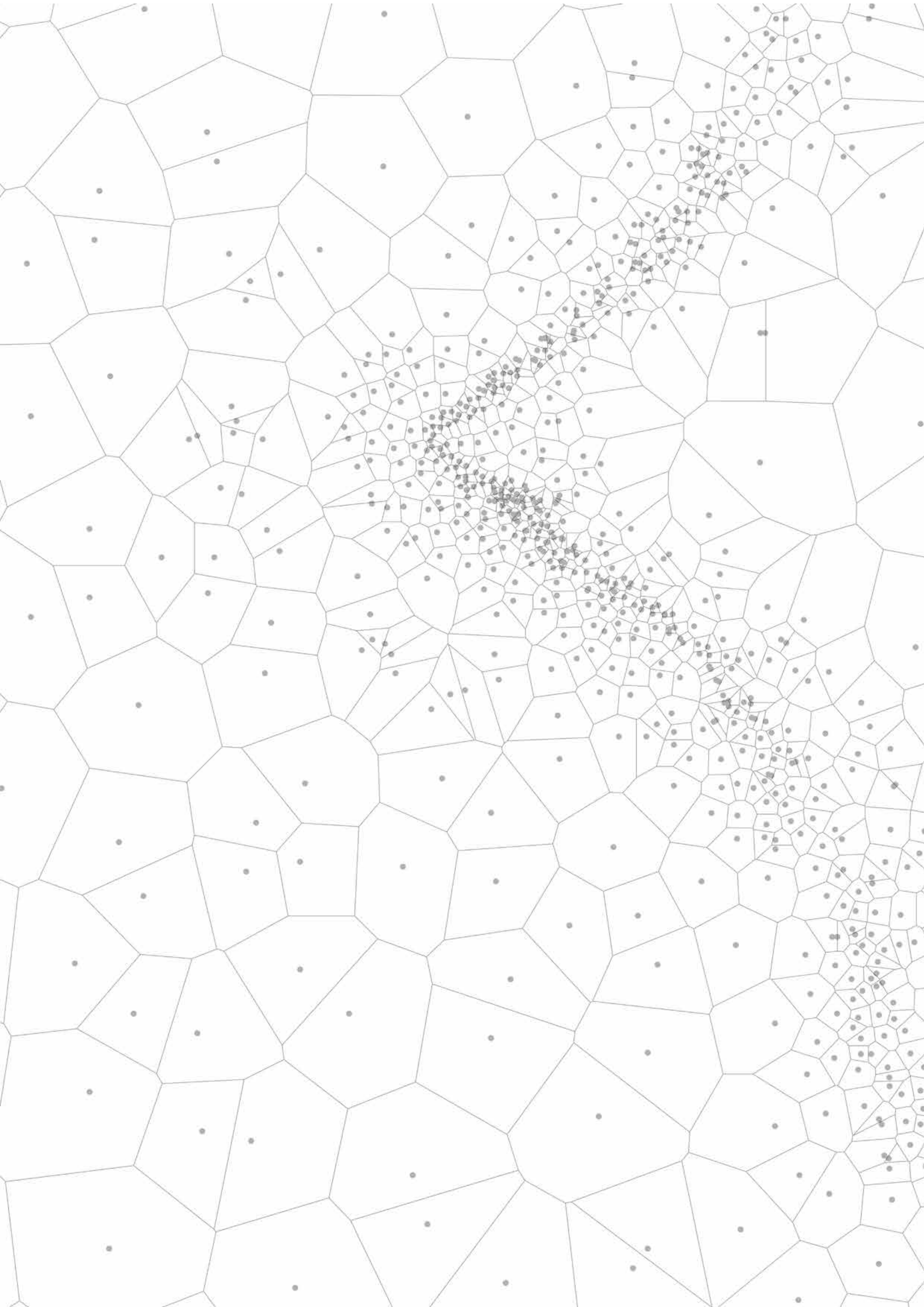

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