Politecnico di Torino

DEPARTMENT OF STRUCTURAL, GEOTECHNICAL AND BUILDING ENGINEERING


# Regenerating the urban outskirts

## A self-sufficient ecovillage in Milan's Bovisasca area

MASTER'S DEGREE IN BUILDING ENGINEERING


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# Index

# 1 Abstract

The current climate emergency combined with the contingent energy crisis is pushing with increasing urgency in the direction of a progressive decarbonization of the built environment. This one can only be achieved through design choices aimed at a modelling resilient to climate change, that can mitigate its negative effects, as well as making a positive contribution to environmental quality through regenerative design.
This means designing energy-efficient buildings while simultaneously containing land consumption. It also means decreasing the amount of energy required for the production, decommissioning and construction of building matter while reducing the exploitation of resources for food and water production. On the other hand, environmentally friendly and less impactful building implies a new way of living, bringing cities and housing back to a human scale, thus improving the quality of life.

In this current landscape, energy autonomy from fossil fuels is increasingly pressing, and it is clear that this can only be achieved through an urban design aimed at decarbonizing cities. In the context of this decarbonization and urban regeneration, the concepts of energy community and self-sufficiency assume fundamental relevance.

The thesis starts from the conceptual impulse given by the ReGen Village project, conceived in 2016 by entrepreneur James Ehrlich in order to be the model of an ecovillage of the future, modeled as self-sufficient, hyperconnected and founded on circular economy principles.
Starting from the study of ecovillages of the second half of the twentieth century, we have integrated the requirement framework, distributional analysis and dimensional assessment that characterize the ReGen project to arrive at a design experiment of a self-sufficient village, both energy and food-wise, of limited size, located in a suburban Italian site.

For this purpose, the project is made as a simulation of participation in the international competition Reinventing Cities, promoted by C40 Cities Climate Leadership Group in 2022 for the regeneration of the Bovisasca site on the outskirts of Milan.

The project masterplan includes four housing modules of two different sizes, a community house, seen as an inclusive socialization space open to the entire neighborhood, and an area for the shared cultivation of vegetables. The thesis work focuses in particular on the design of one of the housing typologies, developed down to the scale of maximum detail, which aims to be characterized as a Net Zero Carbon Building thanks to the technological and plant engineering choices adopted.
Starting from significant case studies, we defined the necessary spaces, the load-bearing structure, the stratigraphy of the envelope, and finally the plant engineering equipment, until we obtained two different types of housing units, modular and conceived with dry technology, on which an energy analysis was performed to verify their performance.

In this way, the minimum village project, which was the objective of this study, was defined, according to criteria that can be re-proposed, through specific calibrations, in other locations, paying attention to the context of insertion and respectfully grasping the resources offered by the area.

# 2 Thesis introduction

The thesis we are going to present deals with the design of a self-sufficient ecovillage in the Bovisasca area in the city of Milan. The work starts from the study of self-sufficient villages and energy communities, based on the project called ReGen Village, a self-sufficient village born from the mind of James Ehrlich[1].

We started, therefore, from an analysis of the state of the art of research regarding self-sufficient villages, both for the Italian reality and for the foreign one. We then analyzed the main characteristics that distinguish these communities, like the types of buildings usually present in them and the mentality with which they are designed.
Then we went on to analyze what are the current construction standards for buildings, so the NZEB and CZEB. Right after we presented the ReGen Village project from which we started for the development of our work.
Finally, it was presented and characterized the competition within which takes place the project subject of this study: the Reinventing Cities competition, which develops globally and is promoted by the C40 Cities Climate Leadership Group (a network of about 100 cities that aims to combat climate change) with the support of Climate KIC.
The aim of the program is to identify in the different cities, abandoned sites or non-used ones, in order, then, to redevelop them, with particular attention to energy efficiency and climate protection.

Finally, we moved on to the design part, proceeding with the choice of the building envelope, external closures, internal partitions and transparent envelope. We tried to propose two (?) different layouts, exploiting the principle of modularity at the base of the proposed design, in order to offer an optimal solution for larger or smaller families thus satisfying different needs.

Each housing unit has also been designed in order to be energetically self-sufficient, thanks to the exploitation of different renewable energy sources, thanks to a rainwater collection system and thanks to the exploitation of vertical hydroponic colture. On the other hand, as regards the building materials, these were mainly counted among those used for prefabricated technologies, in order to allow easier assembly on site, as well as easier repeatability and variation of the layout in the case of needs, at the same time promoting as much as possible the dismantling or the controlled demolition then the destructive one.

## 2.1 Aims of the thesis

The aim of the thesis is therefore to design two different housing units to be included in a self-sufficient neighborhood from the point of view of energy production but also from the one of primary resources.
The district is designed with different types of building, there are housing units, but also a building for the breeding of animals, as well as one for community agriculture, which is added to the hydroponic one of the individual units, there is a community house, which acts as the center of the neighborhood, with activities for the inhabitants, play areas for children, covered green areas and space for staging shows or other types of activities, In short, the goal is to design an entire neighborhood fully functional and independent from the rest of the community.

The final goal of the work that we are going to do is to design a small district functioning from the energy point of view that can then be brought back on a larger scale giving the opportunity to design an entire village or a whole community, adapting the units, the dimensions and the spaces to the different needs on a case-by-case basis, while maintaining the concepts and technologies suggested here, having demonstrated their correct operation on a small scale, that provides for proper operation even on a larger one.

# 3 State of the art of research

The research done so far on the topic of self-sufficient villages is countless, being ecovillages already attemped several times over time. They are present all over the world, more or less advanced, even in less ecologically developed realities, such as in Italy, there are several, even if these remain mostly places considered as hippie, as out of the present day life that the outside world plays.
The houses are thatched, the structures made of earth, and the inhabitants reject modern technology and the consumerist and advanced vision of today's world.
Well known are, for example, the Tulou in China, also named a UNESCO World Heritage Site in 2008, which, however, are circular fortress-houses where Hakka peasants settled ten centuries ago after leaving their homeland, and where they live according to the tradition of their people from that time, rejecting innovations. As socially and, at times, traditionally relevant as these areas are, however, they are not viable on a large scale, and thus cannot be taken as a model for world life.

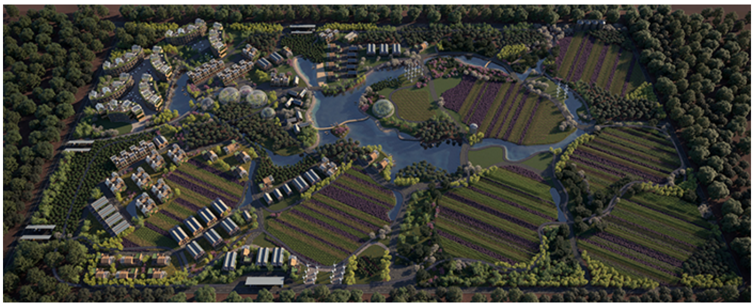
(a) Tulou exterior view

(b) Tulou interior view

**Figura 1:** The Tulou in China, UNESCO heritage site

On the other hand, as for the technologies used within the village, aquaponics, hydroponics and aeroponics, vertical farming, electric cars, composting and biogas plants, the studies behind them are very advanced and each technology has already been widely used in different parts of the world.
These techniques have become necessary given the ever-decreasing availability of fertile land, the increase in population. Depending on the techniques, different are the advantages and different are the needs, later each will, in the dedicated sections, be analyzed in detail.

A great deal of material, although mostly recent, can be found about the ReGen project. Browsing through their website one can read how the project came about, starting from what they defined as an opportunity, that is the growth of the population and with it the growth of a richer class, which will probably bring with it the need for neighborhoods that can offer different services, convenient to reach and use.
So they came up with a solution, neighborhoods formed by positive energy houses, harnessing renewable energy, smart water and waste management, with the goal of providing an optimal place for families and individuals while decreasing the burden on local and national governments.



(a) Regen village bird eye view

(b) Regen village inside

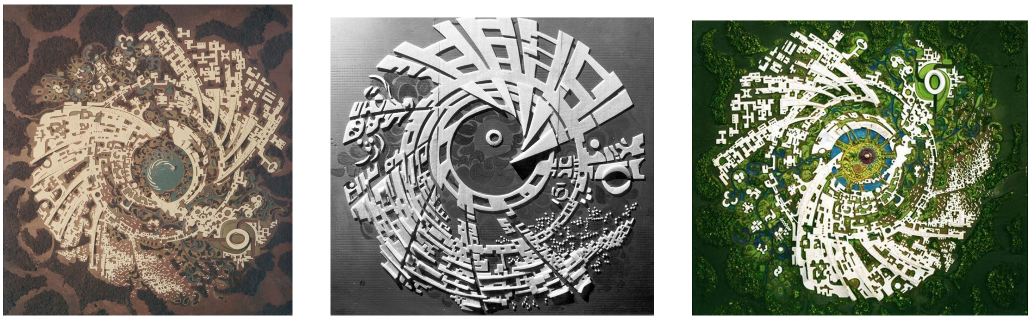
**Figura 2:** The ReGen Village Idea

### 3.1 The self-sufficient villages history

The first examples that can be assimilated, in some ways, to the ecovillage model are, in all likelihood, the religious communities born in Europe until the 1700s, these had as their purpose the aggregation and sharing of ideals, helping each other in the climate of religious persecution that prevailed at that time. In the following century, however, more and more communities were born that aimed precisely at developing a new way of seeing and thinking about the Earth, seeking to pursue the creation of a new and integrated reality with the Planet, at the same time, however, distant from the kind of life that society was proposing.
The first significant realities were born in the 1970s, and in this regard it is worth mentioning the examples of Auroville and Findhorn.

Auroville was born in India, with the ambition of Mère, a French mystic, to create a place where the concept of money, government or religion did not exist: " ...a place where the needs of the spirit and the care for progress would get precedence over the satisfaction of desires and passions, the seeking for pleasures and material enjoyments."[1]
Thus, in what was a red sand desert, an international community, now inhabited by 2,500 permanent residents and designed to accommodate 50,000 people, arose in 1968, structured in what, viewed from above, resembles a spiral or, as one can read on the dedicated website (www.auroville.org), a galaxy.

[1]The words of the founder, called "The Mother," from https://www.auroville.org/contents/197



(a) The 1968 design (b) The 1968 design (c) The design

**Figura 3:** Community plans at different times

Findhorn, on the other hand, was founded in 1962 in Scotland.
Initially it was only a caravan complex, and remained so for a few years. Then by 1992 the construction of a proper city began, after extensive studies of the environment that would surround it.

The community, which is also international, has evolved to present among its activities an Education Center that offers opportunities for growth in the fields of arts and meditation, as well as alternative energies and materials. Over the years it has served as an example for many people who have subsequently founded similar places, intended as educational centers with the purpose of teaching and spreading an alternative and environmentally sustainable way of living. The community currently hosts 4,000 people between permanent residents and annual visitors.

**Figura 4:** Findhorn community plan.

## 3.2 The Ecovillages networks

In 1990 it was then realized that the ecovillages in the World were increasingly numerous, and all characterized by different aspects, so it was decided to make a census of all the existing community realities. Then a meeting took place between the representatives of the most relevant ecovillages and on this occasion it was suggested the idea of creating a worldwide network called G.E.N.

### 3.2.1 The G.E.N.

The G.E.N. (Global Ecovillage Network) was founded in 1996 to concretize the idea of a worldwide network of ecovillages as an association with the aim of connecting the different realities, promoting the experience that they represented, so attention for things like human rights, conflict resolution, mutual acceptance and respect, environmental protection, the importance of the individual and a sustainable life.[2]

The success of the network was immediate and, from the 12 initial villages, the interest has then spread in many countries to count 5 "regional subnets", in Africa, Europe, South and North America, Oceania and Asia.

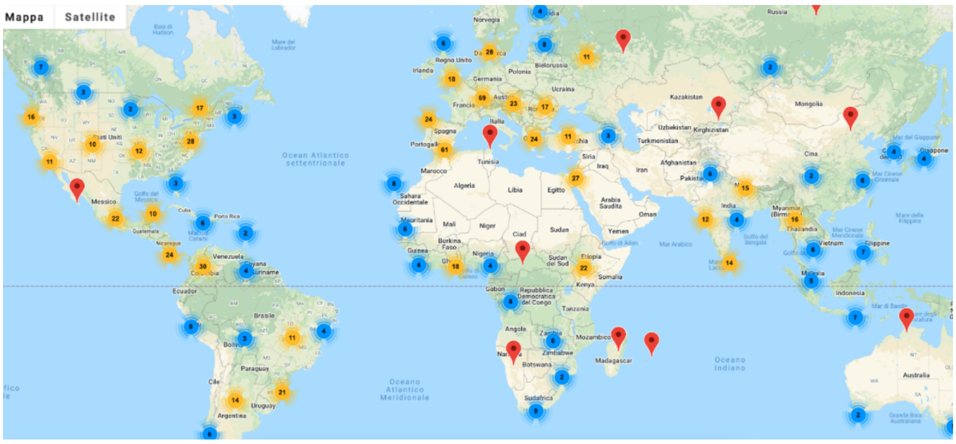



**Figura 5:** The ecovillage map in the World

Since 1996, GEN's mission has been to connect and encourage the ecovillage movement, educating the world for a different and new life.
The system manages a network of thousands of regenerative communities and initiatives that bridges cultures, countries, and continents through its five regional networks and its international youth branch, NextGEN.
GEN is served by the Secretariat, a staff team that takes care of daily operations guided by the Council, an oversight body, that is elected every two years. There is also a General Assembly, that is made up of all full member ecovillages.

### 3.2.2 The European network: E.V.E.N.

In the same year, the European network of ecovillages was born, which took the name of E.V.E.N., Eco-Village European Network, with the intention of dividing the network into national entities

[2] https://ecovillage.org/about/vision-mission-goals/

to facilitate the dissemination of the experience.
The network has objectives very similar to those of the original G.E.N. plus collecting in a database all the information and experiences related to this reality, trying to spread the knowledge of projects, funding and useful information provided by international bodies.
It was at this stage that the meaning of the term "ecovillage" was defined, because it was wanted to avoid that this definition was too specific, thus avoiding possible future clashes or detachments of communities that did not fit in exactly. The current definition is:

> The ecovillage is a type of community based explicitly on environmental sustainability.
>
> The principles of this type of community are as follows:
>
> - Voluntary adherence of participants and sharing of founding principles;
> - Housing units designed to minimise environmental impact;
> - use of renewable energy;
> - food self-sufficiency based on permaculture or other forms of organic farming. [3]

### 3.2.3 The italian network

Just as at the international level, the need and necessity has brought Italy to create some sort of link between the different realities, experiences and communities in the area.
The association Rete Italiana Villaggi Ecologici (R.I.V.E.) was officially founded in December 1996, after having been for many years an informal association, with objectives that are almost the same as those of the larger-scale networks. It offers the possibility of meetings between members, supporters and sympathizers of Italian ecovillages, organizing initiatives open to all. Annually, members organize meetings to discuss initiatives to be pursued and commit to providing support and legal and administrative advice for new projects.
In Italy there are, scattered throughout the territory, about a hundred ecovillages, although not all of them turn out to be members of the network.

[3] https://it.wikipedia.org/wiki/Ecovillaggio

# 4 European attention for energy management

In the global landscape, the focus on reducing consumption acquires a role of primary importance, and at a time when a great responsibility regarding $CO_2$ emissions can be traced to the building sector, it is essential to study new design solutions that allow us to approach the subject differently.

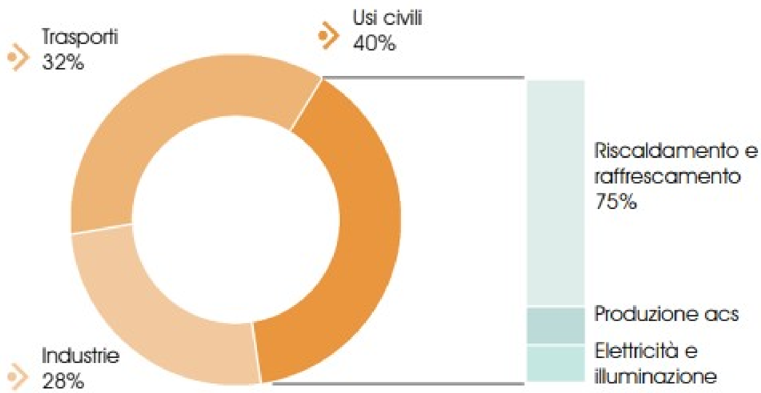



**Figura 6:** Incidence of the building sector in Europe. [18]

Against this backdrop, European initiatives have begun to decrease energy consumption by more than 40% in the near future, a goal that is thought to be realistically achievable through the introduction of nearly zero-energy buildings.

The concept of NZEB (Net Zero Energy Building) was firstly introduced in the early 2000s, becoming more and more structured in the following years and seeing an increasingly rapid diffusion because the concept has been more and more applied to building realities around the world.
NZEB buildings aspire to connect the energy component to the environmental and economic components of the building, in a vision of sustainability and compatibility between the built environment and the planet's natural environment.
Zero-energy building means mitigating environmental and climatic issues purely related to the built environment, there are several assessments of the performance of buildings of the type and several studies on the potential of different technological solutions that can increase their energy efficiency.

Often seen in this regard is a focus on the thermal properties of the envelope, the performance of the generation systems adopted, and the adoption of renewable sources for energy production. Studies in this regard obviously do not stop with the residential environment, although for the purpose of this project this is the main area we focused on.
There are based on dynamic simulations of different scenarios, from which some main recommendations on the subject are inferred. First and foremost, we try to increase the thermal mass of the external envelope, increase natural ventilation in the summer period, try to include solar shading devices to regulate daily inputs, and so on. All this is done to improve the internal thermal comfort conditions of buildings while decreasing their energy consumption.

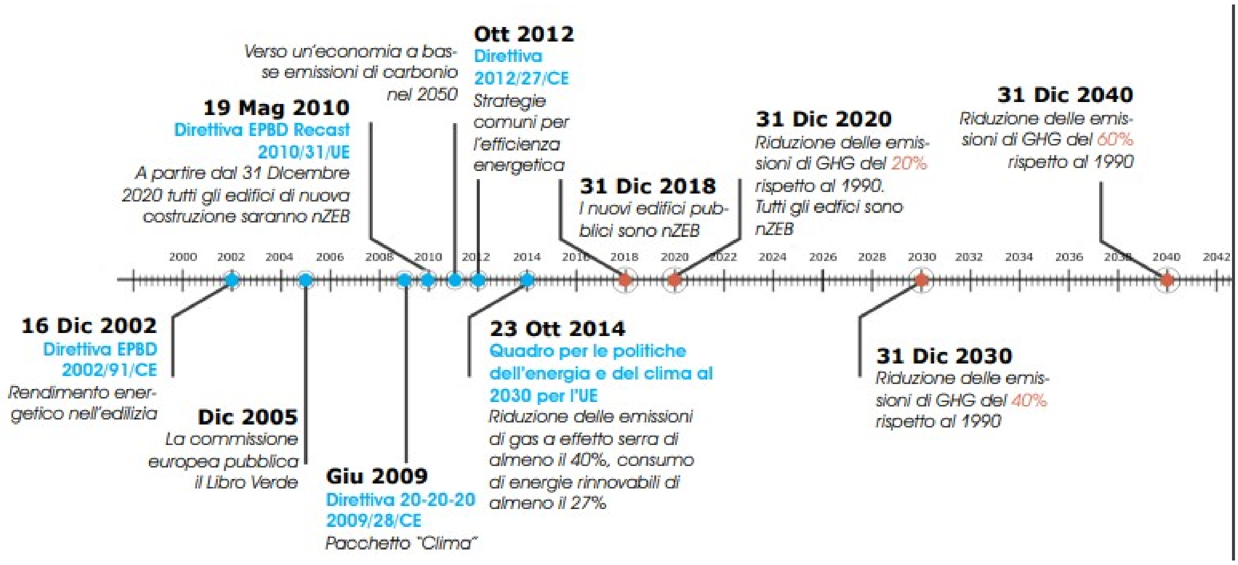



**Figura 7:** Timeline of european directions for building energy efficiency[4]

As mentioned above, the main energy consumption at the European scale is attributable to the construction sector, resulting in about 40% of final energy arising from commercial, office and residential buildings.
The first step toward a different energy efficiency and an innovative policy strategy was taken in 2007 in Brussels during the "Communication from the Commission to the European Council and the European Parliament" in which an Energy Policy for Europe was discussed, with the aim of drafting measures of intervention, called the "20-20-20 Climate Package," that would provide substantial reductions in carbon and other greenhouse gas emissions to start a process toward achieving a strategy for the future.
A process of raising awareness of the use of renewable energy was also triggered.

Achieving energy efficiency for the built environment is therefore a crucial challenge in order to reduce energy consumption, which is precisely why the European Commission has decided to support those practices that favor energy efficiency, going for limiting energy demand in favor of increasing the use of renewable sources.
It was then 2005 when the European Commission drafted the so-called "Green Paper" in order to be able to detail more the strategies to be adopted for improving energy efficiency, such as Europe-wide incentives or the adoption of environmentally friendly techniques and technologies.
It was precisely from this "Green Paper" that further energy strategies were then thought, such as the 2007-2009 European Council Action Plan, which recalled roughly the objectives described within the "Green Paper," flanking it with the energy policies described in the 20-20-20 Climate-Energy Package, with the goal of combating increasing climate change by lowering greenhouse gas emissions by 20% while promoting the use of renewable sources to increase the overall energy efficiency of the built environment.

Although these goals seem difficult to achieve on time Europe has strongly supported the achievement of these goals within the 20-20-20 Climate-Energy Package through the issuance of the new Energy Efficiency Action Plan of 2011, adopting very stringent monitoring and coordination strategies towards member states.


(a) Green building practices social benefits


(b) The goals

### 4.0.1 The Community Directive 2002/91/E

From the energetic point of view, the measures at the European level are different, we find first of all the EU Directive 2002/91/EC concerning the energy performance of buildings, known as the Energy Performance of building Directive (EPBD), published in the Official Journal in January 2003, which required member states to decrease the energy demand within the building sector while adopting strategies to improve the energy performance of buildings, aiming to achieve a 22% decrease in total energy consumption by 2010 in addition to a drastic reduction in $CO_2$ emissions.
A preliminary method of calculating energy performance was also provided, with the application of minimum requirements for those considered to be new construction. Both energy certifications and control of plants components in existing buildings was proposed.

### 4.0.2 The Directive 2010/31/CE

Then Directive 2010/31/EC or EPBD Recast, in July 9 of 2010, comes into force, taking up the basic principles of the 2002 one but expanding its scope and measures regarding energy efficiency, extending the obligations on performance requirements and making them more and more restrictive, toward what turns out to be an NZEB vision.
Another key point of this directive is to further decrease greenhouse gas emissions by going even further in improving energy performance in buildings by imposing an obligation from 2020 for new construction to meet the requirements proper to "nearly zero" energy buildings.

1. Member states shall ensure that:
   - by December 31, 2020, all new buildings are nearly zero-energy buildings;
   - by December 31, 2018, new buildings occupied and owned by public entities are nearly zero-energy buildings.
2. Member States shall develop national plans designed to increase the number of nearly zero-energy buildings. These national plans may include targets differentiated by building type.
3. Member States shall also, following the example of the public sector, develop policies and take measures, such as setting targets, aimed at encouraging the transformation of renovated buildings into nearly zero-energy buildings, and

inform the Commission thereof in the national plans referred to in paragraph 1[19]

### 4.0.3 The Directive 2021/27/CE

Then in 2012, a new directive, Directive 2012/27/EC, is issued, establishing a set of common strategies for the promotion of energy efficiency in order to achieve those goals initially outlined in the 20-20-20 Climate Package.
In addition, with this new directive, member states are obliged to provide training courses for professionals, and it places an obligation on industrial-type buildings to carry out an energy analysis to constrast the energy consumption of all that class of buildings that consumes the most in the built environment.

## 4.1 The transposition by member states

Thus, energy plans to be applied nationwide to achieve the desired energy savings are outlined, and especially the National Energy Strategy (NES) aims precisely to adapt to the European energy market in order to lower costs and meet the targets set by the 20-20-20 Climate Package. In this panorama, the strategy of expanding near-zero energy buildings in the building scene becomes crucial, although from the beginning difficulties have been encountered in bringing local regulations into line with European ones, and so it is precisely for this reason that a set of technical standards has been drawn up to support the Directive and facilitate its transposition by member states.

Currently, we have reached a state where all member states are more or less aligned with what is expressed in the various Directives discussed above.
However, while moving more and more toward an increased focus on the energy performance aspect, further efforts still need to be implemented in order to achieve the right awareness and maturity.

# 5 Italian attention to energy efficiency

To date, Italy appears to be a protagonist in the energy transition process that is going on in the European reality, with the intention of reaching the territorial decarbonization goal. This is possible thanks to the diffusion of new technologiesand thanks to the increased use of renewable sources.
Priority milestones in the legislative arena that represent the process in Italy's energy context are outlined below.
Italy's goal is to succeed in lowering emissions by 33% by 2030 by involving all energy-producing sectors, and special emphasis in this area is given to the building sector and how it can be a leader in changing the outlook in the country through the use of efficiency strategies that see the application of renewable energy.

## 5.1 Italian legislation on energy efficiency

In Italy, the concept of energy efficiency is presented in Legislative Decree 192/2005, which transposes the EPBD directive after what was Law 10/1991. This decree then becomes Law 90/2013 giving strong emphasis to the presence of renewable sources to cover the energy needs of the individual building.
The decree provided for a regulation establishing the organizations and figures in authorized to carry out energy certification and provided for the regulation of the methodologies to be followed for calculation and compliance with the minimum requirements.
It was then established the obligation to produce an Energy Certification Certificate at the time of the intervention on the individual building, in which the obligations related to the intervention and compliance with them were stated.
At the same time, compliance with meeting 50% of projected consumption for domestic hot water, heating, and cooling through the use of renewable sources is established.

A further step, which is fundamental in Italian legislation, was taken in 2015 with the drafting of the DM June 26, 2015, in which the minimum transmittances related to the building envelope in the case of new construction and in the case of interventions on existing buildings are reported. These thermal transmittances are differentiated depending on the type of envelope, depending on the direction of heat flow and also depending on the environment from which the component separates the interior environment of the building. How to apply the performance calculation methodology and the use of renewable sources, prescriptions and requirements for the definition of an nZEB building are also defined.

> All indices, calculated taking into account the minimum requirements (in force since January 1, 2019 for public buildings and since January 1, 2021 for all other buildings), are lower than the corresponding indices, listed below, obtained for the reference building (building equal to the design building in terms of geometry, orientation, location, intended use, and having predetermined thermal characteristics and energy parameters that meet the minimum legal requirements):
>
> - the overall average average coefficient of heat transfer by transmission per unit of dispersing area ($H'_T$) is less than the corresponding limit value given in Table 18 within Appendix A;
> - The summer equivalent solar area per unit of useful area, the $A_{sol,est}/A_{sup,useful}$ is less than the corresponding limit value given in Table 19 within Appendix A of the decree with respect to buildings of category E1;

- The energy performance index for winter air-conditioning ($EP_H$), the thermal performance index for summer air-conditioning, including, if necessary, humidity control ($EP_C$), the overall energy performance index, expressed in primary energy ($EP_{gl}$), both total and non-renewable must be lower than the corresponding limit indices calculated for the reference building;
- the efficiencies of the winter air conditioning (H), summer air conditioning (C) and domestic hot water (W) systems are greater than the values of the respective efficiencies given for the reference building;
- Renewable source integration requirements are met in accordance with the minimum principles in Annex 3, paragraph 1(c).

[20]

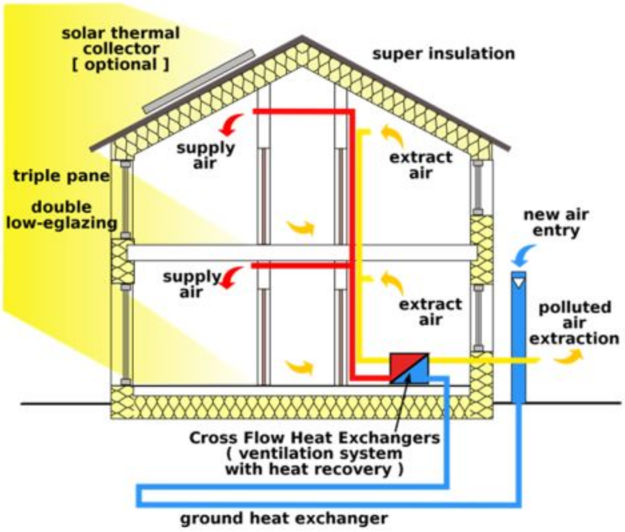

**Figura 8:** Categories of intervention and requirements under the new regulations.

## 5.2 Italian legislation on renewable sources

Subsequently, with the Renewable Decree, it is stipulated that new buildings or buildings undergoing first-level renovation must have renewable energy production systems that can cover at least 50% of the energy expended by the building. This also includes demolition and reconstruction, as well as building extensions of more than 15% by volume over the existing state. Exceptions are made for buildings in historic centers and for listed buildings.

In addition, Italy is transposing European Union directives, whose goals set out in the RED II Directive and the National Integrated Energy and Climate Plan are taken up within the Renewable Decree, which is therefore an important step toward achieving the set climate goals and the decarbonization of the national economy.

# 6 NZEB Building




In 2010 the term NZEB appeared for the first time, within the European Directive 2010/31/EU, also known as EPBD recast (Energy Performance of Building Directive), which was the starting point for the definition of building energy performance. It turns out that a building can be defined as NZEB when its energy consumption is almost zero. Thus, energy-efficient buildings whose energy needs are almost entirely covered by energy produced on-site through renewable sources and whose consumption is very low.
This is precisely why the basis of the definition of NZEB is the calculation of the energy produced and available to the building, specifically we talk about the energy used for heating, cooling and domestic hot water production.


An NZEB building also often features connection to an energy exchange network in which excess energy produced on-site can be transferred to a distribution system to which the dwelling is connected, balancing the fossil-derived energy used.
As mentioned above, an NZEB building must meet requirements in terms of the thermal insulation of the envelope and must comply with rules regarding the systems used.

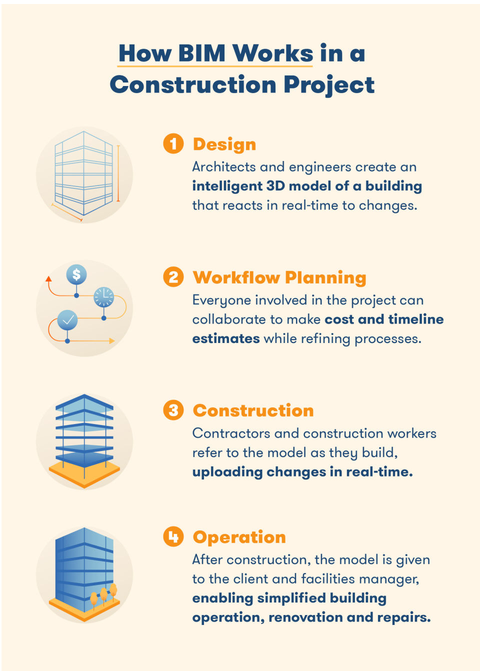
Specifically in the DM June 26, 2015, the one on minimum requirements, a building can be called NZEB when it simultaneously meets:

- All requirements stipulated in (b), subsection 2, of paragraph 3.3 of the Minimum Requirements Decree, calculated with the values in effect drom January 1, 2019 for public buildings and from January 1, 2021 for all other buildings;
- The requirements for the integration of renewable sources in compliance with the minimum principles set out in Annex 3, paragraph 1, letter c) of the Renewable Decree[5]

The above definition allows each member state some autonomy in identifying the specific requirements that an NZEB must meet, which of course allows for the climatic peculiarities of each case study to be taken into account, without neglecting the local characteristics of different countries.

It is therefore fundamental on one hand to consider the different localities and peculiarities involved, but on the other hand to take into account the different types of buildings; in fact, it is necessary to distinguish buildings not only according to their location, but also according to their intended use, whether public or private, also considering a distinction according to the intervention that is going to be made, whether it is a renovation or a new construction, and finally also considering the demand for energy or the production of the latter possible on site.

The economic point of view should also be taken into consideration; in fact, there are several studies in the literature that report data regarding the increased expense of constructing or intervening on a building that have to meet NZEB requirements, coherently with the morphological and geographic characteristics in which the intervention will take place.
In fact, new technologies have a higher cost than more traditional building techniques, although it appears that a new sphere of technologies within the building market characterized by a higher focus on energy efficiency, towards a smarter process management, which integrates the life of the building from the design phase until the decommissioning phase of the building, through a better delivered "facility management" is increasingly established.




[5]Ministerial Decree of June 26, 2015. "Adaptation of the Decree of the Minister of Economic Development, June 26, 2009 - National Guidelines for Energy Certification of Buildings."

In this panorama, the concept of a BIM methodology, the propensity for the use of prefabricated constructions and a continuous and reiterative analysis of all phases of the building's life becomes increasingly important. In addition, it should be mentioned that there are various subsidies and tax rebates that encourage the design of more energy efficient buildings. Finally, it is also worth noting the future savings in both energy and economic terms, not to mention the environmental and climate benefits that a shift to green building would imply.

## 6.1 Reference building

What is called a Reference Building is defined, which is an ideal building from the point of view of energy characteristics while having the same geometric characteristics, location and orientation as the real building:
"This is an ideal building that has the same geometry (shape, walking surfaces, surfaces of dispersing elements) location and orientation as the real building but have predetermined thermo-physical characteristics and energy parameters depending on the climate zone and the period under consideration (2015-2018 and 2019-2021).
Thus, a reference building is defined as a building having a reference structure and reference technical facilities."[6]

This building is taken as a reference for determining the consumption of the actual building and assigning an energy class to it.
Thus, the assessment of the building's energy performance depends on that of the reference building; in fact, is required a direct comparison of $EP_{H,nd}$ (thermal performance index for heating in winter [kWh/m²]), $EP_{C,nd}$ (thermal performance index for cooling in summer [kWh/m²]) and $EP_{gl,tot}$ (overall energy performance index) of the building to be evaluated and of the reference building, which must be greater than those of the actual building.

Thus, the reference building is defined through specific attributes, from the point of view of the building, the following tables are given, in which the values relating to the reference thermal transmittances of the structures that will make up the building envelope are defined, which also take into account the thermal bridges that characterize the specific envelope component.

**Tabella 1:** Thermal transmittance U of vertical opaque structures, to the outside, unconditioned rooms or against the ground

| Climatic zone | U [W/m²K] | U [W/m²K] |
|---|---|---|
| | 2015 | 2019/2021 |
| A e B | 0,45 | 0,43 |
| C | 0,38 | 0,34 |
| D | 0,34 | 0,27 |
| E | 0,3 | 0,26 |
| F | 0,28 | 0,24 |

[6]implementing decree Ministerial Decree June 26, 2015

**Tabella 2:** Thermal transmittance U of horizontal or sloping opaque roofing structures, to the outside and to non-air-conditioned rooms

| Climatic zone | U [W/m²K] | U [W/m²K] |
|---|---|---|
| | 2015 | 2019/2021 |
| A e B | 0,38 | 0,35 |
| C | 0,36 | 0,33 |
| D | 0,3 | 0,26 |
| E | 0,25 | 0,22 |
| F | 0,23 | 0,2 |

**Tabella 3:** Thermal transmittance U of horizontal floor opaques, to the outside, unconditioned rooms or against the ground

| Climatic zone | U [W/m²K] | U [W/m²K] |
|---|---|---|
| | 2015 | 2019/2021 |
| A e B | 0,46 | 0,44 |
| C | 0,4 | 0,38 |
| D | 0,32 | 0,29 |
| E | 0,3 | 0,26 |
| F | 0,28 | 0,24 |

**Tabella 4:** Thermal transmittance U of transparent and opaque technical closures and shutter boxes, including window frames, to the outside and to non-air-conditioned rooms

| Climatic zone | U [W/m²K] | U [W/m²K] |
|---|---|---|
| | 2015 | 2019/2021 |
| A e B | 3,2 | 3 |
| C | 2,4 | 2,2 |
| D | 2 | 1,8 |
| E | 1,8 | 1,4 |
| F | 1,5 | 1,1 |

**Tabella 5:** Thermal transmittance U of vertical and horizontal opaque structures separating neighboring buildings or housing units

| Climatic zone | U [W/m²K] | U [W/m²K] |
|---|---|---|
| | 2015 | 2019/2021 |
| Tutte le zone | 0,8 | 0,8 |

**Tabella 6:** Value of total solar transmittance factor ggl+sh for glazed components with orientation from East to West through South. Appendix A of Ministerial Decree 26/05/2015

| Climatic zone | U [W/m²K] | U [W/m²K] |
|---|---|---|
| | 2015 | 2019/2021 |
| Tutte le zone | 0,35 | 0,35 |

For technical systems, the reference building is considered to be served by the same type of system as the actual building.
Other parameters to be considered for statutory verifications are:

### Overall average heat transfer coefficient, $H'_T$.

To be calculated as the sum of the overall heat transfer coefficients for transmission of the envelope divided by the sum of the surfaces of all opaque and transparent components that constitute the envelope.

$$H'_T = H_{tr,adj} / \sum A_k{}^7$$

### Solar equivalent area, $A_{sol,est}$

Calculated as the summation of the summer equivalent areas of each glazed component.

$$A_{sol,est} = \sum F_{sh,ob} \cdot g_{gl+sh} \cdot (1 - F_F) \times A_{w,p} \times F_{sol,est});$$

The useful thermal performance indexes for heating and cooling services and total building index should also be calculated, these values must be lower than the corresponding limits for the reference building, and the average seasonal efficiency of winter and summer air conditioning and domestic hot water systems with values greater than those for the reference building should be calculated;

# 7 Energy Certifications

The energy assessment of a building, along with the environmental assessment, is fundamental in order to define a building artifact. The energy one identifies the energy consumption levels of a building, tracing if necessary the components that can contribute positively to its performance. The energy assessment is directly linked then to a certification, which must be internationally recognized and use methodologies that have a specific scientific value, contextualizing it according to the building's function and the climatic conditions in which it is located.
Certifying the energy level of a building gives very clear and therefore comparable indications of energy consumption and demand according to uses and utilities. Energy certification also gives us precise data and performance indications, provides guidance on possible incentive strategies, and estimates the efficiency of the building, all based on premises, which are fundamental to achieving a spread of the resulting assessments as uniform and accurate as possible.

### 7.0.1 International energy certifications

Different ways of assessing the energy performance of a building can be identified in the international building scene, made to certify the achievement of different levels of sustainability.
Two different approaches can be distinguished in drawing up an energy certification:

- The first is based on the assessment of the qualitative requirements of the building artifact through a scoring system that then provides the building's level of sustainability;
- The second, on the other hand, is based on the analysis of the entire building process, paying particular attention to the quantification and qualification of the energy used in the various stages of the building's life cycle, thus applying the principles inherent in LCA analysis.

These methodologies have led to the establishment of several internationally recognized certifications, among which we find, for example, the analysis scheme elaborated by the GBC (Green Building Challenge), the BREEAM (Building Research Establishment Environmental Assessment Method) system, the LEED (Leadership in Energy and ENvironmental Design), and many others.


(a) GBC (b) BREEAM (c) LEED

**Figura 9:** Different certifications symbols

### 7.0.2 National energy certifications

In Italy, the same testing procedures have been transposed and have resulted in several nationally recognized certifications. We find several certifications here as well:

- ITACA: this turns out to be the Italian reception of the international GBC system,
- CASACLIMA: this is a system created to inform consumers about the energy requirements of a building using simplified presentation graphics in order to make it easy for users to understand;
- SB100: this is an integrated system created by several public bodies coordinated by ANB (National Association of Bioecological Architecture) that comprehensively addresses all aspects of sustainable development, both ecological, social and economic.

# 8 NZCB Building

We then move to the next level of implementation, bringing to life what are the NZCB buildings. A ZNC (Zero Net Carbon) building is defined as: *"a highly energy efficient building that produces on-site, or procures, enough carbon-free renewable energy to meet building operations energy consumption annually"*.[11] In a ZNC building, carbon-based energy consumption is reduced first through building design strategies and efficiency measures, then through on-site renewable energy generation, and finally through procurement of locally produced off-site renewable energy.

The Net Zero Carbon Buildings Commitment recognises leadership action by businesses, organisations, cities and subnational governments in tackling operational and embodied carbon emissions from the building and construction sector.
This requires deep collaboration across the entire value chain, and radical transformation in the way buildings are designed, built, occupied and deconstructed. It requires new business models that promote circularity, re-use of buildings and materials, whole life cycle thinking, high performance operations, and ultimately a shift away from fossil fuels.

## 8.1 Requirements

The Commitment requires that by 2030:

- Existing buildings reduce their energy consumption and eliminate emissions from energy and refrigerants removing fossil fuel use as fast as practicable (where applicable). Where necessary, compensate for residual emissions;
- New developments and major renovations are built to be highly efficient, powered by renewables, with a maximum reduction in embodied carbon and compensation of all residual upfront emissions.

In order to prevent and mitigate embodied emissions, increase resource efficiency and stimulate the development and market supply of low carbon products, the sector must first of all reduce and account for its impact on the environment and natural resources through design and construction, and, as second, generate a strong and urgent demand signal to activate the necessary finance to decarbonise materials, construction and heavy industry processes.[12]
As this is a global challenge requiring local solutions, the Commitment is outcomes focused and action based, allowing for creative and flexible solutions at asset and portfolio level based on best practice application.

# 9 ReGen Village

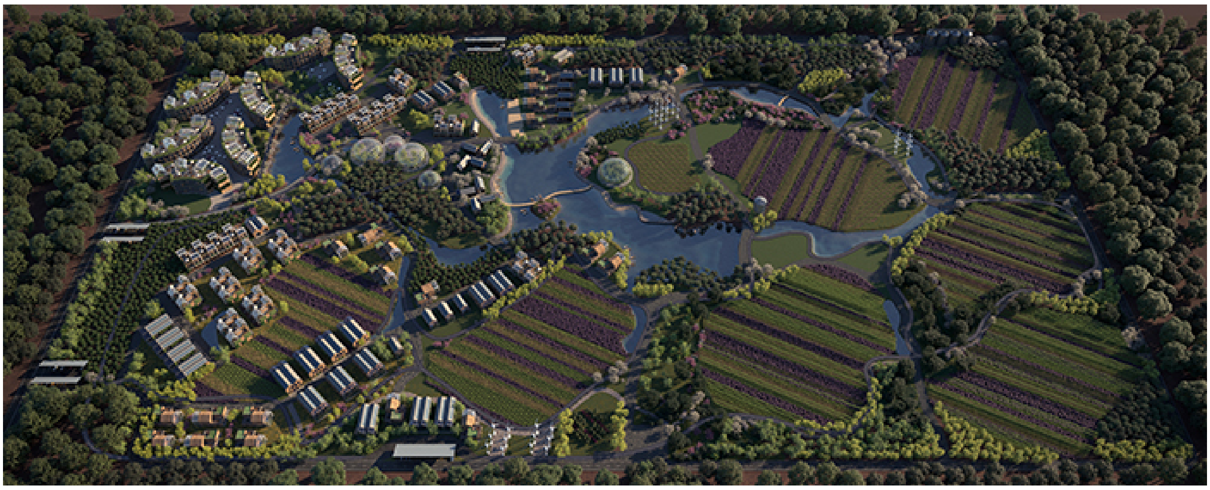


**Figura 10:** Masterplan of the ReGen project.

ReGen Project aims to create a model for a village which can autonomously
The project aims to give life to a village model able to independently provide for its daily needs of power and energy. At the same time, it respects the environment thanks to a circular system that transforms the village waste into nutritional inputs for animals and agricultural production.
The houses, prefabricated modules designed by Effekt, are of different types and sizes according to needs, equipped with a rainwater collection system, used for domestic and agricultural uses, and a veranda, which also serves as a private greenhouse. Electricity is provided by photovoltaic panels togheter with geothermal and wind systems. A recycling system also allows the reuse of waste from the village, thanks to flies and aquatic worms that digest organic waste turning it into food for farm animals while human and animal waste will be the fertilizer for the vegetation. Unused agricultural products will be converted into biogas in special establishments or food for the animals raised.
At the center of the village are located common agricultural areas, and fish and poultry farms which provides the necessary protein supply to the daily diet of village inhabitants. Each house is equipped with passive heating and ventilation systems able to absorb and distribute solar energy in the form of heat during the winter, reflecting it in summer.

An expert staff follows and coordinates all agricultural and livestock activities in the village, thanks to an intelligent network connected to the energy production system of each house, thus controlling consumption and storing excess electricity. It is estimated that the village will be able to provide 50% to 100% of the daily needs to each inhabitant. A machine learning algorithm will also analyze the data collected by the sensors maximizing like that production and energy efficiency.

**Figura 11:** An internal render of the ReGen Village.

## 9.1 Project objectives

The project, presented for the first time at the Venice Biennale in 2016 in the Danish pavilion, has as its main objective a new way to face the increasingly critical situation in which our planet is.
The initiative aims to act at the base, with houses designed till the smallest detail to be as functional and efficient as possible, with plants specifically designed to cooperate with each other both in terms of energy and waste disposal, with systems that connect each of the 25 housing units between each other, which, like that, become part of a single large set. Travel is also seen in an ecological key thanks to the use of rechargeable electric cars. Each housing unit is not only part of the village from the point of view of plant but also in the overall view of the area; in the design of the spaces of the village, in fact, the location of each housing unit, such as the one of free areas and green areas, is taken into account in order to have an integration between each other through the presence of each of them.

## 9.2 Needs planning

The ReGen project starts from a questions: which are the needs, both material and non-, of a three person family in the time of a year, and how those can be satisfied respecting the base principles of the project. So they started exactly from this, in order for them to elaborate a program to plan and meet the needs of the inhabitants, with structures and technologies placed strategically depending on spacial needs.

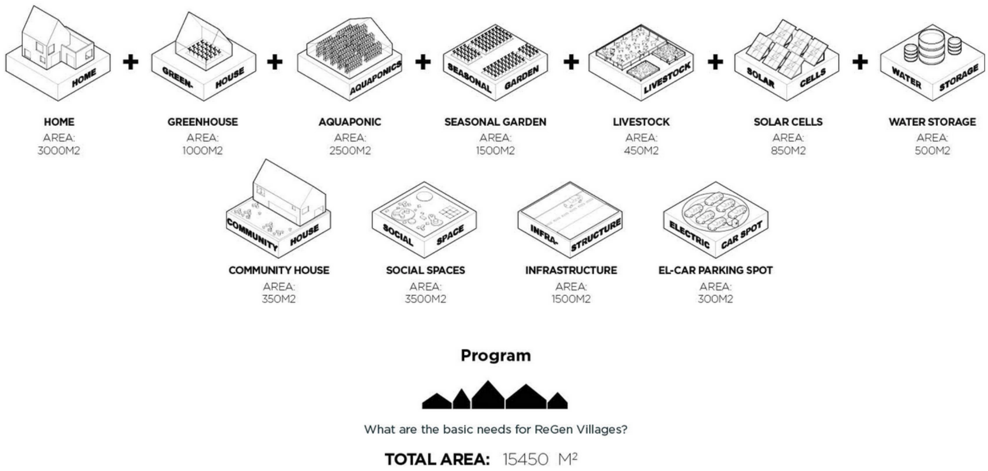



**Figura 12:** Structures for the fulfilment of the basic needs of an average family.

## 9.3 Different housing units kinds

The housing units of the village are of eight different types, even if all of them has some common characteristics. Each house is designed as prefabricated, so easily mountable and disassembled in short time; each of them has a covered and extended outdoor area and a rainwater collection system; finally each house is designed, from the energetical point of view, according to the model of the *Passivhaus*[8], also is heated by passive heat, while glass enclosures allow to prolong the conditions of the warmer season, incorporating solar energy. [14]

[8]The *Passivhaus* is an house that ensures thermal well-being without or with a minimum internal energy source, while maximizing the energy efficiency as the sum of the heat inputs of solar radiation and those generated internally by appliances and occupants since the sum of them compensate the losses of the casing. [13]

**Figura 13:** The housing units in the project.

The village space is designed to accommodate 25 single-family homes arranged in a circle, enclosed in glass casings to accelerate the growth of food grown in greenhouses.
The eight types of housing are divided as seen in Figure: 4.3: two on one floor, four on two levels and two with three floors above ground.

- The 1A is made up of an house of 80 $m^2$ and a greenhouse of 20 $m^2$;
- The 1B has the same dimensions of the 1A but a different subdivision that divide the greenhouse in two parts;
- The 2A is made up of an house of 110 $m^2$, a greenhouse of 20 $m^2$ and a terrace also of 20 $m^2$;
- The 2B is made up of an house of 120 $m^2$ and a greenhouse of 25 $m^2$;
- The 2C is made up of an house of 130 $m^2$ while the greenhouse and the terrace are both of 20 $m^2$;
- The 2D is made up of an house of 120 $m^2$, a greenhouse of 15 $m^2$ and a terrace of 20 $m^2$;
- The 3A is made up of an house of 140 $m^2$, a greenhouse of 5 $m^2$ and a terrace of 40 $m^2$;
- The 1A is made up of an house of 140 $m^2$, a greenhouse of 10 $m^2$ and a terrace of 50 $m^2$;


**Figura 14:** Housing unit typology.

## 9.4 Food requirement satisfaction

For the food requirements of the inhabitants, the techniques used are many and will be examined in detail of their operation later, in the 5.3, however, this section will give an overview of how every single part of the life cycle of something within the ideal regen is part of something bigger, something that does not end with its end but continues to infinity.

**Figura 15:** The agricoltural center of the community.

Starting from household waste, these are divided into different categories so that they can be reused for the most indicated purposes: non compostable organic waste is used in a biogas plant, compostable ones instead become food for a soldier fly farm[9] and for the livestock, the flies are then used to feed the fish and the waste of the latter are used as fertilizer for the plants, while the livestock waste becomes fertilizer for the seasonal gardens.
As for the agricultural methods used, such as areoponic, hydroponic and permaculture, these allow to produce many products compared to the time and resources used. The aquaponics system provides km0 fruits and vegetables for the inhabitants, while the seasonal gardens produce a variety of products for domestic consumption. The production systems will be positioned at the center of the circle formed by the houses, thus making them easily accessible by every inhabitant of the village.

[9]Soldier flies, or black soldier fly, are insects extremely widespread in nature and useful in composting plants because of the voracity of their larvae and the ability to transform organic matter into by-products such as lipids, Chitin and proteins, which can then become biofuels, biodegradable materials or agricultural fertilizers.

**Figura 16:** An example of the seasonal garden present in each housing unit.

## 9.5 Infrastructure

The circle of production systems is divided by 8 squares, connected together to ensure an efficient transport infrastructure system. These squares are also charging stations for electric cars. The energy used by the charging stations comes from the village's energy production plants, solar panel installations and biogas plants. The advantage of electric cars is the energy saving, when the energy used is produced from sustainable sources in fact it can be considered practically as a zero emissions transport form, in addition to that the noise pollution is like that drastically reduced, also, electric cars need much less frequent revisions and in some ways, compared to petrol cars, do not require maintenance, such as oil or filter change. In this way also the movements inside the village are made sustainable.

## 9.6 Social spaces

The regen project itself has not only "environmental" value, but also, and above all, social. In fact, the main objective is not to create a place where eco-sustainability is the basis of everyday life, but actually to sensitize the inhabitants to be an active part of something great. Thanks to the positioning of social spaces within the circle of housing units, and between the production systems, a complete integration between the inhabitants is guaranteed, ensuring that a common life develops.

**Figura 17:** The social space of the village.

## 9.7 Biodiversity

Biodiversity is the result of the evolution of the Planet lasting 3 billion and 800 million years, it is essential for the survival of man, since is only thanks to that biodiversity that there is an availability of fundamental resources such as food, building materials, textile fibers and also the active principles of the medicines, but not only, it is also fundamental for the survival of the Earth itself, often in fact is indicated as the index of health of the Earth.
Nature in itself would be able to self-sustain and self-renewal, providing for its needs; it was the intervention of man, deeper over time, to mess up the mechanisms by which nature was regulated, increasing pressures on ecosystems, fragmentation of habitats, air, water and soil pollution, over-exploitation of resources, forests and soils and the emission of greenhouse gases, leading to the climate change now evident.

**Figura 18:** The biodiversity and the free space around the village.

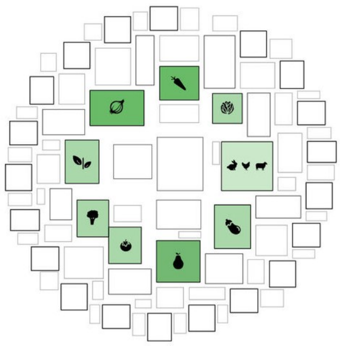
The human being, therefore, considering how he manages his life in industrialized societies, represents a serious threat to the existence of numerous species and numerous places on the Planet.
ReGen village decides to act also in this sense, so, since the urban area with its life irreparably harms the ecosystem, the project provide an area free from any building around the village, but occupied by permacrops and seasonal gardens, with the aim to reduce, like that, the *footprint*[10] of the village while increasing it's biodivesity.

[10]The Ecological Footprint is an indicator used to evaluate human consumption of natural resources compared to the Earth's ability to regenerate them.

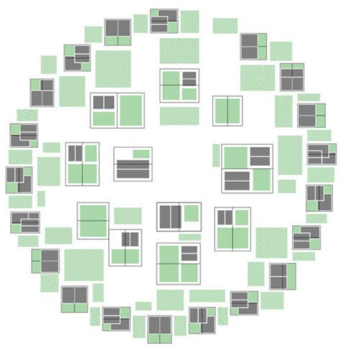
# 10 Services

## 10.1 Spaces organization

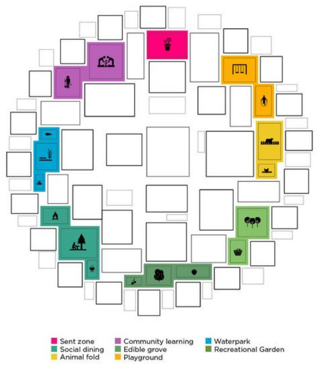
The regen village is designed down to the smallest detail, also regarding the positioning of the different structures in the available area.The area will be organized in a circular way, in order to have in the outer circle the 25 housing units planned, with their greenhouses and their gardens, to this area are dedicated 3000 $m2$. Inside there are facilities for food production, so the areas for aquaculture and greenhouses available to all inhabitants, seasonal gardens and areas for livestock farming occupying a total of 5450 $m2$.
Plants for the production of solar energy and areas for the storage of water stocks are positioned between these two circles, interspersed with spaces dedicated to infrastructure, so the squares and the power stations, arriving at a occupied area of 11600 $m^2$. Finally, the remaining 3850 $m^2$ are used as social spaces and for a common house located exactly in the center of the village.



(a) Food production spaces



(b) Green spaces, housing spaces are also visible




(c) Common spaces organization

## 10.2 Waste management

A fundamental part in the organization of the regen project is the waste disposal system, because it actually doesn't provide an actual disposal but a kind of general reuse, thanks to a closed production cycle every waste is food for something else, from soldier flies to fish to plants as fertilizer, or energy for the whole village.

The waste coming from the different houses is initially accumulated in a storage center waiting to be divided according to the category to which they belong in order to be reused in different areas and with different purposes.

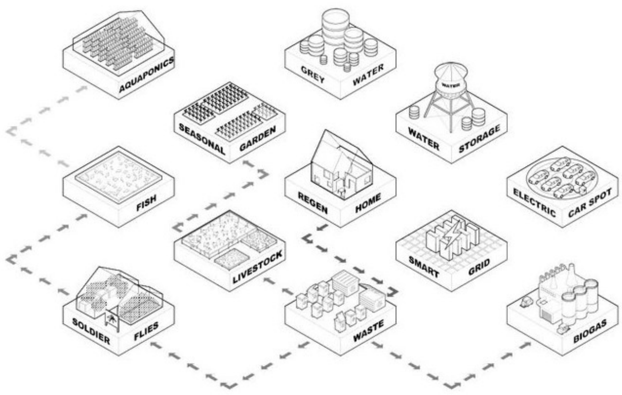



**Figura 19:** Waste management

For example, compostable organic waste is moved to a dedicated biogas plant where, in a special container (the fermenter), in the absence of oxygen and at controlled temperature, a large number of bacteria degrades the substances contained in them, producing biogas (then converted into electricity thanks to a cogenerator), heat (reused for the fermentation process itself and for heating the houses of the village) and other substances. Part of the result of the biogas plant is used as food for the soldier flies, which then become food for fish and animals, the waste of which are instead used as fertilizer for seasonal gardens, for the aquaculture and the hydroponic crops.

In this way, with this idea of a circle in which nothing is wasted and everything is reused, the village is able to remain self-sufficient and completely sustainable

## 10.3 Food production

Food production within the ReGen village is based on different technologies.
First of all, thanks to the seasonal garden and acquaponic culture, a kind of sustainable mixed farming and livestock, the houses receive fruits and vegetables, while, thanks to aquaculture together with animal's livestock, they receive the necessary proteins. The different technologies used are innovative techniques but based on ancient practices that have been used for a long time, but the vision that the project have of them makes them modern and ergonomic, since each of them is designed in order to offer the maximum production in the smallest possible space while being perfectly adaptable to the concept of circularity and reuse.

### 10.3.1 Hydroponics

Hydroponics is an agricultural technique, actually very ancient[11]. It's based on the cultivation of plants out of soil but thanks only to the support of water. There are two different techniques, the first one plans to use instead of the soil a substrate of perlite, sand or expanded clay, while the second does not require the use of the substrate, but simply submerges the roots directly in the nutrient solution. roots of the plants is returned to the tanks for aquaculture and resumes its cycle.

(a) Hydroponic culture example 1

(b) Hydroponic culture example 2

### 10.3.2 Aquaculture

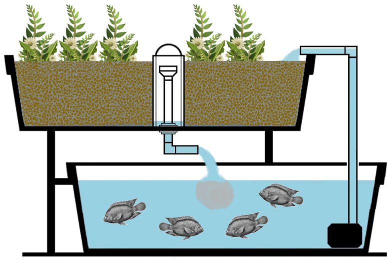
The aquaculture is a method of farming aquatic organism with human intervention, mostly vessels are used, in which fish, clams or algae, grows in order for them to be harvested, this is the biggest difference with, for example, fishing, since when fishing the aquatic organism is a common accessible good, while in this case the growth is controlled.

[11]According to several studies carried out on the subject the legendary *Gardens of Babylon* themselves were realized through the technology of the hydroponic culture

### 10.3.3 Aquaponic

Aquaculture is a type of agriculture that exploits aquaculture and hydroponics together, allowing to obtain a symbiotic environment in which the water of the aquaculture tanks is pumped into the hydroponic ones, so that plants can remove various waste substances of fish from the liquid, drawing nourishment from them. At this point the water filtered from the roots of the plants is returned to the tanks for aquaculture and resumes its cycle.

(c) Aquaponic culture 1



(d) Aquaponic culture 2

### 10.3.4 Greenhouse and heated greenhouse

The technology of *greenhouses* is widely used in the cultivation of crops, mostly are widespread traditional greenhouses, low-tech, However, innovative and cost-effective solutions exist and are used to a lesser extent. The *greenhouse* present inside the regen Village are of two types, simple or heated. For these two types the difference lies in the type of air conditioning adopted, which in turn depends on the crop you want to practice.
Air conditioning in greenhouses means not only controlling the temperature but also the relative humidity, ambient brightness and air exchange. In warm greenhouses this technology is indispensable because they are realized precisely when the "greenhouse effect" is not enough to guarantee the optimal temperature.

To be noted is the fact that the use of the most modern systems of greenhouses (mechanical openings and closures, thermal regulation etc.) allows the entire system to be automated thanks to management IOT technologies based on inputs transmitted by sensors and microprocessors.

(e) Greenhouse example

(f) Greenhouse in the village

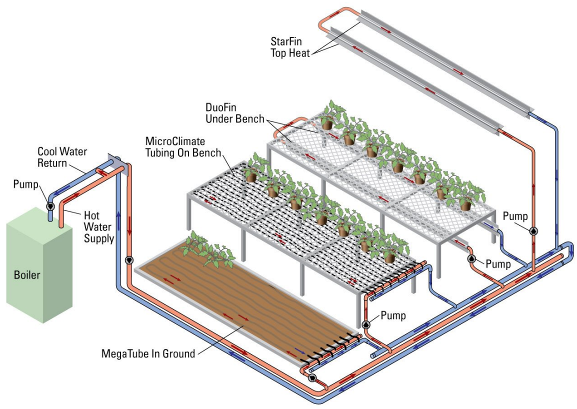
In terms of construction, greenhouses are essentially of two types:

- double-pitched, such as those we find in ReGen village, which often require, to improve ventilation, motorized openings near the ridge or on the sides, and which allow the installation of photovoltaic modules on the roof since the inclination allows the proper incidence of solar rays;

- Tunnels, the vault of which is semicircular or elliptical, often the roofing of this type is made of polyethylene film stretched over the structure, again openings, near the eaves, may be necessary to improve aeration.

The *greenhouse* present inside the ReGen Village are of two types, simple or heated. For these two types the difference lies in the type of air conditioning adopted, which in turn depends on the crop you want to practice.
The distinction is made between cold greenhouses (if they are not air-conditioned), temperate greenhouses (when the temperature at night is maintained between 10 and 14°[12]) and warm greenhouses (in which at night the temperature is maintained between 16 and 20°[12]).

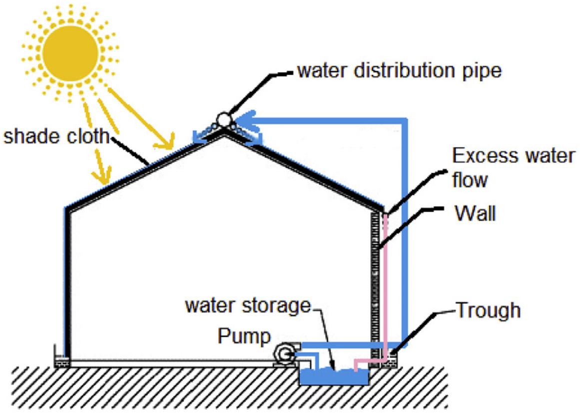
Air conditioning in greenhouses involves not only controlling temperature but also relative humidity, ambient brightness and air exchange. In warm and temperate greenhouses, this technology is indispensable since they are implemented precisely when the ”greenhouse effect” is insufficient to ensure the optimal temperature.
Heating is generally implemented by means of hot air generators equipped with fans, usually suspended, that insufflate hot air into a pipe made of a perforated plastic film that is also suspended. In the case of substrate heating, on the other hand, this is generally accomplished by means of pvc piping placed inside the substrate.
In heated greenhouses, however, in the summer period the ”greenhouse effect,” which was not sufficient in winter, becomes excessive, and causes overheating that makes it necessary to cool the greenhouse through the combined action of shading and ventilation, natural or forced. However, there are also systems, so-called *cooling systems*, which do not require shading. In these cases, a system of fans and a battery of honeycombed humidifying panels (with a flow rate of about 2l per m$^2$ [12]), positioned opposite each other, provide continuous air recirculation that replaces shading; otherwise, the *fog system* can be used, which involves high-pressure water spraying (35-40 bar[12]).



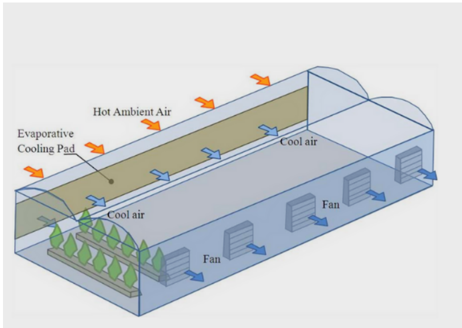

(g) Greenhouse heating system 1

(h) Greenhouse heating system 2

[12]Typologies of greenhouses and cultivation techniques, codipd




(i) Greenhouse cooling system 1




(j) Greenhouse cooling system 1

One of the most cost-effective systems is thermal storage in the ground: in this system, advantage is taken of the fact that temperatures in the ground are more constant than those in the air and less affected by external climatic variations as the depth increases.
In the summertime, outside air, which is warmer than the ground, enters in pipes inside the latter, passing through it it gives up its heat to the ground, which warms up, and comes out cooler, thus cooling the greenhouse. In the cold season, the system involves recirculation of the greenhouse air, with heat accumulating in the ground during daylight hours and returning it at night, thus keeping the temperature higher at night.
Another issue to consider is that of illumination, in fact, in Northern Europe, especially in the winter period, the reduced number of hours of natural light severely limits the possibilities of plant growth, in these cases artificial lighting is used. The recommended electrical power is usually in the order of $50 \frac{W}{m^2}$[12]), in addition, since much of the electrical energy is converted into heat, artificial lighting also contributes to heating.
Of note is the fact that the use of the most modern greenhouse systems (mechanized openings and closings, thermal regulation etc.) means that the entire system can be automated by management through IOT technologies based on inputs transmitted by sensors and microprocessors.

## 10.4 Water resources

Within the regen project an important part of sustainability and respect for the ecosystem is also represented by the water management system used.
The reuse of water, meteoric and not, is, in fact, essential given how quickly the water reserves of the planet are finishing. Unfortunately, it is not possible, even through thorough treatments, to reuse water of any kind for drinking purposes, so the reuse is only possible for sanitary purposes (toilet and bidet), household uses (washing machine, washing dishes and irrigation), irrigation ones (crops for food production and for non-food purposes), industrial purposes (fire, process, washing and thermal cycles) and civil uses (street washing, feed cooling and heating cycles, feed supply networks).
Within the regen Village this principle is followed where possible, and also in this case too the idea of a circular kind of system is followed. So we start from a rainwater collection center in which rainwater is collected and treated for reuse, for example for irrigation, subsequently the water that is extracted in the biogas plant, is collected in a storage facility, while gray water[13] is separated to be treated and reused.

[13] Water from kitchens or laundries

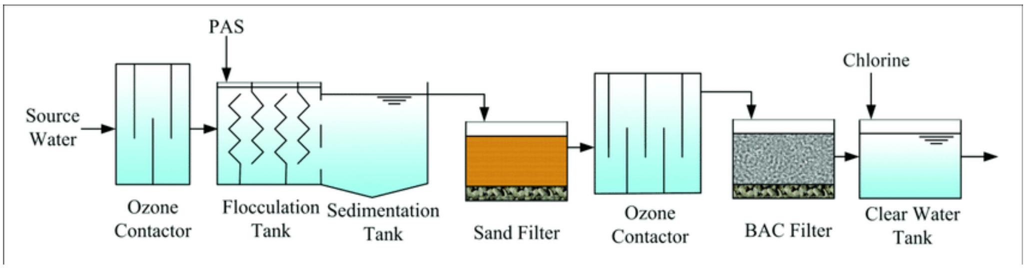



**Figura 20:** Water reuse cycle

### 10.5 Energy reserves

Energy reserves are carefully controlled and managed via the *smart grid*. So each source of energy, from solar panels to the wind system, transmits the excess energy to the grid that accumulates or re-flows where necessary.
Part of the energy is produced by plants that exploit renewable energy, other part is produced by the biogas plant, which sees the decomposition of organic material by bacteria, producing carbon dioxide, hydrogen and methane, in this way not only the $CO_2$ produced by the combustion of methane allows to balance the budget of carbon dioxide emitted into the atmosphere [14], as opposed to the $CO_2$ emitted from the combustion of fossil fuels, but also the energy produced by the heat generated in the plant is completely and totally gained.
Finally, as for the electric car stations they are powered thanks to the excess energy produced by the village and stored in the appropriate structure, thus avoiding waste or dispersion.

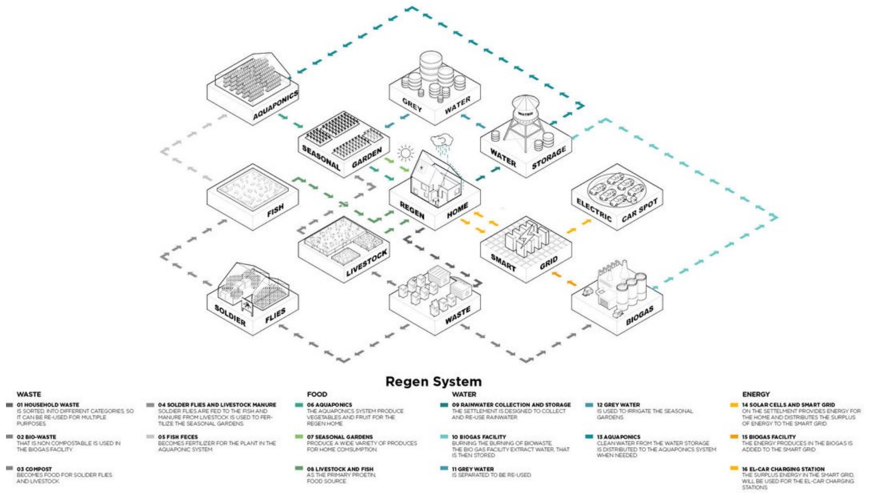



**Figura 21:** The Regen Village infrastructure system

#### 10.5.1 Smart Grid

In the current era of progress, modern technologies and attention to sustainability, are increasingly relevant, especially thanks to the advantages that the use of them leads to the economy and environment.
Although currently the exploitation of resources from renewable energy is increasing, the limits are obvious, from those imposed by nature itself to those of technologies not yet totally affordable, For this reason, efficient energy management and distribution, which follows the productive rhythms, is increasingly necessary. This is what *smart grid* does, the purpose is to put in "communication" the production of energywith the consumption of the end user.
Currently, the electricity grid operates through a one-way system: the flows move exclusively from the

[14]the $CO_2$ emitted by the combustion of biogas is the same $CO_2$ set by plants (or taken by animals indirectly via plants)

power plants to the distribution, which is continuous and constant, regardless of the amount of energy actually needed or consumed. Instead the system defined *smart* connects producers and consumers, integrating into the network the functionality of an information network, which draws information in real time from all products and tools connected to users, to then rationalize and distribute energy efficiently, avoiding overloads and voltage changes.
Thanks to dedicated monitoring tools, it keeps track of the electrical flow of the system, avoiding interruptions and reducing the load where possible.

The advantages are quite obvious, starting from the savings, not only economic, but also in terms of energy and reduction of $CO_2$ emissions, for the benefit and protection of the environment, till the most efficient transmission and the fastest recovery of energy after a possible interruption.

# 11 "Reinventing cities" competition

*"A vast majority of the world's greenhouse gas emissions come from cities. As the urban population increases, it is urgent to harness a model of low-carbon urban future where everyone can thrive. Reinventing cities is an initiative led by C40 to stimulate sustainable development and to celebrate innovative solutions to environmental and urban challenges."*
This is the first sentence that you can find on the reinventing cities website[15], that perfectly describes the aim of the project.
So Reinventing Cities is a global competition that aims to help the urban regeneration across the globe in a new resilient and decarbonised point of view.
The competition identify under-utilised sites that can be transformed into new realities, and invites creative multi-disciplinary teams to submit proposals that can provide a model for city landmarks of the future.
Reinventing Cities considers the city as an opportunity, as the urban density can create, using more efficient infrastructure and improved urban planning, the possibility for a better quality of like and a lower carbon footprint. So the main aim is to develop new solutions and models for decarbonized and greener buildings, services and ways to live the cities, in order for them to be adopted and widespread.
The hope is that this competition can set a new standard of carbon-neutral and resilient development to be implemented in the design of projects in different fields of study to bring a kind of *City of Tomorrow*.

On the website you can find the sites where the competition is taking place, and you can see that those are all across the world, between them you can find for example, Auckland (New Zealand), Bristol (England), Izmir (Turkey), Madrid (Spain), Oslo (Norway), Phoenix (Arizona), Reykjavik (Iceland), San Paolo (Brazil), Singapore, and much more, like Milan, the one of our interest.

## 11.1 Project objectives

The thesis proposal simulates the participation to the Reinventing Cities competition regarding the Bovisasca site, in Milan, which is in a neighbourhood in the north of the city, the goal is to take that area and, through the inclusion of public services, green areas, new buildings while stimulating a social and functional mix, transform it in a new collective engine with a greener and more sustainable way of living.
The project is also connected to the MoLeCoLa project (*"MoLeCoLa – Mobility Learning Community Lab: reinventing the Nodo Bovisa site as an integrated, sustainable idea-generating neighbourhood*[16]), which aims to promote the re-qualification of the Bovisasca neighbourhood thanks to the commitment of the Park Associati and of Politecnico di Milano. The proposal wants to create a space where housings, student residences, commercial activities, co-working and the Ferrovie Nord headquarters are integrated within a public space full of equipped green areas to create a harmonious landscape that meets the objective of achieving zero $CO_2$ emissions by 2050.
The main objective of the thesis is to bring together the Reinventing cities project and the ReGen Village project in order to develop a kind of small reality in which the principles of both the projects are respected, which can represent a new way of living together with nature and Hearth and in accordance with her necessities.

[15] https://www.c40reinventingcities.org/
[16] https://parkassociati.com/progetti/nodo-bovisa-molecola

## 11.2 Bovisa site

The Bovisa is a district in the northern part of Milan. It belongs to City Hall 9 and is physically bounded by the tracks of the railway, which encircles the district for much of its extension.
It takes its name from a farmhouse of ancient date, the Cascina Bovisa, around which was formed an agricultural village that was then incorporated into Milan in 1873.

**Figura 22:** "La Goccia" park, by Federico Bianchini

### 11.2.1 Characteristics

The district is divided into two areas by the route of the North Railways, which runs from North to South. The railway can be crossed only by pedestrian way, through the stairs to the railway station of Bovisa: this has meant that from the construction of the railway the development of the two areas evolved independently.


(a) The railway of the station


(b) The Bovisa station

### 11.2.2 Infrastructure and transport

Lines S1, S2, S3, S4, S12 and S13, regional lines and Malpensa Express: Bovisa FN station The Bovisa district is bordered to the south by the outer ring road. Bovisa is served by the Bovisa FN station, which is located at the junction between the Milan-Asso/Saronno railway and the railway passage. The station, managed by the FNM Group, is served by suburban trains (lines S1, S2, S3, S4, S12 and S13), regional trains to and from Como, Varese, Laveno-Mombello, Novara and Asso with terminus in Milan Cadorna and Malpensa Express, all armies from Trenord. The area of Goccia is also served by the station of Villapizzone, located in the neighboring neighborhood of the same name, which in 1998 replaced the old station FS. It passes the suburban lines S5, S6 and S11 and the regional trains to Bergamo and Cremona (both via Treviglio) attested at the station of Porta Garibaldi. The district is crossed by bus, trolleybus and tram lines, managed by ATM, that connect the Bovisa to the neighboring districts, to the center of Milan and to all the other neighborhoods that rise along the ring road. La Bovisa is not directly served by the metro; the nearest station is Dergano, in the homonymous district not far away, on the M3 line.

The Bovisa district is a popular but not suburban neighborhood, it's name has an undoubted agricultural vocation, that you can easily recall in the root of the "bove", the cow. It was, in fact, the name of a farmhouse just outside Milan, in which there were, obviously, cows.
Anyway Bovisa was mainly known for its industrial past, for the modern and fascist architecture, for factories and gas meters. Then the Polytechnic of Milan has opened a pole in the Bovisa area and, from then, the Bovisa has always been mainly known so, like a center of the Polytechnic and a university district.

(c) The Polytechnic pole in Bovisa

(d) 2501 in Milan, Bovisa

But let's go with order, Bovisa was born as an agricultural area of Milan, and so far it was clear to everyone. Oxen, fields, farmsteads, the "*scighera*" - that is the peculiar term with which in Milan the mist is indicated, the one that clogs everything and from all sides. As evidence of this past, there is the *Cascina Albana*, with a pit in the center of the court, a niche dedicated to *Madonna della Frutta* (-literally "fruit lady"), adorned with grapes, pears, apples and so on.
Then Bovisa became the industrial pole that is known today, in the district there were, during the centuries, the Candiani plant that made sulphuric acid in the late nineteenth century, the Ceretti Tanfani that made long metal cables for the chairlifts, the Glassworks, the Gas Company and the transport of coal by railway; in short, there is a whole industrial landscape that gives in to the passage of time, becoming halfway between ruins and playgrounds, and til the late twentieth century some little activities such as blacksmiths, potters and butchers, survived.[15]

(e) Old chemical plant

(f) Old glassworks Livellara

Then the boost of the Polytechnic with the opening of the Design department and the headquarters of Mechanical, Energy and Aerospace Engineering, together with the construction of the North Railway Station gave life to the actual Bovisa that can be seen by any of us.

We are at the Bovisa district of today: the one of students, of people coming and going, of the coming and going also of ideas, the ideas of the figures who live there: from the international artists made by the graffiti in industrial architecture, such as *2501* or *Fabio Roncato*, to the brand new active partecipant of the Bovisa's life, such as the girls of *Spazio Meta*, from the many musicians who are rooted in the neighborhood such as *Irbis* and *HÅN* up to the technique fashion brands such as *Ekor Corp*.
Another effect of the "studentalization" occurred during the last twenty years, together with the profusion of ideas, is the birth of more and more places for the sustenance of the student: copy shops and the paradises of bread and stealthy lunch.[15]

(g)

(h)

**Figura 23:** From Noemi Barzaghi, a representation of the daily life in Bovisa

In this atmosphere the Bovisa neighborhood present itself as something spectacular in the technique field, thinking in fact of the Engineering Department we can talk about the experimental laboratories. Here the wind is blowing at two hundred and fifty km/h, the impacts of birds is simulated by a ballistic jelly, here the most famous VR driving simulators in the world are, and much more.

(a)

(b)

**Figura 24:** From Mattia Balsamini, a sneak peak inside the engineering lab inside the Polytechnic

### 11.2.3 The redevelopment

In this reality the Bovisa district is living and is trying to redevelop itself. The re-qualification of the neighborhood is, in fact, growing, it is expected that by 2030, in line with the major European cities, Milan will have a scientific and technological park that meets international standards.
The Bovisa Campus of the Polytechnic University will be expanded with the birth of a new large university and two large parks: the Drop Park of over 160 thousand square meters and the Gas Meter Park, equipped for leisure and sports, of about 200 thousand square meters. The two green areas will be connected by a network of pedestrian crossings that will wind between the buildings of the industrial past, such as the two old gas meters, which will be recovered and combined by new buildings planned for the expansion of the Polytechnic.
The intervention will also bring the development of infrastructure and of the existing urban fabric through the construction of university residences as well as buildings for productive, receptive and commercial activities.

Among the suburbs of Milan, Bovisa is certainly the best connected, not only with the city but also with all the North of Lombardy, Lake Como and Malpensa airport. Lapped south by the outer ring road, the area is strongly marked by the massive presence of the railway: that of Trenord with Villapizzone stop, and that of Ferrovienord that runs north-south, which, as already said, split the neighborhood into two separate areas connected by the staircase of the station Bovisa FN.
All the lines of the railway stop in Bovisa, allowing its residents to reach any metro line in a few minutes. The neighborhood is also crossed by numerous bus, trolleybus and tram lines that connect it with neighboring neighborhoods and lead to the center.[16]

Innovation, technology and sustainability are the three key words of a Milan that is trying to restart thanks to new urban projects. In this the main project that involves the Bovisa neighbourhood is the MoLeCoLa project (Mobility Learning Community Lab), founded by the architecture studio Park Associated, founded in 2000 by Filippo Pagliani and Michele Rossi, which aims to reinvent the Bovisa node as an integrated, sustainable district and producer of ideas.
This project, like that of the new face of Piazzale Loreto recently announced to the microphones of

the Municipal Administration led by Mayor Beppe Sala, was promoted by C40 Reinventing Cities - the plan to regenerate the dormant spaces of the cities. Park Associati won the international competition presenting a masterplan that has redesigned, for an area of over 90 thousand square meters, to develop an intervention that dialogues with the Politecnico di Milano. In the project, the railway station, a very little pulsating area of the area, would become an important and central resource.[16]

(a) (b)

**Figura 25:** The MoLeCoLa Masterplan

## 12 MoLeCoLa Project

The project for the development of the Bovisa node is called MoLeCoLa (Mobility, Learning, Community, Lab), which stems from the desire to stitch together the urban fabric of the city, a desire within which the Bovisa station becomes the key element around which the new district will be unravelled, becoming, from a simple place of passage, a central multimedia hub in a new and more active district, enhanced by the creation of squares, gardens, cycle paths and green areas.

The master plan of the MoLeCoLa project covers an area of approximately 90,000 square metres, creating a connection between the Bovisa area and the surrounding areas, mainly through two bicycle paths.
Our project is going to connect with the existing routes through another path all around the area of interest, thus allowing the new reality to be integrated into the existing and developing one.
Three environments were redesigned and developed within the MoLeCoLa project:

- Piazza Alfieri, which has been redesigned to host temporary activities by exploiting the width of the space and the wooden roofing that allows it to also host temporary indoor activities (markets and other functions);
- The station forecourt is designed to be an interchange node between the different mobilities available within the project;
- The square in Via Lambruschini is conceived instead as a new entrance to the western area of the station, which is then the area dedicated to the students of the new Drop.

**Figura 26:** The MoLeCoLa project

Two new student halls of residence and accommodation are planned within the project, which can offer solutions for students, young workers and professionals even for short periods of time.
The buildings are developed in a courtyard layout, interconnected by green areas, vegetable gardens and multipurpose spaces. They are also enhanced by the presence on the ground floors of spaces for coworking, commercial activities and citizen services.

The building structures are made entirely of wood, can be dismantled and have a reduced environmental impact. They are connected to district heating and provided with cooling, and are also equipped with renewable energies such as photovoltaic panels and green roofs.
Mobility within the district is predominantly electric, being the area mainly walkable, but with provision

of infrastructure for charging vehicles, dedicated parking spaces and other incentives that push residents and visitors towards electric mobility.
From the point of view of energy certifications, the MoLeCoLa project falls within the provisions of LEED for Neighbourhood certification, a sustainability protocol that assesses both energy performance and water use, the impact of new buildings in the context, and the presence of green spaces and pedestrian spaces.

The redevelopment of the Bovisa Node is therefore part of the project. *"The regeneration of Bovisa is one of the strategic elements of Milan 2030. We are talking about a district with enormous potential, characterised by a lively cultural and social ferment and an increasingly marked university vocation. The development of the Nodo, with the expansion of the railway and the recovery of disused areas, together with the large projects of the Politecnico for the expansion of the Campus and the creation of a park of over 300,000 square metres, represent an extraordinary opportunity to mend disconnected parts of the area and strengthen the station as a reference point for mobility, creating a strong connection along the axis that from Porta Nuova and Scalo Farini arrives at Mind and Cascina Merlata. We therefore trust that the conditions will be created to realise this project".*[17]

**Figura 27:** A render from the ParkAssociati website[18]

[17]The words of the town planning councillor Pierfrancesco Maran

# 13 Design Solution

We are fitting into a real case study, the project comes to life in the Bovisa node, on the outskirts of milan, where we are aiming at the rebirth of the neighbourhood, at a revolution that includes the enhancement of public transport, housing and services for students, adding cycle paths and green areas with a system of squares connecting the outside to the inside of the neighbourhood. We thus fit in with the objectives of the MoLeCoLa project, which aims first and foremost to revive the entire area with the creation of an interchange hub reconnecting the areas to the east and west of the bovisa station, which would complement the polytechnic's existing university campus. An active place from the community and non-community point of view, a sort of pilot space in which to test new technological solutions.

This is where the C40 project comes into play, that's a global competition for innovative and resilient urban projects, that wants to improve the development of a new resilient urban regeneration across the globe.

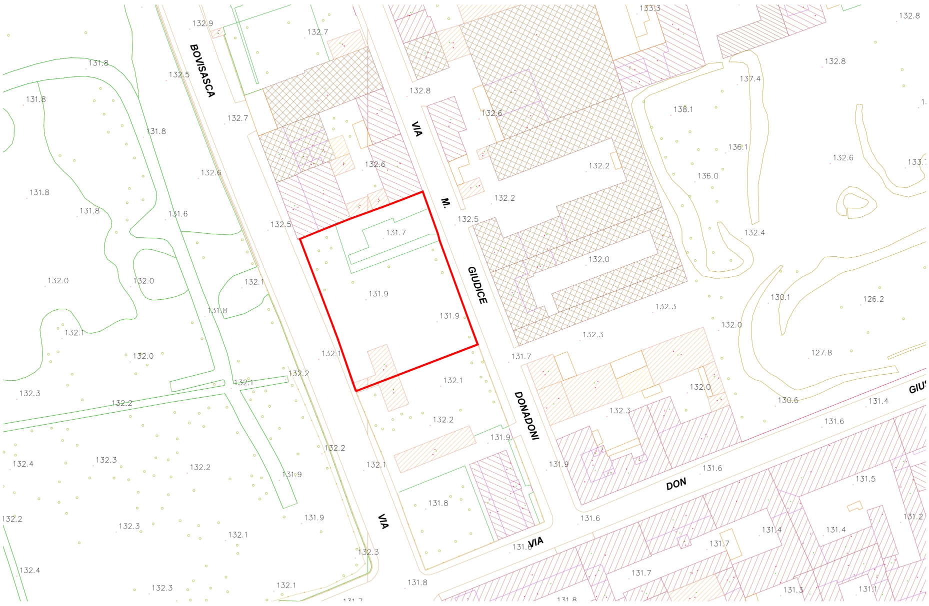



**Figura 28:** The site perimeter for the Reinventing Cities competition

This is precisely why a site was taken, underdeveloped and not yet used to its full potential, and then called in multidisciplinary teams that could bring proposals for models of the city of the future, composed of architects, urban designers, investors, environmentalists, and other professionals who together could compose something comprehensive and innovative.
We are therefore entering the real world, virtually taking part in the competition organised by C40 Reinventing Cities for the Bovisa node, but in our own small way bringing something much broader, or at least with greater objectives. The basic idea is based on traditional ecovillages, which according to the European Global Ecovillages Network (GEN) are *"a manifestation of conscious human innovation and creativity: groups of people living out their principles, regenerating their environment, and increasing their sense of belonging and purpose as a community."*[17]
As already mentioned, GEN is the European network of ecovillages and sustainable communities established in 1996 to support existing ecovillages and encourage the emergence of new ones.

In our view, this idea has been taken to a more visceral level, considering the direction in which world development is heading, considering the recent climate changes and taking into account the situation

to which these will lead in the near future, we realise how a different urban development with a greater focus on the way we relate to everyday life is increasingly crucial.
It is no longer a building to enable human beings to live, to have a roof over their heads or to have all the comforts we are accustomed to; it has become more a building to try to live in symbiosis with the world around us, to be able to stop exploiting the planet but to live in respect of it as any other living species on the planet does.

We therefore turned to the study of NZEB and NZCB buildings, which represent zero energy and zero carbon buildings. The entire lifecycle of the building product is considered, starting from its design, through to its decommissioning, the production of the necessary materials, the construction and the use and maintenance of the building. We have taken into account the concept of LCA (Life Cycle Assessment) of the different materials hypothesised, trying to use technologies that were locally produced, preferring dry technologies that would allow, when the building is decommissioned, not to demolish but simply to disassemble the building, reusing the materials as much as possible, thus facilitating, among other things, a more functional maintenance of the product.
It is no longer a building to allow human beings to live, to have a roof over their heads or to have all the comforts to which we are accustomed; it has become more a building to try to live in symbiosis with the world around us, to be able to stop exploiting the planet but to live in respect of it as any other living species on the planet does.

## 13.1 Objective of the design

In designing the solution in question for the project of a small self-sufficient reality, we set ourselves a series of challenges and objectives, which could serve as guidelines in our design and which could, in the end, represent the beating heart of the project.

The first challenge we faced was the design of energy-efficient green buildings. In this case, the main objective was to reduce greenhouse gas emissions at the same time as reducing the environmental impact of energy production and consumption.
The buildings proposed and the design solutions developed are based on a passive design that also considers a strategic arrangement of spaces, through the use of external greenhouses, ventilated roofs, rainwater harvesting and innovative technological solutions to ensure thermo-hygrometric comfort inside the building while ensuring the lowest possible impact on the context.
The buildings have been conceived as 'intelligent', i.e. the systems inside them are managed in an intelligent and automated manner, to be able to minimise energy consumption while guaranteeing the comfort, safety and health of the occupants.
Provision has been made for the on-site production of energy from renewable sources and at the same time the consumption of externally produced renewable energy if on-site energy is not sufficient, as well as the possibility, thanks to the smart building concept, of exporting the energy produced and stored in excess, some of which is simply stored for use at a later date or is sold or exported to other realities.

Finally, the last aspect taken into consideration was the replacement from an environmental point of view that the construction of such an area would allow. A precise balance was maintained between the planned green area and that dedicated to residential units or other buildings, thus guaranteeing a sort of compensation, as well as facilitating oxygen production, climate mitigation and all the benefits brought about by the presence of vegetation.

The main objective here was therefore to design a building that would reduce the amount of energy used for heating, air conditioning, hot water, lighting, ventilation and services.
We tried to reduce energy consumption on site through passive design and through the use of more efficient forms and structures, until we arrived at a design that could be counted within the concept of 'positive energy', which means that the building produces more energy than it actually consumes.[21]
In order to arrive at a design of this type, several aspects were taken into consideration. We set out to design improved structural features of the buildings that would optimise solar inputs and shaded areas, while also optimising the thermal mass of the structures, reducing the incidence of thermal bridges and

improving air tightness. An attempt was made to make maximum use of daylight by designing a shading system that would be as useful as possible in summer and not negatively affect winter, while studying the positioning of openings to take advantage of natural and passive ventilation.

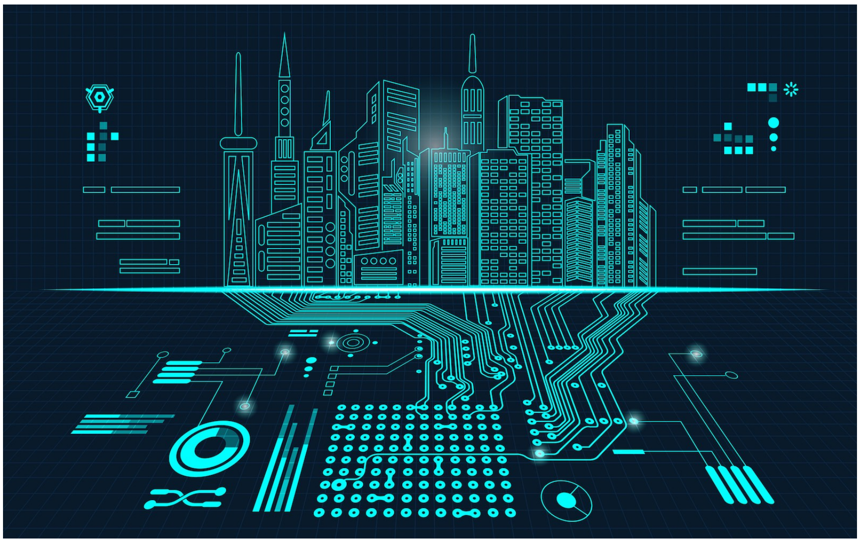
From a plant engineering point of view, we tried to achieve the highest possible efficiency, both for air conditioning (HVAC) and lighting etc.
An analysis was also carried out from a plant engineering point of view, which, taking into account the planned plant engineering devices, made it possible to calculate the incidence of energy consumption, looking at what and how much energy is used for the different purposes, seeing, for example, what proportion is covered by renewable energy and what is not.
A Building Information Model (BIM) has been implemented using dedicated design software that gives the possibility to implement intelligent building management.
Augmented reality tools and communicating details of resource management are also used to collect data and other information to inform occupants and stakeholders throughout the project about behaviour and the like in order to monitor equipment and facilitate the control and evaluation of energy consumption.
Each building was also equipped with devices such as centralised socket systems and electric car charging systems.

The last of the objectives identified and within which we tried to bring solutions is that of the social benefits the project could bring to the community. A community house that could connect the district with the outside world was envisaged, as well as a water square that could serve as a water collection for the surrounding area. Also considered was the benefit that the realisation of a self-sufficient reality can bring to a community as large as Bovisa or Milan, helping to develop a new awareness and attention to fundamental issues that underpin future development.

The project developed and presented therefore aims to go beyond the usual energy and building standards, representing a new and positive model of efficiency and energy use, as well as management of life.

### 13.1.1 Smart Building

Buildings are becoming increasingly connected and intelligent through the use of innovative technologies and building automation. This ensures greater comfort and more careful and effective energy and security management and control.
A smart building can be defined as such when it is able to make residents more aware of their consumption and the different ways to reduce it through optimal energy management while at the same time providing the best possible comfort to those living in the building.
Over the last thirty years, the advancement in technology has been remarkable, thanks to the ever-increasing development of the internet and hardware and software solutions, and the concept of smart buildings has thus become increasingly relevant. The BMS (Building Management System) was born and has since been connected to the web, allowing building owners to have access to much more information than before, thus being able to make smarter and better decisions.



The European Commission provides a specific definition for Smart Building: *"A set of communication technologies that enable different objects, sensors and functions within a building to communicate and interact with each other and also to be remotely managed, controlled and automated. In the smart building, technologies help connect a variety of subsystems that originally operated independently. Automated processes enable the control of building operations, including heating, ventilation, air conditioning, lighting, security and other systems.[22]*

The main objective of a Smart Building is related to intelligent energy management. Starting from the need to reduce the impact of buildings, which as already specified are responsible for about 40% of energy consumption, which also generates large quantities of polluting gases, especially in the industrial sphere. Using energy in an intelligent manner becomes a central point, and it is precisely this that provides a great incentive for the realisation of smart buildings, especially in the commercial or industrial sphere.
Thanks to the use of smart building technologies, it is possible to control the energy used for lighting, HVAC (Heating Ventilation Air Conditioning) systems, and for any appliance, by linking them to each other or to smart windows and the like, which, through the use of sensors, are able to regulate solar inputs or ventilation or other depending on the inputs received after an analysis of the situation inside the building.

In addition to being a fundamental step towards the development of more sustainable construction, the use of intelligent buildings also brings great benefits from an economic point of view. The construction industry is responsible for about 9% of Europe's GDP and provides many jobs. The renovation and regeneration of existing buildings to make them more efficient can therefore trigger new opportunities in an already growing buisness that is fundamental to our countries' economies. In addition, thanks to

smarter design, it will be possible to save on the energy consumed, especially on the purchased portion of energy, and it will also be possible, in some cases, to generate revenue thanks perhaps to excess on-site production.
Already nowadays, thanks to the BMS (Building Management System) connected to the systems of a building, such as the lighting one, and appropriately networked, it is possible to control the systems and services in accordance with the different schedules and situations that may occur, e.g. lights can be switched on and off at optimal times, lighting levels can be varied, and window and door openings can be adjusted according to outdoor weather conditions and indoor needs. All of this can result in savings of up to 25 per cent on heating and cooling and up to 67 per cent on lighting.[19]

An intelligent building also means the possibility of ensuring greater comfort and quality of life, not only in terms of health, but also in terms of thermo-hygrometry.
Optimised environments increase indoor well-being and greatly reduce health problems in residential or working environments.
The sick building syndrome is known to exist, with occupants of public or office buildings presenting complaints with an incidence of 15-50%. These disorders are often related to factors dependent on the building in which one is located, such as the air conditioning and ventilation system, or to planned maintenance programmes.
All this can be avoided through the use of a predictive and proactive HVAC system that uses IoT and BMS to monitor and operate systems correctly, which can ensure proper air quality and healthy environments. One can, for example, through the use of sensors, monitor indoor air quality and pollutant levels in real time, thus being able to act promptly in the event of unforeseen changes.

Next to BMS (Building Management System) we find BEMS (Building Energy Management System), which indicates a building energy management system with the objective of reducing consumption and optimising performance throughout the building's life cycle.
Such a system is based on the use of platforms that utilise new digital technologies, which allow the intergration of hardware, software and ICT services to enable the collection and processing of data and their monitoring, thus guaranteeing a very high level of automation and control of the various devices and systems connected to the building.

Such a platform becomes the heart of an intelligent building, allowing occupants to centrally control the operation of various systems in real time, while also controlling temperature, humidity and microclimate levels within rooms. This ensures not only maximum energy savings, but also the best comfort and well-being for those living in the rooms.
Using the systems we have discussed so far provides a number of different benefits:

- The control and monitoring of energy consumption, reducing waste and optimising the energy efficiency of a building;
- Improves the well-being and liveability of facilities;
- Extending the life of a building;
- Reducing the environmental impact of the building;
- Monitor plants ensuring timely intervention in case of malfunctioning or breakdowns, thus increasing productivity.

**Smart building in our project** In our project we included the technologies of a smart building, there is both the part of plants for the production of energy (photovoltaic panels, storage systems, solar thermal and cogeneration) and the one of technologies for efficiency such as glass closures and heat pumps.
Modern sensors are provided inside our building, to optimize the energy efficiency of it. We can see real-time Energy Monitoring, to record energy consumption in real time and provide information on how to use energy, both of lighting and heating/air conditioning. These monitoring devices are able to detect

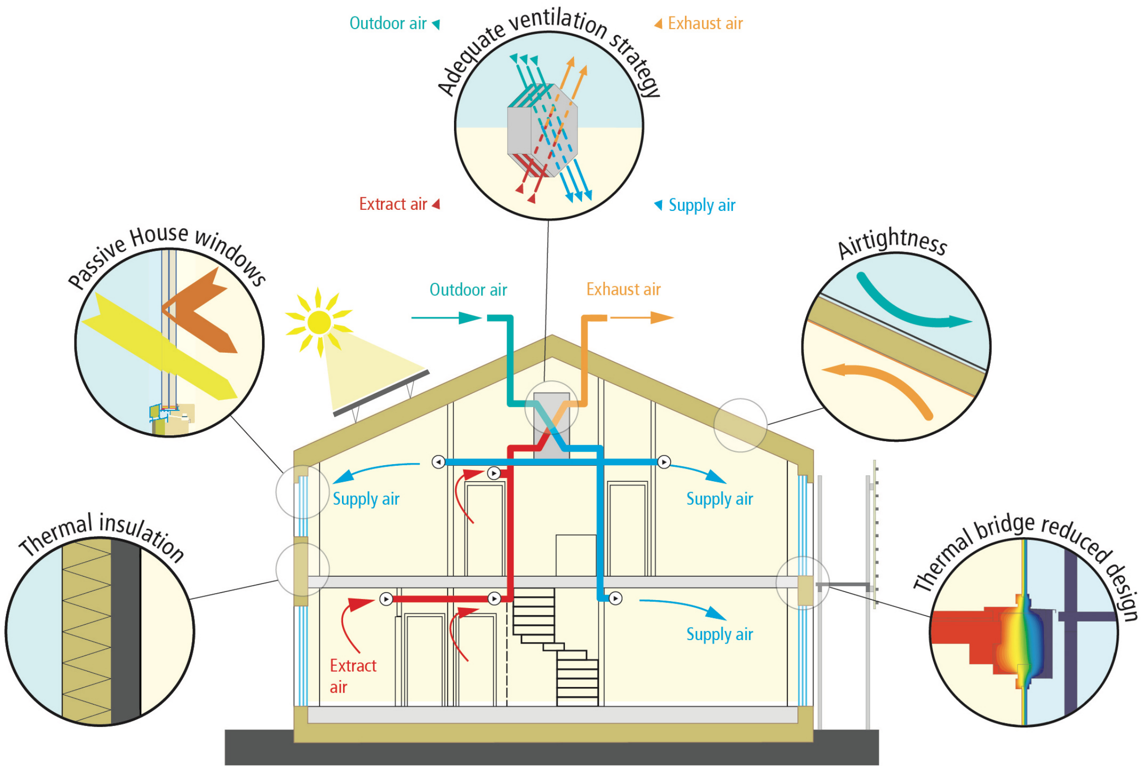
[19]Report of the California Energy Commission

any anomalies in the energy functioning of the different devices and to signal them through special alerts to the energy management system.
Also is provided a system for automatic response in order to optimize the energy consumption of the building and to coordinate these actions there are a software able to manage the building in an integrated way.

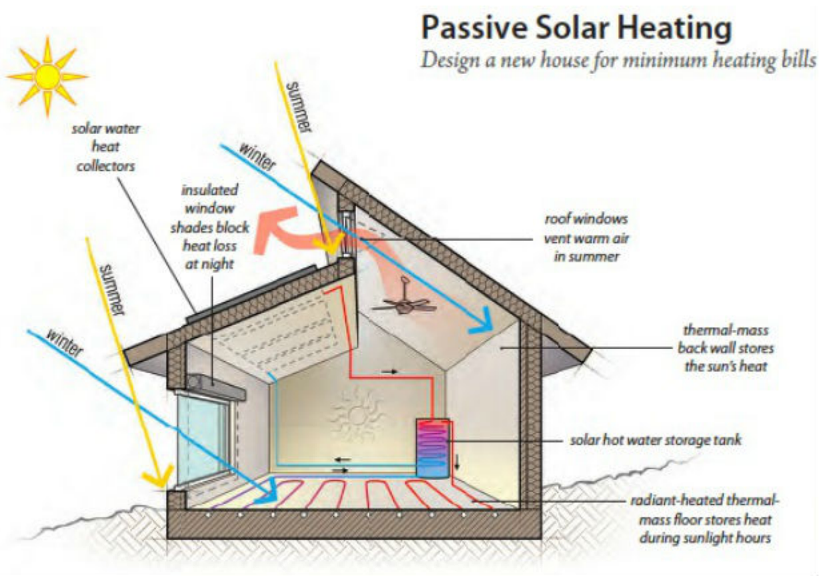
The system of the buildings is made up of remote control and regulation of plants and of a system for the self-production of energy from renewable sources, solar and photovoltaic.
Also there is an energy management system operating in an iot logic, which collects comfort data inside and outside buildings, to measure energy consumption and production at district level, so as to analyze the effects of different reconditioning interventions and their interaction.

### 13.1.2 Passive House

A passive house is a building that is designed and constructed according to specific criteria to limit energy needs for heating and cooling, and in some cases to eliminate them completely.
They can be seen as NZEB buildings in accordance with European Directive 2010/31/EU, implemented by the Italian government with Law 90/2013, which sets the obligation for new constructions and major renovations to reach the passive building standard by 2020 as mentioned in the previous paragraphs.



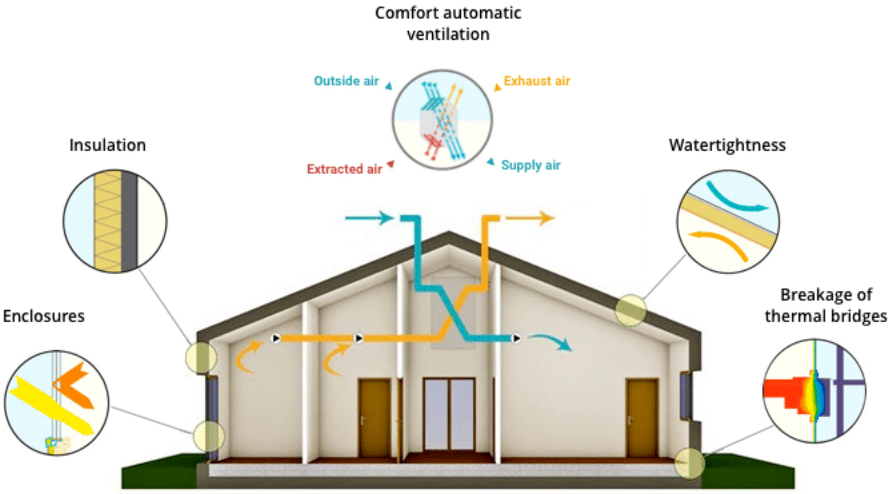

They originated in Northern Europe and then quickly spread throughout Central Europe (Holland, Germany, Austria, Switzerland) until they reached Italy.
This term is used in green building to identify buildings that almost entirely cover their energy needs through passive devices. Devices, therefore, that do not require energy supplies from outside.
Passive houses use systems and materials that minimise heat loss, apply studies on solutions to improve solar radiation, limiting it in the summer months and making the most of it in the winter months.
Through the use of controlled mechanical ventilation (CMV) and its heat exchanger, the share of thermal energy that is usually dispersed is recovered.
The walls are insulated, the roof ventilated, the windows and doors are thermally treated and the building is strategically positioned to make the most of the best sun exposure.




Going into more detail, we find that Passivhaus certification is based on five fundamentals:

- Thermal envelope: The envelope is the body of the building and therefore the basis of the building's performance. The study of its characteristics and those of its materials is therefore fundamental. The performance of the envelope has a huge influence on the consumption of a building, both in terms of heating and cooling.
- Windows: we often talk about double-glazed windows, in passive houses triple-glazed or treated double-glazed windows are usually used to guarantee specific performance. Window frames also influence performance, not only the transparent part of the window should be taken into account but also the opaque part, frame and screens play a key role.
- Thermal bridges: a thermal bridge is given by a constructive discontinuity in a building; from a thermo-hygrometric point of view, they represent the weak point of a building. The thermal bridge can be given by the coupling of different materials that behave differently in terms of thermal conduction, geometric variations of a construction part, or significant thickness variations while maintaining the same material. Thermal bridges are always present but careful design allows them to be eliminated or limited to a minimum. tightness: as already mentioned, windows and doors are fundamental in the design of a passive house, where air tightness must be absolute, which means that every point of the building must be designed very carefully. During construction and on completion, the 'Blower door test' is performed to certify this parameter. Two large fans are applied in place of the door, which feed or suck in air, thus verifying any areas where air passes or certifying the absence of weak points.
- Ventilation system: inside a passive house ideally windows should never be opened, the ventilation system draws air from rooms that produce 'dirty' air, such as bathrooms and kitchens, and draws in outside air, which is treated and then fed into rooms that need clean air, such as bedrooms and living rooms.
  This system allows for a recovery of thermal energy and therefore savings, and at the same time allows for clean air at all times while guaranteeing a climatic comfort that would not be achieved by simply opening the windows, as all the pollutants and particles that would be released into the room with natural ventilation are avoided.

The first evidence of houses built to save energy and have an almost zero environmental impact dates back to the early 1970s, when the first buildings with solar panels and mechanical air exchange were built in Denmark and Canada.
However, the passive house concept was born in 1988 when buildings with heat recovery efficiencies 90 per cent higher than those existing at the time began to be designed. The first real passive house was built in 1990 in Germany, where the Passivhaus Institut was founded six years later.




To date, there have been some 20 international conferences and 40,000 buildings constructed, as well as several situation monitoring campaigns sponsored by the European Commission.
A passive house brings numerous benefits to its occupants and the environment in which it is built. Among the former are comfort and safety, given by the homogeneity of the internal temperature and constantly clean air. As far as the environment is concerned, the high efficiency of passive houses drastically reduces $CO_2$ emissions and the materials with which they are built are almost entirely renewable and recyclable.

**Passive house in our project** For what regards our project we studied the thermal insulation of the envelope, providing both insulation on the vertical closure and on the horizontal one.
We runned an analysis on the thermal performance of the building (read last paragraphs of this work to check it in detail), seeing both the transmittance of each component, both the interaction between them, seeing how the thermal bridges that develops can be solved and solving them.
The same has been done for windows and transparent envelope, for which we also studied the shading needs.

From the plants point of view the housing units are served by an heat pump which mainly use electricity, generated in loco by the panels owned by each house, both photovoltaic and solar, with a radiant floor, which maximize the efficiency of the system.

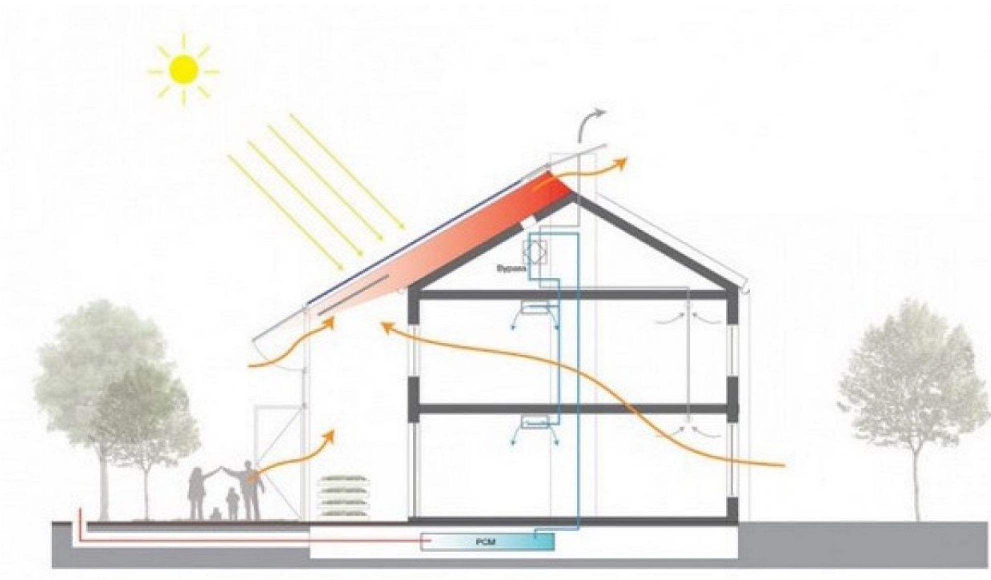
### 13.1.3 Natural and passive ventilation

An excellent tool to ensure passive cooling of buildings, especially in warmer climates and in the summer season, is natural ventilation. This means exploiting the movement and renewal of air caused by temperature and pressure differences between the inside of a building and the outside, removing heat from building structures by thermal convection.
Natural ventilation can be of different types, it can be based on the stack effect, ventilative cooling, convective cooling or evaporative cooling. In any case, the phenomena underlying natural ventilation take place without the use of any mechanical fans and without energy consumption, which provides cooling benefits and also improves air purity and freshness.

In order to design the natural ventilation of a building, several aspects must be considered, such as:

- The urban fabric;
- The orientation of the building (in relation to the position of the sun and the direction of the winds);
- The characteristics of the enclosure;
- The characteristics of the environment around the building, such as its morphology and materials.

Relevant factors are, for example, elevation position, proximity to bodies of water, distance from reliefs that may shade the building or change the winds, atmospheric pressure, the nature of the soil or the presence of greenery.




Natural ventilation is based on the fact that when the wind hits a building it causes an overpressure on the upwind side and a depression on the downwind side. This effect can be exploited by placing windows and doors on opposite sides with a relative size, giving those downwind a larger size.

The amount of air flowing through the building is directly proportional to the difference in temperature and pressure between the outside air and the inside air. Normally, these differences, especially those of pressure, increase with increasing height; the lower floors are usually cooler while the higher ones are warmer, which leads them to be in depression in the case of the lower floors and in overpressure in the case of the upper floors.

**The stack effect**
This principle is directly exploited by the stack effect, which utilises the natural tendency of hot air to rise upwards, being lighter as it is less dense, exiting from areas with less air-tightness. Another aspect

to consider is the tendency of the cold air to enter from the areas near the basement to compensate for the depression created by the hot air escaping.

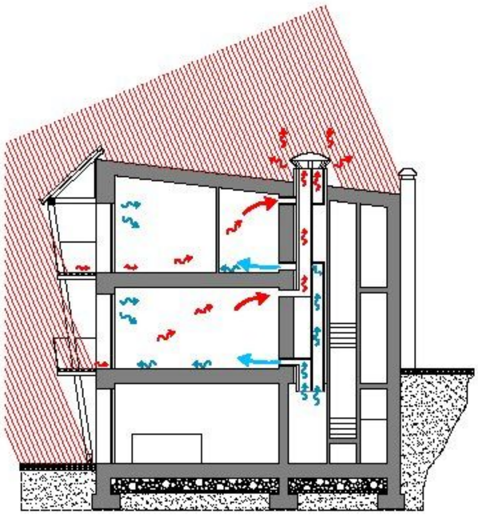


**Figura 29:** The stack effect

Obviously, this effect is reversed in summer, when the outside air temperature is higher than the inside air temperature.
The syack effect can be used to naturally cool a building by exploiting a height difference in the building's openings, which must be shaded in order to decrease the air temperature. The most obvious cases in which this phenomenon occurs are in vertically developed buildings, such as stairwells or climatic cavities.

The stack effect is maximised when solar radiation is incident on the outer surface of the chimney, which obviously causes the air temperature inside the chimney to rise and thus a greater buoyancy of ventilation.

**Passive cooling**

The effect of wind pressure can also be exploited, using what is known as ventilative cooling. In fact, the side of the building oriented perpendicular to the wind direction is exposed to greater pressure than the opposite side, which will be under pressure.
The air pushed by the wind will enter through openings in the downwind wall, move through the building to the opposite wall, from where it will be expelled again through the openings there.

The effectiveness of this type of ventilation is also given by a difference in the cross-sectional area of the openings on the two parts of the building: as the cross-section decreases, there is an increase in the velocity of the air flow and a decrease in the pressure[20].

[20]Venturi effect: when a fluid moves in a stationary manner, as the cross-section varies, the velocity and pressure of the motion vary

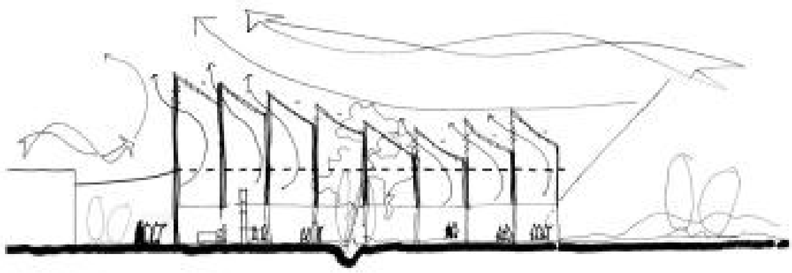


**Figura 30:** Designing a building taking wind direction and the position of the sun into account

For natural ventilation of this type, therefore, particular attention must be paid to the location and size of the surrounding buildings, a certain distance must be maintained between the different buildings, the openings and the façades where these are located must be carefully designed, protective barriers (such as rows of trees) must be provided in the case of excessively strong winds, and the possible need to lower the temperature of the incoming air must be considered. The morphology of the surrounding terrain and the possible presence of water masses should also be considered.

**Wind Conveying**

Another passive cooling system is the so-called wind tower, mainly used in hot climates. In this system, the conformation of a building is exploited, allowing it to channel the wind and transport it downwards to the rooms to be cooled, which have openings to allow a pressure difference to be created.

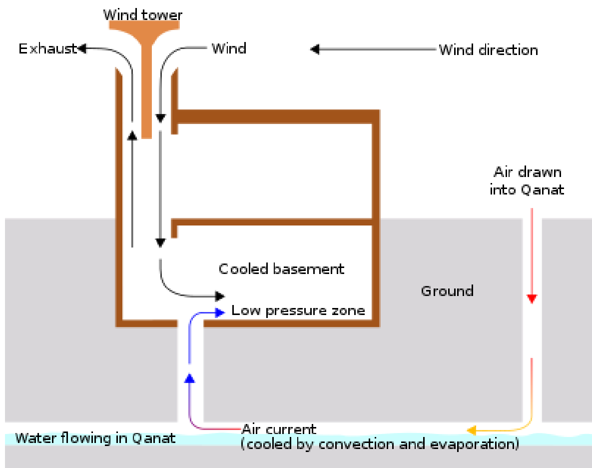



**Figura 31:** The operating diagram of a wind tower

At the top of the tower, openings oriented towards the main wind direction are inserted, the air is then channelled and transported through shafts with a particularly humid internal atmosphere, so that the temperature of the passing air can be lowered by evaporative cooling. The air can then be passed into an underground duct in which it can undergo further cooling.
Finally, it is expelled through the lower openings of the building.

**Convective cooling**

Convective cooling exploits the lower temperature of the night air, which is introduced into the interior spaces to remove the heat accumulated by the structure during the daytime hours. Obviously, this system is particularly exploited in climates where there is a high temperature range between day and night, and is characterised by the presence of walls with a high thermal mass, which exploits the phase shift it creates to release heat into the room during the night while absorbing it during the day.
In this case, the internal walls and openings must be designed to favour cross-ventilation, correctly defining

the position of the fixtures so as to also exploit the chimney effect and convective motion of air.

The most innovative systems also include automatic window opening systems, which regulate the flow of air and internal temperature to prevent excessive cooling of the rooms, while allowing maximum benefits in summer and reducing ventilation losses in winter.

**Evaporative cooling**

Evaporative cooling exploits the cooling potential of evaporating water. During evaporation, water undergoes a phase change from a liquid to a vapour state, removing heat from the environment. During this phase change, water molecules absorb heat from the environment to increase their energy.

**Natural and passive ventilation in our project** For what regard our project we tried to integrate the principles of natural and passive ventilation by positioning the windows after studying winds and their effect and by adding a greenhouse and a lot of glazed surface that can act as a greenhouse to heat up the building without using any electricity.
Also the roof designed is a ventilated roof, that helps with the ventilation and the thermal comfort inside.

### 13.1.4 BIM

Building Information Modeling, or BIM, indicates the digital information system composed of the 3D model integrated with the physical, functional and performance data of the building.
BIM is the foundation of digital transformation in the construction industry. It allows a management of the constructions that allows a saving on the times and costs of realization really remarkable.
The BIM methodology is based on the use of a single system of 3D models instead of separate design drawings, thus favoring the collaboration between all the subjects of the life process of a building, starting from architects, engineers, contractors and manufacturers. This ensures access to up-to-date information, which reduces the percentage of errors and the number of changes in the iterative design process. par

The National Institutes of Building Science (NIBS) defines BIM as: *"digital representation of the physical and functional characteristics of an object"*.
As can be seen from the above definition, this methodology does not simply represent a new 3D representation, but above all the realization of a multidisciplinary and shared information model that contains the information at every stage of the design, from architectural to executive and management.

This allows information to be reported simultaneously on the geometry of the building, the geographical location, the properties of the materials that make it up and their thermal and energy characteristics, You can report information about installations, maintenance and the like, until you have a total and complete model.
The use of such a technology greatly facilitates project management and improves control of the construction process, interdisciplinary collaboration and communication between the various parties, greatly helping risk management.
BIM consists of four levels of maturity:

- Level 0 - Standardized CAD: requires the organisation of traditional work around a system of standards in which information is produced and shared via paper documents;
- Level 1 - BIM Solitaire (lonely BIM) or non-cooperative: Parametric design and data management are used in your workflow, but no collaboration with other professionals is established. In this case a Common Data Environment (CDE) is used, it is an online shared archive in which all the project data is collected, stored and organized;
- Level 2 - BIM Collaborative: in this case there is collaboration between the parties involved in the design, coordinated by BIM Leading consulting, and the information is shared through a common file format;
- BIM Shared: All professionals work on the same model at the same time to receive updates in real time.


**Figura 32:** The 7 dimensions of BIM according to the Italian standard UNI 1137-6

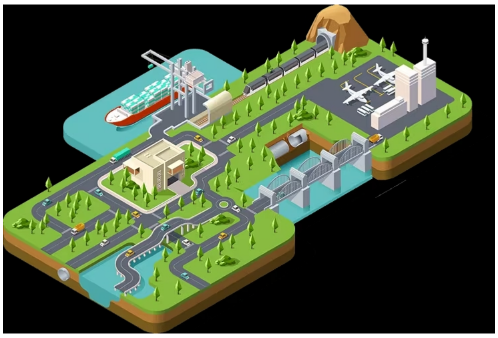
The Italian legislation identifies seven dimensions of Building Information Modeling, these refer to the different levels of information that can be found in the BIM model:

- 1D: Concept design;
- 2D: 2D elaborates as plans, elevations and sections;
- 3D: Three-dimensional representation of the product;
- 4D: Duration or time analysis (programming);
- 5D: Economic management (cost analysis, estimates and economic assessments);
- 6D: Work management phase (use, maintenance and disposal);
- 7D: Sustainability assessment (social, economic and environmental).

The BIM process supports the creation of intelligent data that can be used throughout the life cycle of a building or infrastructure project.
Let's see four main stages, the first is planning, which serves to optimize the planning of the projects by combining, the second is the design during which the processes of conceptual design and analysis are carried out, then we find the construction, where project construction logistics information is shared with the professionals and contractors involved. Finally we find the operational management, where BIM data can be used in view of the future life of the building.

(a) Buildings

(b) Construction



(c) Civil Infrastructure

(d) Oil and gas

(e) Utilities

(f) Plant

**Figura 33:** The different aspects of the BIM process

**BIM in our project** For what concerns our project the methodology used is the one of BIM. We used several interoperable software that allowed us to bring our solutions from a general detail to a particular detail, knowing the materials used and the systems provided.
From the design point of view we stopped at a 3D, although an analysis of 5D (economic analysis) and 7D (sustainability) was carried out for completeness, arriving at a capillary and almost complete knowledge.

# 14 Design Characteristics

## 14.1 Modularity

Modular construction involves building the structure off-site, in a factory. Prefabrication offers a very attractive option for projects where time is tight or weather and/or site conditions are difficult. Large modules are manufactured, which are then transported and assembled on site.[23]

**Figura 34:** Modular constructions samples

Modular constructions are prefabricated entirely in-company and are perfectly suited for agglomeration or temporary use.
Modular construction offers environmental advantages such as resource and waste reduction, reusability, adaptability and recyclability of all components. Prefabricated buildings are proven to be fundamental for material savings, waste reduction, component reuse and various other forms of optimisation for the construction sector.
Modularity also makes it possible to modify, dismantle and relocate the building, reusing its parts almost like Lego blocks. Modular buildings represent a new concept of the living building. These buildings, capable of thinking, feeling and adapting, will be the cornerstone of modern, sustainable cities.

**Figura 35:** Volumetric modular construction has a key role to play in pushing the industry forward.[28]

The construction sector consumes a significant amount of global resources and generates a large amount of waste. However, it counteracts this by contributing to the transition to a circular economy with more sustainable construction.

**Figura 36:** What is Volumetric Modular Construction?[27]

Modular construction fits perfectly with the principles of the circular economy and can contribute to the sustainability of the construction sector. It could potentially be a key factor in reducing the carbon footprint of the building sector, improving its sustainability credentials.

For more than a century, modular construction has been a popular practice for many types of projects around the world.
Adopting a modular approach involves the decentralised construction of prefabricated modules that are then transported to the site, this reduces the workload on the main construction site and, as a result,

proves to be a viable, safe, economical and environmentally friendly solution in many types of projects.

Although not always the most suitable choice, modular construction has proven to be one of the most advantageous solutions even in today's changing economic conditions. In this reality, sustainable solutions that ensure maximum efficiency have become necessary, and this is where modularity comes in. This approach makes it possible to complete projects more safely, smoothly and efficiently, on time and at a lower cost.
This is precisely why in recent years we have seen a strong growth in demand for modular construction, not only in residential construction but also in public buildings, such as schools and hospitals, and in commercial buildings, such as hotels and shopping centres.[24]
Modular construction offers several advantages over conventional building systems, many of which are exploited for specific sectors where cost, time and site difficulties make it particularly advantageous.

**Figura 37:** Modular construction sample

The main advantages are:

- Faster construction time: By producing the modules in a well-protected environment such as a factory, the time and personnel required on site are substantially reduced. Invasive work on the construction site and weather-related constraints are also reduced, benefiting system efficiency. Site work and construction of the modular units can take place simultaneously, leading to significant reductions in the time schedule.
- Improved quality and consistency: the factory production process allows quality assurance control systems, typical of manufacturing, to be integrated into the entire construction process. This avoids problems that would lead to order delays and supports consistently high quality construction standards.
- Lower costs: reducing the duration of the construction site and the number of personnel involved often results in cost savings, allowing a larger share of the project budget to be dedicated to high quality materials.

- Reduced health and safety risk: as most construction work is carried out in a controlled factory environment, the overall health and safety risks associated with the construction phase are significantly reduced.
- Possibility to adapt/reuse/relocate: the customer has the freedom to relocate or adapt the building modules after construction.

[25]

The modular construction model is frequently chosen both at sea and on land, and for very good reasons. All aspects of the construction can be designed in a modular manner: from steel structures, piping, equipment, electrical systems, to the installation of insulation and metal cladding.
To ensure that the prefabrication process of a specific project goes smoothly, a certain degree of planning and coordination is certainly required. However, modularity generally reduces field processing time and thus labour costs; it also increases safety, has less environmental impact, is more efficient in hard-to-reach locations and adverse weather conditions, and improves the overall quality of execution. In light of these obvious advantages and the success rate in a number of recent projects, modularity is growing in popularity globally, and is increasingly being adopted as a standard approach. [24]

Thanks to today's technologies, in particular effective transport and lifting solutions, the modular construction has become an economical and efficient way to build. Modularity differs from the traditional method, which involves the use of a lot of labour on one main construction site. If prefabrication and pre-assembly take place elsewhere, less work will need to be done at the main site, saving space, time and money.
Once completed, the pre-constructed modules can be transported (usually by ship, barge or overland) to the construction site.
The modular approach also reduces the exposure of operators to risks in the field, as work carried out on the main site involves interference and involvement in sometimes dangerous day-to-day operations. In fact, it reduces the risk of serious accidents, which can compromise the performance of daily tasks and interrupt the work programme in other areas of the site.
Overall, the modular construction model also requires less labour, which means that fewer workers need to be hired to complete the project. This is an advantage especially in locations where the labour pool is limited, making recruitment difficult.

**Figura 38:** Modular prefabricated construction sample

Finally, from an economic point of view, the modular construction method is overall more cost-efficient than traditional projects. In addition to lower labour requirements, the economic advantages of modularity are evident when one considers that the project is completed in several parts and at different locations, rather than all at once on one construction site. This method eliminates unnecessary costs and, by improving overall safety, reduces the risk of accidents and replacements.

The arrival of ready-to-assemble modules at the main construction site, according to many, makes the process less difficult than when the work is all done at one site. Firstly, the modules take up much less space on the site, which means they can be stored easily until final assembly.

Modular construction allows the same building elements to be used in one project as well as in several building projects. Through an optimal organisation of space, modules offer an economical utilisation of available floor space. The modular construction system is therefore best suited to the concentration of buildings within a single building area or to constructions with different uses.
Prefabricated modules are ideal for new buildings or renovations of hospitals, care centres and homes for the elderly, communal housing, hotels, schools or for temporary solutions. In short, anywhere where, through intelligent planning, buildings can be broken down into spatial modules of the same dimensions. Buildings can also be aligned and composed to create real agglomerations.

The strength of these constructions lies in having in one place (the factory) specialised workers, resources and materials: in other words, all the elements and resources needed to build the modules. This would not be the case on a classic construction site where workers and suppliers alternate depending on the progress of the work.
During a normal construction site it is estimated that up to eight thousand kilos of waste can be generated, while recycling is becoming an increasingly common practice in the construction of modular houses where it is common to reuse residual material from other projects. Take for example the use of wood: pieces are often pre-cut ready to be assembled and the residual wood can be ground and recycled for further purposes. The waste of wood, and thus the production of construction waste, is practically zero.

**Figura 39:** Modular constructions[29]

As already said modular construction, in addition to its considerable environmental benefits, therefore also offers the possibility of substantial energy and time savings; an element, the latter, not to be underestimated because it further reduces the building's impact on the environment. In fact, with modular buildings, where the construction of the house takes place in a factory, all those delays due to exogenous phenomena are eliminated, such as adverse weather conditions that could force the suspension or slowing down of on-site processing times or the transport of materials and labour.[25]

**Modularity in our project** The design of our project is based on modularity in every point. We started from the study of tiny houses, buildings by definition built with environmentally friendly materials and modular solutions.
Many of these give the possibility, for example, to move some walls to create different internal arrangements in case of need, and in any case offer a very careful study of the interior spaces that makes the most of every point of the building.

This leads to the development of small modules of houses on their own that, when they are composed, give rise to more or less satisfactory complexes.
In our case we started from the module of the smallest unit, which is designed to accommodate 3 people, which is based on a spatial module of 1m by 0.5m, which can be found in the internal dimensions, dimensions of windows, in the dimensions of the posts and throughout the structure.
This unit is developed so that it can be replicated and developed in order to expand the building, thus we arrived at the 5/4 person building which is the second type of unit we considered.

The presence of a staircase outside the building allows it to be considered "secondary", so that it can be somewhat detached from the design and then reattached after adding rooms or changing the layout. The fact that the greenhouse is managed as the basis of what is the balcony or terrace allows you to detach this if necessary and reposition it if necessary, also offering the possibility to take advantage of the space used in our design solutions as a balcony for another room if necessary.

Finally, the basic module of 1mx0,5m greatly facilitates the internal composition, thus offering the possibility to manage in a modular way also the entire arrangement of spaces.
To see in more detail these provisions and solutions, please refer again to the tables at the end of the thesis

## 14.2 Prefabrication

Prefabricated construction, sometimes known as "prefab," is a style of building that is gaining popularity across North America, particularly in cities like Los Angeles and Arizona. In this method, building components are manufactured off-site in a factory and then transported and assembled on-site.[30]

To simplify it the prefabrication is the technique of assembling structural parts in a factory or other manufacturing location before shipping the finished assemblies to the building site where the project is intended to be built. This method lowers construction expenses by saving money on labor, materials, and time. Doors, wall panels, floor panels, staircases, windows, walls, roof trusses, room-sized components, and occasionally even entire structures can be found in prefabricated pieces.

Builders all over the world are using factory efficiency and precision to build high-quality structures thanks to the growing popularity of this building method.
Prefabs come in a few different, widely used varieties, each with unique advantages. You might wish to take some of these actions into consideration depending on the particular building project you are working on.

**Figura 40:** Panelized prefab systems[31]

Prefabrication has a lot of advantages, like the fact that construction workers are not subject to weather-related delays, vandalism, intrusions, or other complication-causing factors. Owners can streamline the building process and reduce waste in this safe, controlled environment. So prefabrication is really affordable.[30]
Prefab also helps to reduce environmental impact.
It can reduce the pollution that a building project causes to the air, water, and noise. We can use prefabrication in the best way when we have a project with a lot of redundancy, so when many of the building's rooms are identical or similar to one another, situations like student housing, motels, medical facilities, and institutional structures are a few examples.

Prefab can help you manage to finish a project with a smaller crew as the industry struggles to deal with a talent shortage. Fewer people can accomplish more because most of the work is done indoors, where it is less taxing. Additionally, these locations are thought to be safer for workers than standard locations.

Although prefab and modular construction are frequently confused, they are not the same, even if they work really well together.
Actually, prefabricated construction falls within the category of modular construction. All modular building is prefab, but not all prefab projects are modular.

Building full project sections off-site before delivering them to a job site is known as modular construction. This covers the electrical, plumbing, and everything that is needed for a unit to function.
The least amount of on-site labor and the maximum specificity are required by this strategy. Every prefabricated structure makes it challenging to shift direction, but a modular project requires extra planning because of this. Once a project is underway, there is little room for error.

**Figura 41:** Modular prefabricated constructions

Another type of prefab is panelization, but it necessitates a little more work on the job site. Panelization involves building walls, floors, and roofs in a factory and then transporting them to the construction site. The pre-existing structure on the site is then connected to those components. Infrastructure such as plumbing and other systems are then installed.
Since it helps to speed up a portion of the construction process without committing to a fully prefab project, this could be a good middle ground for many projects.

**Figura 42:** Prefabricated constructions

Since production through a production line is more controlled, prefabrication is more efficient than traditional on-site construction. Because the walls, roofs, and floors of most buildings are repeating units, a manufacturing process can be created by connecting a series of steps. The manufacturing process can be researched and improved to make these operations more effective.

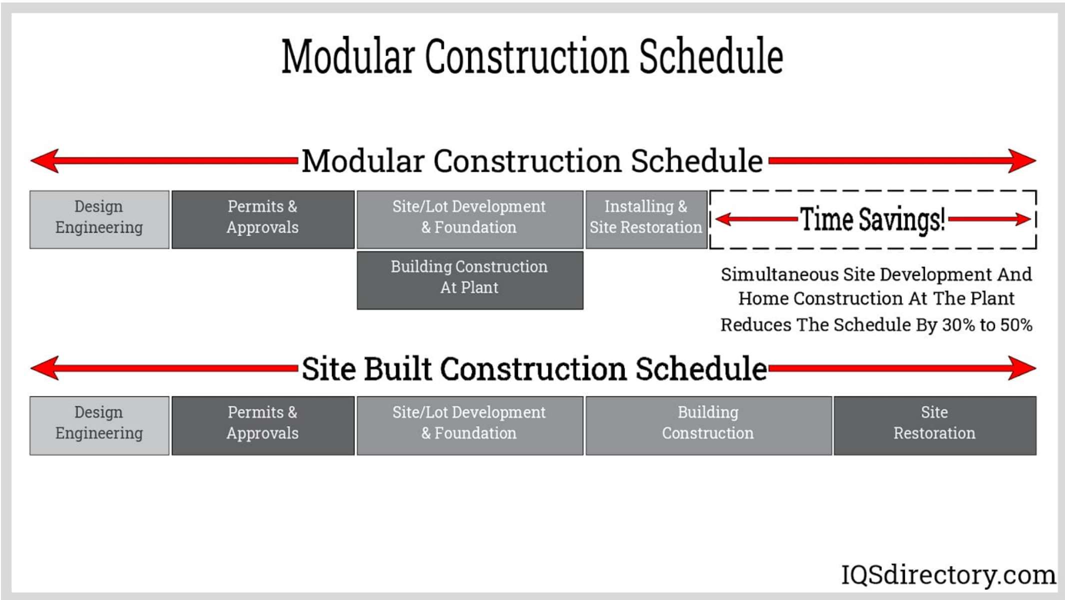



**Figura 43:** Prefabricated constructions

Prefabricated constructions must adhere to the same building codes as permanent structures even when they are made from modules. Construction codes might differ from one state or county to another, making compliance challenging. For manufacturers of permanent and prefabricated buildings, this aspect of construction presents a hurdle. Prefabricated or modular buildings in the United States must adhere to the International Building Code, which differs from state to state but is regularly revised to reflect new advancements.

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Prefabricated structures are continuously being innovated in place of conventional construction due to advancements and standardization of construction and building rules, as well as the increased need for

housing and office spaces. By digitally describing the properties of the structure, modeling tools and methods like BIM (Building Information Modeling) aid architects, engineers, and contractors. BIM makes it possible to effectively manage on-site assembly, lowering the commercial risks connected to prefabricated building.

Manufacturers, builders, and end users all gain greatly from prefabricated buildings. If the planners are proficient in project management, the idea of splitting up tasks on- and off-site allows for more flexibility in the project timeline and expenses.
With regards to market opportunities, prefabricated buildings will ride the trend of eco-friendly or green sustainability. In the upcoming years, market share in the sector, both residential and non-residential, is anticipated to increase.
Faster turnaround is one of the key advantages of producing on a production line. Employees are more productive than those on a typical construction site because they repeatedly carry out their specific responsibilities according to predetermined operational sequences.
Moreover, some of the processes can be automated.
Prefabricated construction is quicker in terms of project planning because some of the tasks can be completed concurrently. Consider clearing the site and building the foundation. Prior to clearing the site and giving the foundation enough time to cure, building of the walls, roof, floors, and even finishing cannot begin. This means that after delivery, a finished facility can be used in just a few days or weeks.[31]

Another big advantage of the prefabrication is the resistance to uncontrollable factors.
Given that it cannot be influenced or controlled, weather is a significant factor in the building business. Projects are slowed down, deadlines are postponed, and workflow is typically disrupted.
All businesses must take the weather into consideration when planning a project.

Prefabricated building assembly is less affected by weather than permanent construction projects because 90% of the process is carried out in controlled environments. Prefabricated structures are constructed "off-site" in a controlled factory setting, enabling the construction of new facilities in any weather. In order to finish a project in inclement weather or in conditions requiring immediate replacement, where normal building methods are impossible, site construction and "off-site" construction are combined.
The external influences can be minimized through prefabrication. In highly controlled circumstances, structural components can be created without being influenced by the environment outside. Manufacturing of precast concrete and shop welding are two techniques with little impact from outside forces.

**Figura 44:** Modular cleanroom

We can reach a higher quality and with prefabrication. A significant advantage of prefabricated building construction is quality control.

Inspections and examination are necessary at every stage of the production process when prefabricated buildings are being produced.

At every level of production, prefabricated components are approved for strict adherence to drawing and quality control by inspectors and the majority of prefabricated building manufacturing facilities. Key personnel and crew foremen in a modular plant have extensive backgrounds in a variety of project types and designs.

Unskilled laborers are used in traditional construction, and local employment agencies send them to projects. Without taking into account their skill level, they are assigned to projects to meet the need for labor. Construction workers for traditional projects work for businesses on a project-by-project basis as temporary or part-time employees, while in modular construction employers people with years of expertise.
When structural components are created with repeated features, quality control is easier to execute than on-site building. Dimensions and tolerances of components can more easily be standardized.
For a typical building component that yields fixed dimensions, the molds, formworks, and temporary fasteners are the same. Also, if two prefabricated buildings are erected in separate areas and use the same components, their quality is more likely to be consistent. So site circumstances closer to the construction are less of an issue.

From an economic point of view a prefabricated building might cost as much as or more than conventional construction. The main benefits of using it are time savings and increased effectiveness.
Conventional building tasks can be finished in six to nine months while prefabrication manufacturers can finish these projects in half the time and with the same quality, which results in cost savings and quick structural implementation. Prefabricated buildings have the advantage of having components and features that are tailored and unique to each project, necessitating careful engineering and design.
Some prefabricated structures are intended to be temporary. They are preferred when project-based work is involved, such as remote healthcare services, research, etc.
Prefabricated structures are simple to disassemble and move to other locations. Also, this functionality ensures that the job site is maintained and altered as little as possible.

[32]

**Figura 45:** Prefabricated offices

Also regardin the environment prefabricated constructions are better than traditional ones.
This advantage results from the method's effective use of raw materials and reusability. Traditional construction produces more waste materials and transient elements that are discarded after construction, including formwork, transient fasteners, jigs, and fixtures.
On-site building typically results in permanent structures. The building will remain vacant after its intended usage until it is either repurposed or torn down.
Because of their mobility, instead, prefabricated, modular buildings are simpler to repurpose.

Finally, we have to take into account the better conditions in which workers are, that leads to an improved worker safety.
Compared to the conditions on-site, fabrication shops have a more controlled atmosphere.
Since the majority of the work for a prefabricated construction is done there, where construction operations can be easily separated and ergonomically designed, the exposure of workers to safety hazards and threats like working at heights, weather, constrained spaces, and adjacent construction operations is significantly reduced.[33]

We can find different kind of prefabricated constructions.
Prefabricated agricultural buildings were employed during the Gold Rush of 1848, and movable houses first appeared in Great Britain at the same time. Prefabricated buildings have been developed, adapted, transformed, and adjusted over the centuries to fit the needs of society.
Prefabricated home kits were offered as foundations from the start of the 20th century and were marketed through catalogs. Following World War Two, which saw the introduction of Quonset huts as temporary barracks for soldiers fighting in the conflict, the prefabricated building industry began to expand quickly.

**Figura 46:** Quonset huts

A business that offers several types of prefab houses to meet the demands of factories, farmers, and homeowners has grown out of the straightforward Quonset hut concept. Volumetric or modular and panelized prefabrication are the two main forms. Both types are built from materials such wood, steel, concrete, and fiberglass, with some variants using a combination of these. Galvanized steel in a light gauge is used to make steel kinds. Prefabricated houses made of wood typically have sheathing and studs made of wood. In order to increase their strength, panel buildings contain fewer studs and are joined by an outside sheathing and stiff insulating core. Foam core fiberglass is used for the walls and roofs of prefab fiberglass structures.

### 14.2.1 Prefabricated panels

Two-dimensional components known as prefabricated panels are assembled on-site to create buildings. These parts are frequently offered as sub-assemblies with installed features like windows, doors, and insulation that are fully finished and installed. The additional components can also be added on-site after the panels have been installed.
Panels can also be delivered as basic structural frameworks. Prefabricated panel types differ in terms of form and substance.

**Structural Insulated Panels (SIPs):**
SIPs, or structural insulated panels, are made up of two structural facings and an insulating layer placed in between.
Metal sheets, plywood, and cement are all acceptable options for the two structural facings or boards.
Polymer foams like expanded polyurethane and polystyrene foams can be used as insulation. They are created by either allowing the foam to expand and cure while forming between the facings or by gluing the three sections together using powerful adhesives. The facings are clamped together in both procedures. Until the adhesive or foam has hardened, pressure and heating are used.

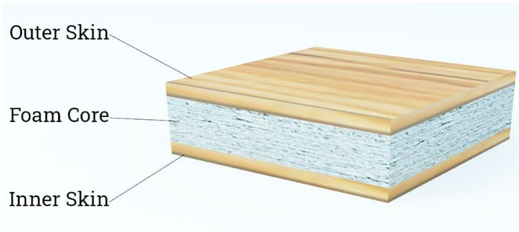



**Figura 47:** SIP panels[32]

**Insulated Precast Concrete Panels:**
Precast concrete panels with insulation are built similarly to SIPs, with two structural facings enclosing insulation.
The facings in this kind are concrete layers known as "wythes". In order to obtain better structural performance, these wythes are typically pre-stressed.
Insulation is made of a hard substance with unique designs. The three parts can be merged or separated depending on the desired function because they are all rigid and capable of serving as load-bearing members.
The wythes' connection may be rigid, sliding, or deflecting. Because they are permanently attached, fully composite panels can withstand greater loads. Non-composite connectors are robust in tension but weak in shear, and they can slide or deflect.
These allow the wythes to interact freely among themselves. Non-composites are typically utilized in applications requiring high insulation, like cooling and refrigeration.[32]

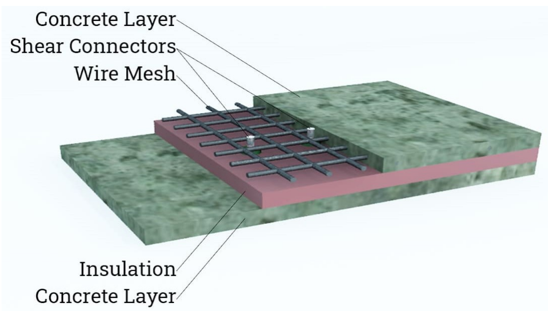



**Figura 48:** Insulated Precast Concrete Panels

**Insulated Concrete Forms (ICFs)**

For the construction of reinforced concrete walls, this type of panel uses hard insulation materials as long-lasting formwork.
The supporting structures, such as formworks and ties, are prefabricated and placed on site.
They can be produced as modular pieces that fit together to form a structure. On-site ready-mix concrete is poured to provide a long-lasting wall. The insulating material can then be immediately covered with finishes and cladding systems.
Even though the building wasn't entirely prefabricated, most of the time and labor were spent off-site.
Since steel-reinforced concrete serves as the primary load-bearing structure, most ICFs perform better than alternative panels.
They are stronger and more resistant to moisture intrusion because of their monolithic composition.

**Figura 49:** Insulated Concrete Forms (ICFs)

**Timber Frame Panels:**

These prefabricated panel types consist of timber stud walls with plywood or special facings connected to each side.
Afterwards insulation is added to the insulating materials. Installing access for utilities like cable conduits and piping is simpler than with other panels.
Although timber frame panels are less expensive, they have drawbacks like lower load bearing capacity, poor sound insulation, and a greater vulnerability to biological threats like termites and mold.
To stop such biological attacks, chemical preservatives, fungicides, and insecticides are used.

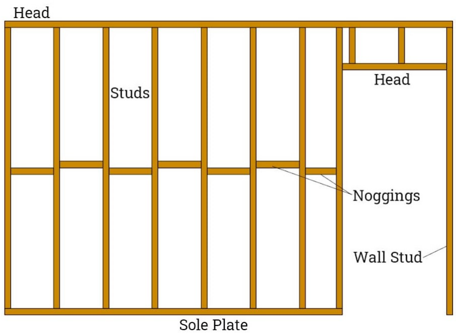



**Figura 50:** Timber Frame Panels

**Lightweight Steel Frame Panels:**

The cold-formed steel studs for the primary load-bearing elements in this kind are typically C-sections. They are put together via bolting, welding, or other fastening techniques. Gypsum board, stone wool, oriented strand boards (OSB), and expanded polystyrene foams (EPS) are used as facings and insulation materials.
The insulation can either be positioned outside the steel framing (cold frame) or inside the thickness of the steel (warm frame). Compared to other panels, lightweight steel frames offer a better strength-to-weight ratio, but they are only able to withstand some lateral loads like wind and earthquakes and largely static loads.

Steel's strong thermal conductivity and potential for interstitial condensation are further drawbacks. A thicker insulating material is therefore needed.[32]

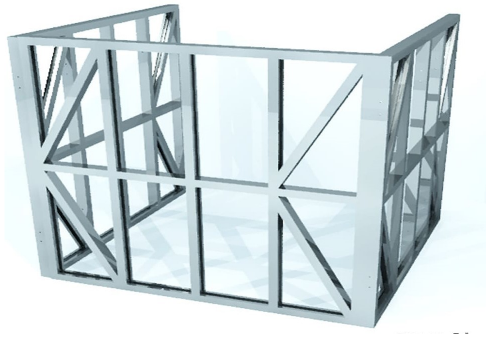


**Figura 51:** Lightweight Steel Frame Panels

### 14.2.2 Prefabricated Modules

The three-dimensional construction of prefabricated modules typically consists of four shop-assembled panels.
The entire structure is created by stacking a number of modules next to or on top of one another. Inter-module connectors, which are bolted on site, link modules together.
Because to its popularity among all types, the terms "modular buildings" and "prefabricated buildings" are often used interchangeably. A modular structure has all the benefits of a prefabricated structure.
Buildings can be constructed entirely from a single module with little to no site preparation. According to how they are constructed, modular structures can be classified into various categories.

**Four-sided Modules:**
This particular sort of module has four closed sides that together form a cellular space.
The load-bearing panel frames may transfer both lateral and vertical loads.
Depending on the site conditions, this design can normally reach a maximum height of 6 to 10 stories.
Hotels, modest homes, housing developments, and dorms are among the uses for four-sided modules.

**Partially Open-sided Modules:**
This type of module has one or more walls consisting of a collection of panels that do not entirely span the wall.
Open partitions connect nearby modules by acting as accessways or corridors.
The corners or intermediary columns or posts on the partially open sides of the structure transfer the vertical load in place of the load-bearing panel.
Similar to four-sided modules, this design often has the same height and uses.

**Open-sided Modules:**
These modules have one or two sides that can be completely opened.
The long sides are typically cut off so that the module can be attached to other nearby open-sided modules to expand the space.
The corner posts, which are joined to the edge beams by gusset plates and bracings, receive the loads before being transferred to them.
Since open-sided modules have fewer load-bearing elements, tall buildings cannot be constructed using them.
This kind of form often rises two to three floors in height. Hospitals and schools are two potential applications for these modules.

**Modules Supported by Primary Structure:**
Modules Supported by Primary Structure: For this kind of module, a load-bearing external steel structural frame is added. As the modules are stacked above, the external construction can create open areas at or

below ground levels. The walls and partitions can be non-load bearing while nevertheless serving as full support for the modules. These buildings are frequently used in residential and mixed-retail settings.[32]

### 14.2.3 Hybrid Prefab Systems

Hybrid prefab systems combine two- and three-dimensional elements from panel and modular systems to construct an entire or a portion of a building.
Also known as mixed modular and panel systems, this category.
When it comes to building quality and detail, modular modules have an advantage, but they might occasionally be constrained by assembly and transportation requirements.
The more valuable and highly serviced components, including kitchens and bathrooms, are constructed using three-dimensional modules.
Due to the flat pack or ready-to-assemble nature of its manufacturing, panelized components are added to the assembly.
For the flooring and walls of more open spaces, two-dimensional panels are used.

### 14.2.4 Temporary Prefabricated Buildings

Prefabricated structures can be utilized both indoors and outside as movable temporary structures.
They are built of panels and have a roof over a steel or aluminum frame.
Glass, fiberglass, and polyvinyl chloride are just a few examples of materials that can be used to construct shelters' walls (PVC).
Temporary shelters that are prefabricated can be swiftly erected. They are resilient, require no maintenance, and can tolerate extreme weather conditions like humidity and temperature variations.

Prefabricated shelters are frequently utilized as storage units for rescue equipment, sound dampening for pumps, and protection for sound room equipment, even though they can be used as huts to protect employees.
Prefabricated shelters can be customized to fulfill the requirements of a wide range of applications because they are available in a variety of shapes and sizes.
They are perfect for usage in emergency situations because they take half as long to put together and implement.

Temporary, mobile modular structures can be relocated to various locations and are frequently reused or refurbished.
They are made to be quickly disassembled and moved because they are meant to be temporary structures.
The word "temporary" describes the way the buildings are put in place.
Temporary prefabricated buildings can endure for 25 to 30 years with regular maintenance; after that time, the parts are usually recycled or put to other uses.

### 14.2.5 Some reflections

Prefabricated buildings, also known as prefabs, are structures containing parts (such as walls, roofs, and floors) made at a factory or manufacturing facility.
These parts can be built entirely or in part in a factory before being transported to the location. Since production through a production line is more controlled, prefabrication is more efficient than traditional on-site construction.
Prefabricated buildings have a number of advantages, including quicker on-site construction, less impact from uncontrollable elements, improved quality and uniformity, economic effectiveness, reusability, less waste of raw materials, and decreased safety risks.

Prefabricated structures can be categorized based on their level of construction. Component, panel, module, hybrid, and complete buildings are the various construction kinds.
The cost of prefabricated buildings is comparable to or higher than that of conventional buildings. The

quicker they can be installed and used, the more money can be saved from using them, which boosts the ROI (ROI).

**Prefabrication in our project** The buildings within our project are entirely managed through prefabricated elements, leaving aside only the elements of foundations, which are in concrete cast in place. Each element of the casing is prefabricated, from the outer walls to the floors.
The use for the casing of a solution type AQUAPANEL[45], by definition prefabricated, with a metal structure allows prefabrication and therefore all the benefits and facilities that a solution of this type allows and offers.

To see in detail the stratigraphic solutions that have been proposed, please refer to the tables at the end of the thesis.

## 14.3 Water harvesting

Technology that collects and stores rainwater for human use is known as a rainwater harvesting system, also known as a rainwater collecting system or a rainwater catchment system.

Simple rain buckets and sophisticated constructions with pumps, tanks, and purifying systems are both examples of rainwater gathering systems.

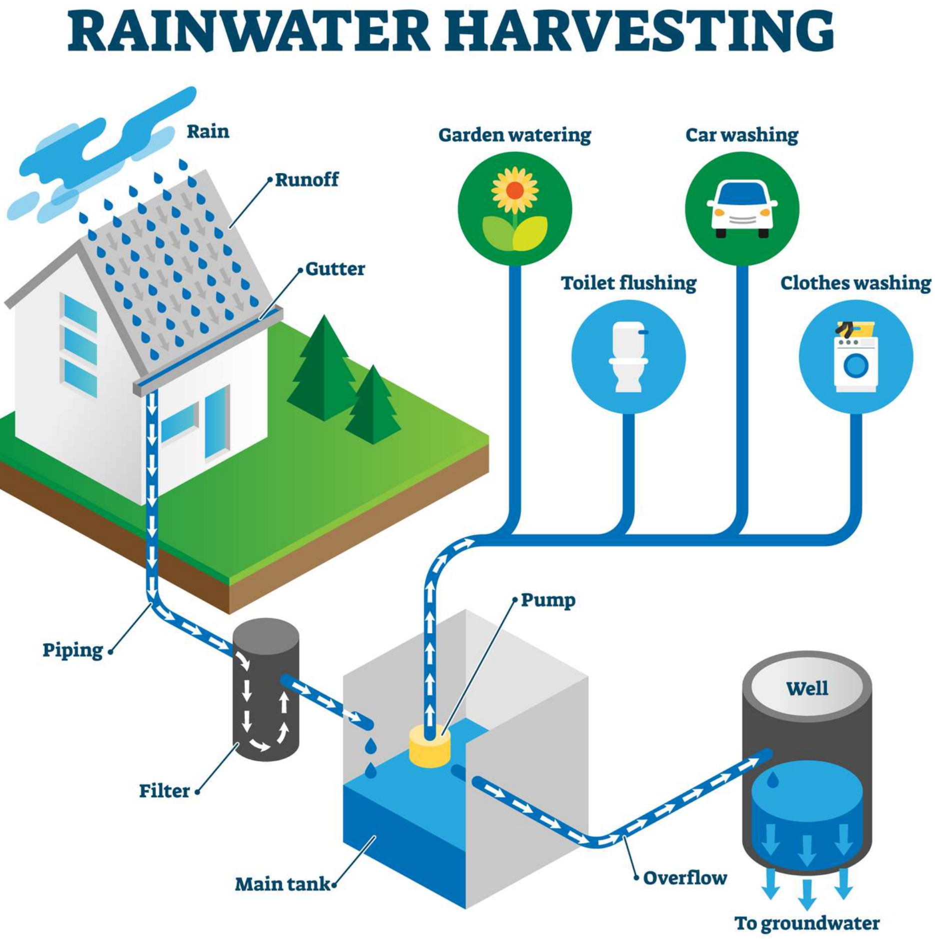



**Figura 52:** Rainwater harvesting system

The nonpotable water can be filtered for use as drinking water and utilized to irrigate lawns, wash automobiles, wash clothes, and flush toilets.
Rainwater harvesting systems can supply homes and businesses with water for use during dry seasons and reduce the strain on municipal systems, which is a major issue in many densely populated places.[34]

Rainwater collecting is an effective way to obtain this valuable resource because rainfall is intermittent and only a small part of the world's precipitation is readily used.
In cities, a large portion of the rain that falls on structures, roofs, roads, and other hard landscaping is channeled into storm drains for disposal rather than penetrating into the soil.
Many impermeable surfaces contribute to urban flooding and produce tainted, useless water that is diverted away from sources of potable water. Local groundwater can become depleted during dry months, and many communities struggle to continuously supply enough drinkable water to fulfill demand.

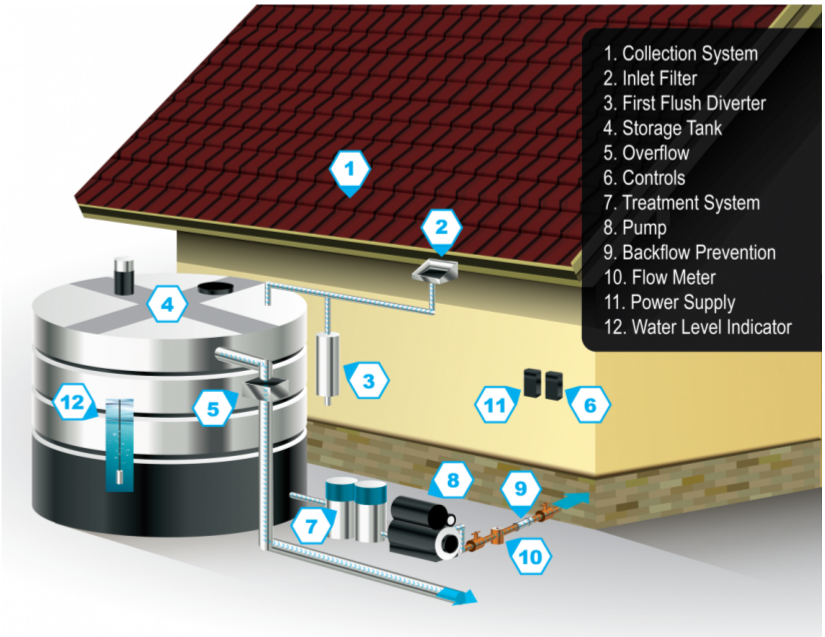
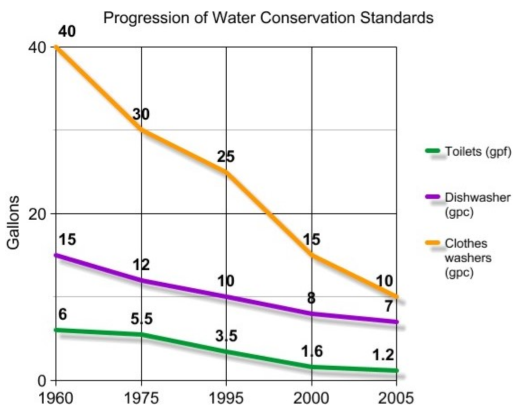
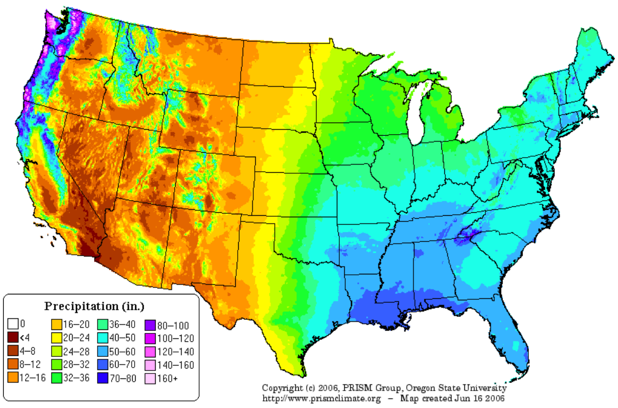



**Figura 53:** Rainwater harvesting system

Rainwater collection for non-potable uses like gardening and laundry greatly lowers the demand for freshwater overall and eases the burden on stormwater infrastructure.
In big cities, that reduction in the demand and availability of drinkable freshwater is significant.
Although many communities support and even financially support the use of rain barrels and other rainwater collection devices, some regions, particularly those in the Southwest of the United States, see rainwater gathering as a matter of water rights and impose limits on its use.




(a) Progression of water conservation standards




(b) Precipitation concentration

### 14.3.1 Design suggestions

Simple nonpressurized devices, such rain barrels, in which pipes flow from gutters into tanks, are the most effective ways to collect rainwater.
Called as "dry systems," those constructions don't retain any water in the pipes after it stops raining, preventing the development of mosquito and other insect breeding grounds.

**Figura 54:** Dry system

When the pipes cannot be set up to go directly into the tanks, "wet systems" are required. Pipes from the gutter travel underground and then up through a riser into the tank in locations where the tanks are set back from the collection surfaces or when there are multiple tanks to serve several buildings. Such systems are frequently pressured to prevent stagnant water buildup in the lengthy pipe lines.

**Figura 55:** Wet system

Insect-proof pipes and all other holes are guaranteed in well-designed rainwater collection systems, especially in wet systems.
Furthermore, wire mesh screen covers on all tank inlets might aid in preventing the entry of debris.
Tanks should be made of nontoxic and noncorrosive materials, and collection surfaces, including roofs, should be made of harmless materials. Lead-based paints and membranes should be avoided.
To prevent drawing out any sludge that may have accumulated in the water supply, care should be taken to position the tank outlet taps or draw-off pipes at least 10 cm above the tank floor.

Although some systems incorporate a washout pipe and sump pump to remove sludge, it is advised for all systems to perform routine cleaning of the inside surfaces of the tank.
Moreover, accumulations of dirt, moss, lichens, and other detritus need to be removed from catchments. Cut back any tree branches that dangle over such catchment surfaces.
For proper operation, regular gutter cleaning, tank intake cleaning, and tank inspection are required. In an ideal world, the water's purity would be checked on a regular basis.

### 14.3.2 Quality

Rainfall combines with both soluble and insoluble components from the surfaces it rains on, and as it descends through the atmosphere, it picks up dust and pollutants.
Plants, fungus, and other organic items may be contaminants, as well as inorganic elements like dissolved minerals, metals, chemicals, or paints that are water soluble.
Rainwater collected from filthy surface runoffs is not acceptable for drinking or cooking, even though it doesn't require a high level of cleanliness for garden or agricultural purposes.

The water quality in the rainwater storage tank can be improved by separating the first flush of rainfall from the roof, gutters, and other collection surfaces.
Purification is required before using rainwater that has been collected for domestic purposes. To get rid of bacteria, organic matter, and chemicals that form films on surfaces or settle to the bottom of the tanks as sludge, use flocculation, settlement, and biofilm skimming.
The incoming raw water can alternatively be mixed with a liquid alum solution to bind small suspended particles into larger ones that can be removed by settling and filtering. This clears the water of any undesirable color, turbidity (cloudiness), and aluminum.

If the supply is meant for potable uses, the prefiltered water may next go through solar water disinfection or be treated with chlorine or other chemicals to kill infectious agents.
Fluoride, calcium hydroxide, and potassium permanganate are additional chemicals used to purify water.

### 14.3.3 Applications

**Household use**
Water for cattle, home usage, drinking, small irrigation projects, and groundwater replenishment are all provided through rooftop rainwater gathering.

**Agriculture**
Rainwater collection in urban settings lessens the effects of runoff and flooding on urban agriculture.
It has been discovered that adding rainwater catchments and urban "green" rooftops to buildings can lower their inside temperatures by more than 1.3 degrees Celsius[35].
It would be possible to accomplish the Sustainable Development Goals of the United Nations for healthier and more sustainable cities, as well as for food and water security, by combining rainwater harvesting and urban agriculture (Sustainable Development Goal 6).
Although the technology is there, it needs to be updated in order to use water more effectively, particularly in metropolitan areas.


**Figura 56:** Sustainable Development Goals

Rainwater collecting is used by many nations, particularly those with arid climates, as a cheap and dependable source of clean water.

Ridges of soil are built to catch and stop precipitation from rushing down hills and slopes, improving irrigation in arid conditions. There is always enough water gathered to support agricultural growth, even during dry periods.
Roofs can be used to collect water, and dams and ponds can be built to store a lot of rainwater so that crops can be watered even on days with little to no precipitation.

### 14.3.4 Advantages

In affluent nations, rainwater collection is frequently used to augment the primary supply of water during times of regional water shortages.

When a drought strikes, it supplies water, can lessen flooding in low-lying areas, and lessens the need for wells, which might allow groundwater levels to be sustained.
By increasing the number of dried borewells and wells, rainwater collection increases the amount of water that is available during dry seasons.
Surface water supply is readily available for many applications thereby minimizing dependence on sub-surface water. By reducing salinity, it elevates ground quality. It is environmentally friendly and does not pollute. It is reasonably priced and cost-effective.

Rainwater is largely free of salinity and other salts, which increases the availability of drinking water. By lowering the demand for clean water in water distribution systems, generating less stormwater in sewer systems, and reducing stormwater runoff that pollutes freshwater bodies, applications of rainwater harvesting in urban water systems significantly benefit both the water supply and wastewater subsystems.

A substantial amount of research has concentrated on the development of life cycle assessment and related costing approaches to evaluate the degree of environmental impacts and financial savings that may be realized by putting rainwater harvesting devices in place.

**Independent water supply**
Rainwater harvesting provides an independent water supply during water restrictions.
In areas where clean water is costly, or difficult to come by, rainwater harvesting is a critical source of clean water.

In developed countries, rainwater is often harvested to be used as a supplemental source of water rather than the main source, but the harvesting of rainwater can also decrease a household's water costs or overall usage levels.
Rainwater is safe to drink if the consumers do additional treatments before drinking. Boiling water helps to kill germs. Adding another supplement to the system such as a first flush diverter is also a common procedure to avoid contaminants of the water.

**Supplemental in drought**
In times of drought, rainfall collected in previous months can be used.
The usage of a rainwater harvesting system can be essential to catching the rain when it does fall if it is unexpected and limited.
Rainwater harvesting is a popular and dependable source of clean water in many desert nations. Ridges of soil are built to catch precipitation and stop it from going downhill, improving irrigation in arid conditions.
There is always enough water gathered to support agricultural growth, even during dry spells. Roofs can be used to collect water, and massive rainwater collection tanks can be built.
Additionally, rainwater collection reduces the need for well water, allowing groundwater levels to be maintained even further.

**Life-cycle assessment**
A process called life-cycle assessment is used to examine a system's environmental effects during its entire lifetime.
There is a methodology for rainwater collecting in which the building's design (such as its size) and function (such as its use for residential, educational, or other purposes) have a significant impact on the system's environmental performance.

**Cost-effectiveness**
Standard RWH systems can give impoverished developing areas access to water, however depending on the technology utilized, the typical cost of a RWH setup might be high.
Governments assistance can help communities struggling with poverty by offering the tools and instruction needed to create and sustain RWH installations.
Because to its affordability and environmental friendliness, some research indicate that rainwater harvesting is a broadly applicable option for water scarcity and other numerous uses.

Particularly in emerging nations or underdeveloped areas, building new, large-scale, centralized water delivery infrastructure, like dams, is prone to harm local ecosystems, creates external societal costs, and has limited uses.
Installing rainwater harvesting systems, on the other hand, has proven by numerous studies to offer local populations a sustainable water source, along with other varied benefits, like flood protection and control of water runoff, even in underdeveloped areas.

Rainwater harvesting systems that do not necessitate extensive building work or routine maintenance by a specialist from outside the community are more environmentally friendly and more likely to benefit the locals for a longer period of time.
Rainwater harvesting devices therefore have a greater chance of being adopted and used by more people if they can be installed and maintained locally.

Using in-situ technologies can lower rainwater collection investment costs.
Since less material is needed to build them, in-situ technology for rainwater harvesting may be a viable choice for rural areas.
They could offer a steady supply of water that could be used to increase agricultural output. Water can be collected for home use in above-ground tanks, but such systems may be out of reach for those living in poverty.

**Water harvesting in our project** The housing units in our project are equipped with a system of rainwater collection, the roof pitches are inclined and managed in order to facilitate this task, and provides a reservoir for district water in which you go to channel the water collected from the different buildings.
The presence of a green roof helps both from this point of view both as regards the air conditioning of the interior but also of the outdoor spaces.

There is also a water square in the district.
Water squares are an innovative way to manage and collect rainwater in cities.
Water squares, located in strategic places of cities, are the appearance of simple multifunctional public spaces that, in reality, in the event of heavy rains and floods, turn into rainwater collection and storage basins, in order to relieve the pressure on the sewage system and to have the possibility to reuse them in times of greater drought and water stress.


**Figura 57:** Water squares samples

The water squares are presented as areas for play and relaxation that in 90% of the time turn out to be "dry" and usable like any other traditional public space, while in the remaining 10%, and according to the intensity of the rains, can be more or less "flooded".

During mild and medium rainfall, the water will simply be filtered and stored in hidden storage basins so that it can be reused in the future. On the contrary, in case of heavy rainfall, the square, flooding, will act as a real basin for collecting and decanting water, in order to manage the intake into the sewer system, thus avoiding its overload.
The square, regardless of the level of flooding, will always be accessible and some spaces will always be available to citizens.
Adults will enjoy new and ever-changing urban scenarios, and children will experience new forms of play with water. The stagnation of water in the square at its highest levels, statistically on average once every two years, will not exceed 32 hours.

## 14.4 Agricolture

Ensuring food for humans despite the impact of climate change and population growth on the earth, while respecting water, land and biodiversity.
These are the goals of sustainable agriculture, which can benefit greatly from emerging technologies such as IoT, data analytics and Blockchain in the so-called Agriculture 4.0.

Respecting natural resources such as water, land and biodiversity, while at the same time ensuring food for human beings despite the impact of climate change and population growth on the earth.
These are the objectives of sustainable agriculture, where the word sustainability does not only refer to the environment, but also to the social sphere: thus ensuring people's health, the quality of life of those involved in production, the human rights of those working in the sector and social equity.[36]

In order to achieve these goals, emerging technologies can come to play a major role, starting with the so-called agriculture 4.0, where connectivity, artificial intelligence and IoT can be used to make a contribution in one of the sectors that has traditionally remained most sheltered from innovation, and that has long been considered as one of the sectors most tied to tradition, and therefore to dated production and distribution methods with great potential to be made more efficient.

### 14.4.1 What is sustainable agriculture

At the heart of the concept of sustainable agriculture is the objective of meeting the needs of mankind, be it for food or textiles, without this activity penalising the needs of future generations. The Agricultural Sustainability Institute provides the definition.
To go deeper, the FAO, which drew up the list of five principles that sustainable agriculture must be inspired by, published a paper in 2018 that aims to indicate the 20 actions needed, in the field of agriculture, to achieve the 17 development goals, the so-called Sustainable Development Goals (SDGs), by adopting an integrated approach to the subject.

### 14.4.2 The 5 principles of sustainable agriculture

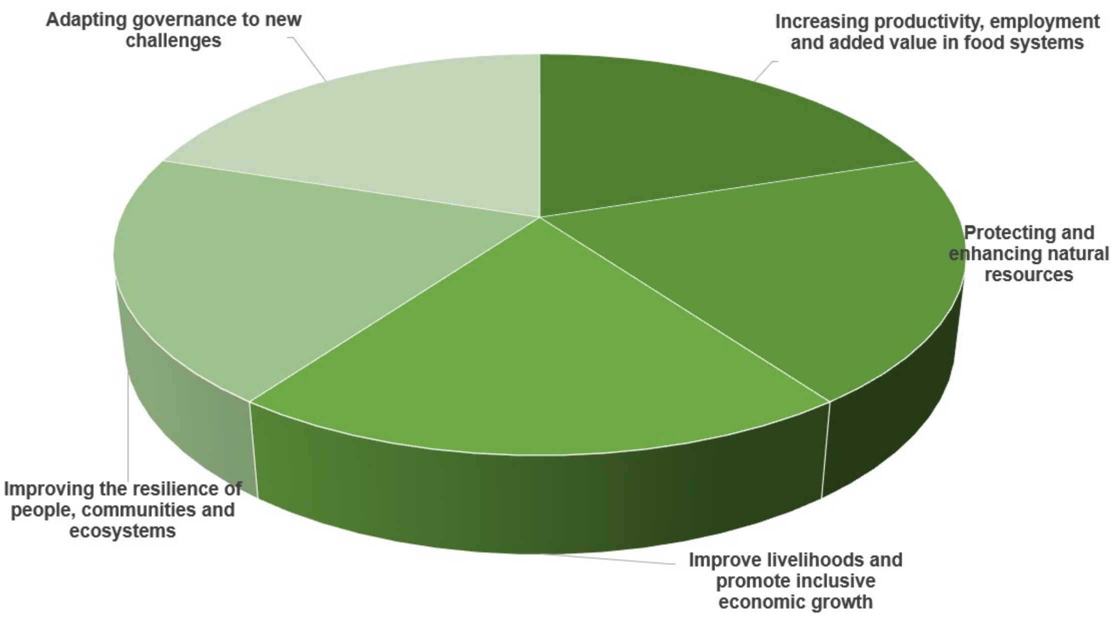



**Figura 58:** The 5 principles of sustainable agriculture

- Increasing productivity, employment and added value in food systems
- Protecting and enhancing natural resources
- Improve livelihoods and promote inclusive economic growth
- Improving the resilience of people, communities and ecosystems
- Adapting governance to new challenges

In this vision, farmers, herders, fishermen, foresters and other rural dwellers make their voices heard, benefit from economic development and enjoy decent employment.
Rural men and women live in security, have control over their livelihoods and equal access to resources that they use efficiently.[37]

It was the Food and Agriculture Organisation (FAO), an organisation under the United Nations, that drew up the five cornerstones of sustainable agriculture.

The first is the objective of increasing productivity, employment and added value in food systems through a change in agricultural practices and processes aimed at securing food supplies and reducing water and energy consumption.

The second principle aims to protect and improve natural resources: this includes preserving the environment, limiting pollution of water sources, combating the destruction of habitats and ecosystems, and land degradation.

The third principle is about improving livelihoods, fostering inclusive economic growth.

The fourth focuses on increasing resilience, whether of people, communities or ecosystems.
This implies the transformation of production models to ensure that the impact of extreme events due to climate change or market price variability is minimised as much as possible.

The fifth and final point is the challenge of adapting the governance of the sector to the new challenges, by means of a set of rules that makes it possible to balance the public and private sectors while ensuring transparency and fairness.[36]

### 14.4.3 Four directions to work


**Figura 59:** The 4 directions in which we should work

Promoting sustainable agriculture means working in four directions:

- improving the living conditions of workers and producers, increasing their access to the market and promoting fairer trade;

- the granting of more opportunities to a greater number of producers, especially the most disadvantaged, and protecting them from exploitation;
- the dissemination of information on economic mechanisms of exploitation, promoting awareness among consumers of an alternative economic model to the dominant one;
- the promotion of social justice and respect for fundamental human rights.

### 14.4.4 Technological innovation and sustainable agriculture

A fundamental impetus for the modernisation of agriculture in the direction of sustainability can come from new technologies, but also from the evolution of regenerative agricultural practices.
It is precisely in this direction that Agriculture 4.0 is heading, which was born on the wave of innovations previously introduced in other productive sectors, such as manufacturing and industry.

In the case of agriculture, too, it is thus a question of using massive doses of new technologies, such as the digitisation of processes, the Internet of Things, geolocalisation and Internet connection.[39]

Making the best use of these tools leads to precision agriculture, which makes it possible to use ad hoc cultivation and plant care methods according to the characteristics of the land and the areas in which they are located, optimising energy consumption, rationalising the use of water and fertilisers even according to real-time weather conditions.
This ensures, on the one hand, the best care of crops, and on the other hand, the reduction of waste and consequently of the environmental impact, and last but not least, having tools to counter the consequences of extreme weather events.

### 14.4.5 The Italian agriculture 4.0 market

The Italian Agriculture 4.0 market, driven by technologies that improve the quality and sustainability of crops, solutions for the competitiveness of companies, and innovations for the traceability of products, continues to grow, and in 2020 was worth EUR 540 million, growing by 20% compared to the previous year.


**Figura 60:** Sustainable agriculture

An even more significant growth if we consider that currently the land cultivated in our country using agriculture 4.0 technologies is still 3-4% of the total.
In 2019, the market was worth 450 million euros and grew by 22% compared to 2018.

Taking the snapshot is the Smart Agrifood Observatory of the School of Management of the Politecnico di Milano, which highlights how among the issues on which digital can bring greater added value are product quality, food safety and certification, which can find answers in terms of food traceability solutions.
The mapping carried out by the Observatory also shows that 157 of the total 538 agriculture 4.0 solutions available in Italy refer to this area, with a growth of more than 100 units compared to 2019.
79% of these applications focus on the cultivation phase, 45% on sowing, 35% on harvesting, and 16% on planning.[36]

### 14.4.6 The most promising technologies

Sustainable agriculture can be declined in different models and using more than one technique.
One example is the organic farming model, in which production is carried out in compliance with the European EC Regulation 2092/91.
In practice, only natural substances are used, avoiding over-exploitation of natural resources and without synthetic chemical substances, but only natural fertilisers.

Another model is that of biodynamic agriculture.
The basic principle is to respect the earth's ecosystem by referring to cosmic laws, such as the phases of the moon, and the activation of life in the soil.
The aim is to make the plants self-regulate and adapt to external conditions as best they can.
Again, no chemical fertilisers or pesticides are used, which are replaced by the administration of natural preparations that promote soil fertility.[37]

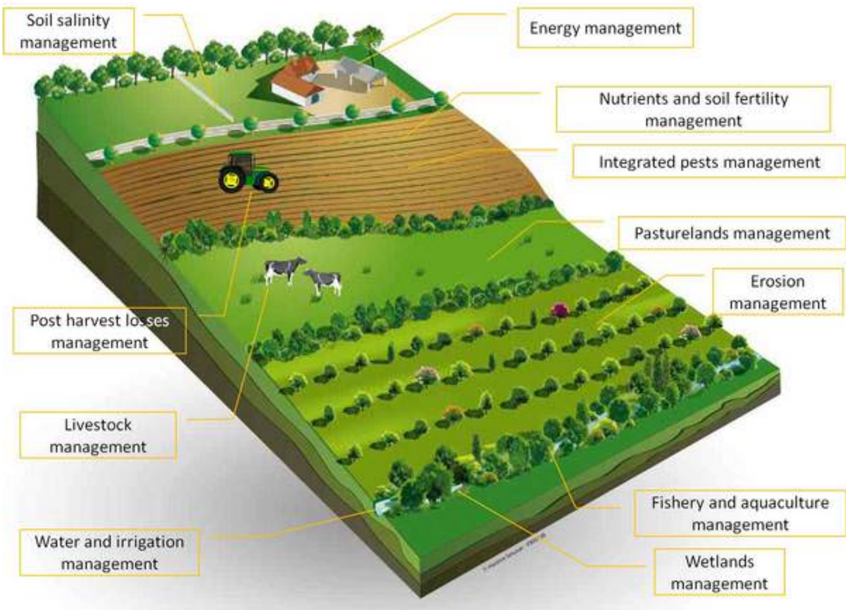



**Figura 61:** Sustainable agriculture

Turning to permaculture, this is the set of agricultural practices geared towards the natural maintenance of soil fertility, but also an integrated design system that interweaves issues from architecture, economics, ecology and legal systems for businesses and communities.
In other words, it is about designing and managing man-made landscapes in a way that meets the needs of the population, such as food and energy, without disrupting the sustainability of natural ecosystems.

Finally, other models of sustainable agriculture include ecovillages, sustainability-oriented communities experimenting with new lifestyles, ranging from designing dwellings to minimise environmental impact to food self-sufficiency.
And finally, it will also be useful to mention fair trade agriculture, characterised by the fact that products grow on land free from exploitation, blackmail, extortion and mafias.
The focus here is simultaneously on respect for people and the environment and on reducing the distance between those who cultivate the land and those who enjoy its fruits.[39]

As for the techniques used by sustainable agriculture, among the most popular are:

- crop rotation, which aims to improve or maintain soil fertility;
- biological control, which consists of monitoring agricultural pests and disease-transmitting insects using their natural enemies, which can be other beneficial insects, predators, parasitoids and microorganisms such as fungi, viruses and bacteria;
- covering the soil with straw or organic matter, which is useful for maintaining optimal soil moisture and regulating soil temperature.

### 14.4.7 Ecovillages

This is a type of community whose main objective is environmental sustainability, experimenting with lifestyles different from those imposed by the current socio-economic system.
Participants' membership is voluntary and involves the design of housing units to minimise environmental impact, the use of renewable energy sources and food self-sufficiency based on permaculture or organic farming.
In short, the ecovillage makes it possible to satisfy many basic needs, such as housing, food and work, guaranteeing the community a better quality of life not tied to the dynamics of consumption and globalisation proposed by today's society.[38]

### 14.4.8 Examples of sustainable agriculture

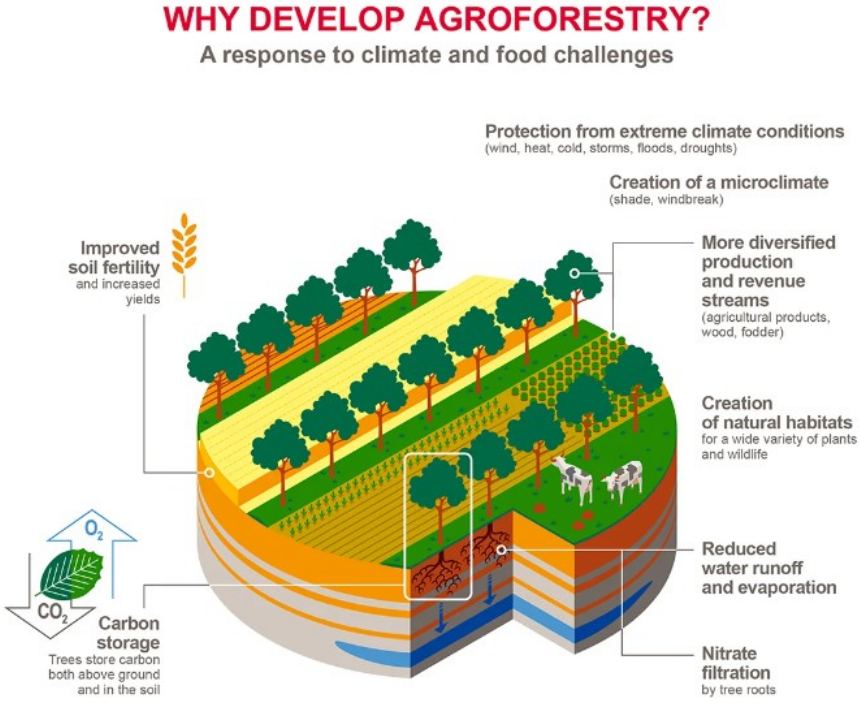



**Figura 62:** The 4 directions in which we should work

Since soil exploitation and soil erosion is one of the main problems associated with intensive farming systems, with today's population growth rates, it will be increasingly necessary to turn to alternatives.

This is why, in recent years, people have begun to talk about hydroponics, aeroponics and even aquaponics, which in addition to plant cultivation includes the rearing of aquatic animals.
These are agricultural production methods that do not involve the use of soil.

As far as aquaponics is concerned, an interesting project is that of the American non-profit Green-Wave, which uses '3D ocean farming', a regenerative aquaculture technique, to grow algae and molluscs in water.
Hydroponic farming, on the other hand, is a soil-less cultivation method that uses only mineral nutrient solutions dissolved in water.
In Italy, hydroponic farming is mainly chosen by start-ups, one of the most important of which is Sfera Agricola, founded in 2016 near Grosseto. The company produces two varieties of tomatoes and several salads and herbs, all nickel-free.[39]

In the case of aeroponic agriculture, plants grow with their roots floating in the air.
This production system is developing more and more, also because it reduces water consumption compared to both traditional cultivation and hydroponics.[36]
In Italy, among the best known is the example of the Turin-based start-up Agricooltur, founded in 2018, which uses a system that is sustainable from several points of view.
*"The roots are sprayed with water and nutrients in a completely controlled environment that almost completely reduces the spread of parasites and diseases typical of growing in soil, without having to use insecticides or pesticides that are potentially harmful to the health of humans, plants and the environment"*[21]

[21] reads the website of the Turin-based start-up.

It is clear that these models and techniques have much to gain from a 'technological' approach, where real-time data collection and analysis can help make the best decisions in real time, avoiding waste and damage to crops, which can then grow to their full potential.

### 14.4.9 The objectives of Agriculture 4.0

By making digital technologies available to agriculture, it is possible to achieve a number of fundamental results from the perspective of sustainability, such as calculating precisely how much water a plant or plantation needs, thus avoiding wastage of resources, but also to be able to make predictions about the risks to crops, e.g. with regard to diseases, by knowing in advance which pests might attack the plants.

Then there is the area of supply chain traceability, in order to monitor each step of the production process and thus guarantee product quality.[37]
This is also due to the fact that products in a high-tech supply chain keep their properties intact and are therefore healthier, with a 20% increase in productivity.

### 14.4.10 The aims of sustainable and solidarity-based agriculture

Solidarity-based agriculture proposes an economic model based on a code of ethics that is binding for all those working in this sector and aimed at:

- improve the livelihoods of producers by increasing their market access, paying a fairer price for their goods and ensuring continuity of trade relations;
- promoting development opportunities for disadvantaged producers, especially women's groups and indigenous peoples, and protecting children from exploitation;
- disseminating information on the economic mechanisms of exploitation through the sale of products, encouraging and stimulating in consumers the growth of an alternative attitude to the dominant economic model and the search for new models of development;
- protect human rights by promoting social justice, environmental sustainability, economic security, fair and sustainable use of environmental resources.[39]


**Figura 63:** Agricultural sustainability

### 14.4.11 At wich point we are in Italy

According to data from the latest Greenitaly 2020 report, in the Covid-19 epidemic emergency that hit Italy hard, the made-in-Italy agrifood sector confirmed its strategic value both in the supply of necessary primary goods and in the environmental field.[39]
*"The Italian agricultural sector, is confirmed as the greenest in Europe (...) A national specificity composed of various ingredients: starting from land management, which not only contributes to the beauty of our landscapes, but also prevents adverse hydrogeological events; from the protection of biodiversity, to the growing spread of organic farming, to the efficient use of chemicals and water; from renewable energies (from biogas to photovoltaics), which often valorise by-products or production waste with a view to the circular economy, to new technologies and the contribution, in this path towards innovation, of new skills".*[22]

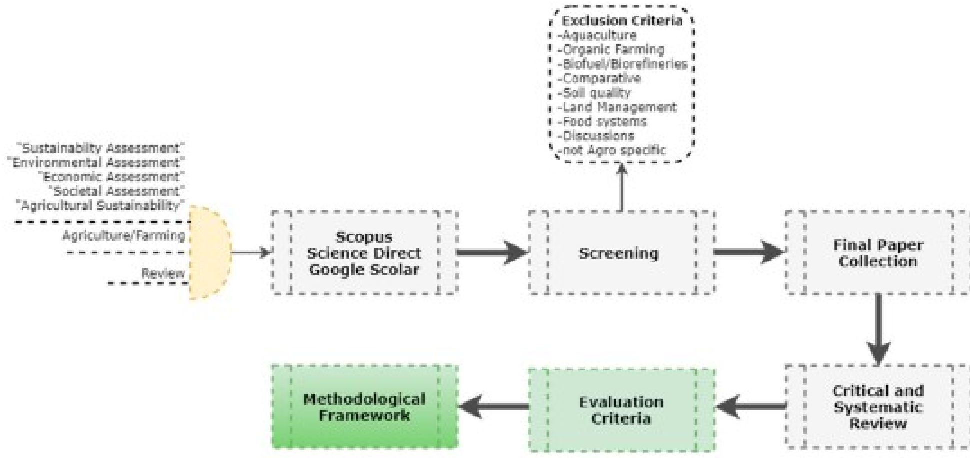



**Figura 64:** The methodology

**Agricolture in our project** In our project the need to use cutting-edge agricultural techniques has been taken into account.
Based on the example of the ReGen village and what is in the literature, several solutions for the production of food in the village have been proposed.
Each housing unit is equipped with a greenhouse that allows you to grow small vegetables and similar to the inhabitants.

The district is then served by a structure dedicated to aquaponic culture, of which we have spoken in the section of this thesis 10.3.3.
This facility serves the entire district and represents the main source of power, along with a large greenhouse again shared present in the productive area of the village.

[22]From the GreenItaly report

# 15 Building envelope

A structure's outside and internal environments are physically separated from one another by the building envelope.
The building envelope, which shields the inner space from environmental factors such as precipitation, wind, temperature, humidity, and ultraviolet radiation, is often made up of a number of parts and systems.

**Figura 65:** The envelope of a building

The interior environment is made up of the people who reside there, their possessions, the architecture, lighting, tools, machinery, and HVAC (heating, ventilation, and air conditioning) equipment.
One of the best methods to improve a home's energy efficiency is to improve the building envelope.

**Tight and loose building envelopes**
Typically, a building envelope is described as either "tight" or "loose".
Whereas a tight envelope confines air or modifies how it is admitted, a loose envelope allows air to move more freely around the building.

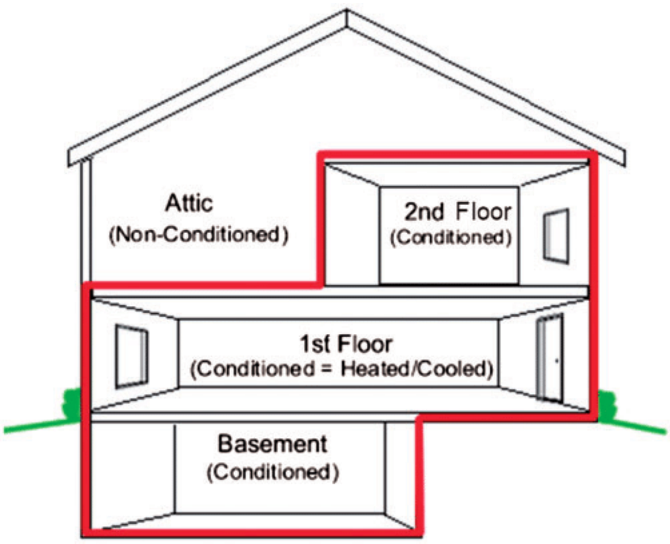



**Figura 66:** A tight envelope

We are increasingly able to take advantage of the environment and control the internal climate thanks to advancements in the design and composition of outer walls.

**Building support**
The building envelope must be structurally sound first and foremost.

The ability of external walls to support their own weight as well as that of the roof and any above stories is crucial.
Purpose-built walls (load bearing walls) absorb this weight and then transmit it to the foundations.
Walls must be strengthened to withstand lateral pressure in places that are vulnerable to powerful winds and earthquakes.

**Climate control**
While planning a building envelope, there are a variety of environmental factors that needs to be taken into mind.
A residence should have adequate fresh air ventilation for comfort, while also being shielded from gusty winds and draughts.
In a chilly or humid climate, wet air entering a home can promote the growth of mold and mildew, which is dangerous and must be avoided.
You might use walls that will trap and release heat in response to external conditions as part of the building envelope in regions that suffer extreme temperatures.
Your home will be healthier, cozier, and more effective if it has a building envelope that is sensitive to its surroundings and responsive to those changes.

**Finish and visual appeal**
The ideal house is one that not only appears attractive but also operates in harmony with its environment.
Building envelope finishes should consider both form and function.
It's fantastic to come home to a beautiful property, and a high-quality finish will always raise the value of your house.

**A building envelope functions**
A building envelope serves many functions.

Three categories can be used to group these functions:

- Support: giving structural support against internal and external loads and forces; ensuring strength and stiffness.
- Control: to regulate the flow of heat, air, water, and condensation between the inside and outside of the building.
- Finish: this serves purely decorative purposes. to maintain support and control while maintaining the building's aesthetic appeal.

**Figura 67:** The envelope of a building functions

### 15.0.1 Physical components

The components of the foundation, wall assembly, roofing systems, glazing, doors, and any other penetrations are all included in the building envelope.
It is crucial that these components work together and complement one another for the building envelope to perform as intended.

**Foundation**

The structural element that transfers loads from the building to the subsurface is the foundation.
Generally, the foundation's structural elements consist of a mix of reinforced concrete footings, slabs, and walls.
The foundation must, however, be built with thermal energy and moisture transfer into the interior area under control.

Insulating the interior and outside environments can limit the amount of thermal energy that is transferred through the foundation, but sometimes this insulation is neglected in order to cut construction expenses.

A liquid asphaltic dampproofing is often used to finish waterproofing the foundation.
Other waterproofing solutions include built-up systems, liquid membranes, cementitious waterproofing, and sheet-applied membranes.

To prevent the waterproofing membrane from staying submerged underwater for an extended period of time, drainage must be installed around the foundation's perimeter.
Weeping tile set in a trench with gravel backfill, often known as a french drain, is one illustration of a perimeter foundation drain.
In some circumstances, in addition to the perimeter drain, a sump pit and pump system will be needed.

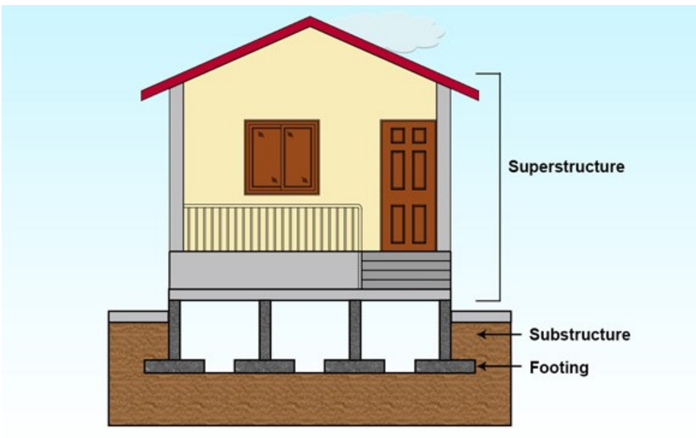



**Figura 68:** The foundations of a building

**Wall assembly**

The wall assembly is made up of a number of parts that carry out the building envelope's control, support, and finishing functions.
The following elements are frequently found in the wall assembly (from the exterior to the interior).

- Exterior cladding
- Exterior sheathing membrane
- Exterior sheathing
- Insulation

- Structural components
- Vapour barrier
- Interior sheathing
- Roofing system: Any house needs a sturdy roofing system to keep the elements out.
  It has shingles covering the outside and tar sheets that acts as a vapor barrier within. Wood sheathing is located inside of the tar paper.
  Beyond this, insulation is needed to insulate the attic spaces if it is thought to be liveable.
- Glazing: The term glazing describes the glass panels that let light in, as windows, doors, and skylights.
- Doors: The housing envelope includes doors since they frequently have the largest holes. A house's ability to retain heat is significantly increased by having exterior doors that seal well.
- Further penetrations: A chimney or the vents for a stove or dryer are examples of these.

## 15.1 Thermal performance of the enevelope

To keep us isolated from the outside world, walls are one of the key reasons we have them in our homes.


**Figura 69:** The thermal performance of buildings

The comfort of an house can be greatly improved by having well-insulated walls, which can help to retain heat inside or outside of your home and reduce your heating and cooling expenditures.
In order to effectively control the climate in your home, the materials you employ are essential, especially those that are utilized to construct and insulate your walls.

**Thermal insulation**
Most homes have some sort of insulation in the wall cavities.
Insulation is made of a variety of materials, some of which are better at resisting thermal energy (or heat) than others.

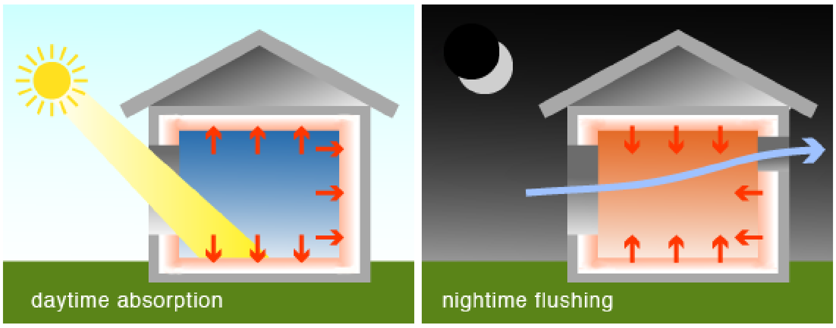



**Figura 70:** The envelope of a building functions

Houses constructed in regions that frequently suffer extreme cold and/or heat should be equipped with insulation that does not effectively transmit temperature.
These substances are regarded as having a high R-value (Thermal resistance).
Wool and polyester are two materials with high R-values for insulation.
You can also try to to use an acoustic soundproofing insulation with the appropriate R-value for your environment to accomplish two goals at once.

**Timber frames** Insulation for homes with a typical timber frame is installed by sandwiching solid or loose-fill batt insulation between the wall studs.

Before the final outside cladding is attached, the inside face of the stud will be covered in plasterboard, and the outer side will be lined with a sheathing material such oriented strand board.
This creates a small cavity into which insulation can be placed.
In locations with harsh temperatures, double framing should be taken into consideration since it allows for the installation of greater insulation.

**Metal frames**
When using traditional construction methods, the house frame frequently act as a thermal bridge, allowing cold to enter the house when it is not needed and vice versa.
Metal frames, which are particularly good at conducting heat, are especially problematic in this regard.
Metal frames may need to be covered or insulated in certain climates to lessen the amount of heat they radiate.

**Alternative frames** Alternative framing techniques frequently lead to the frame, interior walls, and exterior walls being made up of the same single solid thing.
Even though this can lead to a tighter building envelope, more insulation is occasionally needed.

In order to introduce insulation, a small space may be left between two rows of bricks in solid brick and masonry walls.
Better blocks, which operate on a similar concept, provide similar advantages in thermal performance to double-row bricks in terms of thermal insulation.
Log and stone dwellings might have insulation added between the logs or stone and a plasterboard wall if necessary.
Since insulation is already present in structural insulated panel frames, additional insulation is typically not needed.
Mud brick and cob framed homes might be required to install insulation on the external wall, sandwiched between the bricks/cob and the render.[41]

## 15.2 Insulation and passive design

Simply said, passive design entails planning a house so that it uses little to no mechanical heating or cooling.

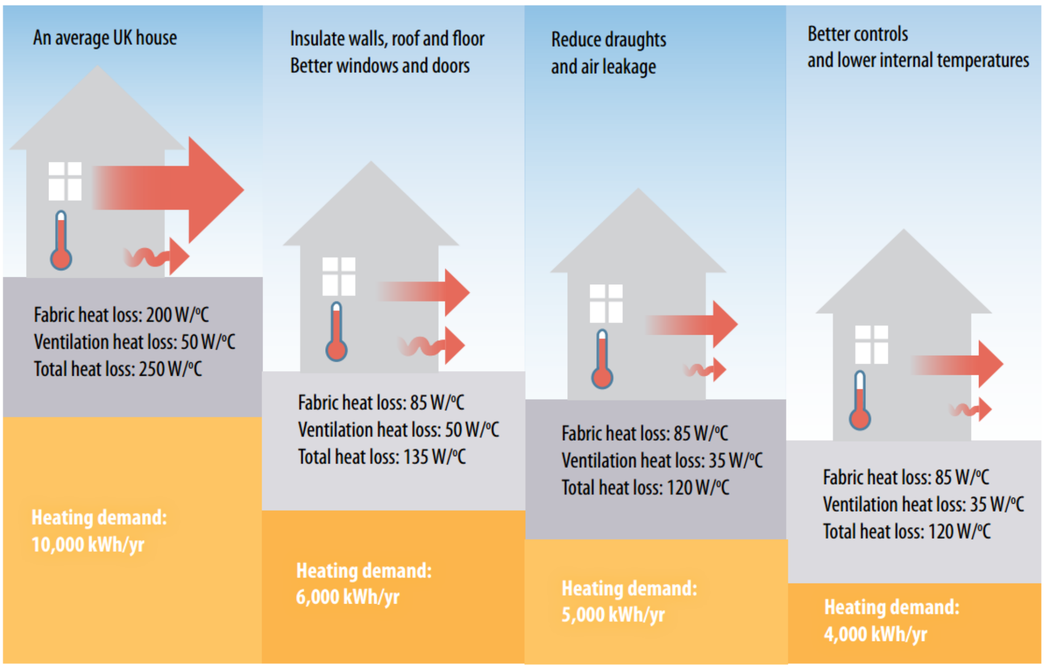



**Figura 71:** The difference made by insulation and careful design

The principles guiding passive design are:

- to allow solar heat into your home through correctly shaded windows,
- to store solar heat utilizing the thermal mass of your home's walls,floors, roofs, and other structures,
- to avoid allowing heat to be transmitted into your home during the summer.

The placement and orientation of the building, natural shadowing, the size and design of the eaves and windows, the materials used, and other factors can all have an impact on how well your home either absorbs or dissipates heat at different times of the year.

A good passive design typically relies heavily on insulation; by isolating the temperature on one side of the building element, you can be sure that the heat directed by your building design will remain where it should.
It will be simpler to plan if insulation is taken into account very early in the design.
Where necessary, adding additional thicknesses or a reflecting barrier can dramatically improve performance.

The thermal envelope should ideally have insulation in the walls, ceiling, and floor.
To keep any heat where you need it, the walls and ceiling should have a strong combination of bulk and reflective insulation.
Depending on the type of subfloor you have, you can insulate the floor in a variety of methods.
For example, insulation can be applied directly underneath joists and stumps, while thermal insulation may need to be poured into an elevated concrete slab to prevent heat loss.

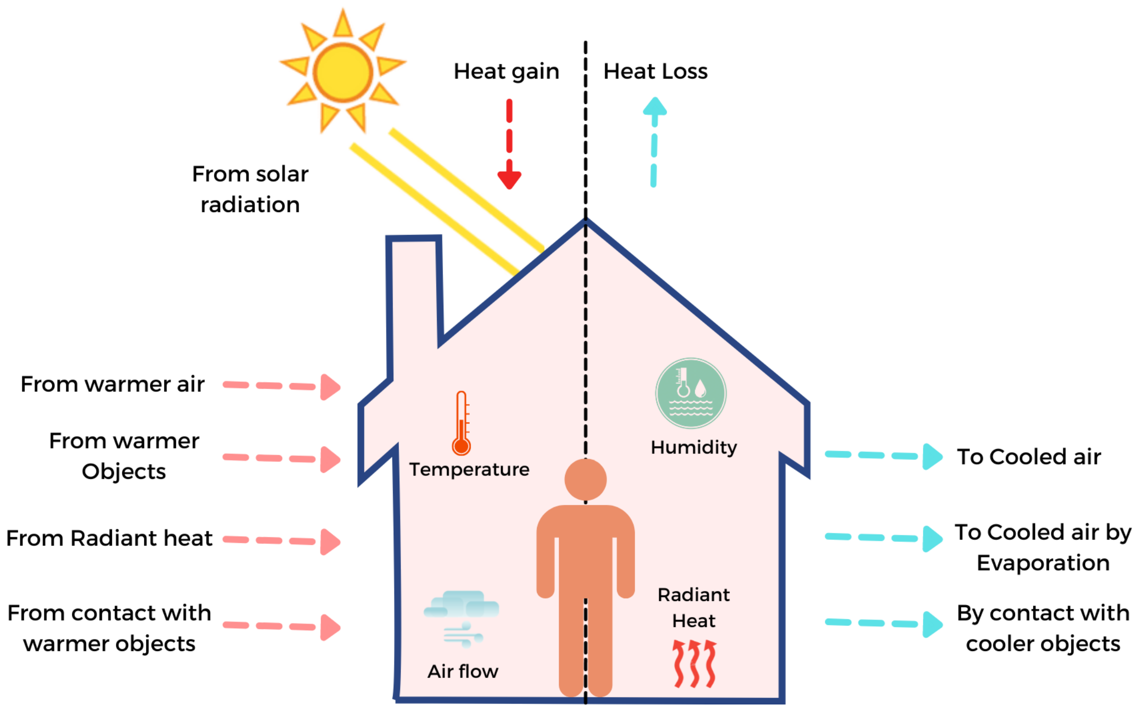



**Figura 72:** The thermal advantages of the envelope

Thermal mass, which is frequently an issue in design, can potentially be used to your advantage if it is positioned wisely and well insulated.
Many designers won't necessarily plan for this, but judicious use of thermal mass can be accomplished extremely well through computer modeling.

It may seem paradoxical to be able to manage air flow through your thermal envelope in order to keep it sealed, but you also need to consider air quality in design—the law actually demands it.
Moreover, ventilation is a particularly efficient strategy to reduce the internal thermal mass of your building at night.
The way the air will flow through your home should be taken into consideration in your house plan.
When you close up your building, the insulation will keep the cool air within, helping to maintain the proper temperatures for the following day.
This will increase the ventilation's efficiency in removing heat from your walls and floors. Without careful insulation, improper ventilation in the cold will swiftly dissipate heat.

An HRV is a good compromise for homes with a small thermal envelope (heat recovery ventilator). These appliances circulate air around the house while simultaneously transferring a significant amount of heat from the emitted air into the incoming fresh air.
One clever compromise in houses with a tight thermal envelope is an HRV (heat recovery ventilator). These devices cycle air through the home, while also transferring much of the heat from the outgoing air into the fresh air being pumped into the house.[42]

## 15.3 Wall insulation

Building a strong thermal envelope for your home requires paying close attention to the insulation of your walls.
Without even taking into consideration heat loss or gain through windows, up to 10%–20% of heat can be lost through the walls during colder months, and up to 15%–25% of heat can be gained through the walls during warmer months.
The ability to control the temperature in your home is greatly improved by insulating to stop heat from escaping and entering via your walls.

**Figura 73:** The insulation of walls

How do thermal bridges effect the insulation in walls, and what are they?
Thermal bridges (or heat bridges) are routes for heat to pass through your house's walls and structure from the inside to the outside (and vice versa).
The simplest examples are doors and windows (or door and window frames).
Heat bridges, which resemble thermal envelope leaks in some ways, can reduce your home's overall R-value, particularly in the walls.

To lessen their effects, incorporate thoughtful thermal breaks and thoroughly insulate to account for any thermal bridges.

Almost any form of insulation can be utilized in a wall, but some are inherently more suited for walls than others.
The more typical wall insulation materials include:

- Fibreglass / glass wool
- Polystyrene
- Rock wool
- Blow-in cellulose
- Natural wool
- Polyurethane foam
- Structural insulated panels (SIPs), as autoclaved aerated concrete (AAC) and certain other structural wall materials.

It is considerably simpler and less expensive to install quality insulation while your walls are being built than it is to attempt to improve it later.
These days, there are minimum R-value standards that must be met by all new residences.
Therefore, it's far preferable to go over these from the start rather than discover afterwards that the minimal values are insufficient for your requirements.

Some insulation types can be retrofitted more easily than others; for example, blow-in cellulose or foam insulation can be piped into your walls through a small hole drilled into the wall cavity.
On the other hand, retrofitting a wall with batts necessitates tearing the wall down to the frame.
Plastering over a few minor drilled holes obviously takes considerably less time and money than completely resealing the wall.[43]

## 15.4 Thermal mass and wall insulation

Homes that have been constructed in response to the local climate are the most useful and comfortable.
This entails considering the average temperature range that your neighborhood sees, paying close attention to the highs and lows that happen during the year as well as during the day and night.
The sun, shade, and wind are examples of passive heating and cooling systems that you should use whenever possible rather than solely relying on technological means to control temperature (heaters and air conditioners).

Your home's temperature can be controlled, or its "thermal comfort" can be maintained, by making sure your walls are sufficiently insulated and have an adequate thermal mass.
When walls are built with the proper thermal mass, insulation, and thermal mass in consideration of the environment, they will:

- Keep your living space comfortable
- Lower your heating and cooling costs
- Preserve natural resources

**Thermal mass**
The capacity of a material to absorb and store thermal energy is referred to as thermal mass.
Some substances are said to have high thermal masses, whilst others have lower thermal masses.
A wall constructed of materials with a high thermal mass can be used to maintain the temperature inside your home pretty steadily in climates with cool winters and a reasonable difference between day and night temperatures.
High thermal mass wall-building materials include stone, concrete, earth, and brick.

To avoid building walls that draw heat indoors on warm days and then absorb it from your heating systems on cold days, thermal mass must be adequately harnessed.
For thermal mass to function effectively, insulation, passive heating, and passive cooling are frequently required.

**Insulation**

Your home can benefit from insulation by being shielded from unpleasant weather.
The walls definitely play a significant role in successful insulation, but the roof and ceiling account for the majority of the thermal energy gained or lost in a house.
The correct kind of wall insulation may also have the extra benefit of soundproofing in addition to helping to control temperature and keep the interior of your home dry.
Nevertheless, unless your home uses passive design principles, insulation is frequently ineffective and may even make the uncomfortable temps worse.
The incorrect insulation might also work against you by obstructing heat when you wish to retain it and vice versa.
Determine if you need to keep your home warm, cool, or a combination of the two before selecting the appropriate type of insulation.
You can get advice from local councils on what kind of insulation will best meet your needs.

**Draughts**

Remember to shield yourself from draughts when deciding how to effectively control the temperature inside your house! In cold climates, these can cause significant heat loss.[44]

**Building envelope in our proect** For what regards our project we studied the thermal insulation of the envelope, providing both insulation on the vertical closure and on the horizontal one.
We runned an analysis on the thermal performance of the building (read last paragraphs of this work to check it in detail), seeing both the transmittance of each component, both the interaction between them, seeing how the thermal bridges that develops can be solved and solving them.
The same has been done for windows and transparent envelope, for which we also studied the shading needs.

The buildings within our project are entirely managed through prefabricated elements, leaving aside only the elements of foundations, which are in concrete cast in place.
Each element of the casing is prefabricated, from the outer walls to the floors.
The use for the casing of a solution type AQUAPANEL[45], by definition prefabricated, with a metal structure allows prefabrication and therefore all the benefits and facilities that a solution of this type allows and offers.

To see in detail the stratigraphic solutions that have been proposed, please refer to the tables at the end of the thesis.

# 16 Design of the masterplan

A master plan is a dynamic long-term planning document that provides a conceptual layout to guide the growth and development of an area.

A master plan is a dynamic long-term planning document that provides a conceptual layout to guide the growth and development of an area.
A masterplan concerns the connection between buildings, social contexts and surroundings, and includes analyses, recommendations and proposals for the population, economy, housing, transport, community facilities and land use of a site.

## 16.1 How to draw up a master plan

To draw up a master plan, it is necessary to:

- develop a phasing and implementation programme and identify priorities for action;
- act as a framework for regeneration and attract private sector investment;
- conceptualise and model the three-dimensional urban environment;
- defines public, semi-private and private spaces and public services;
- determine the mix of uses and their physical relationship;
- involves the local community and acts as a consensus builder.

Since city regeneration initiatives are generally proposed for the long term, it is important to consider the master plan as a dynamic document that can be modified according to changing project conditions over time.

## 16.2 Importance of a masterplan in the development of an area in urban regeneration

Masterplans can play an important role in determining the shape of the urban environment. If poorly designed, they can lead to major problems in the future.

What are the steps to draw up a master plan correctly?
Depending on the role of the master plan, it could have various sections and be developed in different ways.

**Feasibility study**
The feasibility study is an objective review of available options for development.
It includes the results, analysis and conclusions of visioning and scoping exercises for a given site or town centre area.
It indicates whether the chosen site is suitable for the intended function, taking into account the financial, social and environmental aspects of each proposal.
Many masterplans begin with a feasibility study to understand the geographical, environmental and historical context of the site.
This process is based on the information gathered and analysis developed during the scoping phase. Any background reports deemed necessary (i.e. hydrology, environment, cultural heritage, transport, etc.) to inform the master planning process should also be commissioned at this stage.

**Strategic framework**
The strategic framework accompanies the master plan and lays the foundation for establishing basic information about the physical, social and economic context of the site and its surroundings.
This basic information should outline the location and size of the site, topography and existing uses.
It should highlight current zoning regulations and relevant/applicable planning policies, as well as any

particularly important opportunities and constraints relating to the site.

In summary, the strategic framework of a master plan includes:

- The plan should show the integration of contextual features.
  The surrounding topography, water and distinctive landscape and heritage features should be incorporated into the plan design wherever possible.
  These elements have a huge impact on the character of the urban area.
- Characteristics of urbanised lots.
  The plan must show the location of various types of uses, densities, yields and lot sizes.
  When developing housing, a variety of housing types, sizes and properties must be considered. In this context, the plan should also ensure adequate housing density and diversity.
  The master plan should also be flexible enough to allow for a change in housing diversity over time as communities mature.
  Similarly, commercial areas should be planned within other areas to promote mixed-use neighbourhoods that are vibrant at all hours of the day. Entertainment and retail land uses should be integrated into the general plan.
  Finally, the general plan should contain a strategy for street layout that will best suit the character of the site.
- Open space and public realm.
  States all over the world require different prescriptions regarding the use of open spaces.
  Plans should show the location of open spaces including function, size and scale. However, both qualitative and quantitative measures, as well as the relationship between active and passive uses, should be taken into account in the design and layout.
  The broader connection to the wider open space network as a whole should also be considered.
- Biodiversity and green building.
  The master plan must show the location of significant biodiversity values and whether and how these are to be incorporated into the development of the site.
  Biodiversity and environmental factors must also be planned at the beginning of regeneration projects in order to protect, enhance, manage and balance development uses with the sustainability of flora and fauna.
  This will help to avoid possible political problems at a later stage. For example, a site may host an endangered species, which may require site redesign or relocation of the species.
  Therefore, it is particularly important to examine the area and assess biodiversity at the beginning of the process.
- Integrated water management and services.
  The design of the plan must be based on the waterways of the site, making careful decisions to preserve wetlands and catchment areas.
  Similarly, the capacity and flow rate of watercourses (a subject we have tragically seen in Italy) must be given very strong consideration.
- Transport.
  The development plan of a city must show the hierarchy of roads, pedestrian and bicycle routes, the public transport network and trade routes.

The masterplan can be understood as a plan that refers to a complex programme or initiative that can be broken down into projects and sub-projects.
In this sense, the Master Plan constitutes a summary plan, summarising what is contained in the plans of the individual projects that make it up.

The underlying logic is to divide a complex initiative into smaller, easily manageable parts.
In a programme, each of its component projects contributes to achieving the programme's objectives.
Similarly to the WBS for a project, the Programme Breakdown Structure can be defined with the programme work packages that give rise to the projects that make up the programme.

In this way, a Master Plan can be developed for the urban works of a city, for the construction of a nuclear power plant, for sending a probe to a planet, etc.
These are all initiatives characterised by their long duration, high financial impact and articulated in projects and sub-projects.
When such initiatives are launched, it can be useful to visualise both the articulation of each project as well as the overall situation for the projects as a whole.
Having a Master Plan therefore makes it possible to follow the progress of both the whole and its parts.

Large and articulated initiatives usually involve a large number of stakeholders.
This requires managing communications and negotiations both with the parties involved in the implementation aspects and with those interested in achieving the benefits linked to the whole.
For this reason, the Master Plan makes it possible to convey basic information on progress to all those stakeholders who need to understand not so much the implementation details as the overall results.

The ability to obtain and maintain the "political" consensus necessary for the successful outcome of a programme depends in fact on the ability to make key stakeholders understand the essential and positive elements of the initiative and their evolution and sustainability over time.In this sense, the Master Plan constitutes a summary plan, summarising what is contained in the plans of the individual projects that compose it.

## 16.3 The idea of our masterplan

So the first aspect of our project we considered was the depelopment of the masterplan.
Starting from the masterplan of the MoLeCoLa project we developed our in order to fit in with the biggest already existing one.

**Figura 74:** The MoLeCoLa Masterplan

In this, we have identified a number of characteristics that we consider fundamental and which we have decided to maintain in the project of our district.
The aesthetics of the buildings were important in order to fit coherently into what is a well-defined context.
The focus on community development, which the MoLeCoLa project demonstrated, was fundamental. We included a central square in order to connect our district with the context, cycle routes were planned to connect the project with the cycle routes provided by the MoLeCoLa project.

We then went on to consider what the masterplan of the ReGen Village, to take into account the fundamental points also of this one, considering exactly those that would effectively make it a self-sufficient village and an ecovillage, and looking for a way to decline them in the different reality of Milan and in particular the Bovisa node.

This will effectively be a point of passage and exchange, which actually gives us a strong push and a great opportunity, representing a chance for us to positively influence as many people as possible.

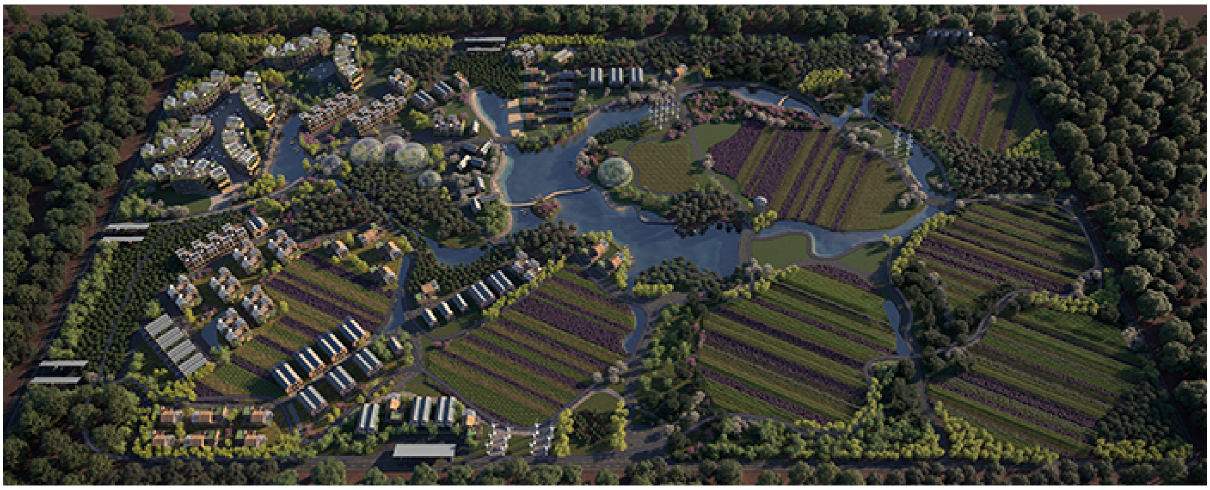


**Figura 75:** Masterplan of the ReGen project.

The initiative of the ReGen aims to start at the ground level, with homes that are as functional and efficient as possible down to the last detail, plants that are specifically made to work together both in terms of energy and waste disposal, and systems that connect each of the housing units to one another so that they form a single, massive set.
In the project is seen the use of rechargeable electric vehicles, making transportation more ecological.

In fact, when designing the spaces of the village, the location of each housing unit, such as the one of free areas and green areas, is taken into consideration in order to have an integration between each of them through their presence. Each housing unit is a part of the village from both a physical and an overall perspective of the area and this is a fundamental point of the project that we wanted to keep also in our.

The ReGen project begins with the challenge of how to meet the material and non-material demands of a three-person family over the course of a year while adhering to the project's fundamental principles, and this question fits perfectly also in our design and in our project.
This question permitted them to develope a program to plan and meet the needs of the inhabitants, placing structures and technologies in strategic locations based on spatial requirements.

The village's housing units come in different varieties, yet they all share similar traits, those are the ones that we wanted to keep.
Each home is prefabricated, making it simple to assemble and disassemble in a short amount of time.
Additionally, each home has a covered and extended outdoor space as well as a rainwater collection system.
Finally, each home is designed from an energy efficiency perspective using the Passivhaus model, which includes passive heating as well as glass enclosures that extend the warmer months by utilizing solar energy.

They also thought on how to meet the food requirements of the inhabitants.
By doing this each stage of an object's life cycle within the ideal ReGen is a part of something bigger, something that does not end with its end but continues to infinity and this is the base concept that has to be kept in the design of an ecovillage.

Starting with household garbage, these are separated into many categories to allow for reuse for the most suitable uses: compostable organic waste for example is used to feed the plants that grows in the greenhouse of heach housing unit, while the waste from the livestock is used as fertilizer for the seasonal gardens.
Different kind of agricultural techniques are used in the village.
According to the time and resource requirements, agricultural techniques such areoponics, hydroponics, and permaculture enable the production of a large number of products. While the seasonal gardens generate a range of goods for domestic consumption, the aquaponics system feeds the community with

fruits and vegetables.

**Figura 76:** An example of the greenhouse present in each housing unit.

In the ReGen village there are squares connected to one another to create a network of transportantion, in our case we connected each house to one of the roads outside the district, while providing a pedestrian and cyclable path.
Also electric car charging facilities can be found near each housing unit.
The energy used by the charging stations is generated by solar power systems installed in each housing unit, and energy production facilities in the village.

Electric cars have several advantages over gasoline-powered vehicles, including the ability to save energy and practically qualify as a zero-emissions mode of transportation when the energy used is derived from sustainable sources.

In addition to having "environmental" worth, the regen project itself offers social value as well.
In reality, the major goal is to sensitize the locals to taking an active role in something magnificent, rather than to establish a place where environmental sustainability is the foundation of daily life.
The placement of social spaces within the cluster of housing units and between the production systems ensures complete integration of the residents and the emergence of a common life.
This point is fundamental as already said and we took it and incorporated it inside our project as well.

Another important part of the project is the attention to the biodiversity, since that's essential for the survival of the Earth itself and is frequently used as a measure of the health of the planet. Biodiversity is the result of the planet's three billion and eight hundred million year long evolution.
Nature would be able to sustain itself and regenerate itself, taking care of its own needs.
However, man's deeper involvement over time messed up the mechanisms by which nature was regulated, increasing pressures on ecosystems, habitat fragmentation, air, water, and soil pollution, over-exploitation of resources, forests, and soils, and the emission of greenhouse gases, which led to the now obvious climate change.

Hence, given how he lives in industrialized countries, the human being poses a severe threat to the continued existence of many species and places on the planet.
The Ecological Footprint is an indicator used to compare human consumption of natural resources to the Earth's capacity to regenerate them.
ReGen village decides to act in this sense as well, so the project provides an area free from any buildings around the village, but occupied by permacrops and seasonal gardens, with the aim to reduce the emphfootprint of the village while maintaining ecological sustainability, we tried to keep this aspetc in our

project by keeping as mus space as possible green and cultivated.

Taking all these aspects into consideration, we also focused on food production and water harvesting. In the ReGen Village, food is produced through hydroponics, aquaculture and greenhouses, complemented by a dedicated farm.

In our case, a seasonal garden was planned, which would allow the harvesting of all those species that are present in nature at different times of the year, a dedicated aquaculture facility and a greenhouse that could supply the entire district.
Each house also has its own greenhouse.
This is then complemented by relying on an external farm, since the district does not have enough people to justify the presence of a dedicated farm.

As far as rainwater harvesting is concerned, a water square has been provided, along with the fact that each dwelling is equipped with its own water collection tank, as well as each other building.

Finally, we concentrated on the community aspect of the project, going on to provide not only a square that could welcome both people from outside and inside the district, but also a community house that would act precisely as a meeting place for both the inhabitants of the neighborhood and for the outsiders.
A place where it is possible to organize events or small gatherings or simply to meet.

The last attention made in the developing the masterplan is about the smart grid connection.
Modern technology and a focus on sustainability are becoming more and more important in the current period of growth, especially given the benefits their use brings to the economy and environment.
Although the use of renewable energy resources is currently expanding, there are clear limitations, including those set by nature and those imposed by technologies that are not yet completely affordable. As a result, effective energy management and distribution that coincides with productive rhythms is becoming more and more important. This is what the *smart grid* does; its goal is to "communicate" between energy generation and end-user usage.

The electricity grid now runs on a one-way basis, with all flows going from power plants directly to distribution, which is continuous and constant regardless of how much energy is really required or used. Instead, the smart system links producers and consumers by incorporating information network functionality into the network, which collects data in real time from all tools and products connected to users in order to rationalize and distribute energy effectively while preventing overloads and voltage changes.
Due to specialized monitoring tools, it keeps track of the system's electrical flow, preventing disruptions and minimizing load where possible.

The benefits are pretty clear, starting with the financial savings, but also with the energy savings and the reduction of $CO_2$ emissions for the environment's sake, up to the most effective transmission and the quickest recovery of energy after a potential interruption.

## 16.4 Our masterplan design

As a result our masterplan looks something like that


**Figura 77:** Planar representation of our masterplan, out of scale

Here the yellow line is the path for bicycles while the blue one is the pedestrian road.

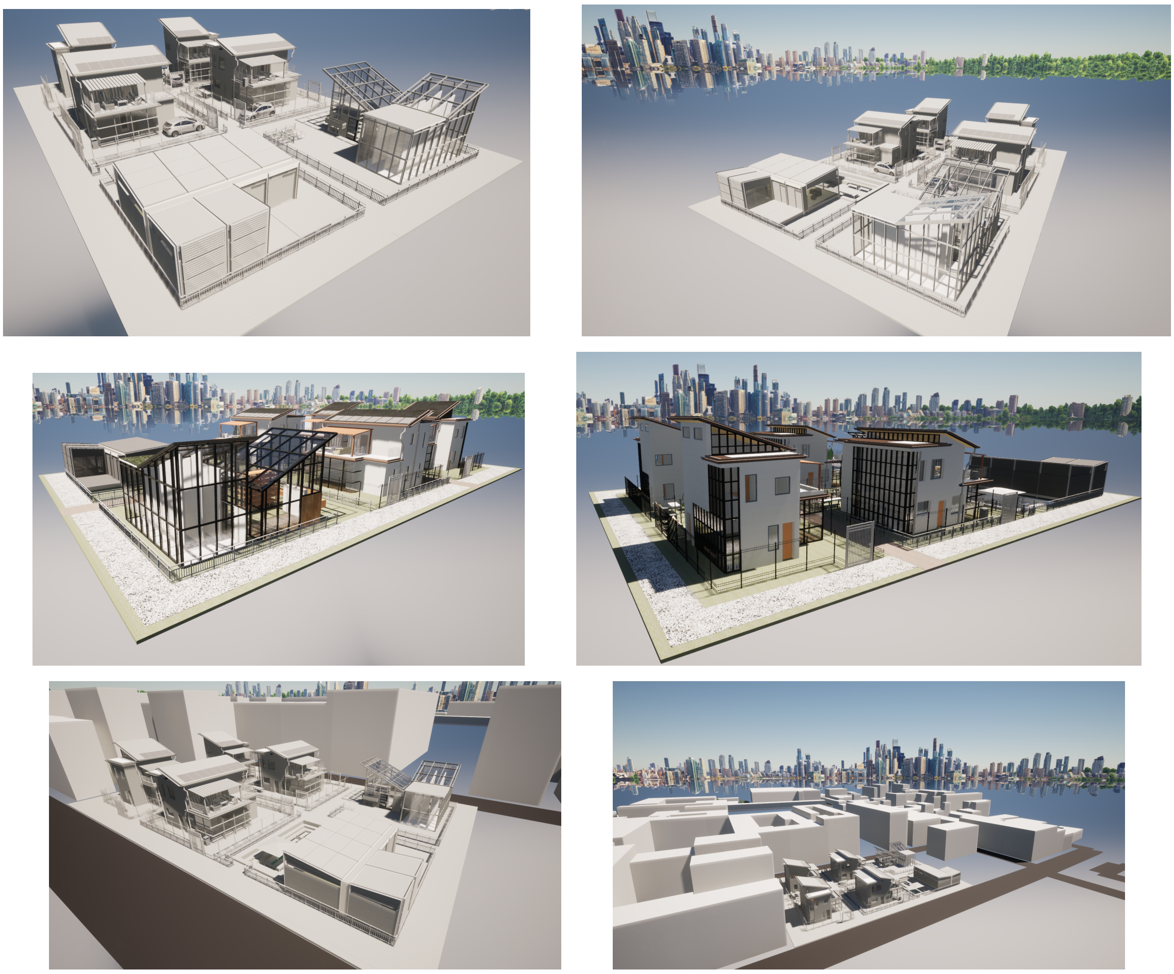


**Figura 78:** Some 3D view of our masterplan

To have a better view and idea of what the masterplan of the project actually is like please check the sheets at the end of this relation.

## 17 Housing units design

After designing the masterplan of our project and establishing the layout of the buildings we planned to include, we moved on to the design of residential buildings.
For their design we started from the idea of tiny houses, in particular we saw that most of it was based on modular and prefabricated technologies, including new sustainable technologies, from photovoltaic panels to rainwater collection.[**?**]

We saw mainly two of them, The third prize winner of the competition (*Standardization / Customization*) and the *Urban Shelter*.
You can see both of them here.

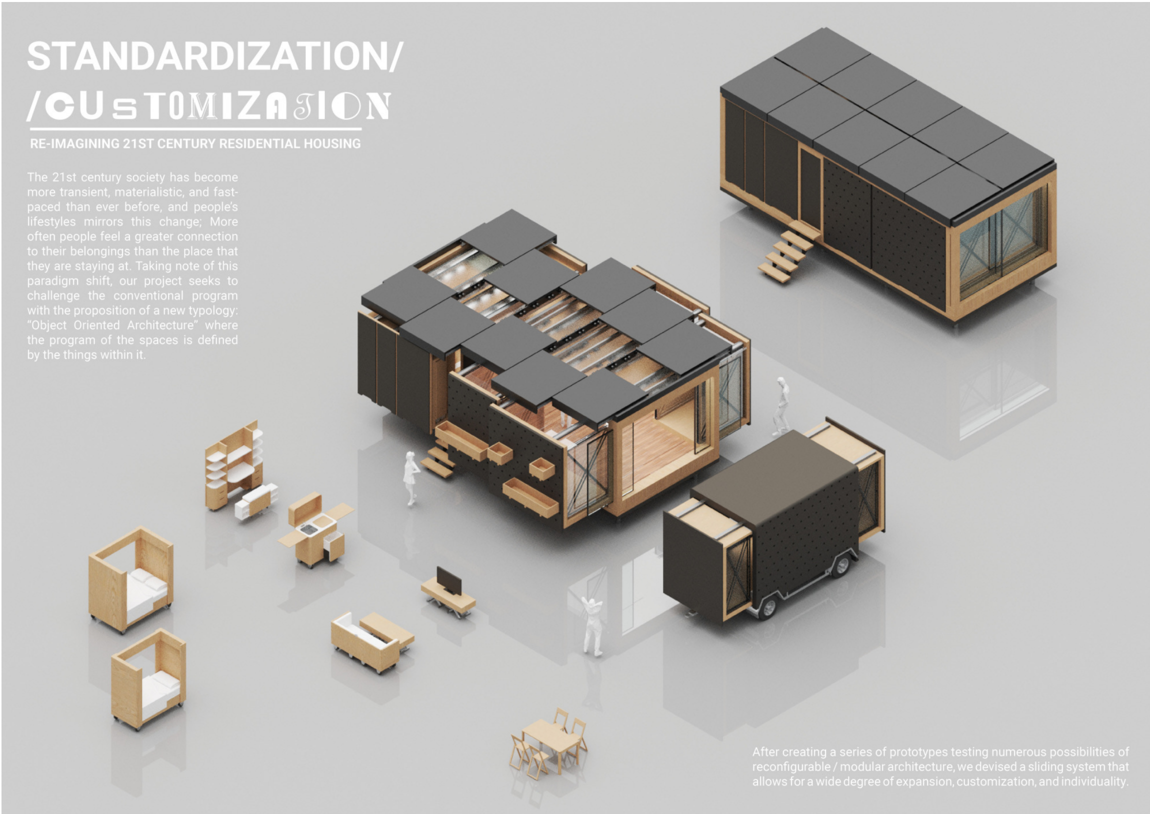
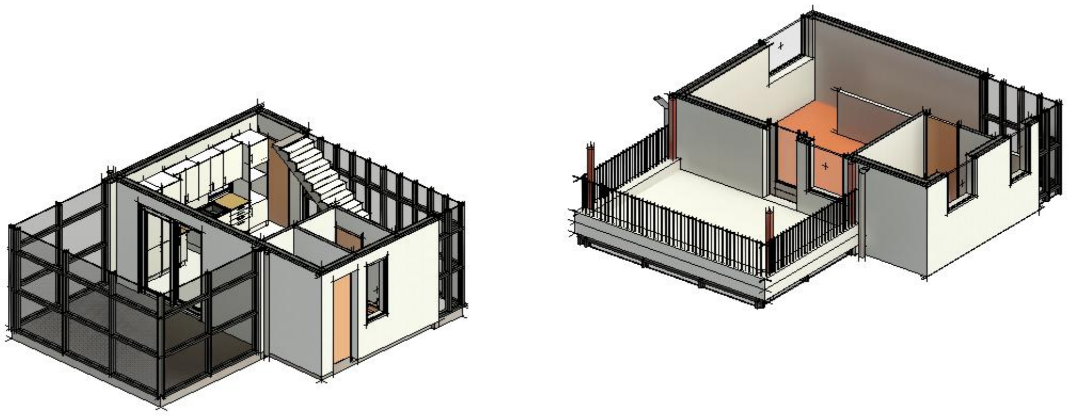



**Figura 79:** Standardization / Customization


**Figura 80:** Planar representation of our masterplan, out of scale

Starting from those and the houses designed within the ideal ReGen we began to design our units. As already mentioned, the units of our project will be of two types, the first one for 3 people and the second for 5. Both are based on a module of 1m by 5m and both see applied the principles we have talked about so far.

Here are the plans of both units and a 3D view of both.



(a) Ground floor (b) First floor

**Figura 81:** The views of the floors of the unit for 2 persons

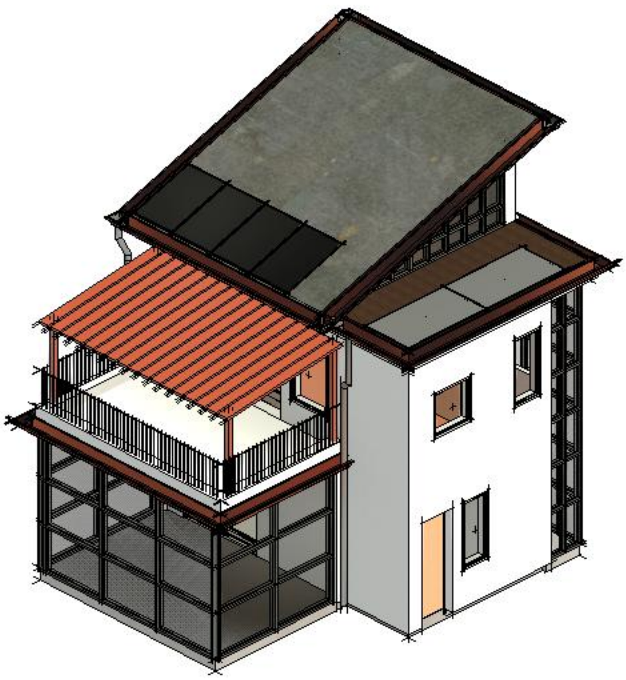
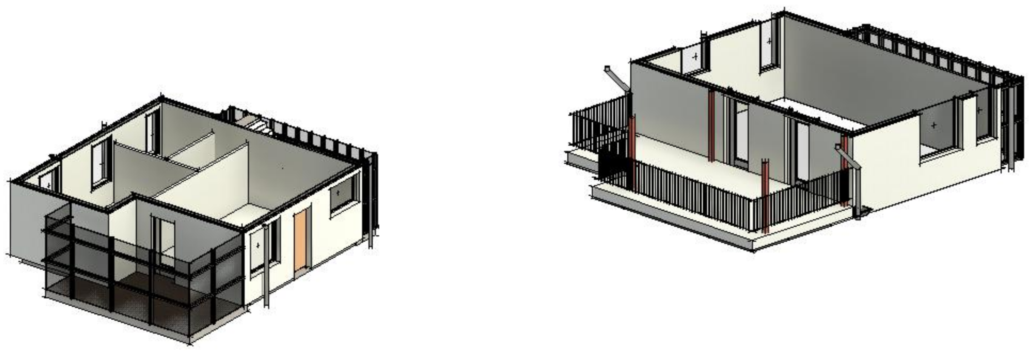


**Figura 82:** A 3D view of the unit for 2 persons



(a) Ground floor (b) First floor

**Figura 83:** The views of the floors of the unit for 5 persons

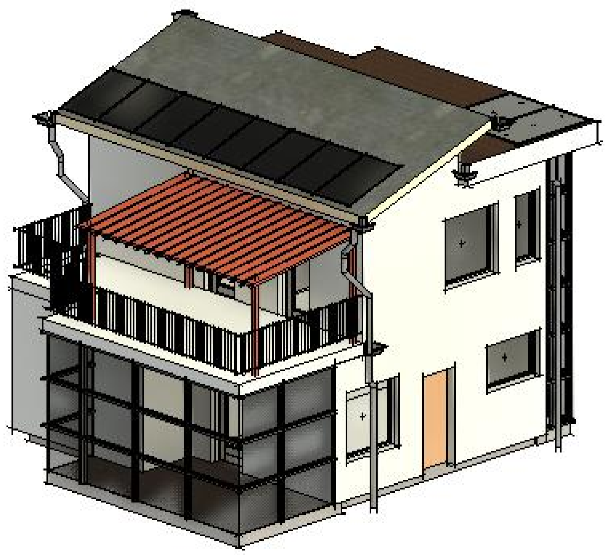


**Figura 84:** A 3D view of the unit for 5 persons

From the design point of view we have gone into more detail with regard to the 3-person typology, although the applied technologies and nodes designed for this will be the same and will also be valid for the second type, in any case in the tables at the end of the thesis you can see the construction details elaborated for this type.

# 18 Envelope Design

At this point of the work we proceeded to design the envelope of the building, searching for something that could allow us to use a metallic frame for the walls and a wood structure for the slabs, something that can be seen as a modular and dry solution and that ensure us the thermal performances seen till now.
We used a software to analyse the solutions founded from an energetic point of view and the results are the following

## 18.1 Opaque envelope

The envelope we designed is made up of 2 main tipes of exterior walls, the one facing outside and the one facing the greenhouse, for both of them we runned some analysis on the performances of them. We have also 2 kinds of floors (the one above the ground and the one internal) and 3 types of roofs (the pitched one, the green roof and the internal one). The results of those components are the following.

| Description | Sp [mm] | Ms [kg/m²] | $Y_{IE}$ [W/m²K] | P.S. [h] | $C_T$ [kJ/m²K] | ε [-] | α [-] | θ [°C] | Ue [W/m²K] |
|---|---|---|---|---|---|---|---|---|---|
| Exterior | 269,1 | 4 | 0,047 | -9,15 | 27,053 | 0,9 | 0,6 | -8 | 0,133 |
| Wall towards | 224,9 | 3 | 0,094 | -5,971 | 27,606 | 0,9 | 0,6 | -13,6 | 0,159 |

**Figura 85:** Thermal characteristics of walls

| Description | Sp [mm] | Ms [kg/m²] | $Y_{IE}$ [W/m²K] | P.S. [h] | $C_T$ [kJ/m²K] | ε [-] | α [-] | θ [°C] | Ue [W/m²K] |
|---|---|---|---|---|---|---|---|---|---|
| Counterfloor | 526 | 466 | 0,005 | -20,295 | 58,191 | 0,9 | 0,6 | -8 | 0,186 |
| Interior floor | 273 | 70 | 0,159 | -8,193 | 28,744 | 0,9 | 0,6 | - | 0,37 |

**Figura 86:** Thermal characteristics of floors

| Description | Sp [mm] | Ms [kg/m²] | $Y_{IE}$ [W/m²K] | P.S. [h] | $C_T$ [kJ/m²K] | ε [-] | α [-] | θ [°C] | Ue [W/m²K] |
|---|---|---|---|---|---|---|---|---|---|
| Roof | 340 | 73 | 0,048 | -8,324 | 26,51 | 0,9 | 0,6 | -8 | 0,163 |
| Green Roof | 460 | 93 | 0,022 | -13,342 | 26,077 | 0,9 | 0,6 | -8 | 0,183 |
| Interior roof | 273 | 70 | 0,201 | -7,284 | 27,939 | 0,9 | 0,6 | - | 0,402 |

**Figura 87:** Thermal characteristics of roofs

Symbol legend:

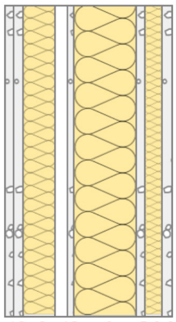
- Sp Structure thickness
- Ms Surface mass of structure without plaster
- $Y_{IE}$ Periodic thermal transmittance of structure
- P.S. Thermal wave phase shift
- CT Heat capacity areic
- Emissivity
- Absorption factor
- Outdoor temperature or adjacent room temperature
- Ue Energy transmittance of the structure

### 18.1.1 Vertical closure

For what concernes the vertical closures some specific analysis have been runned, the results are the followings.
The external wall have been designed and analysed giving the next results.

Description of structure: Exterior Wall Code: M1

| | | |
|---|---|---|
| Thermal transmittance | 0,133 | W/m K$^2$ |
| Thickness | 269 | mm |
| Outdoor temperature ( winter power calculation) | -8,0 | °C |
| Permeance | 17,581 | $10^{-12}$ kg/sm$^2$ Pa |
| Surface mass ( with plasters) | 69 | kg/m$^2$ |
| Surface mass ( without plasters) | 4 | kg/m$^2$ |
| Periodic transmittance | 0,047 | W/m K$^2$ |
| Attenuation factor | 0,357 | - |
| Thermal wave phase shift | -9,1 | h |




Stratigraphy:

| N. | Layer description | s | Cond. | R | M.V. | C.T. | R.V. |
|---|---|---|---|---|---|---|---|
| - | Internal surface resistance | - | - | 0,130 | - | - | - |
| 1 | Plasterboard sheets | 15,00 | 0,2500 | 0,060 | 900 | 1,00 | 10 |
| 2 | Plasterboard sheets | 15,00 | 0,2500 | 0,060 | 900 | 1,00 | 10 |
| 3 | Gas-tight rigid polyurethane foam | 51,40 | 0,0220 | 2,336 | 35 | 1,40 | 60 |
| 4 | Unventilated cavity Av<500 mm²/m | 20,00 | 0,1143 | 0,175 | - | - | - |
| 5 | Plasterboard sheets | 10,00 | 0,2500 | 0,040 | 900 | 1,00 | 10 |
| 6 | Sintered expanded polystyrene (improved thermal conduc.) (EPS 100) | 98,90 | 0,0300 | 3,297 | 17 | 1,45 | 60 |
| 7 | Plasterboard sheets | 14,60 | 0,2500 | 0,058 | 900 | 1,00 | 10 |
| 8 | Gas-tight rigid polyurethane foam | 27,20 | 0,0220 | 1,236 | 35 | 1,40 | 60 |
| 9 | Plasterboard sheets | 17,00 | 0,2500 | 0,068 | 900 | 1,00 | 10 |
| - | External surface resistance | - | - | 0,071 | - | - | - |

Symbol legend

| | | |
|---|---|---|
| s | Thickness | mm |
| Cond. | Thermal conductivity, including any correction coefficients | W/mK |
| R | Thermal resistance | m K/W$^2$ |
| M.V. | Mass density | kg/m$^3$ |
| C.T. | Specific heat capacity | kJ/kgK |
| R.V. | Vapour diffusion resistance factor in dry garment | - |

| | | |
|---|---|---|
| Description of the structure: | Exterior Wall | Code: M1 |

[x] The structure is not subject to surface condensation.

[x] The structure is not subject to interstitial condensation.

[] The structure is subject to interstitial condensation, but the amount is re-evaporated during the summer season.

Boundary conditions

Variable outdoor temperatures and relative humidity, monthly averages

| | | | |
|---|---|---|---|
| Indoor temperature during the heating period | | 20,0 | °C |
| Criterion for increasing indoor humidity | | Vapour concentration class ( 0.006 kg/m )[3] | |

Checking for surface condensation

| | | | |
|---|---|---|---|
| Surface condensation check ($fRSI_{,max} \leq f_{RSI}$) | | Positive | |
| Critical month | | November | |
| Temperature factor of the critical month | $fRSI_{,max}$ | 0,725 | |
| Component temperature factor | $f_{RSI}$ | 0,967 | |
| Acceptable surface relative humidity | | 80 | % |

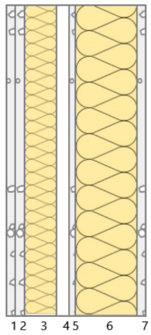
Verification of interstitial condensation risk (according to EN ISO 13788)

There is no interstitial condensation in the structure throughout the year.

The wall facing the greenhouse have been designed and analysed giving the next results.

Description of structure: Wall U Code: M2

| | | |
|---|---|---|
| Thermal transmittance | 0,159 | W/m K$^2$ |
| Thickness | 225 | mm |
| Outdoor temperature ( winter power calculation) | -13,6 | °C |
| Permeance | 20,890 | $10^{-12}$ kg/sm$^2$ Pa |
| Surface mass ( with plasters) | 53 | kg/m$^2$ |
| Surface mass ( without plasters) | 3 | kg/m$^2$ |
| Periodic transmittance | 0,094 | W/m K$^2$ |
| Attenuation factor | 0,592 | - |
| Thermal wave phase shift | -6,0 | h |




Stratigraphy:

| N. | Layer description | s | Cond. | R | M.V. | C.T. | R.V. |
|---|---|---|---|---|---|---|---|
| - | Internal surface resistance | - | - | 0,130 | - | - | - |
| 1 | Plasterboard sheets | 15,00 | 0,2500 | 0,060 | 900 | 1,00 | 10 |
| 2 | Plasterboard sheets | 15,00 | 0,2500 | 0,060 | 900 | 1,00 | 10 |
| 3 | Gas-tight rigid polyurethane foam | 51,40 | 0,0220 | 2,336 | 35 | 1,40 | 60 |
| 4 | Unventilated cavity Av<500 mm$^2$/m | 20,00 | 0,1143 | 0,175 | - | - | - |
| 5 | Plasterboard sheets | 10,00 | 0,2500 | 0,040 | 900 | 1,00 | 10 |
| 6 | Sintered expanded polystyrene (improved thermal conduc.) (EPS 100) | 98,90 | 0,0300 | 3,297 | 17 | 1,45 | 60 |
| 7 | Plasterboard sheets | 14,60 | 0,2500 | 0,058 | 900 | 1,00 | 10 |
| - | External surface resistance | - | - | 0,130 | - | - | - |

Symbol legend

| | | |
|---|---|---|
| s | Thickness | mm |
| Cond. | Thermal conductivity, including any correction coefficients | W/mK |
| R | Thermal resistance | m K/W$^2$ |
| M.V. | Mass density | kg/m$^3$ |
| C.T. | Specific heat capacity | kJ/kgK |
| R.V. | Vapour diffusion resistance factor in dry garment | - |

| | | |
|---|---|---|
| Description of the structure: | Wall U | Code: M2 |

[x] The structure is not subject to surface condensation.

[x] The structure is not subject to interstitial condensation.

[] The structure is subject to interstitial condensation, but the amount is re-evaporated during the summer season.

Boundary conditions

Variable outdoor temperatures and relative humidity, monthly averages

| | | | |
|---|---|---|---|
| Indoor temperature during the heating period | | 20,0 | °C |
| Criterion for increasing indoor humidity | | Vapour concentration class ( 0.006 kg/m )[3] | |

Checking for surface condensation

| | | | |
|---|---|---|---|
| Surface condensation check ($fRSI_{,max} \leq f$ $)_{RSI}$ | | Positive | |
| Critical month | | December | |
| Temperature factor of the critical month | $fRSI_{,max}$ | 0,812 | |
| Component temperature factor | $f_{RSI}$ | 0,962 | |
| Acceptable surface relative humidity | | 80 | % |

Verification of interstitial condensation risk (according to EN ISO 13788)

There is no interstitial condensation in the structure throughout the year.

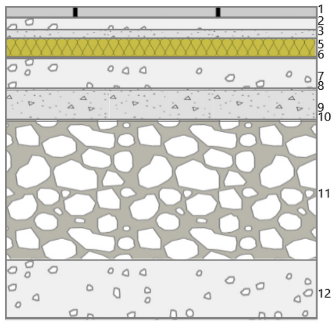
### 18.1.2 Horizontal ground closure

The ground closure have been designed and analysed giving the next results.

Description of structure: G 40cm — Code: P1

| | | |
|---|---|---|
| Thermal transmittance | 0,213 | W/m K[2] |
| Transmittance against ground | 0,186 | W/m K[2] |

| | | |
|---|---|---|
| Thickness | 526 | mm |
| Outdoor temperature ( winter power calculation) | -8,0 | °C |
| Permeance | 0,001 | $10^{-12}$ kg/sm[2] Pa |
| Surface mass ( with plasters) | 506 | kg/m[2] |
| Surface mass ( without plasters) | 466 | kg/m[2] |




| | | |
|---|---|---|
| Periodic transmittance | 0,005 | W/m K[2] |
| Attenuation factor | 0,025 | - |
| Thermal wave phase shift | -20,3 | h |

Stratigraphy:

| N. | Layer description | s | Cond. | R | M.V. | C.T. | R.V. |
|---|---|---|---|---|---|---|---|
| - | Internal surface resistance | - | - | 0,170 | - | - | - |
| 1 | Ceramic tiles (tiles) | 20,00 | 1,3000 | 0,015 | 2300 | 0,84 | 9999999 |
| 2 | Cement mortar | 20,00 | 1,4000 | 0,014 | 2000 | 1,00 | 22 |
| 3 | Additives for panels | 14,00 | 1,0000 | 0,014 | 1800 | 0,88 | 30 |
| 4 | Panel tube - R979NY005 | 0,00 | - | - | - | - | - |
| 5 | Synthetic expanded polystyrene for R979NY005 | 31,00 | 0,0344 | 0,900 | 23 | 1,25 | 50 |
| 6 | Oriented fibreboard panel | 2,00 | 0,1300 | 0,015 | 650 | 1,70 | 50 |
| 7 | 50 mm thick Perlimix lightened subfloor | 50,00 | 0,0633 | 0,790 | 300 | 0,85 | 7 |
| 8 | Waterproofing with bitumen | 2,00 | 0,1700 | 0,012 | 1200 | 1,00 | 188000 |
| 9 | Reinforced concrete (1% steel) | 50,00 | 2,3000 | 0,022 | 2300 | 1,00 | 130 |
| 10 | Non-woven fabric | 2,00 | 0,0500 | 0,040 | 1 | 2,10 | 200 |
| 11 | Loose expanded clay granules 3-25 mm (hum. 1%) | 235,00 | 0,0900 | 2,611 | 280 | 1,00 | 3 |
| 12 | Sand and gravel | 100,00 | 2,0000 | 0,050 | 1950 | 1,05 | 50 |
| - | External surface resistance | - | - | 0,040 | - | - | - |

| | | |
|---|---|---|
| Description of the structure: | G 40cm | Code: P1 |

[x] The structure is not subject to surface condensation.

[x] The structure is not subject to interstitial condensation.

[] The structure is subject to interstitial condensation, but the amount is re-evaporated during the summer season.

Boundary conditions

Variable outdoor temperatures and relative humidity, monthly averages

| | | |
|---|---|---|
| Indoor temperature during the heating period | 20,0 | °C |
| Criterion for increasing indoor humidity | Vapour concentration class ( 0.006 kg/m )[3] | |

Checking for surface condensation

| | | | |
|---|---|---|---|
| Surface condensation check ($fRSI_{,max} \leq f_{RSI}$) | | Positive | |
| Critical month | | March | |
| Temperature factor of the critical month | $fRSI_{,max}$ | 0,635 | |
| Component temperature factor | $f_{RSI}$ | 0,948 | |
| Acceptable surface relative humidity | | 80 | % |

Verification of interstitial condensation risk (according to EN ISO 13788)

There is no interstitial condensation in the structure throughout the year.

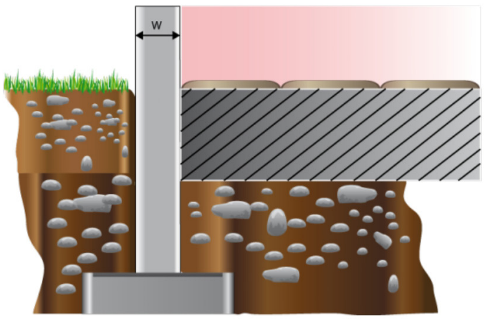
## Symbol legend

| | | |
|---|---|---|
| s | Thickness | mm |
| Cond. | Thermal conductivity, including any correction coefficients | W/mK |
| R | Thermal resistance | m K/W$^2$ |
| M.V. | Mass density | kg/m$^3$ |
| C.T. | Specific heat capacity | kJ/kgK |
| R.V. | Vapour diffusion resistance factor in dry garment | - |

## Floor laid on the ground:

G 40cm    Code: P1

| | | |
|---|---|---|
| Floor area | 17,00 | m$^2$ |
| Dispersing perimeter of the floor | 16,00 | m |
| External perimeter wall thickness | 405 | mm |
| Thermal conductivity of soil | 2,00 | W/mK |

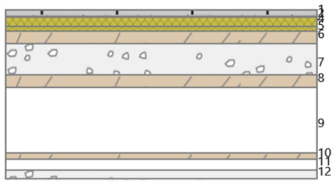


### 18.1.3 Interior floor

The interior slab have been designed and analysed giving the next results.

Description of the structure: D Code: P2

| | | |
|---|---|---|
| Thermal transmittance | 0,370 | W/m $K^2$ |
| Thickness | 273 | mm |
| Permeance | 0,002 | $10^{-12}$ kg/s$m^2$ Pa |
| Surface mass ( with plasters) | 84 | kg/$m^2$ |
| Surface mass ( without plasters) | 70 | kg/$m^2$ |
| Periodic transmittance | 0,159 | W/m $K^2$ |
| Attenuation factor | 0,431 | - |
| Thermal wave phase shift | -8,2 | h |



Stratigraphy:

| N. | Layer description | s | Cond. | R | M.V. | C.T. | R.V. |
|---|---|---|---|---|---|---|---|
| - | Internal surface resistance | - | - | 0,170 | - | - | - |
| 1 | Ceramic tiles (tiles) | 10,00 | 1,3000 | 0,008 | 2300 | 0,84 | 999999 9 |
| 2 | Additives for panels | 3,00 | 1,0000 | 0,003 | 1800 | 0,88 | 30 |
| 3 | Panel tube - R979NY005 | 0,00 | - | - | - | - | - |
| 4 | Expanded polystyrene for V-ZETA - V-ERRE | 15,00 | 0,0320 | 0,469 | 30 | 1,30 | 100 |
| 5 | Synthetic stretch polystyrene foam for ACUSTIC ULTRA | 7,00 | 0,0300 | 0,233 | 18 | 1,15 | 40 |
| 6 | Oriented fibreboard panel | 20,00 | 0,1300 | 0,154 | 650 | 1,70 | 50 |
| 7 | 50 mm thick Perlimix lightened subfloor | 50,00 | 0,0633 | 0,790 | 300 | 0,85 | 7 |
| 8 | Spruce wood flow perpend. to fibres | 20,00 | 0,1200 | 0,167 | 450 | 1,60 | 625 |
| 9 | Unventilated cavity Av<500 $mm^2$/m | 105,00 | 0,4767 | 0,220 | - | - | - |
| 10 | Spruce wood flow perpend. to fibres | 10,00 | 0,1200 | 0,083 | 450 | 1,60 | 625 |
| 11 | Unventilated cavity Av<500 $mm^2$/m | 18,00 | 0,1023 | 0,176 | - | - | - |
| 12 | Plasterboard sheets | 15,00 | 0,2500 | 0,060 | 900 | 1,00 | 10 |
| - | External surface resistance | - | - | 0,170 | - | - | - |

Symbol legend

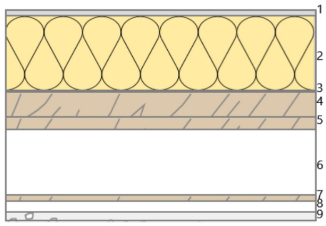
| | | |
|---|---|---|
| s | Thickness | mm |
| Cond. | Thermal conductivity, including any correction coefficients | W/mK |
| R | Thermal resistance | m K/$W^2$ |
| M.V. | Mass density | kg/$m^3$ |
| C.T. | Specific heat capacity | kJ/kgK |
| R.V. | Vapour diffusion resistance factor in dry garment | - |

## 18.1.4 Roofs

The pitched roof have been designed and analysed giving the next results.

Description of structure: Roof                                        Code: S1

| | | |
|---|---|---|
| Thermal transmittance | 0,163 | W/m $K^2$ |
| Thickness | 340 | mm |
| Outdoor temperature ( winter power calculation) | -8,0 | °C |
| Permeance | 0,002 | $10^{-12}$ kg/s$m^2$ Pa |
| Surface mass ( with plasters) | 87 | kg/$m^2$ |
| Surface mass ( without plasters) | 73 | kg/$m^2$ |
| Periodic transmittance | 0,048 | W/m $K^2$ |
| Attenuation factor | 0,294 | - |
| Thermal wave phase shift | -8,3 | h |




Stratigraphy:

| N. | Layer description | s | Cond. | R | M.V. | C.T. | R.V. |
|---|---|---|---|---|---|---|---|
| - | External surface resistance | - | - | 0,071 | - | - | - |
| 1 | Aluminium alloys | 10,00 | 160,0000 | 0,000 | 2800 | 0,88 | 9999999 |
| 2 | Factory foamed polyurethane between sealed sheets | 120,00 | 0,0240 | 5,000 | 30 | 1,30 | 140 |
| 3 | Pure bitumen vapour barrier | 2,00 | 0,1700 | 0,012 | 1050 | 1,00 | 50000 |
| 4 | Oriented fibreboard panel | 40,00 | 0,1300 | 0,308 | 650 | 1,70 | 50 |
| 5 | Spruce wood flow perpend. to fibres | 20,00 | 0,1200 | 0,167 | 450 | 1,60 | 625 |
| 6 | Unventilated cavity Av<500 mm²/m | 105,00 | 0,6563 | 0,160 | - | - | - |
| 7 | Spruce wood flow perpend. to fibres | 10,00 | 0,1200 | 0,083 | 450 | 1,60 | 625 |
| 8 | Unventilated cavity Av<500 mm²/m | 18,00 | 0,1125 | 0,160 | - | - | - |
| 9 | Plasterboard sheets | 15,00 | 0,2500 | 0,060 | 900 | 1,00 | 10 |
| - | Internal surface resistance | - | - | 0,100 | - | - | - |

Symbol legend

| | | |
|---|---|---|
| s | Thickness | mm |
| Cond. | Thermal conductivity, including any correction coefficients | W/mK |
| R | Thermal resistance | m K/$W^2$ |
| M.V. | Mass density | kg/$m^3$ |
| C.T. | Specific heat capacity | kJ/kgK |
| R.V. | Vapour diffusion resistance factor in dry garment | - |

| | | |
|---|---|---|
| Description of the structure: | Roof | Code: S1 |

[x] The structure is not subject to surface condensation.

[] The structure is not subject to interstitial condensation.

[x] The structure is subject to interstitial condensation, but the amount is re-evaporated during the summer season.

Boundary conditions

Variable outdoor temperatures and relative humidity, monthly averages

| | | | |
|---|---|---|---|
| Indoor temperature during the heating period | | 20,0 | °C |
| Criterion for increasing indoor humidity | Vapour concentration class ( 0.006 kg/m )[3] | | |

Checking for surface condensation

| | | | |
|---|---|---|---|
| Surface condensation check ($fRSI_{,max} \leq f_{RSI}$) | | Positive | |
| Critical month | | November | |
| Temperature factor of the critical month | $fRSI_{,max}$ | 0,725 | |
| Component temperature factor | $f_{RSI}$ | 0,960 | |
| Acceptable surface relative humidity | | 80 | % |

Verification of interstitial condensation risk (according to EN ISO 13788)

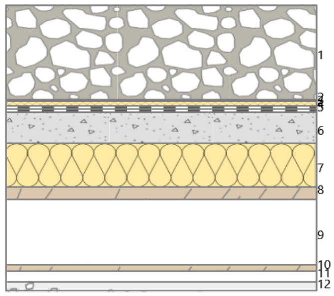
| | | | |
|---|---|---|---|
| Checking interstitial condensation | | Positive | |
| Maximum amount of condensation during the year | $M_a$ | 10 | g/m$^2$ |
| Permissible amount of condensate | $M_{lim}$ | 72 | g/m$^2$ |
| Permissible condensation test ($M_a \leq M_{lim}$) | | Positive | |
| Month with maximum accumulated condensation | | March | |
| Evaporation at the end of the season is | | Complete | |

The green roof have been designed and analysed giving the next results.

Description of the facility: Green Roof

Code: S2

| | | |
|---|---|---|
| Thermal transmittance | 0,183 | W/m K² |
| Thickness | 460 | mm |
| Outdoor temperature ( winter power calculation) | -8,0 | °C |
| Permeance | 0,195 | $10^{-12}$ kg/sm² Pa |
| Surface mass ( with plasters) | 107 | kg/m² |
| Surface mass ( without plasters) | 93 | kg/m² |
| Periodic transmittance | 0,022 | W/m K² |
| Attenuation factor | 0,121 | - |
| Thermal wave phase shift | -13,3 | h |




Stratigraphy:

| N. | Layer description | s | Cond. | R | M.V. | C.T. | R.V. |
|---|---|---|---|---|---|---|---|
| - | External surface resistance | - | - | 0,071 | - | - | - |
| 1 | Loose expanded clay granules 3-25 mm (hum. 1%) | 152,00 | 0,0900 | 1,689 | 280 | 1,00 | 3 |
| 2 | Non-woven fabric | 2,00 | 0,0500 | 0,040 | 1 | 2,10 | 200 |
| 3 | Sintered expanded polystyrene (improved thermal cond.) (EPS 250) | 8,00 | 0,0300 | 0,267 | 34 | 1,45 | 60 |
| 4 | Polyethylene sheet vapour barrier | 5,00 | 0,3300 | 0,015 | 920 | 2,20 | 100000 |
| 5 | Polyethylene sheet vapour barrier | 5,00 | 0,5000 | 0,010 | 980 | 1,80 | 100000 |
| 6 | C.l.s. of expanded clay internal walls with open structure (um. 4%) | 50,00 | 0,1600 | 0,313 | 500 | 1,00 | 7 |
| 7 | Sintered expanded polystyrene (improved thermal cond.) (EPS 250) | 70,00 | 0,0300 | 2,333 | 34 | 1,45 | 60 |
| 8 | Spruce wood flow perpend. to fibres | 20,00 | 0,1200 | 0,167 | 450 | 1,60 | 625 |
| 9 | Unventilated cavity Av<500 mm²/m | 105,00 | 0,6563 | 0,160 | - | - | - |
| 10 | Spruce wood flow perpend. to fibres | 10,00 | 0,1200 | 0,083 | 450 | 1,60 | 625 |
| 11 | Unventilated cavity Av<500 mm²/m | 18,00 | 0,1125 | 0,160 | - | - | - |
| 12 | Plasterboard sheets | 15,00 | 0,2500 | 0,060 | 900 | 1,00 | 10 |
| - | Internal surface resistance | - | - | 0,100 | - | - | - |

Symbol legend

| | | |
|---|---|---|
| s | Thickness | mm |
| Cond. | Thermal conductivity, including any correction coefficients | W/mK |
| R | Thermal resistance | m K/W$^2$ |
| M.V. | Mass density | kg/m$^3$ |
| C.T. | Specific heat capacity | kJ/kgK |
| R.V. | Vapour diffusion resistance factor in dry garment | - |

| Description of the structure: | Green Roof | Code: S2 |
|---|---|---|

[x] The structure is not subject to surface condensation.

[] The structure is not subject to interstitial condensation.

[x] The structure is subject to interstitial condensation, but the amount is re-evaporated during the summer season.

Boundary conditions

Variable outdoor temperatures and relative humidity, monthly averages

| | | | |
|---|---|---|---|
| Indoor temperature during the heating period | | 20,0 | °C |
| Criterion for increasing indoor humidity | | Vapour concentration class ( 0.006 kg/m )$^3$ | |

Checking for surface condensation

| | | | |
|---|---|---|---|
| Surface condensation check ($f_{RSI,max} \leq f_{RSI}$) | | Positive | |
| Critical month | | November | |
| Temperature factor of the critical month | $f_{RSI,max}$ | 0,725 | |
| Component temperature factor | $f_{RSI}$ | 0,955 | |
| Acceptable surface relative humidity | | 80 | % |

Verification of interstitial condensation risk (according to EN ISO 13788)

| | | | |
|---|---|---|---|
| Checking interstitial condensation | | Positive | |
| Maximum amount of condensation during the year | $M_a$ | 15 | g/m$^2$ |
| Permissible amount of condensate | $M_{lim}$ | 100 | g/m$^2$ |
| Permissible condensation test ($M_a \leq M_{lim}$) | | Positive | |
| Month with maximum accumulated condensation | | February | |
| Evaporation at the end of the season is | | Complete | |

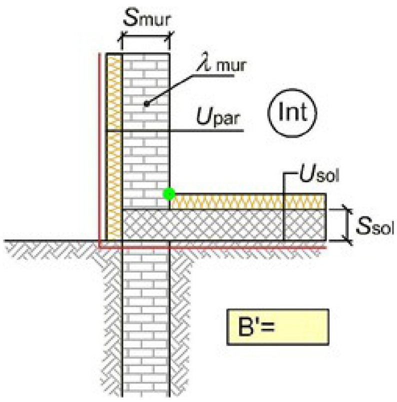
## 18.1.5 Thermal bridges

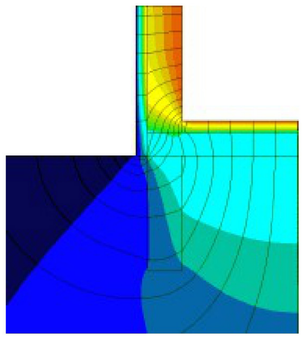
The thermal bridges have been also analysed, here we report the results regarding them.

Description of thermal bridge: GF - Wall - Floor to floor | Code: Z1

| | | |
|---|---|---|
| Type | GF - Wall - Floor to floor | |
| Linear thermal transmittance calculation | -0,011 | W/mK |
| Reference Linear Thermal Transmittance | -0,023 | W/mK |
| Temperature factor $f_{rsi}$ | 0,817 | - |
| Reference | UNI EN ISO 14683 and UNI EN ISO 10211 | |

Notes: GF5 - Wall joint with external insulation - floor to ceiling with extrados insulation
Reference Linear Thermal Transmittance (φe) = -0.023 W/mK.



Features

| | | | |
|---|---|---|---|
| Characteristic floor size | B' | 2,13 | m |
| Floor thickness | Ssol | 100,0 | mm |
| Wall thickness | Smur | 100,0 | mm |
| Floor thermal transmittance | Usol | 0,120 | W/m²K |
| Wall thermal transmittance | Upar | 0,133 | W/m²K |
| Thermal conductivity wall | λmur | 0,250 | W/mK |

Critical temperature check

Interior condition:

| | | |
|---|---|---|
| Vapour concentration class | 0,004 | kg/m³ |
| Inside temperature heating period | 20,0 | °C |
| Permissible relative surface humidity | 80 | % |

External conditions:

| | | |
|---|---|---|
| Monthly average temperatures | - | °C |

| Month | $\theta_i$ | $\theta_e$ | $\theta_{si}$ | $\theta_{acc}$ | Verification |
|---|---|---|---|---|---|
| October | 20,0 | 15,9 | 19,2 | 16,3 | POSITIVE |
| November | 20,0 | 12,5 | 18,6 | 15,2 | POSITIVE |
| December | 20,0 | 9,7 | 18,1 | 13,3 | POSITIVE |
| January | 20,0 | 7,6 | 17,7 | 12,5 | POSITIVE |
| February | 20,0 | 6,9 | 17,6 | 12,7 | POSITIVE |
| March | 20,0 | 7,9 | 17,8 | 14,3 | POSITIVE |
| April | 20,0 | 10,5 | 18,3 | 13,6 | POSITIVE |

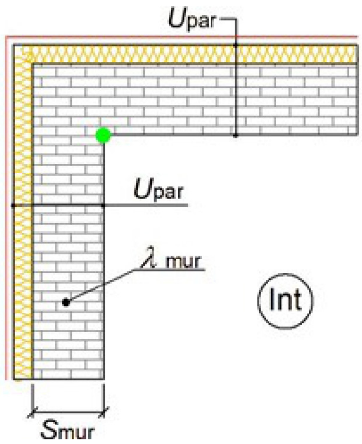
Symbol legend

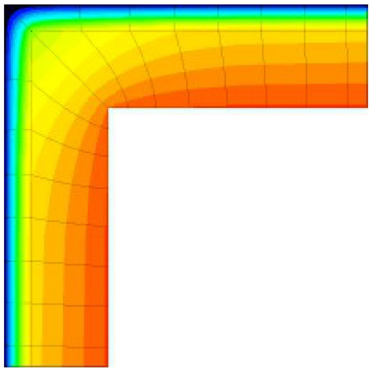
| | | |
|---|---|---|
| $\theta_i$ | Room temperature | °C |
| $\theta_e$ | Outside temperature | °C |
| $\theta_{si}$ | Internal surface temperature in place of thermal bridge | °C |
| $\theta_{acc}$ | Minimum acceptable temperature to avoid condensation | °C |

Description of thermal bridge: C - Angle between walls Code: Z2

| | | |
|---|---|---|
| Type | C - Angle between walls | |
| Linear thermal transmittance calculation | -0,029 | W/mK |
| Reference Linear Thermal Transmittance | -0,058 | W/mK |
| Temperature factor $f_{rsi}$ | 0,915 | - |
| Reference | UNI EN ISO 14683 and UNI EN ISO 10211 | |

Notes
C1 - Joint between two walls with external insulation (projecting)
Reference Linear Thermal Transmittance (φe) = -0.058 W/mK.



Features

| | | | |
|---|---|---|---|
| Wall thickness | Smur | 100,0 | mm |
| Wall thermal transmittance | Upar | 0,133 | W/m²K |
| Thermal conductivity wall | λmur | 0,250 | W/mK |

Critical temperature check

Interior condition:

| | | |
|---|---|---|
| Vapour concentration class | 0,004 | kg/m³ |
| Inside temperature heating period | 20,0 | °C |
| Permissible relative surface humidity | 80 | % |

External conditions:

| | | |
|---|---|---|
| Monthly average temperatures | - | °C |

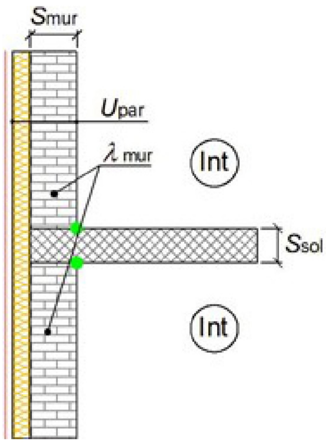
| Month | $\theta_i$ | $\theta_e$ | $\theta_{si}$ | $\theta_{acc}$ | Verification |
|---|---|---|---|---|---|
| October | 20,0 | 12,3 | 19,3 | 16,3 | POSITIVE |
| November | 20,0 | 6,8 | 18,9 | 15,2 | POSITIVE |
| December | 20,0 | 2,6 | 18,5 | 13,3 | POSITIVE |
| January | 20,0 | 1,2 | 18,4 | 12,5 | POSITIVE |
| February | 20,0 | 3,1 | 18,6 | 12,7 | POSITIVE |
| March | 20,0 | 8,3 | 19,0 | 14,3 | POSITIVE |
| April | 20,0 | 11,9 | 19,3 | 13,6 | POSITIVE |

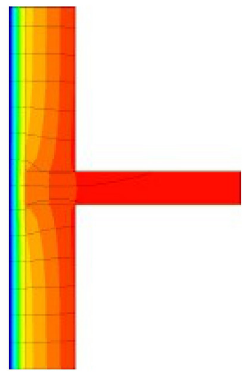
Symbol legend

| | | |
|---|---|---|
| $\theta_i$ | Room temperature | °C |
| $\theta_e$ | Outside temperature | °C |
| $\theta_{si}$ | Internal surface temperature in place of thermal bridge | °C |
| $\theta_{acc}$ | Minimum acceptable temperature to avoid condensation | °C |

Description of thermal bridge: IF - Wall - Inter floor slab　　　　　　　　　　　　　　　　　　　Code: Z3

| | | |
|---|---|---|
| Type | IF - Wall - Intermediate floor | |
| Linear thermal transmittance calculation | -0,001 | W/mK |
| Reference Linear Thermal Transmittance | -0,002 | W/mK |
| Temperature factor $f_{rsi}$ | 0,968 | - |
| Reference | UNI EN ISO 14683 and UNI EN ISO 10211 | |
| Notes | IF1 - Wall joint with continuous external insulation - intermediate floor<br>Reference Linear Thermal Transmittance (φe) = -0.002 W/mK. | |



Features

| | | | |
|---|---|---|---|
| Floor thickness | Ssol | 100,0 | mm |
| Wall thickness | Smur | 100,0 | mm |
| Wall thermal transmittance | Upar | 0,133 | W/m²K |
| Thermal conductivity wall | λmur | 0,250 | W/mK |

Critical temperature check

Interior condition:

| | | |
|---|---|---|
| Vapour concentration class | 0,004 | kg/m³ |
| Inside temperature heating period | 20,0 | °C |
| Permissible relative surface humidity | 80 | % |

External conditions:

Monthly average temperatures - °C

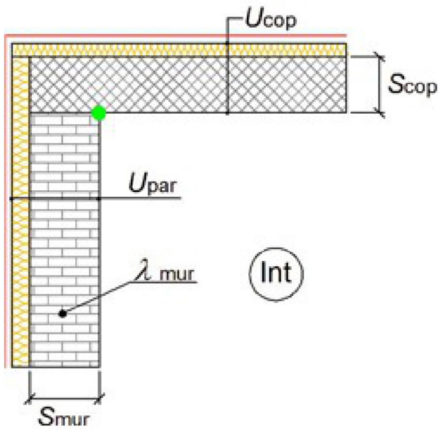
| Month | $\theta_i$ | $\theta_e$ | $\theta_{si}$ | $\theta_{acc}$ | Verification |
|---|---|---|---|---|---|
| October | 20,0 | 12,3 | 19,8 | 16,3 | POSITIVE |
| November | 20,0 | 6,8 | 19,6 | 15,2 | POSITIVE |
| December | 20,0 | 2,6 | 19,4 | 13,3 | POSITIVE |
| January | 20,0 | 1,2 | 19,4 | 12,5 | POSITIVE |
| February | 20,0 | 3,1 | 19,5 | 12,7 | POSITIVE |
| March | 20,0 | 8,3 | 19,6 | 14,3 | POSITIVE |
| April | 20,0 | 11,9 | 19,7 | 13,6 | POSITIVE |

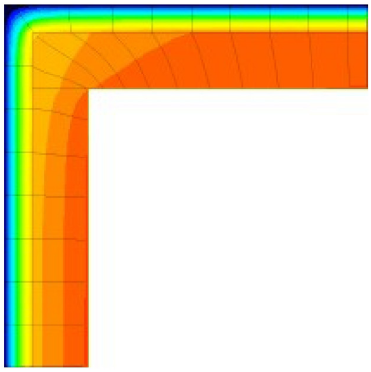
Symbol legend

| | | |
|---|---|---|
| $\theta_i$ | Room temperature | °C |
| $\theta_e$ | Outside temperature | °C |
| $\theta_{si}$ | Internal surface temperature in place of thermal bridge | °C |
| $\theta_{acc}$ | Minimum acceptable temperature to avoid condensation | °C |

Description of thermal bridge: R - Wall - Roof Code: Z4

| | |
|---|---|
| Type | R - Wall - Roof |
| Linear thermal transmittance calculation | -0,028 W/mK |
| Reference Linear Thermal Transmittance | -0,056 W/mK |
| Temperature factor $f_{rsi}$ | 0,923 - |
| Reference | UNI EN ISO 14683 and UNI EN ISO 10211 |
| Notes | R9 - Wall joint with continuous external insulation - externally insulated covering<br>Reference Linear Thermal Transmittance (φe) = -0.056 W/mK. |



Features

| | | | |
|---|---|---|---|
| Cover thickness | Scop | 100,0 | mm |
| Wall thickness | Smur | 100,0 | mm |
| Thermal transmittance roofing | Ucop | 0,164 | W/m²K |
| Wall thermal transmittance | Upar | 0,133 | W/m²K |
| Thermal conductivity wall | λmur | 0,250 | W/mK |

Critical temperature check

Interior condition:

| | | |
|---|---|---|
| Vapour concentration class | 0,004 | kg/m³ |
| Inside temperature heating period | 20,0 | °C |
| Permissible relative surface humidity | 80 | % |

External conditions:

| | | |
|---|---|---|
| Monthly average temperatures | - | °C |

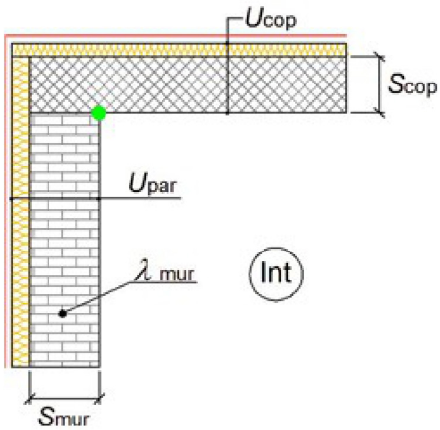
| Month | $\theta_i$ | $\theta_e$ | $\theta_{si}$ | $\theta_{acc}$ | Verification |
|---|---|---|---|---|---|
| October | 20,0 | 12,3 | 19,4 | 16,3 | POSITIVE |
| November | 20,0 | 6,8 | 19,0 | 15,2 | POSITIVE |
| December | 20,0 | 2,6 | 18,7 | 13,3 | POSITIVE |
| January | 20,0 | 1,2 | 18,5 | 12,5 | POSITIVE |
| February | 20,0 | 3,1 | 18,7 | 12,7 | POSITIVE |
| March | 20,0 | 8,3 | 19,1 | 14,3 | POSITIVE |
| April | 20,0 | 11,9 | 19,4 | 13,6 | POSITIVE |

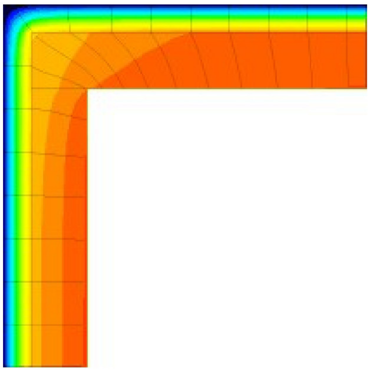
Symbol legend

| | | |
|---|---|---|
| $\theta_i$ | Room temperature | °C |
| $\theta_e$ | Outside temperature | °C |
| $\theta_{si}$ | Internal surface temperature in place of thermal bridge | °C |
| $\theta_{acc}$ | Minimum acceptable temperature to avoid condensation | °C |

Description of thermal bridge: R - Wall - Roof Green Code: Z5

| | |
|---|---|
| Type | R - Wall - Roof |
| Linear thermal transmittance calculation | -0,028 W/mK |
| Reference Linear Thermal Transmittance | -0,056 W/mK |
| Temperature factor $f_{rsi}$ | 0,919 - |
| Reference | UNI EN ISO 14683 and UNI EN ISO 10211 |
| Notes | R9 - Wall joint with continuous external insulation - externally insulated covering<br>Reference Linear Thermal Transmittance (φe) = -0.056 W/mK. |



Features

| | | | |
|---|---|---|---|
| Cover thickness | Scop | 100,0 | mm |
| Wall thickness | Smur | 100,0 | mm |
| Thermal transmittance roofing | Ucop | 0,183 | W/m²K |
| Wall thermal transmittance | Upar | 0,133 | W/m²K |
| Thermal conductivity wall | λmur | 0,250 | W/mK |

Critical temperature check

Interior condition:

| | | |
|---|---|---|
| Vapour concentration class | 0,004 | kg/m³ |
| Inside temperature heating period | 20,0 | °C |
| Permissible relative surface humidity | 80 | % |

External conditions:

Monthly average temperatures - °C

| Month | $\theta_i$ | $\theta_e$ | $\theta_{si}$ | $\theta_{acc}$ | Verification |
|---|---|---|---|---|---|
| October | 20,0 | 12,3 | 19,4 | 16,3 | POSITIVE |
| November | 20,0 | 6,8 | 18,9 | 15,2 | POSITIVE |
| December | 20,0 | 2,6 | 18,6 | 13,3 | POSITIVE |
| January | 20,0 | 1,2 | 18,5 | 12,5 | POSITIVE |
| February | 20,0 | 3,1 | 18,6 | 12,7 | POSITIVE |
| March | 20,0 | 8,3 | 19,0 | 14,3 | POSITIVE |
| April | 20,0 | 11,9 | 19,3 | 13,6 | POSITIVE |

Symbol legend

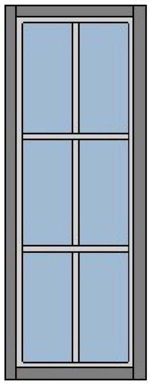
| | | |
|---|---|---|
| $\theta_i$ | Room temperature | °C |
| $\theta_e$ | Outside temperature | °C |
| $\theta_{si}$ | Internal surface temperature in place of thermal bridge | °C |
| $\theta_{acc}$ | Minimum acceptable temperature to avoid condensation | °C |

## 18.2 Transparent envelope

The transparent envelope of the building have been also analysed, here we report the results regarding them.

Window description: Curtain Wall — Code: W1

The window frame is a curtain wall module.



**Features of the window frame**

| | | | |
|---|---|---|---|
| Type of window | - | | |
| Permeability class | Without classification | | |
| Thermal transmittance | $U_{cw}$ | 1,000 | W/m K$^2$ |
| Transmittance glass only | $U_g$ | 0,700 | W/m K$^2$ |

**Data for the calculation of solar contributions**

| | | | |
|---|---|---|---|
| Emissivity | ε | 0,200 | - |
| Curtain factor (winter) | $f_{c\ inv}$ | 1,00 | - |
| Curtain factor (summer) | $f_{c\ est}$ | 1,00 | - |
| Solar transmittance factor | $g_{gl,n}$ | 0,500 | - |
| Total solar transmission factor | $g_{gl+sh}$ | 0,494 | - |

**Features of blackout closures**

| | | | |
|---|---|---|---|
| Thermal resistance closures | | 0,00 | m K/W$^2$ |
| f shut | | 0,6 | - |

**Frame dimensions**

| | | | |
|---|---|---|---|
| Width | | 100,0 | cm |
| Height | | 300,0 | cm |

**Chassis features**

| | | | |
|---|---|---|---|
| K spacer | $K_d$ | 0,00 | W/mK |
| Total area | $A_w$ | 3,000 | m$^2$ |
| Glass area | $A_g$ | 2,380 | m$^2$ |
| Frame area | $A_f$ | 0,620 | m$^2$ |
| Form factor | $F_f$ | 0,79 | - |
| Glass perimeter | $L_g$ | 16,300 | m |

**Module features**

| | | | |
|---|---|---|---|
| Module thermal transmittance | U | 1,000 | W/m K$^2$ |

Mullions and transoms of the curtain wall module

Traversi

| | | | |
|---|---|---|---|
| Thickness | $s_t$ | 10,0 | cm |
| Area | $A_t$ | 0,10 | $m^2$ |

Uprights

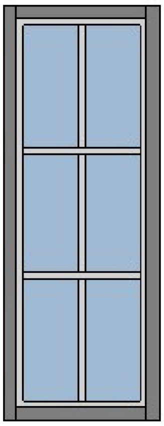
| | | | |
|---|---|---|---|
| Thickness | $s_m$ | 10,0 | cm |
| Area | $A_m$ | 0,31 | $m^2$ |

Window description: Curtain Wall greenhouse — Code: W2

The window frame is a curtain wall module.

Features of the window frame

| | | | |
|---|---|---|---|
| Type of window | - | | |
| Permeability class | Without classification | | |
| Thermal transmittance | $U_{cw}$ | 1,000 | W/m K² |
| Transmittance glass only | $U_g$ | 0,700 | W/m K² |



Data for the calculation of solar contributions

| | | | |
|---|---|---|---|
| Emissivity | $\varepsilon$ | 0,200 | - |
| Curtain factor (winter) | $f_{c\ inv}$ | 1,00 | - |
| Curtain factor (summer) | $f_{c\ est}$ | 1,00 | - |
| Solar transmittance factor | $g_{gl,n}$ | 0,500 | - |
| Total solar transmission factor | $g_{gl+sh}$ | - | - |

Features of blackout closures

| | | |
|---|---|---|
| Thermal resistance closures | 0,00 | m K/W² |
| f shut | 0,6 | - |

Frame dimensions

| | | |
|---|---|---|
| Width | 100,0 | cm |
| Height | 300,0 | cm |

Chassis features

| | | | |
|---|---|---|---|
| K spacer | $K_d$ | 0,00 | W/mK |
| Total area | $A_w$ | 3,000 | m² |
| Glass area | $A_g$ | 2,380 | m² |
| Frame area | $A_f$ | 0,620 | m² |
| Form factor | $F_f$ | 0,79 | - |
| Glass perimeter | $L_g$ | 16,300 | m |

Module features

| | | | |
|---|---|---|---|
| Module thermal transmittance | U | 1,000 | W/m K² |

Mullions and transoms of the curtain wall module

Traversi

| | | | |
|---|---|---|---|
| Thickness | $s_t$ | 10,0 | cm |
| Area | $A_t$ | 0,10 | $m^2$ |

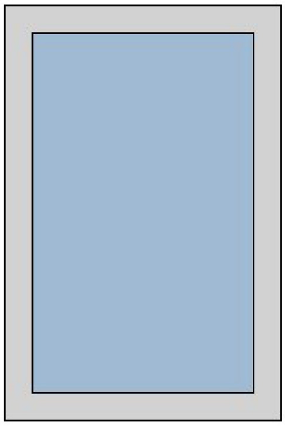
Struts

| | | | |
|---|---|---|---|
| Thickness | $s_m$ | 10,0 | cm |
| Area | $A_m$ | 0,31 | $m^2$ |

Description of window: 100x150 — Code: W3

Features of the window frame

| | | | |
|---|---|---|---|
| Type of window | - | | |
| Permeability class | Without classification | | |
| Thermal transmittance | $U_w$ | 1,000 | W/m $K^2$ |
| Transmittance glass only | $U_g$ | 0,700 | W/m $K^2$ |



Data for the calculation of solar contributions

| | | | |
|---|---|---|---|
| Emissivity | $\varepsilon$ | 0,200 | - |
| Curtain factor (winter) | $f_{c\ inv}$ | 1,00 | - |
| Curtain factor (summer) | $f_{c\ est}$ | 1,00 | - |
| Solar transmittance factor | $g_{gl,n}$ | 0,500 | - |
| Total solar transmission factor | $g_{gl+sh}$ | 0,494 | - |

Features of blackout closures

| | | | |
|---|---|---|---|
| Thermal resistance closures | | 0,00 | m $K/W^2$ |
| f shut | | 0,6 | - |

Frame dimensions

| | | | |
|---|---|---|---|
| Width | | 100,0 | cm |
| Height | | 150,0 | cm |

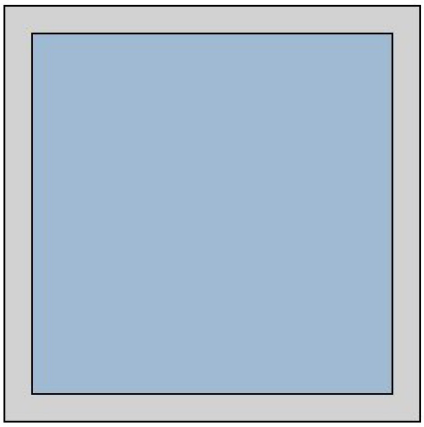
Chassis features

| | | | |
|---|---|---|---|
| K spacer | $K_d$ | 0,00 | W/mK |
| Total area | $A_w$ | 1,500 | $m^2$ |
| Glass area | $A_g$ | 1,040 | $m^2$ |
| Frame area | $A_f$ | 0,460 | $m^2$ |
| Form factor | $F_f$ | 0,69 | - |
| Glass perimeter | $L_g$ | 4,200 | m |
| Frame perimeter | $L_f$ | 5,000 | m |

Module features

| | | | |
|---|---|---|---|
| Module thermal transmittance | U | 1,000 | W/m $K^2$ |

Description of window: 150x150 Code: W4



Features of the window frame

| | | | |
|---|---|---|---|
| Type of window | - | | |
| Permeability class | Without classification | | |
| Thermal transmittance | $U_w$ | 1,000 | W/m K$^2$ |
| Transmittance glass only | $U_g$ | 0,700 | W/m K$^2$ |

Data for the calculation of solar contributions

| | | | |
|---|---|---|---|
| Emissivity | $\varepsilon$ | 0,200 | - |
| Curtain factor (winter) | $f_{c\ inv}$ | 1,00 | - |
| Curtain factor (summer) | $f_{c\ est}$ | 1,00 | - |
| Solar transmittance factor | $g_{gl,n}$ | 0,500 | - |
| Total solar transmission factor | $g_{gl+sh}$ | 0,494 | - |

Features of blackout closures

| | | | |
|---|---|---|---|
| Thermal resistance closures | | 0,00 | m K/W$^2$ |
| f shut | | 0,6 | - |

Frame dimensions

| | | | |
|---|---|---|---|
| Width | | 150,0 | cm |
| Height | | 150,0 | cm |

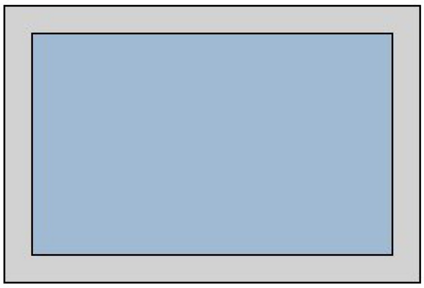
Chassis features

| | | | |
|---|---|---|---|
| K spacer | $K_d$ | 0,00 | W/mK |
| Total area | $A_w$ | 2,250 | m$^2$ |
| Glass area | $A_g$ | 1,690 | m$^2$ |
| Frame area | $A_f$ | 0,560 | m$^2$ |
| Form factor | $F_f$ | 0,75 | - |
| Glass perimeter | $L_g$ | 5,200 | m |
| Frame perimeter | $L_f$ | 6,000 | m |

Module features

| | | | |
|---|---|---|---|
| Module thermal transmittance | U | 1,000 | W/m K$^2$ |

Description of window: 150x100 Code: W5



Features of the window frame

| | | | |
|---|---|---|---|
| Type of window | - | | |
| Permeability class | Without classification | | |
| Thermal transmittance | $U_w$ | 1,000 | W/m K$^2$ |
| Transmittance glass only | $U_g$ | 0,700 | W/m K$^2$ |

Data for the calculation of solar contributions

| | | | |
|---|---|---|---|
| Emissivity | ε | 0,200 | - |
| Curtain factor (winter) | $f_{c\ inv}$ | 1,00 | - |
| Curtain factor (summer) | $f_{c\ est}$ | 1,00 | - |
| Solar transmittance factor | $g_{gl,n}$ | 0,500 | - |
| Total solar transmission factor | $g_{gl+sh}$ | 0,494 | - |

Features of blackout closures

| | | |
|---|---|---|
| Thermal resistance closures | 0,00 | m K/W$^2$ |
| f shut | 0,6 | - |

Frame dimensions

| | | |
|---|---|---|
| Width | 150,0 | cm |
| Height | 100,0 | cm |

Chassis features

| | | | |
|---|---|---|---|
| K spacer | $K_d$ | 0,00 | W/mK |
| Total area | $A_w$ | 1,500 | m$^2$ |
| Glass area | $A_g$ | 1,040 | m$^2$ |
| Frame area | $A_f$ | 0,460 | m$^2$ |
| Form factor | $F_f$ | 0,69 | - |
| Glass perimeter | $L_g$ | 4,200 | m |
| Frame perimeter | $L_f$ | 5,000 | m |

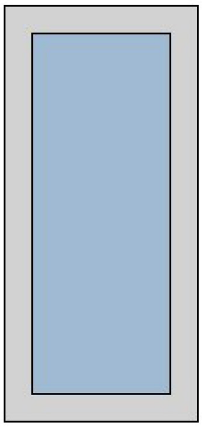
Module features

| | | | |
|---|---|---|---|
| Module thermal transmittance | U | 1,000 | W/m K$^2$ |

Description of window: 70x150 Code: W6

Features of the window frame

| | | | |
|---|---|---|---|
| Type of window | - | | |
| Permeability class | Without classification | | |
| Thermal transmittance | $U_w$ | 1,000 | W/m K$^2$ |
| Transmittance glass only | $U_g$ | 0,700 | W/m K$^2$ |



Data for the calculation of solar contributions

| | | | |
|---|---|---|---|
| Emissivity | $\varepsilon$ | 0,200 | - |
| Curtain factor (winter) | $f_{c\ inv}$ | 1,00 | - |
| Curtain factor (summer) | $f_{c\ est}$ | 1,00 | - |
| Solar transmittance factor | $g_{gl,n}$ | 0,500 | - |
| Total solar transmission factor | $g_{gl+sh}$ | 0,494 | - |

Features of blackout closures

| | | | |
|---|---|---|---|
| Thermal resistance closures | | 0,00 | m K/W$^2$ |
| f shut | | 0,6 | - |

Frame dimensions

| | | | |
|---|---|---|---|
| Width | | 70,0 | cm |
| Height | | 150,0 | cm |

Chassis features

| | | | |
|---|---|---|---|
| K spacer | $K_d$ | 0,00 | W/mK |
| Total area | $A_w$ | 1,050 | m$^2$ |
| Glass area | $A_g$ | 0,650 | m$^2$ |
| Frame area | $A_f$ | 0,400 | m$^2$ |
| Form factor | $F_f$ | 0,62 | - |
| Glass perimeter | $L_g$ | 3,600 | m |
| Frame perimeter | $L_f$ | 4,400 | m |

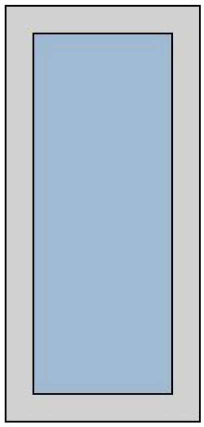
Module features

| | | | |
|---|---|---|---|
| Module thermal transmittance | U | 1,000 | W/m K$^2$ |

Description of window: 70x150 Code: W6

Features of the window frame

| | | | |
|---|---|---|---|
| Type of window | - | | |
| Permeability class | Without classification | | |
| Thermal transmittance | $U_w$ | 1,000 | W/m K² |
| Transmittance glass only | $U_g$ | 0,700 | W/m K² |



Data for the calculation of solar contributions

| | | | |
|---|---|---|---|
| Emissivity | ε | 0,200 | - |
| Curtain factor (winter) | $f_{c\ inv}$ | 1,00 | - |
| Curtain factor (summer) | $f_{c\ est}$ | 1,00 | - |
| Solar transmittance factor | $g_{gl,n}$ | 0,500 | - |
| Total solar transmission factor | $g_{gl+sh}$ | 0,494 | - |

Features of blackout closures

| | | |
|---|---|---|
| Thermal resistance closures | 0,00 | m K/W² |
| f shut | 0,6 | - |

Frame dimensions

| | | |
|---|---|---|
| Width | 70,0 | cm |
| Height | 150,0 | cm |

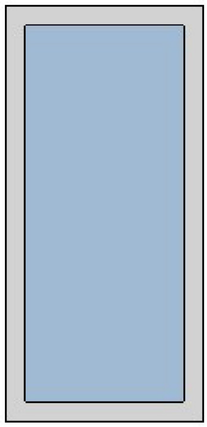
Chassis features

| | | | |
|---|---|---|---|
| K spacer | $K_d$ | 0,00 | W/mK |
| Total area | $A_w$ | 1,050 | m² |
| Glass area | $A_g$ | 0,650 | m² |
| Frame area | $A_f$ | 0,400 | m² |
| Form factor | $F_f$ | 0,62 | - |
| Glass perimeter | $L_g$ | 3,600 | m |
| Frame perimeter | $L_f$ | 4,400 | m |

Module features

| | | | |
|---|---|---|---|
| Module thermal transmittance | U | 1,000 | W/m K² |

Description of window: 100x210 Code: W8



Features of the window frame

| | | | |
|---|---|---|---|
| Type of window | - | | |
| Permeability class | Without classification | | |
| Thermal transmittance | $U_w$ | 1,000 | W/m K$^2$ |
| Transmittance glass only | $U_g$ | 0,700 | W/m K$^2$ |

Data for the calculation of solar contributions

| | | | |
|---|---|---|---|
| Emissivity | $\varepsilon$ | 0,200 | - |
| Curtain factor (winter) | $f_{c\ inv}$ | 1,00 | - |
| Curtain factor (summer) | $f_{c\ est}$ | 1,00 | - |
| Solar transmittance factor | $g_{gl,n}$ | 0,500 | - |
| Total solar transmission factor | $g_{gl+sh}$ | 0,494 | - |

Features of blackout closures

| | | |
|---|---|---|
| Thermal resistance closures | 0,00 | m K/W$^2$ |
| f shut | 0,6 | - |

Frame dimensions

| | | |
|---|---|---|
| Width | 100,0 | cm |
| Height | 210,0 | cm |

Chassis features

| | | | |
|---|---|---|---|
| K spacer | $K_d$ | 0,00 | W/mK |
| Total area | $A_w$ | 2,100 | m$^2$ |
| Glass area | $A_g$ | 1,520 | m$^2$ |
| Frame area | $A_f$ | 0,580 | m$^2$ |
| Form factor | $F_f$ | 0,72 | - |
| Glass perimeter | $L_g$ | 5,400 | m |
| Frame perimeter | $L_f$ | 6,200 | m |

Module features

| | | | |
|---|---|---|---|
| Module thermal transmittance | U | 1,000 | W/m K$^2$ |

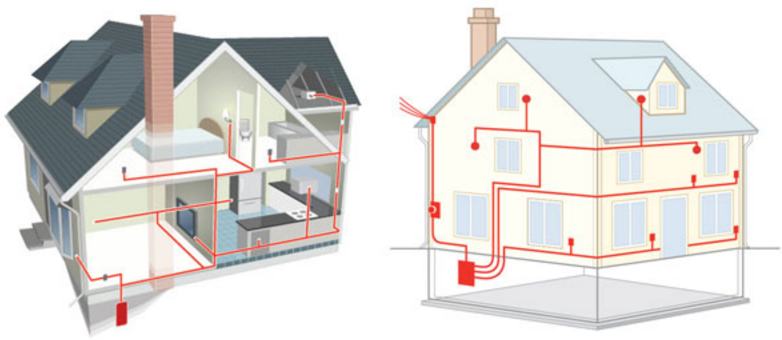
## 18.3 Plants design

In the unit we designed we also inserted and designed the plants, since the analysis carried out, which led us to confirm that the projected building turns out to be an NZEB building and that it meets all the required requirements, would not have been complete without an analysis of the plants present and how they interact with the casing and everything else.

The plants guarantee the functionality of the building; in fact, no building could be used in the absence of systems.
We can compare the implants of the building, to the network system that runs through our body blood system, nervous system, lymphatic system and so on.
Under the city streets are buried the canalizations of the distribution systems of drinking water, electricity, gas, sewage and telephony. During the construction of the building the connections are made and the derivations of the individual systems are installed, each in a special pipe from which the distribution inside the building and the individual apartments.

**The electrical system** The electrical system is that system of conductive wires, cables and accessories that have the function of bringing electricity inside our homes.
This presupposes the existence of a supplier (electricity operator) and a user (we), who conclude a contract for the supply of electricity. Today, electricity can no longer be supplied by a single operator (as was the case in the past with ENEL), but can also be supplied by other entities not necessarily Italian (this has allowed in some cases, competition and lower costs).

From the power plant the current travels very fast to our homes.
An underground network of cables runs through our cities and from this reaches every user served. The first electrical object that we find in our building (whether it is a condominium or a single house) is the so-called METER; a box that aims to record the consumption made in order to define the expense to be charged.



If the meter represents the instrument of electricity input in our building, the differential magnetic-thermal switch also called LIFESAVING represents the first electrical element inside our house.
It is a safety device capable of interrupting the electrical flow in case of an excessive difference between the input and output current due to short circuits or overloads.

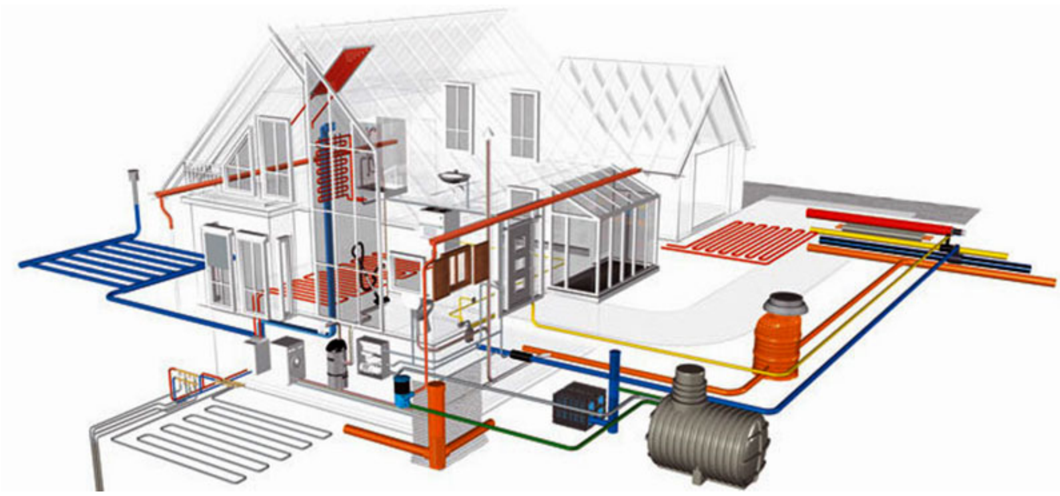
The LIFESAVER therefore performs three functions:

- Short circuit protection (magnetic protection)
  This type of fault occurs when two conductors come into direct contact with each other, causing a very high and instantaneous flow of current.

- Overload protection (thermal protection)
  This problem occurs when the current intensity exceeds a preset value for example for too many devices turned on at the same time.
- Dispersion or contact protection (differential protection)
  This problem occurs when the current takes a different route from the one it should normally follow. For example, through the body of a person (electric shock) or by direct contact or through a connected appliance due to insulation failure or manufacturing defect.

**The thermal plant** In our latitudes, the alternation of the seasons is evident, passing from very hot summers to winters, on the contrary, very cold.
Hence the need to ensure in the interior space of the building, the correct micro-climate can allow during the year the performance of all the functions and activities for which it was thought (work, recreation, study, sleep, etc.).

Today, the watchword is ENERGY SAVING, so the first intervention to be carried out is on the building envelope, on the elements that divide the interior space from the outside to make the shell of the building perfectly insulating, in order to allow considerable energy savings; but apart from this, a good heating system allows those who occupy the house in winter to obtain excellent living comfort.
The heating system is that system that realizes the heating of the air in the interior spaces of the building to ensure well-being of the occupants.
The way he succeeds in this task is manifold. There may be many fuels used for heating (natural gas, solar, electric, etc.), there may be many ways (radiant system, heat pumps, floor system, etc.), there may be many solutions (collective system, autonomous system, shared system, etc.).



Here we will take care of the autonomous systems, able to guarantee an entire apartment the achievement of optimal conditions, and the centralized systems capable of heating entire buildings.
They are characterized, although with due differences, by certain elements in common. They are both equipped with a heat generator (boiler) powered by a liquid or gaseous fuel and equipped with a chimney for the evacuation outside the combustion products (fumes), a system of distribution of the heat transfer fluid (water, air or steam) and terminals to provide individual rooms with the thermal power needed to control the internal temperature (radiators or radiators).

**Heat generator (heater)** All heating systems need a heat generator.
This is composed of two main elements: the burner and the heater.
The burner is that equipment that allows you to inject into the heater the right amount of fuel required, making sure that it mixes properly with the necessary air.
The heat produced by combustion is used to heat the water circulating in the heater.

**Meter** In general, today, the most used fuel is methane, chosen due to the fact that among fossil fuels is the cleanest, the cheapest and equipped with a widespread distribution network that crosses our cities under the road surface. As a result of this, the first element of a heating system is a connection to a distribution network and therefore the presence near the user of a meter.
This is an instrument that records (as in the case of the electric meter), the passage of the gas allowing a quantification and consequently its monetization.

**Distribution system** Through a system of pipes connected to radiant metal plates (RADIATORS) or embedded in coils in the floor screed (FLOOR SYSTEM), the heat is distributed in every room of the house.
In the past, the heating systems were single-pipe, that is a pipe that went out and re-entered the boiler to which they were connected by two to six radiators. This, while facilitating the design and construction of the system, had the disadvantage that the fluid as it proceeded along the path cooled, so the last radiator of the system was always the coldest. Today, to avoid this, the boilers are connected to the radiators through the MANIFOLD, a system that allows the sorting of the fluid in a network of pipes equal to the number of radiators present in the system.

**Radiators and radiators** Insulated pipes that run under the floor, emerge from this at specific points of the rooms and enter the interior of plant elements called radiators or radiators, which have the function of radiating heat into the room and the efficiency of this function depends on several factors such as the material, the number of elements and the size.

**Radiant floor system** A solution that is catching on in the field of indoor heating, which is better from the point of view of thermal performance and aesthetics, but obviously more expensive, is radiant floor heating.
Basically, an insulating layer is laid on the subfloor foundation so that heat cannot be lost downward, and a series of pipes with a serpentine pattern of flexible pipe are laid over it. Then the built-up work is drowned in the screed for laying the floor covering (usually tiles)

**The water-sanitary system** Among the indispensable systems for homes, we cannot fail to mention the water-sanitary system, that is, the system that supplies homes with drinking water.
The distribution of water today is through a single system and a single pipe, so that, the potable water supplied by the managing body, is largely wasted because it is used not only for drinking purposes, but also for industrial uses and sanitary services.
Recent regulations, and common sense directions, are making sure that all this, changes. In fact, two different service networks are planned, one for potable water and one for water for other uses.

## 18.4 Our plant design

In our design, we included a heat pump to serve heating, domestic hot water and cooling simultaneously. The presence of a solar panel and photovoltaic panels that are coupled with the planned heat pump was also planned.

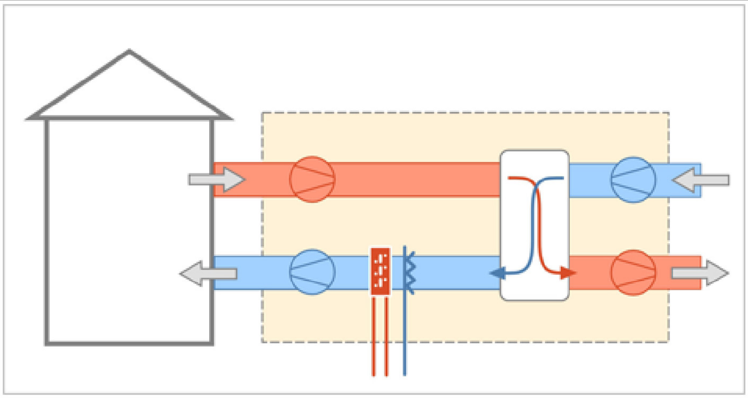
### 18.4.1 Heating service, aeraulic system

| HEATING SERVICE (aeraulic system) |
|---|

| Building : Residential Unit |
|---|

Aeraulic system characteristics:

| | |
|---|---|
| Type of plant | Balanced mechanical ventilation |
| Devices present | Heat recovery, Air heating, Humidification |



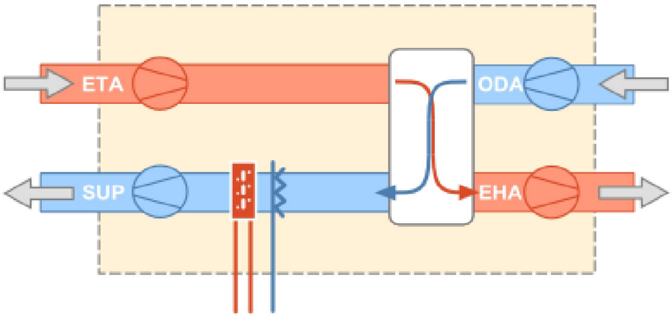
Data for calculating effective mechanical ventilation:

| | | | |
|---|---|---|---|
| Air exchange at 50 Pa | $n_{50}$ | 1 | $h^{-1}$ |
| Wind exposure coefficient | e | 0,10 | - |
| Wind exposure coefficient | f | 15,00 | - |
| Average air exchange for natural ventilation in rooms with hybrid mechanical ventilation | n | 0,5 | $h^{-1}$ |
| Adjustment efficiency factor | $FC_{ve,H}$ | 1,00 | - |
| Plant operating hours | hf | 24,00 | - |
| Nominal recuperator efficiency | $\eta H_{nom}$ | 0,90 | |

Room capacities

| Zone | No. | Local description | Type | $qve_{,sup}$ [$m^3$ /h] | $qve_{,ext}$ [$m^3$ /h] | $q_{ve,0}$ [$m^3$ /h] |
|---|---|---|---|---|---|---|
| 1 | 1 | Living Room+Kitchen | Extraction + Input | 272,16 | 272,16 | 272,16 |
| 1 | 2 | Bathroom | Extraction + Input | 26,52 | 26,52 | 26,52 |
| 1 | 3 | Technical compartment | Extraction + Input | 2,78 | 2,78 | 2,78 |
| 1 | 4 | Room | Extraction + Input | 36,37 | 36,37 | 36,37 |
| 1 | 5 | Bathroom | Extraction + Input | 45,92 | 45,92 | 45,92 |
| | | | Total | 383,75 | 383,75 | 383,75 |

Duct characteristics




Room Extraction Duct (ETA):

| | | |
|---|---|---|
| Room extraction temperature | 20,0 | °C |
| Electric power of fans | 0 | W |
| Duct flow rate | 383,75 | m /h$^3$ |

Exhaust Duct (SUP):

| | | |
|---|---|---|
| Room inlet temperature | 20,0 | °C |
| Electric power of fans | 0 | W |
| Duct flow rate | 383,75 | m /h$^3$ |

Outside air intake duct (ODA):

| | | |
|---|---|---|
| Temperature difference due to soil exchange | 0,0 | °C |
| Electrical power of fans | 0 | W |
| Duct flow rate | 383,75 | m /h$^3$ |

## Humidification

Internal steam production:

| Zone | Description | Presidential Decree 412/93 | $m_{vap}$ [g/h] |
|---|---|---|---|
| 1 | Air-conditioned zone | E.1 (1) | 250,00 |

Humidification characteristics:

Type of humidification    Adiabatic

Building : Residential Unit

## Modes of operation

## Heating circuit

Intermittence

Operating regime    Continued

### 18.4.2 Heating service, hydronic system

## HEATING SERVICE (hydronic system)

Seasonal plant yields:

| Description | Symbol | Value | u.m. |
|---|---|---|---|
| Emission yield | $\eta_{H,e}$ | 98,0 | % |
| Control performance | $\eta_{H,rg}$ | 99,0 | % |
| Utility distribution yield | $\eta_{H,du}$ | 98,1 | % |
| Accumulation yields | $\eta_{H,s}$ | 99,6 | % |
| Generation yield (resp. to en. pr. non renn.) | $\eta H_{,gen,p,nren}$ | 229,5 | % |
| Generation yield (resp. to total en. pr.) | $\eta H_{,gen,p,tot}$ | 75,2 | % |
| Seasonal average overall efficiency (vs. non renn. en. pr.) | $\eta H_{,g,p,nren}$ | 77,6 | % |
| Seasonal average overall efficiency (vs. total en. pr.) | $\eta H_{,g,p,tot}$ | 25,2 | % |

Performance details of individual generators:

| Generator | $\eta H_{,gen,ut}$ [%] | $\eta H_{,gen,p,nren}$ [%] | $\eta H_{,gen,p,tot}$ [%] |
|---|---|---|---|
| Heat pump - according to UNI/TS 11300-4 | 447,5 | 229,5 | 75,2 |

Symbol legend

$\eta H_{,gen,ut}$ Generation efficiency versus useful energy

$\eta H_{,gen,p,nren}$ Generation efficiency compared to non-renewable primary energy

$\eta H_{,gen,p,tot}$ Generation efficiency in relation to total primary energy

Data per circuit

Heating circuit

Emission subsystem characteristics:

| | | |
|---|---|---|
| Type of dispensing terminal | Panels embedded in the floor | |
| Correction factor $f_{emb}$ | 0,99 | |
| Power rating of heating elements | 5223 | W |
| Electrical requirements | 0 | W |
| Emission yield | 97,0 | % |

Control subsystem characteristics:

| | |
|---|---|
| Type | For single room + climate |
| Features | PI or PID |

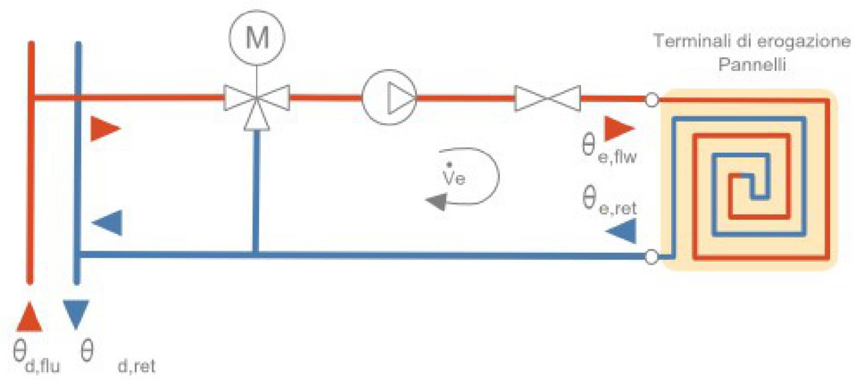
| | | |
|---|---|---|
| Control performance | 99,0 | % |

Utility distribution subsystem characteristics:

| | |
|---|---|
| Calculation method | Simplified |
| Type of plant | Centralised with horizontal distribution |
| Plant position | Unheated, ground floor system with single-pipe distribution |
| Pipe position | - |
| Pipe insulation | Insulation with thicknesses complying with the requirements of Presidential Decree No. 412/93 |
| Number of floors | 1 |
| Correction factor | 0,47 |
| Utility distribution yield | 98,1 % |
| Electrical requirements | 200 W |

Water temperature - Heating

Circuit type Modulating thermostat, 2-way valve




| | | |
|---|---|---|
| Increased heating body power | 10,0 | % |
| ΔT nominal air side | 15,0 | °C |
| Heating body exponent n | 1,10 | - |
| ΔT design water side | 10,0 | °C |
| Nominal flow rate | 494,43 | kg/h |
| Calculation criterion | Variable flow temperature | |
| Maximum flow temperature | 80,0 | °C |
| ΔT flow/return | 20,0 | °C |

Mixing valve overtemperature 5,0 °C

| | | ISSUERS | | |
|---|---|---|---|---|
| Month | days | θe,avg [°C] | θe,flw [°C] | θe,ret [°C] |
| October | 17 | 20,0 | 30,0 | 20,0 |
| November | 30 | 20,8 | 30,8 | 20,0 |
| December | 31 | 22,0 | 32,0 | 20,0 |
| January | 31 | 22,2 | 32,2 | 20,0 |
| February | 28 | 21,0 | 31,0 | 20,0 |
| March | 31 | 20,0 | 30,0 | 20,0 |
| April | 15 | 20,0 | 30,0 | 20,0 |

Symbol legend

| | |
|---|---|
| θe,avg | Average temperature of circuit emitters |
| θe,flw | Discharge temperature of circuit emitters |
| θe,ret | Return temperature of circuit emitters |

Common data

Storage subsystem characteristics:

Thermal dispersion 1,200 W/K

Installation environment --

Loss recovery factor 1,00

Ambient installation temperature 20,0 °C

Water temperature:

| | | DISTRIBUTION | | |
|---|---|---|---|---|
| Month | days | θd,avg [°C] | θd,flw [°C] | θd,ret [°C] |
| October | 17 | 17,5 | 35,0 | 0,0 |
| November | 30 | 27,9 | 35,8 | 20,0 |
| December | 31 | 28,5 | 37,0 | 20,0 |
| January | 31 | 28,6 | 37,2 | 20,0 |
| February | 28 | 28,0 | 36,0 | 20,0 |
| March | 31 | 17,5 | 35,0 | 0,0 |
| April | 15 | 17,5 | 35,0 | 0,0 |

Symbol legend

| | |
|---|---|
| $\theta_{d,avg}$ | Average distribution network temperature |
| $\theta_{d,flw}$ | Distribution network flow temperature |
| $\theta_{d,ret}$ | Return temperature of the distribution network |

### 18.4.3 Domestic Hot Water service

## DOMESTIC HOT WATER SERVICE

Seasonal plant yields:

| Description | Symbol | Value | u.m. |
|---|---|---|---|
| Delivery performance | $\eta_{W,er}$ | 100,0 | % |
| Utility distribution yield | $\eta_{W,du}$ | 92,6 | % |
| Accumulation efficiency | $\eta_{W,s}$ | 73,6 | % |
| Generation yield (resp. to useful en.) | $\eta W_{,gen,ut}$ | 272,3 | % |
| Generation yield (resp. to en. pr. non renn.) | $\eta W_{,gen,p,nren}$ | 139,6 | % |
| Generation yield (resp. to en. pr. non tot.) | $\eta W_{,gen,p,tot}$ | 65,7 | % |
| Seasonal average overall efficiency (vs. non renn. en. pr.) | $\eta W_{,g,p,nren}$ | 167,4 | % |
| Seasonal average overall efficiency (vs. en. pr. tot.) | $\eta W_{,g,p,tot}$ | 49,7 | % |

Data by zone

Zone: Air-conditioned zone

Daily domestic water demand [l/g]:

| Jan | Feb | Mar | Apr | Mag | Jun | Jul | Ago | Set | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 93 | 93 | 93 | 93 | 93 | 93 | 93 | 93 | 93 | 93 | 93 | 93 |

Category DPR 412/93 E.1 (1)

Dispensing temperature 40,0 °C

Supply temperature [°C]

| Jan | Feb | Mar | Apr | Mag | Jun | Jul | Ago | Set | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 12,6 | 12,6 | 12,6 | 12,6 | 12,6 | 12,6 | 12,6 | 12,6 | 12,6 | 12,6 | 12,6 | 12,6 |

Useful surface area 53,05 $m^2$

Dispensing subsystem features:

Delivery performance 100,0 %

Utility distribution subsystem characteristics:

Calculation method Simplified

Systems installed after the entry into force of Law 373/76, current network partially in air-conditioned rooms

| Other data |
|---|

<u>Centralised storage subsystem features</u>:

| | | |
|---|---|---|
| Thermal dispersion | 1,200 | W/K |
| Average accumulation temperature | 60,0 | °C |
| Installation environment | Interior | |
| Loss recovery factor | 1,00 | |
| Ambient installation temperature | 20,0 | °C |

### 18.4.4 Generation subsystem

## GENERATION SUBSYSTEM

General data:

| | |
|---|---|
| Service | Heating, ventilation and hot water |
| Generator type | Heat pump |
| Calculation method | according to UNI/TS 11300-4 |

| | |
|---|---|
| Brand/Series/Model | DAIKIN/ALTHERMA 3 H/EPGA11 |
| Type of heat pump | Electric |

| | | | | |
|---|---|---|---|---|
| Deactivation temperature | | $\theta_{H,off}$ | 20,0 | °C (for heating) |
| Cold source | Outside air | | | |
| Operating temperature (cut-off) | | minimum | -28,0 | °C |
| | | maximum | 35,0 | °C |
| Hot source | Plant water | | | |
| Operating temperature (cut-off) | | minimum | 25,0 | °C |
| | | maximum | 60,0 | °C |
| Hot source temperature (domestic water) | | | 55,0 | °C |

Declared performance:

Coefficient of Performance COP

| Cold source temperature $\theta_f$ [°C] | Hot source temperature $\theta_c$ [°C] | | |
|---|---|---|---|
| | 35 | 45 | 55 |
| -7 | 2,72 | 2,43 | 2,28 |
| 2 | 3,61 | 2,84 | 2,33 |
| 7 | 4,73 | 3,50 | 2,89 |
| 12 | 5,96 | 4,10 | 3,62 |

Power output Pu [kW]

| Cold source temperature $\theta_f$ [°C] | Hot source temperature $\theta_c$ [°C] | | |
|---|---|---|---|
| | 35 | 45 | 55 |
| -7 | 11,06 | 10,66 | 10,12 |

| | | | |
|---|---|---|---|
| 2 | 10,79 | 11,65 | 10,67 |
| 7 | 14,57 | 14,71 | 15,19 |
| 12 | 14,07 | 14,61 | 14,54 |

Power input Pass [kW]

| Cold source temperature $\theta_f$ [°C] | Hot source temperature $\theta_c$ [°C] | | |
|---|---|---|---|
| | 35 | 45 | 55 |
| -7 | 4,07 | 4,39 | 4,44 |
| 2 | 2,99 | 4,10 | 4,58 |
| 7 | 3,08 | 4,20 | 5,26 |
| 12 | 2,36 | 3,56 | 4,02 |

Corrective factors of the heat pump:

Design power Pdes (at -10°C) 11,00 kW

| Partialisation conditions | A | B | C | D |
|---|---|---|---|---|
| Reference temperature [°C] | -7 | 2 | 7 | 12 |
| Climatic load factor (PLR) [%]. | 88 | 54 | 35 | 15 |
| DC power at full load [kW] | 11,06 | 10,79 | 14,57 | 14,07 |
| Partial load COP | 3,07 | 4,15 | 5,86 | 7,88 |
| COP at full load | 2,70 | 3,61 | 4,73 | 5,96 |
| Load factor CR [-] | 1,00 | 0,55 | 0,26 | 0,12 |
| Correction factor fCOP [-]. | 1,00 | 1,15 | 1,24 | 1,32 |

Electrical needs:

Electrical power of independent auxiliaries 0 W

Water temperature of the heat generator:

Sliding temperature heat generator

Circuit type Direct connection

| | | GENERATION | | |
|---|---|---|---|---|
| Month | days | $\theta gn_{,avg}$ [°C] | $\theta gn_{,flw}$ [°C] | $\theta gn_{,ret}$ [°C] |
| October | 17 | 0,0 | 0,0 | 0,0 |
| November | 30 | 27,9 | 35,8 | 20,0 |
| December | 31 | 28,5 | 37,0 | 20,0 |
| January | 31 | 28,6 | 37,2 | 20,0 |

| | | | | |
|---|---|---|---|---|
| February | 28 | 28,0 | 36,0 | 20,0 |
| March | 31 | 0,0 | 0,0 | 0,0 |
| April | 15 | 0,0 | 0,0 | 0,0 |

Symbol legend

| | |
|---|---|
| $\theta gn_{,avg}$ | Average temperature of the heat generator |
| $\theta gn_{,flw}$ | Heat generator flow temperature |
| $\theta gn_{,ret}$ | Heat generator return temperature |

Energy carrier:

| | | | | |
|---|---|---|---|---|
| Type | Electricity | | | |
| Primary energy conversion factor (renewable) | | $f_{p,ren}$ | 0,470 | - |
| Primary energy conversion factor (non-renewable) | | $fp_{,nren}$ | 1,950 | - |
| Primary energy conversion factor | | $f_p$ | 2,420 | - |
| CO emission factor$_2$ | | | 0,4600 | kg /kWh$_{CO2}$ |

### 18.4.5 Monthly calculation results

## MONTHLY CALCULATION RESULTS

Monthly results ventilation service - aeraulic system

Building : Residential Unit

Thermal and electrical needs

| | | Thermal requirements | | | | Electrical requirements | | | |
|---|---|---|---|---|---|---|---|---|---|
| Month | gg | $QH_{,risc,sys,out}$ [kWh]. | $QH_{,hum,sys,out}$ [kWh]. | $QH_{,risc,gen,out}$ [kWh]. | $QH_{,risc,gen,in}$ [kWh]. | $QH_{,risc,dp,aux}$ [kWh]. | $QH_{,risc,gen,aux}$ [kWh]. | $QWV_{,aux,el}$ [kWh]. | $QH_{,hum,el}$ [kWh]. |
| January | 31 | 358 | 834 | 1192 | 290 | 0 | 0 | 0 | 0 |
| February | 28 | 291 | 669 | 960 | 208 | 0 | 0 | 0 | 0 |
| March | 31 | 223 | 324 | 547 | 88 | 0 | 0 | 0 | 0 |
| April | 15 | 75 | 126 | 201 | 27 | 0 | 0 | 0 | 0 |
| May | - | - | - | - | - | - | - | - | - |
| June | - | - | - | - | - | - | - | - | - |
| July | - | - | - | - | - | - | - | - | - |
| August | - | - | - | - | - | - | - | - | - |
| September | - | - | - | - | - | - | - | - | - |
| October | 17 | 80 | 0 | 80 | 10 | 0 | 0 | 0 | 0 |
| November | 30 | 243 | 264 | 507 | 86 | 0 | 0 | 0 | 0 |
| December | 31 | 331 | 685 | 1016 | 225 | 0 | 0 | 0 | 0 |
| TOTALS | 183 | 1600 | 2903 | 4504 | 935 | 0 | 0 | 0 | 0 |

Symbol legend

| | |
|---|---|
| gg | Days included in the calculation period for heating |
| $QH_{,risc,sys,out}$ | Ideal thermal energy requirement for air preheating |
| $QH_{,hum,sys,out}$ | Ideal thermal energy requirement for humidification |
| $QH_{,risc,gen,out}$ | Generation output needs |
| $QH_{,risc,gen,in}$ | Generation input requirements |
| $QH_{,risc,dp,aux}$ | Primary distribution auxiliary power requirements |
| $QH_{,risc,gen,aux}$ | Auxiliary power requirements generation |
| $QWV_{,aux,el}$ | Electrical requirement nozzles |
| $QH_{,hum,el}$ | Electrical requirement humidification with steam injection |

Thermal system details

| Month | gg | $\eta H_{,risc,dp}$ [%]. | $\eta H_{,risc,gen,p,nren}$ [%]. | $\eta H_{,risc,gen,p,tot}$ [%]. |
|---|---|---|---|---|
| January | 31 | - | 211,1 | 72,6 |
| February | 28 | - | 236,3 | 76,1 |
| March | 31 | - | 318,9 | 84,9 |
| April | 15 | - | 374,7 | 89,3 |
| May | - | - | - | - |
| June | - | - | - | - |
| July | - | - | - | - |
| August | - | - | - | - |
| Septemb er | - | - | - | - |
| October | 17 | - | 405,2 | 91,3 |
| Novemb er | 30 | - | 304,0 | 83,5 |
| Decembe r | 31 | - | 231,1 | 75,4 |

Symbol legend

| | |
|---|---|
| gg | Days included in the calculation period for heating |
| $\eta H_{,risc,dp}$ | Monthly primary distribution efficiency for air heating |
| $\eta H_{,risc,gen,p,nren}$ | Monthly generation efficiency compared to non-renewable primary energy |
| $\eta H_{,risc,gen,p,tot}$ | Monthly generation efficiency versus total primary energy |

Primary energy requirement of aeraulic system

| Month | gg | $QH_{,risc,gn,in}$ [kWh]. | $QH_{,heating,aux}$ [kWh]. | $QH_{,risc,p,nren}$ [kWh]. | $QH_{,risc,p,tot}$ [kWh]. |
|---|---|---|---|---|---|
| January | 31 | 290 | 290 | 565 | 1644 |
| February | 28 | 208 | 208 | 406 | 1287 |
| March | 31 | 88 | 88 | 171 | 644 |
| April | 15 | 27 | 27 | 54 | 225 |
| May | - | - | - | - | - |
| June | - | - | - | - | - |
| July | - | - | - | - | - |
| August | - | - | - | - | - |
| Septemb er | - | - | - | - | - |
| October | 17 | 10 | 10 | 20 | 88 |
| Novemb | 30 | 86 | 86 | 167 | 619 |

| | | | | | |
|---|---|---|---|---|---|
| er | | | | | |
| December | 31 | 225 | 225 | 440 | 1347 |
| TOTALS | 183 | 935 | 935 | 1822 | 5855 |

Symbol legend

gg Days included in the calculation period for air heating
$QH_{,risc,gn,in}$ Total thermal energy input to the generation subsystem for air heating
$QH_{,risc,aux}$ Total electricity requirement for air heating
$QH_{,r,p,nren}$ Primary non-renewable energy demand for air heating
$QH_{,risc,p,tot}$ Total primary energy requirement for air heating

Monthly results heating service - hydronic system

Building : Residential Unit

Thermal and electrical needs

| | | Thermal requirements | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Month | gg | $Q_{H,nd}$ [kWh]. | $QH_{,sys,out}$ [kWh]. | $Q'_{H,sys,out}$ [kWh]. | $QH_{,sys,out,int}$ [kWh]. | $QH_{,sys,out,cont}$ [kWh]. | $QH_{,sys,out,corr}$ [kWh]. | $QH_{,gen,out}$ [kWh]. | $QH_{,gen,in}$ [kWh]. |
| January | 31 | 678 | 881 | 491 | 491 | 491 | 491 | 514 | 125 |
| February | 28 | 330 | 493 | 180 | 180 | 180 | 180 | 160 | 35 |
| March | 31 | 21 | 71 | 0 | 0 | 0 | 0 | 0 | 0 |
| April | 15 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| May | - | - | - | - | - | - | - | - | - |
| June | - | - | - | - | - | - | - | - | - |
| July | - | - | - | - | - | - | - | - | - |
| August | - | - | - | - | - | - | - | - | - |
| September | - | - | - | - | - | - | - | - | - |
| October | 17 | 4 | 18 | 0 | 0 | 0 | 0 | 0 | 0 |
| November | 30 | 289 | 425 | 156 | 156 | 156 | 156 | 150 | 25 |
| December | 31 | 630 | 818 | 455 | 455 | 455 | 455 | 479 | 106 |
| TOTALS | 183 | 1953 | 2708 | 1283 | 1283 | 1283 | 1283 | 1304 | 291 |

Symbol legend

gg Days included in the calculation period for heating
$Q_{H,nd}$ Useful heat energy requirement of the building (natural ventilation)
$QH_{,sys,out}$ Useful thermal energy requirement of the building (mechanical ventilation)
$Q'_{H,sys,out}$ Ideal net requirement
$QH_{,sys,out,in}$ Intermittency-corrected demand

| | |
|---|---|
| $QH_{sys,out,cont}$ | Corrected needs for accounting |
| $QH_{sys,out,corr}$ | Needs adjusted for additional factors |
| $QH_{gen,out}$ | Generation output needs |
| $QH_{gen,in}$ | Generation input requirements |

| | | Electrical requirements | | | |
|---|---|---|---|---|---|
| Month | gg | $QH_{em,aux}$ [kWh]. | $QH_{du,aux}$ [kWh]. | $QH_{dp,aux}$ [kWh]. | $QH_{gen,aux}$ [kWh]. |
| January | 31 | 0 | 19 | 0 | 0 |
| February | 28 | 0 | 7 | 0 | 0 |
| March | 31 | 0 | 0 | 0 | 0 |
| April | 15 | 0 | 0 | 0 | 0 |
| May | - | - | - | - | - |
| June | - | - | - | - | - |
| July | - | - | - | - | - |
| August | - | - | - | - | - |
| September | - | - | - | - | - |
| October | 17 | 0 | 0 | 0 | 0 |
| November | 30 | 0 | 6 | 0 | 0 |
| December | 31 | 0 | 18 | 0 | 0 |
| TOTALS | 183 | 0 | 51 | 0 | 0 |

Symbol legend

| | |
|---|---|
| gg | Days included in the calculation period for heating |
| $QH_{em,aux}$ | Auxiliary power requirement emission |
| $QH_{du,aux}$ | Auxiliary power distribution requirements |
| $QH_{dp,aux}$ | Primary distribution auxiliary power requirements |
| $QH_{gen,aux}$ | Auxiliary power requirements generation |

Thermal system details

| Month | gg | $\eta_{H,rg}$ [%]. | $\eta_{H,d}$ [%]. | $\eta_{H,s}$ [%]. | $\eta_{H,dp}$ [%]. | $\eta H_{gen,p,nren}$ [%]. | $\eta H_{gen,p,tot}$ [%]. | $\eta H_{g,p,nren}$ [%]. | $\eta H_{g,p,tot}$ [%]. |
|---|---|---|---|---|---|---|---|---|---|
| January | 31 | 99,0 | 98,1 | 99,7 | 100,0 | 211,1 | 72,6 | 79,5 | 28,2 |
| February | 28 | 99,0 | 98,1 | 99,3 | 100,0 | 236,3 | 76,1 | 66,5 | 21,6 |
| March | 31 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 12,0 | 3,2 |
| April | 15 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,3 | 0,1 |
| May | - | - | - | - | - | - | - | - | - |
| June | - | - | - | - | - | - | - | - | - |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| July | - | - | - | - | - | - | - | - | - |
| August | - | - | - | - | - | - | - | - | - |
| September | - | - | - | - | - | - | - | - | - |
| October | 17 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 20,6 | 4,6 |
| November | 30 | 99,0 | 98,1 | 99,2 | 100,0 | 304,0 | 83,5 | 123,9 | 35,1 |
| December | 31 | 99,0 | 98,1 | 99,7 | 100,0 | 231,1 | 75,4 | 91,5 | 31,0 |

Symbol legend

| | |
|---|---|
| gg | Days included in the calculation period for heating |
| $\eta_{H,rg}$ | Monthly control yield |
| $\eta_{H,d}$ | Monthly distribution yield |
| $\eta_{H,s}$ | Monthly accumulation yield |
| $\eta_{H,dp}$ | Monthly primary distribution yield |
| $\eta H_{,gen,p,nren}$ | Monthly generation efficiency compared to non-renewable primary energy |
| $\eta H_{,gen,p,tot}$ | Monthly generation efficiency versus total primary energy |
| $\eta H_{,g,p,nren}$ | Monthly average overall efficiency compared to non-renewable primary energy |
| $\eta H_{,g,p,tot}$ | Monthly average total primary energy efficiency |

Generator details: 1 - Heat pump

| Month | gg | $QH_{,gn,out}$ [kWh]. | $QH_{,gn,in}$ [kWh]. | $\eta H_{,gen,ut}$ [%]. | $\eta H_{,gen,p,nren}$ [%]. | $\eta H_{,gen,p,tot}$ [%]. | Fuel [ kWh] |
|---|---|---|---|---|---|---|---|
| January | 31 | 1706 | 414 | 411,7 | 211,1 | 72,6 | 0 |
| February | 28 | 1120 | 243 | 460,7 | 236,3 | 76,1 | 0 |
| March | 31 | 547 | 88 | 621,8 | 318,9 | 84,9 | 0 |
| April | 15 | 201 | 27 | 730,8 | 374,7 | 89,3 | 0 |
| May | - | - | - | - | - | - | - |
| June | - | - | - | - | - | - | - |
| July | - | - | - | - | - | - | - |
| August | - | - | - | - | - | - | - |
| September | - | - | - | - | - | - | - |
| October | 17 | 80 | 10 | 790,2 | 405,2 | 91,3 | 0 |
| November | 30 | 657 | 111 | 592,8 | 304,0 | 83,5 | 0 |
| December | 31 | 1496 | 332 | 450,7 | 231,1 | 75,4 | 0 |

| Month | gg | COP [-] |
|---|---|---|
| January | 31 | 4,12 |
| February | 28 | 4,61 |
| March | 31 | 6,22 |
| April | 15 | 7,31 |
| May | - | - |
| June | - | - |
| July | - | - |
| August | - | - |
| September | - | - |
| October | 17 | 7,90 |
| November | 30 | 5,93 |
| December | 31 | 4,51 |

Symbol legend

| | |
|---|---|
| gg | Days included in the calculation period for heating |
| $QH_{,gn,out}$ | Thermal energy supplied by the generator for heating |
| $QH_{,gn,in}$ | Thermal energy input to generator for heating |
| $\eta H_{,gen,ut}$ | Monthly generator efficiency versus useful energy |
| $\eta H_{,gen,p,nren}$ | Monthly generator efficiency versus non-renewable primary energy |
| $\eta H_{,gen,p,tot}$ | Monthly generator efficiency in relation to total primary energy |
| Fuel | Monthly fuel consumption |
| COP | Monthly average useful effect coefficient |

## Hydronic system primary energy demand

| Month | gg | $QH_{gn,in}$ [kWh]. | $Q_{H,aux}$ [kWh]. | $QH_{p,nren}$ [kWh]. | $QH_{p,tot}$ [kWh]. |
|---|---|---|---|---|---|
| January | 31 | 125 | 144 | 289 | 765 |
| February | 28 | 35 | 42 | 90 | 242 |
| March | 31 | 0 | 0 | 0 | 0 |
| April | 15 | 0 | 0 | 0 | 0 |
| May | - | - | - | - | - |
| June | - | - | - | - | - |
| July | - | - | - | - | - |
| August | - | - | - | - | - |
| Septemb er | - | - | - | - | - |
| October | 17 | 0 | 0 | 0 | 0 |
| Novemb er | 30 | 25 | 31 | 66 | 204 |
| Decembe r | 31 | 106 | 124 | 249 | 687 |
| TOTALS | 183 | 291 | 342 | 694 | 1899 |

Symbol legend

gg — Days included in the calculation period for heating
$QH_{gn,in}$ — Total thermal energy input to the heating generation subsystem
$Q_{H,aux}$ — Total electricity requirement for heating
$QH_{p,nren}$ — Primary non-renewable energy demand for heating
$QH_{p,tot}$ — Total primary energy demand for heating

## Hydronic and aeraulic primary energy demand

| Month | gg | $QH_{,gn,in}$ [kWh]. | $Q_{H,aux}$ [kWh]. | $QH_{,p,nren}$ [kWh]. | $QH_{,p,tot}$ [kWh]. |
|---|---|---|---|---|---|
| January | 31 | 414 | 434 | 854 | 2409 |
| February | 28 | 243 | 250 | 496 | 1530 |
| March | 31 | 88 | 88 | 171 | 644 |
| April | 15 | 27 | 27 | 54 | 225 |
| May | - | - | - | - | - |
| June | - | - | - | - | - |
| July | - | - | - | - | - |
| August | - | - | - | - | - |
| Septemb er | - | - | - | - | - |
| October | 17 | 10 | 10 | 20 | 88 |
| Novemb er | 30 | 111 | 117 | 233 | 824 |
| Decembe r | 31 | 332 | 350 | 689 | 2035 |
| TOTALS | 183 | 1226 | 1277 | 2517 | 7754 |

Symbol legend

| | |
|---|---|
| gg | Days included in the calculation period for hydronic and aeraulic systems |
| $QH_{,gn,in}$ | Total thermal energy input to the generation subsystem for hydronic and aeraulic systems |
| $Q_{H,aux}$ | Total electricity requirement for hydronic and aeraulic system |
| $QH_{,p,nren}$ | Non-renewable primary energy demand for hydronic and aeraulic systems |
| $QH_{,p,tot}$ | Total primary energy requirement for hydronic and aeraulic systems |

## Photovoltaic solar panels

Electricity from photovoltaic production [kWh]:

| Jan | Feb | Mar | Apr | Mag | Jun | Jul | Ago | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

| | | | |
|---|---|---|---|
| Primary non-renewable energy demand | $QH_{,p,nren}$ | 2517 | kWh/year |
| Total primary energy demand | $QH_{,p,tot}$ | 7754 | kWh/year |
| Seasonal average overall efficiency (compared to non-renewable primary energy) | $\eta H_{,g,p,nren}$ | 77,6 | % |
| Seasonal average overall efficiency (in relation to total primary energy) | $\eta H_{,g,p,tot}$ | 25,2 | % |
| Actual power consumption | | 1291 | kWh/year |

Monthly hot water service results

Building : Residential Unit

Thermal and electrical needs

| | | Thermal requirements | | | | | Electrical requirements | | |
|---|---|---|---|---|---|---|---|---|---|
| Month | gg | $QW_{,sys,out}$ [kWh]. | $QW_{,sys,out,rec}$ [kWh]. | $QW_{,sys,out,cont}$ [kWh]. | $QW_{,gen,out}$ [kWh]. | $QW_{,gen,in}$ [kWh]. | $QW_{,ric,aux}$ [kWh]. | $QW_{,dp,aux}$ [kWh]. | $QW_{,gen,aux}$ [kWh]. |
| January | 31 | 92 | 92 | 92 | 125 | 51 | 0 | 0 | 0 |
| February | 28 | 83 | 83 | 83 | 93 | 37 | 0 | 0 | 0 |
| March | 31 | 92 | 92 | 92 | 41 | 13 | 0 | 0 | 0 |
| April | 30 | 89 | 89 | 89 | 17 | 5 | 0 | 0 | 0 |
| May | 31 | 92 | 92 | 92 | 0 | 0 | 0 | 0 | 0 |
| June | 30 | 89 | 89 | 89 | 0 | 0 | 0 | 0 | 0 |
| July | 31 | 92 | 92 | 92 | 0 | 0 | 0 | 0 | 0 |
| August | 31 | 92 | 92 | 92 | 0 | 0 | 0 | 0 | 0 |
| September | 30 | 89 | 89 | 89 | 16 | 4 | 0 | 0 | 0 |
| October | 31 | 92 | 92 | 92 | 57 | 16 | 0 | 0 | 0 |
| November | 30 | 89 | 89 | 89 | 112 | 39 | 0 | 0 | 0 |
| December | 31 | 92 | 92 | 92 | 126 | 51 | 0 | 0 | 0 |
| TOTALS | 365 | 1083 | 1083 | 1083 | 587 | 216 | 0 | 0 | 0 |

Symbol legend

| | |
|---|---|
| gg | Days included in the calculation period for domestic water |
| $QW_{,sys,out}$ | Ideal domestic water demand |
| $QW_{,sys,out,rec}$ | Corrected demand for heat recovery from shower effluent |
| $QW_{,sys,out,cont}$ | Corrected need for accounting |
| $QW_{,gen,out}$ | Generation output needs |
| $QW_{,gen,in}$ | Generation input requirements |
| $QW_{,ric,aux}$ | Recirculation auxiliary power requirement |
| $QW_{,dp,aux}$ | Primary distribution auxiliary power requirements |
| $QW_{,gen,aux}$ | Auxiliary power requirements generation |

Thermal system details

| Month | gg | $\eta_{W,d}$ [%]. | $\eta_{W,s}$ [%]. | $\eta_{W,ric}$ [%]. | $\eta_{W,dp}$ [%]. | $\eta W_{,gen,p,nren}$ [%] | $\eta W_{,gen,p,tot}$ [%]. | $\eta W_{,g,p,nren}$ [%]. | $\eta W_{,g,p,tot}$ [%]. |
|---|---|---|---|---|---|---|---|---|---|
| January | 31 | 92,6 | 73,6 | - | - | 125,6 | 61,7 | 90,8 | 42,8 |
| February | 28 | 92,6 | 73,6 | - | - | 130,0 | 63,0 | 108,3 | 45,4 |
| March | 31 | 92,6 | 73,6 | - | - | 155,0 | 69,8 | 197,3 | 51,7 |
| April | 30 | 92,6 | 73,6 | - | - | 177,8 | 75,1 | 258,6 | 53,3 |
| May | 31 | 92,6 | 73,6 | - | - | 215,0 | 82,6 | 309,3 | 53,5 |
| June | 30 | 92,6 | 73,6 | - | - | 0,0 | 0,0 | 275,9 | 52,1 |
| July | 31 | 92,6 | 73,6 | - | - | 0,0 | 0,0 | 259,3 | 51,4 |
| August | 31 | 92,6 | 73,6 | - | - | 0,0 | 0,0 | 294,0 | 52,9 |
| September | 30 | 92,6 | 73,6 | - | - | 223,0 | 84,1 | 289,7 | 54,6 |
| October | 31 | 92,6 | 73,6 | - | - | 181,8 | 76,0 | 193,5 | 53,1 |
| November | 30 | 92,6 | 73,6 | - | - | 146,7 | 67,6 | 110,5 | 47,0 |
| December | 31 | 92,6 | 73,6 | - | - | 127,8 | 62,4 | 91,5 | 43,1 |

Symbol legend

| | |
|---|---|
| gg | Days included in the calculation period for domestic water |
| $\eta_{W,d}$ | Monthly distribution yield |
| $\eta_{W,s}$ | Monthly accumulation yield |
| $\eta_{W,ric}$ | Monthly yield of the recirculation network |
| $\eta_{W,dp}$ | Monthly primary distribution yield |
| $\eta W_{,gen,p,nren}$ | Monthly generation efficiency compared to non-renewable primary energy |
| $\eta W_{,gen,p,tot}$ | Monthly generation efficiency versus total primary energy |
| $\eta W_{,g,p,nren}$ | Monthly average overall efficiency compared to non-renewable primary energy |
| $\eta W_{,g,p,tot}$ | Monthly average total primary energy efficiency |

Generator details: 1 - Heat pump

| Month | gg | $QW_{,gn,out}$ [kWh]. | $QW_{,gn,in}$ [kWh]. | $\eta W_{,gen,ut}$ [%]. | $\eta W_{,gen,p,nren}$ [%]. | $\eta W_{,gen,p,tot}$ [%]. | Fuel [ kWh] |
|---|---|---|---|---|---|---|---|
| January | 31 | 125 | 51 | 245,0 | 125,6 | 61,7 | 0 |
| February | 28 | 93 | 37 | 253,5 | 130,0 | 63,0 | 0 |
| March | 31 | 41 | 13 | 302,2 | 155,0 | 69,8 | 0 |
| April | 30 | 17 | 5 | 346,7 | 177,8 | 75,1 | 0 |
| May | 31 | 0 | 0 | 419,2 | 215,0 | 82,6 | 0 |
| June | 30 | 0 | 0 | 0,0 | 0,0 | 0,0 | 0 |
| July | 31 | 0 | 0 | 0,0 | 0,0 | 0,0 | 0 |
| August | 31 | 0 | 0 | 0,0 | 0,0 | 0,0 | 0 |
| September | 30 | 16 | 4 | 434,8 | 223,0 | 84,1 | 0 |
| October | 31 | 57 | 16 | 354,5 | 181,8 | 76,0 | 0 |
| November | 30 | 112 | 39 | 286,0 | 146,7 | 67,6 | 0 |
| December | 31 | 126 | 51 | 249,2 | 127,8 | 62,4 | 0 |

| Month | gg | COP [-] |
|---|---|---|
| January | 31 | 2,45 |
| February | 28 | 2,53 |
| March | 31 | 3,02 |
| April | 30 | 3,47 |
| May | 31 | 4,19 |
| June | 30 | 0,00 |
| July | 31 | 0,00 |
| August | 31 | 0,00 |
| September | 30 | 4,35 |
| October | 31 | 3,54 |
| November | 30 | 2,86 |
| December | 31 | 2,49 |

Symbol legend

| | |
|---|---|
| gg | Days included in the calculation period for domestic water |
| $QW_{,gn,out}$ | Thermal energy supplied by the generator for domestic water |
| $QW_{,gn,in}$ | Thermal energy input to generator for domestic hot water |
| $\eta W_{,gen,ut}$ | Monthly generator efficiency versus useful energy |

| | |
|---|---|
| $\eta W,_{gen,p,nren}$ | Monthly generator efficiency versus non-renewable primary energy |
| $\eta W,_{gen,p,tot}$ | Monthly generator efficiency in relation to total primary energy |
| Fuel | Monthly fuel consumption |
| COP | Monthly average useful effect coefficient |

Primary energy requirement of hot water system

| Month | gg | $QW,_{gn,in}$ [kWh]. | $Q_{W,aux}$ [kWh]. | $QW,_{p,nren}$ [kWh]. | $QW,_{p,tot}$ [kWh]. |
|---|---|---|---|---|---|
| January | 31 | 51 | 51 | 101 | 215 |
| February | 28 | 37 | 37 | 77 | 183 |
| March | 31 | 13 | 13 | 47 | 178 |
| April | 30 | 5 | 5 | 34 | 167 |
| May | 31 | 0 | 0 | 30 | 172 |
| June | 30 | 0 | 0 | 32 | 171 |
| July | 31 | 0 | 0 | 35 | 179 |
| August | 31 | 0 | 0 | 31 | 174 |
| Septemb er | 30 | 4 | 4 | 31 | 163 |
| October | 31 | 16 | 16 | 48 | 173 |
| Novemb er | 30 | 39 | 39 | 81 | 189 |
| Decembe r | 31 | 51 | 51 | 100 | 213 |
| TOTALS | 365 | 216 | 216 | 647 | 1776 |

Symbol legend

| | |
|---|---|
| gg | Days included in the calculation period for domestic water |
| $QW,_{gn,in}$ | Total thermal energy input to the domestic water generation subsystem |
| $Q_{W,aux}$ | Total electricity requirement for domestic water |
| $QW,_{p,nren}$ | Primary non-renewable energy demand for domestic water |
| $QW,_{p,tot}$ | Total primary energy demand for domestic water |

Photovoltaic solar panels

Electricity from photovoltaic production [kWh]:

| Jan | Feb | Mar | Apr | Mag | Jun | Jul | Ago | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

| | | | |
|---|---|---|---|
| Primary non-renewable energy demand | $QW_{,p,nren}$ | 647 | kWh/year |
| Total primary energy demand | $QW_{,p,tot}$ | 2177 | kWh/year |
| Seasonal average overall efficiency (compared to non-renewable primary energy) | $\eta W_{,g,p,nren}$ | 167,4 | % |
| Seasonal average overall efficiency (in relation to total primary energy) | $\eta W_{,g,p,tot}$ | 49,7 | % |
| Actual electricity consumption | | 332 | kWh/year |

### 18.4.6 Primary energy requirements

# PRIMARY ENERGY REQUIREMENTS
## according to UNI/TS 11300-3

Building : Residential Unit

Modes of operation of the system:
Continued

## COOLING SERVICE

Seasonal plant yields:

| Description | Symbol | Value | u.m. |
|---|---|---|---|
| Emission yield | $\eta_{C,e}$ | 97,0 | % |
| Control performance | $\eta_{C,rg}$ | 98,0 | % |
| Distribution yield | $\eta_{C,d}$ | 100,0 | % |
| Accumulation yields | $\eta_{C,s}$ | 98,2 | % |
| Generation yield (resp. to useful en.) | $\eta C_{,gen,ut}$ | 384,6 | % |
| Generation yield (resp. to en. pr. non renn.) | $\eta C_{,gen,p,nren}$ | 116,1 | % |
| Generation yield (resp. to en. pr. non tot.) | $\eta C_{,gen,p,tot}$ | 93,5 | % |
| Seasonal average overall efficiency (vs. non renn. en. pr.) | $\eta C_{,g,p,nren}$ | 94,6 | % |
| Seasonal average overall efficiency (vs. en. pr. tot.) | $\eta C_{,g,p,tot}$ | 76,2 | % |

Emission subsystem characteristics:

| | |
|---|---|
| Type of dispensing terminal | Insulated panels embedded in the floor |
| Electrical requirements | 0 W |

Control subsystem characteristics:

| | |
|---|---|
| Type | Single room control |
| Features | Modulating control (1°C band) |

Storage subsystem characteristics:

| | |
|---|---|
| Thermal dispersion | 1,200 W/K |
| Average accumulation temperature | 10,0 °C |
| Installation environment | Interior |
| Ambient installation temperature | 26,0 °C |

# GENERATION SUBSYSTEM

General data:

| | |
|---|---|
| Service | Cooling |
| Generator type | Heat pump |
| Calculation method | according to UNI/TS 11300-3 |

| | | | |
|---|---|---|---|
| Brand/Series/Model | DAIKIN/ALTHERMA 3 H/EPGA11 | | |
| Type of heat pump | Electric | | |
| Rated cooling capacity | $\Phi gn_{,nom}$ | 10,70 | kW |

Outdoor unit source Air

Outside air dry bulb temperature 31,0 °C

Indoor unit source Water

Condenser outlet water temperature 7,0 °C

Declared performance:

| Fk [%]. | 100% | 75% | 50% | 25% | 20% | 15% | 10% | 5% | 2% | 1% |
|---|---|---|---|---|---|---|---|---|---|---|
| EER [-] | 2,74 | 3,48 | 5,36 | 6,32 | 6,00 | 5,94 | 5,50 | 4,49 | 2,91 | 1,83 |

Symbol legend

| | |
|---|---|
| Fk | Heat pump load factor |
| EER | Heat pump performance |

Outdoor unit data:

| | | | |
|---|---|---|---|
| Duct air flow rate percentage | 100,0 | % | (value in relation to nominal flow rate) |
| Absence of soundproof baffles | | | |
| Delivery pipe length | 10,00 | m | |

Indoor unit data:

| | | |
|---|---|---|
| Thermal jump at the evaporator | 5,0 | °C |
| Fouling factor | 0,04403 | m K/kW[2] |
| Percentage of glycol | 20,0 | % |

Electrical needs:

| | | | | |
|---|---|---|---|---|
| Electrical power of auxiliaries | 200 W | | | |

<u>Energy carrier</u>:

| | | | | |
|---|---|---|---|---|
| Type | Electricity | | | |
| Primary energy conversion factor (renewable) | | $f_{p,ren}$ | 0,470 | - |
| Primary energy conversion factor (non-renewable) | | $fp_{,nren}$ | 1,950 | - |
| Primary energy conversion factor | | $f_p$ | 2,420 | - |
| CO emission factor$_2$ | | | 0,4600 | kg /kWh$_{CO2}$ |

# MONTHLY CALCULATION RESULTS

Monthly results cooling service

Building : Residential Unit

Thermal requirements

| Month | gg | $Q_{C,nd}$ [kWh]. | $QC_{,sys,out}$ [kWh]. | $QC_{,sys,out,cont}$ [kWh]. | $QC_{,sys,out,corr}$ [kWh]. | $Q_{cr}$ [kWh]. | $Q_v$ [kWh]. | $QC_{,gen,out}$ [kWh]. | $QC_{,gen,in}$ [kWh]. |
|---|---|---|---|---|---|---|---|---|---|
| January | - | - | - | - | - | - | - | - | - |
| February | 15 | 1 | 2 | 2 | 2 | 9 | 0 | 9 | 7 |
| March | 31 | 40 | 93 | 93 | 93 | 112 | 0 | 112 | 71 |
| April | 30 | 255 | 397 | 397 | 397 | 432 | 0 | 432 | 135 |
| May | 31 | 899 | 1001 | 1001 | 1001 | 1067 | 0 | 1067 | 265 |
| June | 30 | 1327 | 1375 | 1375 | 1375 | 1460 | 59 | 1520 | 365 |
| July | 31 | 1504 | 1535 | 1535 | 1535 | 1629 | 75 | 1703 | 402 |
| August | 31 | 1195 | 1238 | 1238 | 1238 | 1317 | 149 | 1466 | 353 |
| September | 30 | 633 | 717 | 717 | 717 | 768 | 29 | 798 | 208 |
| October | 31 | 60 | 128 | 128 | 128 | 149 | 0 | 149 | 77 |
| November | 15 | 0 | 1 | 1 | 1 | 8 | 0 | 8 | 6 |
| December | - | - | - | - | - | - | - | - | - |
| TOTALS | 275 | 5916 | 6487 | 6487 | 6487 | 6951 | 313 | 7264 | 1889 |

Symbol legend

| | |
|---|---|
| gg | Days included in the calculation period for cooling |
| $Q_{C,nd}$ | Useful heat energy requirement of the building (natural ventilation) |
| $QC_{,sys,out}$ | Useful thermal energy requirement of the building (mechanical ventilation) |
| $QC_{,sys,out,cont}$ | Corrected needs for accounting |
| $QC_{,sys,out,corr}$ | Needs adjusted for additional factors |
| $Q_{cr}$ | Actual thermal energy demand |
| $Q_v$ | Air treatment requirements |
| $QC_{,gen,out}$ | Generation output needs |
| $QC_{,gen,in}$ | Generation input requirements |

Electrical requirements

| Month | gg | $QC_{,em,aux}$ [kWh]. | $QC_{,du,aux}$ [kWh]. | $QC_{,dp,aux}$ [kWh]. | $QC_{,gen,aux}$ [kWh]. |
|---|---|---|---|---|---|
| January | - | - | - | - | - |
| February | 15 | 0 | 0 | 0 | 72 |
| March | 31 | 0 | 0 | 0 | 149 |
| April | 30 | 0 | 0 | 0 | 144 |
| May | 31 | 0 | 0 | 0 | 149 |
| June | 30 | 0 | 0 | 0 | 144 |
| July | 31 | 0 | 0 | 0 | 149 |
| August | 31 | 0 | 0 | 0 | 149 |
| September | 30 | 0 | 0 | 0 | 144 |
| October | 31 | 0 | 0 | 0 | 149 |
| November | 15 | 0 | 0 | 0 | 72 |
| December | - | - | - | - | - |
| TOTALS | 275 | 0 | 0 | 0 | 1320 |

Symbol legend

gg Days included in the calculation period for cooling
$QC_{,em,aux}$ Auxiliary power requirement emission
$QC_{,du,aux}$ Auxiliary power distribution requirements
$QC_{,dp,aux}$ Primary distribution auxiliary power requirements
$QC_{,gen,aux}$ Auxiliary power requirements generation

## Thermal system details

| Month | gg | Fk [-] | $\eta_{C,rg}$ [%]. | $\eta_{C,d}$ [%]. | $\eta_{C,s}$ [%]. | $\eta_{C,dp}$ [%]. | $\eta C_{,gen,ut}$ [%]. | $\eta C_{,gen,p,nren}$ [%] | $\eta C_{,gen,p,tot}$ [%]. | $\eta C_{,g,p,nren}$ [%]. | $\eta C_{,g,p,tot}$ [%]. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| January | - | - | - | - | - | - | - | - | - | - | - |
| February | 15 | 0,00 | 98,0 | - | 22,5 | - | 127,3 | 5,8 | 4,7 | 0,7 | 0,5 |
| March | 31 | 0,01 | 98,0 | - | 87,3 | - | 158,0 | 26,2 | 21,1 | 9,4 | 7,6 |
| April | 30 | 0,06 | 98,0 | - | 96,8 | - | 320,2 | 79,4 | 64,0 | 46,9 | 37,8 |
| May | 31 | 0,13 | 98,0 | - | 98,7 | - | 402,9 | 132,3 | 106,6 | 111,5 | 89,9 |
| June | 30 | 0,20 | 98,0 | - | 99,1 | - | 416,8 | 153,2 | 123,5 | 133,8 | 107,8 |
| July | 31 | 0,21 | 98,0 | - | 99,1 | - | 423,2 | 158,4 | 127,7 | 139,9 | 112,7 |
| August | 31 | 0,18 | 98,0 | - | 98,9 | - | 415,7 | 149,9 | 120,8 | 122,2 | 98,5 |
| September | 30 | 0,10 | 98,0 | - | 98,2 | - | 384,1 | 116,3 | 93,7 | 92,3 | 74,4 |
| October | 31 | 0,02 | 98,0 | - | 90,4 | - | 192,4 | 33,8 | 27,2 | 13,7 | 11,0 |
| November | 15 | 0,00 | 98,0 | - | 10,8 | - | 127,3 | 5,1 | 4,1 | 0,3 | 0,2 |
| December | - | - | - | - | - | - | - | - | - | - | - |

Symbol legend

| | |
|---|---|
| gg | Days included in the calculation period for cooling |
| Fk | Heat pump load factor |
| $\eta_{C,rg}$ | Monthly control yield |
| $\eta_{C,d}$ | Monthly distribution yield |
| $\eta_{C,s}$ | Monthly accumulation yield |
| $\eta_{C,dp}$ | Monthly primary distribution yield |
| $\eta C_{,gen,ut}$ | Monthly generation efficiency versus useful energy |
| $\eta C_{,gen,p,nren}$ | Monthly generation efficiency compared to non-renewable primary energy |
| $\eta C_{,gen,p,tot}$ | Monthly generation efficiency versus total primary energy |
| $\eta C_{,g,p,nren}$ | Monthly average overall efficiency compared to non-renewable primary energy |
| $\eta C_{,g,p,tot}$ | Monthly average total primary energy efficiency |

Primary energy demand

| Month | gg | $QC_{gn,in}$ [kWh]. | $Q_{C,aux}$ [kWh]. | $QC_{p,nren}$ [kWh]. | $QC_{p,tot}$ [kWh]. | Fuel [ kWh ] |
|---|---|---|---|---|---|---|
| January | - | - | - | - | - | - |
| February | 15 | 7 | 79 | 154 | 191 | 0 |
| March | 31 | 71 | 220 | 429 | 532 | 0 |
| April | 30 | 135 | 279 | 544 | 675 | 0 |
| May | 31 | 265 | 414 | 807 | 1001 | 0 |
| June | 30 | 365 | 509 | 992 | 1231 | 0 |
| July | 31 | 402 | 551 | 1075 | 1334 | 0 |
| August | 31 | 353 | 501 | 978 | 1214 | 0 |
| Septemb er | 30 | 208 | 352 | 686 | 851 | 0 |
| October | 31 | 77 | 226 | 441 | 548 | 0 |
| Novemb er | 15 | 6 | 78 | 152 | 189 | 0 |
| Decembe r | - | - | - | - | - | - |
| TOTALS | 275 | 1889 | 3209 | 6257 | 7765 | 0 |

Symbol legend

gg Days included in the calculation period for cooling
$QC_{gn,in}$ Thermal energy input to the generation subsystem for cooling
$Q_{C,aux}$ Total electricity requirement for cooling
$QC_{p,nren}$ Primary non-renewable energy demand for cooling
$QC_{p,tot}$ Total primary energy requirement for cooling

Photovoltaic solar panels

Electricity from photovoltaic production [kWh]:

| Jan | Feb | Mar | Apr | Mag | Jun | Jul | Ago | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

| | | | |
|---|---|---|---|
| Primary non-renewable energy demand | $QC_{p,nren}$ | 6257 | kWh/year |
| Total primary energy demand | $QC_{p,tot}$ | 7765 | kWh/year |
| Seasonal average overall efficiency (compared to non-renewable primary energy) | $\eta C_{g,p,nren}$ | 94,6 | % |
| Seasonal average overall efficiency (in relation to total primary energy) | $\eta C_{g,p,tot}$ | 76,2 | % |
| Actual power consumption | | 3209 | kWh/year |

### 18.4.7 Total needs and consumptions

# TOTAL NEEDS AND CONSUMPTION

| | | | | | |
|---|---|---|---|---|---|
| Building : Residential Unit | PRESIDENTIAL DECREE 412/93 | E.1 (1) | Useful surface area | 53,05 | $m^2$ |

Primary energy demand and performance indices

| Service | Qp,nren [kWh] | Qp,ren [kWh]. | Qp,tot [kWh]. | EP,nren [kWh/m$^2$] | EP,ren [kWh/m$^2$] | EP,tot [kWh/m$^2$] |
|---|---|---|---|---|---|---|
| Heating | 2517 | 5238 | 7754 | 47,44 | 98,73 | 146,17 |
| Domestic hot water | 647 | 1530 | 2177 | 12,19 | 28,84 | 41,03 |
| Cooling | 6257 | 1508 | 7765 | 117,95 | 28,43 | 146,37 |
| Ventilation | 0 | 0 | 0 | 0,00 | 0,00 | 0,00 |
| TOTAL | 9420 | 8276 | 17696 | 177,58 | 156,00 | 333,57 |

Energy carriers and $CO_2$

| Energy carrier | Consumption | U.M. | $CO_2$ [kg/year]. | Services |
|---|---|---|---|---|
| Electricity | 4831 | kWhel/year | 2222 | Heating, Hot water, Cooling, Ventilation |

| | | | | | |
|---|---|---|---|---|---|
| Zone 1 : Air-conditioned zone | PRESIDENTIAL DECREE 412/93 | E.1 (1) | Useful surface area | 53,05 | $m^2$ |

Primary energy demand and performance indices

| Service | Qp,nren [kWh]. | Qp,ren [kWh]. | Qp,tot [kWh]. | EP,nren [kWh/m$^2$] | EP,ren [kWh/m$^2$] | EP,tot [kWh/m$^2$] |
|---|---|---|---|---|---|---|
| Heating | 2517 | 5238 | 7754 | 47,44 | 98,73 | 146,17 |
| Domestic hot water | 647 | 1530 | 2177 | 12,19 | 28,84 | 41,03 |
| Cooling | 6257 | 1508 | 7765 | 117,95 | 28,43 | 146,37 |
| Ventilation | 0 | 0 | 0 | 0,00 | 0,00 | 0,00 |
| TOTAL | 9420 | 8276 | 17696 | 177,58 | 156,00 | 333,57 |

Energy carriers and $CO_2$

| Energy carrier | Consumption | U.M. | $CO_2$ [kg/year]. | Services |
|---|---|---|---|---|
| Electricity | 4831 | kWhel/year | 2222 | Heating, Hot water, Cooling, Ventilation |

### 18.4.8 Thermal solar panels

# THERMAL SOLAR PANELS
## calculation according to UNI/TS 11300-4

Building : Residential Unit

| | | |
|---|---|---|
| Total number of solar collectors | 1 | |
| Total opening surface of collectors | 3,00 | $m^2$ |
| Annual electricity consumption | 130 | kWh |
| Percentage coverage for domestic water | 63,1 | % |
| Heating coverage percentage | 3,7 | % |

Domestic hot water service

| Month | $QW_{,solar}$ [kWh]. | $Qp_W$ with solar [kWh]. | $Qp_W$ without solar [kWh]. | $\%_{cop,W}$ [%] |
|---|---|---|---|---|
| January | 10 | 101 | 107 | 7,6 |
| February | 29 | 77 | 94 | 23,7 |
| March | 94 | 47 | 87 | 69,8 |
| April | 113 | 34 | 73 | 86,8 |
| May | 135 | 30 | 63 | 99,7 |
| June | 131 | 32 | 54 | 100,0 |
| July | 135 | 35 | 53 | 100,0 |
| August | 135 | 31 | 55 | 100,0 |
| September | 115 | 31 | 59 | 87,7 |
| October | 78 | 48 | 74 | 58,0 |
| November | 18 | 81 | 89 | 14,0 |
| December | 9 | 100 | 106 | 6,6 |
| TOTALS | 1002 | 647 | 914 | 63,1 |

Symbol legend

| | |
|---|---|
| $QW_{,solar}$ | Solar panel hot water production |
| $Qp_W$ with solar | Primary energy demand for domestic water, with solar thermal contribution |
| $Qp_W$ without solar | Primary energy demand for domestic water, without solar thermal contribution |
| $\%_{cop,W}$ | Percentage of solar coverage compared to the energy output requirement of hot water generation |

## Heating service

| Month | $QH_{,solar}$ [kWh]. | $Qp_H$ with solar [kWh]. | $Qp_H$ without solar [kWh]. | $\%_{cop,H}$ [%] |
|---|---|---|---|---|
| January | 4 | 854 | 848 | 0,7 |
| February | 30 | 496 | 502 | 15,9 |
| March | 0 | 171 | 171 | 0,0 |
| April | 0 | 54 | 54 | 0,0 |
| May | 0 | 0 | 0 | 0,0 |
| June | 0 | 0 | 0 | 0,0 |
| July | 0 | 0 | 0 | 0,0 |
| August | 0 | 0 | 0 | 0,0 |
| September | 0 | 0 | 0 | 0,0 |
| October | 0 | 20 | 20 | 0,0 |
| November | 15 | 233 | 234 | 9,4 |
| December | 0 | 689 | 682 | 0,0 |
| TOTALS | 49 | 2517 | 2510 | 3,7 |

Symbol legend

| | |
|---|---|
| $QH_{,solar}$ | Productivity solar heating panels |
| $Qp_H$ with solar | Primary energy demand for heating, with solar thermal contribution |
| $Qp_H$ without solar | Primary energy demand for heating, without solar thermal contribution |
| $\%_{cop,H}$ | Percentage of solar coverage compared to energy output from heating generation |

### Subfield description: New subfield

Panel positioning data

| | | | |
|---|---|---|---|
| Orientation with respect to the south | $\gamma$ | 0,0 | ° |
| Inclination in relation to the horizontal plane | $\beta$ | 18,0 | ° |
| Reflectivity coefficient (albedo) | | 0,26 | |

Shading (none)

Solar collector data

| | | |
|---|---|---|
| Solar collector used | PARADIGMA ITALIA SRL/Aqua Plasma/Aqua Plasma 19/34 | |
| Number of solar collectors | 1 | |
| Single collector opening surface | 3,00 | $m^2$ |
| Gross surface area of individual collector | 3,35 | $m^2$ |

| | | | |
|---|---|---|---|
| Collector efficiency at zero losses | $\eta_0$ | 0,69 | |
| Linear loss coefficient | $a_1$ | 0,613 | W/m $K^2$ |
| Quadratic loss coefficient | $a_2$ | 0,003 | W/m $K^{22}$ |
| Coefficient of change angle of incidence | IAM | 0,90 | |

Solar productivity of the subfield

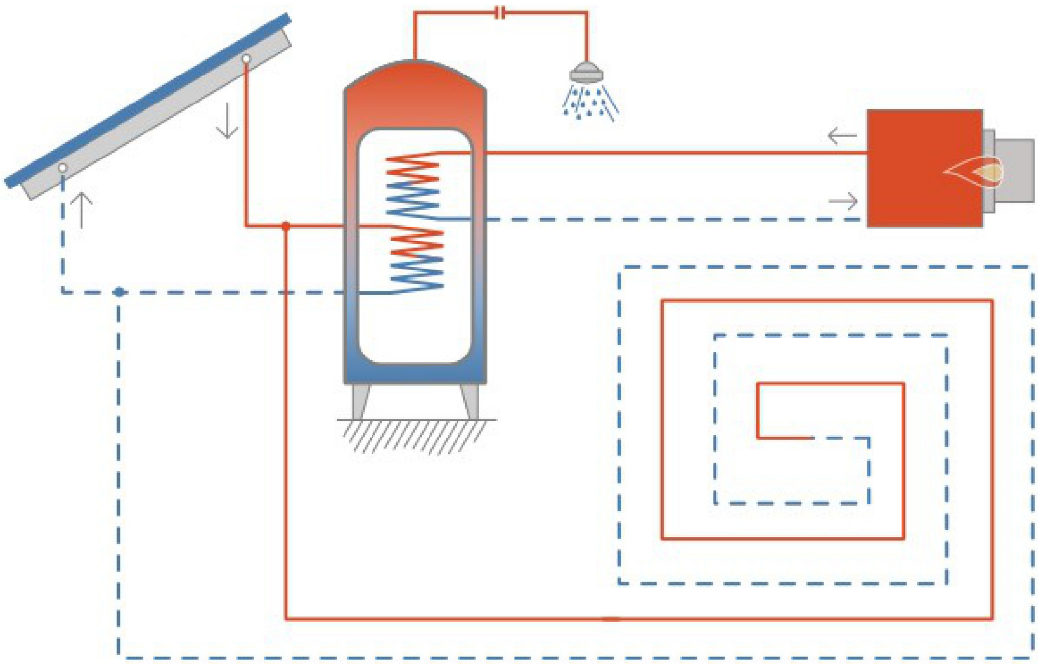
| Month | Ir [kWh/m ]$^2$ | $QW_{,solar}$ [kWh]. | $QH_{,solar}$ [kWh]. |
|---|---|---|---|
| January | 55,5 | 10 | 4 |
| February | 75,9 | 29 | 30 |
| March | 117,8 | 94 | 0 |
| April | 143,1 | 113 | 0 |
| May | 170,9 | 135 | 0 |
| June | 186,7 | 131 | 0 |
| July | 205,3 | 135 | 0 |
| August | 181,1 | 135 | 0 |
| September | 136,1 | 115 | 0 |
| October | 94,3 | 78 | 0 |
| November | 51,8 | 18 | 15 |
| December | 49,0 | 9 | 0 |
| TOTALS | 1467,5 | 1002 | 49 |

Symbol legend

| | |
|---|---|
| $I_r$ | Solar radiation captured by solar collectors |
| $QW_{,solar}$ | Productivity solar panels for domestic water |
| $QH_{,solar}$ | Productivity solar heating panels |

Plant configuration

| | |
|---|---|
| Domestic hot water storage | thermal integration |
| Heating accumulation | absent |



Solar storage data - Domestic hot water

| | | | |
|---|---|---|---|
| Nominal volume | | 200,00 | litres |
| Fraction heated by the auxiliary generator | | 0,60 | |

Distribution data

| | | | |
|---|---|---|---|
| Piping loss coefficient | | 6,50 | W/K |
| Circuit efficiency | $\eta_{loop}$ | 0,80 | |

Electrical requirements

| | | |
|---|---|---|
| Power absorbed by auxiliaries | 65 | W |
| Annual operating hours | 2000 | h |

Solar thermal system details

| Month | Ir [kWh] | Qsolar [kWh] | ηsolar [%] | $QW_{,aux,solar}$ [kWh]. | $QH_{,aux,solar}$ [kWh]. |
|---|---|---|---|---|---|
| January | 167 | 14 | 8,4 | 1 | 4 |
| February | 228 | 59 | 26,0 | 3 | 4 |
| March | 353 | 94 | 26,7 | 10 | 0 |
| April | 429 | 113 | 26,4 | 13 | 0 |
| May | 513 | 135 | 26,2 | 15 | 0 |
| June | 560 | 131 | 23,3 | 17 | 0 |
| July | 616 | 135 | 21,9 | 18 | 0 |
| August | 543 | 135 | 24,9 | 16 | 0 |
| September | 408 | 115 | 28,1 | 12 | 0 |
| October | 283 | 78 | 27,7 | 8 | 0 |
| November | 155 | 34 | 21,8 | 2 | 3 |
| December | 147 | 9 | 6,1 | 1 | 3 |
| TOTALS | 4402 | 1052 | 24 | 116,0 | 14 |

Symbol legend

| | |
|---|---|
| $I_r$ | Solar radiation captured by the solar system |
| Qsolar | Solar panel productivity |
| ηsolar | Solar system efficiency |
| $QW_{,aux,solar}$ | Electricity consumption for domestic water |
| $QH_{,aux,solar}$ | Electricity consumption for heating |

Solar system sizing details (domestic water service)

| Month | Total output [kWh] | Domestic water load [kWh] | Surplus [kWh] | % load coverage [%]. |
|---|---|---|---|---|
| January | 10 | 135 | 0 | 7,6 |
| February | 29 | 122 | 0 | 23,7 |
| March | 94 | 135 | 0 | 69,8 |
| April | 113 | 131 | 0 | 86,8 |
| May | 135 | 135 | 0 | 99,7 |
| June | 143 | 131 | 13 | 100,0 |
| July | 154 | 135 | 19 | 100,0 |
| August | 143 | 135 | 8 | 100,0 |
| September | 115 | 131 | 0 | 87,7 |
| October | 78 | 135 | 0 | 58,0 |
| November | 18 | 131 | 0 | 14,0 |
| December | 9 | 135 | 0 | 6,6 |
| TOTALS | 1042 | 1590 | 40 | 63,1 |

Solar system dimensioning details (heating service)

| Month | Total output [kWh] | Heating load [kWh] | Surplus [kWh] | % load coverage [%]. |
|---|---|---|---|---|
| January | 4 | 518 | 0 | 0,7 |
| February | 30 | 191 | 0 | 15,9 |
| March | 0 | 0 | 0 | 0,0 |
| April | 0 | 0 | 0 | 0,0 |
| May | 0 | 0 | 0 | 0,0 |
| June | 0 | 0 | 0 | 0,0 |
| July | 0 | 0 | 0 | 0,0 |
| August | 0 | 0 | 0 | 0,0 |
| September | 0 | 0 | 0 | 0,0 |
| October | 0 | 0 | 0 | 0,0 |
| November | 15 | 165 | 0 | 9,4 |
| December | 0 | 479 | 0 | 0,0 |
| TOTALS | 49 | 1353 | 0 | 3,7 |

### 18.4.9 Photovoltaic solar panels

# PHOTOVOLTAIC SOLAR PANELS

Building : Residential Unit

| | | |
|---|---|---|
| Electricity from photovoltaic production | 0 | kWh/year |
| Total electrical requirement of the system | 4831 | kWh/year |
| Percentage coverage of annual requirements | 0,0 | % |
| Electricity from the grid | 4831 | kWh/year |
| Electricity produced and not consumed | 0 | kWh/year |

Monthly electrical energy of the photovoltaic system ($Eel_{,pv,out}$)

| Month | $Eel_{,pv,out}$ [kWh]. |
|---|---|
| January | 0 |
| February | 0 |
| March | 0 |
| April | 0 |
| May | 0 |
| June | 0 |
| July | 0 |
| August | 0 |
| September | 0 |
| October | 0 |
| November | 0 |
| December | 0 |
| TOTALS | 0 |

| Subfield description: New subfield |
|---|

| | | | |
|---|---|---|---|
| Module used | SUNPOWER/Modules SPR/SPR-210-BLK | | |
| Number of modules | | 3 | |
| Total peak power | | 900 | Wp |
| Total useful surface area | | 3,39 | $m^2$ |
| <u>Individual module data</u> | | | |
| Peak power | $W_{pv}$ | 300 | Wp |
| Useful surface area | $A_{pv}$ | 1,13 | $m^2$ |
| Efficiency factor | $f_{pv}$ | 0,00 | - |
| Nominal efficiency | | 0,27 | - |

<u>Panel positioning data</u>

| | | | |
|---|---|---|---|
| Orientation with respect to the south | $\gamma$ | 0,0 | ° |
| Inclination in relation to the horizontal plane | $\beta$ | 18,0 | ° |
| Reflectivity coefficient (albedo) | | 0,26 | |

Shading (none)

<u>Monthly electrical energy produced by the subfield</u>

| Month | $E_{pv}$ [kWh/m ]$^2$ | $Eel,_{pv,out}$ [kWh]. |
|---|---|---|
| January | 55,5 | 0 |
| February | 75,9 | 0 |
| March | 117,8 | 0 |
| April | 143,1 | 0 |
| May | 170,9 | 0 |
| June | 186,7 | 0 |
| July | 205,3 | 0 |
| August | 181,1 | 0 |
| September | 136,1 | 0 |
| October | 94,3 | 0 |
| November | 51,8 | 0 |
| December | 49,0 | 0 |
| TOTALS | 1467,5 | 0 |

<u>Symbol legend</u>

$E_{pv}$ Monthly solar irradiation incident on the photovoltaic system

$Eel,_{pv,out}$ Monthly electrical energy produced by the subfield

To verify the building characteristics and their compliance with what are the characteristics a building that is considered NZEB (which have been reported in the chapter on NZEBs), we must first consider some boundary characteristics.

First and foremost, the climatic parameters of the location. Those are

| | | |
|---|---|---|
| Day Degrees (of the settlement area, determined according to Presidential Decree 412/93) | 2617 | GG |
| Minimum design outdoor temperature (according to UNI 5364 and subsequent updates) | -8,0 | °C |
| Maximum summer design outdoor air temperature according to standard | 31,0 | °C |

Then we have to consider the technical and construction data of the building and its structures.

a) Winter conditioning

| Description | V [m]$^3$ | S [m]$^2$ | S/V [1/m] | On [m]$^2$ | $\theta_{int}$ [°C] | $\varphi_{int}$ [%] |
|---|---|---|---|---|---|---|
| Air-conditioned zone | 254,23 | 245,12 | 0,96 | 53,05 | 20,0 | 65,0 |
| Housing Unit | 254,23 | 245,12 | 0,96 | 53,05 | 20,0 | 65,0 |

Presence of heat metering system: [x]

b) Summer air conditioning

| Description | V [m]$^3$ | S [m]$^2$ | S/V [1/m] | On [m]$^2$ | $\theta_{int}$ [°C] | $\varphi_{int}$ [%] |
|---|---|---|---|---|---|---|
| Air-conditioned zone | 254,23 | 245,12 | - | 53,05 | 26,0 | 51,3 |
| Housing Unit | 254,23 | 245,12 | - | 53,05 | 26,0 | 51,3 |

Presence of heat metering system: [x]

| | |
|---|---|
| V | Volume of the habitable or habitable parts of the building gross of the enclosing structures |
| S | External surface delimiting the volume |
| S/V | Building form ratio |
| At | Useful building surface |
| $\theta_{int}$ | Internal temperature design value |
| $\varphi_{int}$ | Indoor relative humidity design value |

For the characteristics of the envelope components we already saw them in the chapter of the envelope and so they will not be reported here.

## 5. PLANT DATA

5.1 Thermal Installations

Technological system intended for winter and/or summer air-conditioning services and/or domestic hot water production, regardless of the energy vector used.

a) Plant description

Type

Heat exchangers, supplied by the hot and chilled fluids produced in the existing thermal power plant

Generation systems

Heat pump

Temperature control systems

Adjustment adapted to experimental needs (basic, maintenance of "standard" comfort conditions is ensured by means of thermostats , room probes servo-assisted valves acting on the supply temperature of radiant circuits

Thermal energy metering systems

Direct metering by means of direct-reading flow meters, probes, and calculation unit

Heat carrier distribution systems

multilayer piping

Forced ventilation systems: types

Air handling unit q,max=800m3/h

Thermal storage systems: types

No.2 tanks for energy storage and higher inertia

Hot water production and distribution systems

Heat pump

Chemical conditioning treatment for water, standard UNI 8065: [x]

Presence of a safety filter: [x]

b) Power generator specifications

Installation of a domestic hot water volume meter: [x]

Installation of a water make-up volume meter: [x]

| | | | |
|---|---|---|---|
| Zone | Housing Unit | Quantity | 1 |
| Service | Heating, ventilation and hot water | Heat transfer fluid | Water |
| Generator type | Heat pump | Fuel | Electricity |
| Make - model | DAIKIN/ALTHERMA 3 H/EPGA11 | | |
| Cold source type | Outside air | | |

Useful heat output in heating mode 14,6 kW

Coefficient of Performance (COP) 4,73

Reference temperatures:

Cold source 7,0 °C Hot source 35,0 °C

| | | | |
|---|---|---|---|
| Zone | Housing Unit | Quantity | 1 |
| Service | Cooling | Heat transfer fluid | Water |
| Generator type | Heat pump | Fuel | Electricity |
| Make - model | DAIKIN/ALTHERMA 3 H/EPGA11 | | |
| Cold source type | Water | | |

Useful heat output in cooling 10,7 kW

Energy Efficiency Index (EER) 2,74

Reference temperatures:

Cold source 7,0 °C Hot source 31,0 °C

For thermal systems with or without domestic hot water production, which use, in whole or in part, machines other than those described above, the performance of these machines is provided using the physical characteristics of the specific equipment, and applying, where applicable, the technical standards in force.

c) Specifications for heating system regulation systems

Type of conduct envisaged [X] continuous with night-time dimming [] intermittent

More according to experimental needs

Type of summer management planned:

Presence of remote management system

Remote management system of the heating system, if any (summary description of functions)

Local network, for remote control and measurement acquisition in the experimental area

d) Heat metering devices in individual building units (only for centralised systems)

Air conditioning use

| | |
|---|---|
| Make - model | Meter |
| Number of luminaires | 1 |
| Brief description of the device | Volumeter meter with electronic integrator and probes on flow and return. |

Domestic hot water use

| | |
|---|---|
| Make - model | Meter |
| Number of luminaires | 1 |
| Brief description of the device | Volumeter meter with electronic integrator and probes on flow and return. |

Summer air-conditioning use

| | |
|---|---|
| Make - model | Meter |
| Number of luminaires | 1 |
| Brief description of the device | Volumeter meter with electronic integrator and probes on flow and return. |

e) Thermal energy supply terminals

| Type of terminals | Number of luminaires | Nominal heat output [W] |
|---|---|---|
| Radiant panels | 1 | 5000 |

g) Water treatment systems (type of treatment)

Safety filter and chemical conditioning for both plant water and domestic water

h) Thermal insulation specifications of the distribution network

| Network Description | Type of insulation | $\lambda_{is}$ [W/mK] | $Sp_{is}$ [mm] |
|---|---|---|---|
| multilayer pipe | Closed cell organic foam materials | 0.040 | 40 |

$\lambda_{is}$ Thermal conductivity of insulation material

$Sp_{is}$ Thickness of insulation material

i) Specifications of the circulation pump(s)

| | | | WORKING POINT | | |
|---|---|---|---|---|---|
| Qty | Circuit | Make - model – speed | G [kg/h] | ΔP [daPa] | $W_{aux}$ [W] |
| 0 | Main | Circulation pump with inverter | 10000 | 3920 | 250 |

G Circulation pump flow rate

ΔP Circulation pump head

$W_{aux}$ Circulation pump power consumption

5.2 Photovoltaic systems

Description and technical features

There is a 3kWp photovoltaic system serving the unit's heating and air conditioning consumers.

5.3 Solar thermal systems

Description and technical features

There is a solar panel serving the unit for domestic hot water utility

## 6. MAIN RESULTS OF CALCULATIONS

Building: Housing Unit

[] It is hereby declared that the building that is the subject of this report can be defined as a 'nearly zero-energy building' as the following are simultaneously fulfilled
- All the requirements set out in letter b), paragraph 2, of paragraph 3.3 of the decree referred to in Article 4, paragraph 1 of Legislative Decree 192/2005, according to the values in force from 1 January 2019 for public buildings and from 1 January 2021 for all other buildings;
- Obligations to integrate renewable sources in compliance with the minimum principles of Annex 3, paragraph 2 of Legislative Decree No. 199 of 8 November 2021.

a) Building envelope and air exchange

Thermal characteristics of opaque building envelope components

| Code | Description | U transmittance [W/m$^2$ K]. | Average transmittance [W/m$^2$ K]. |
|---|---|---|---|
| M1 | Exterior Wall | 0,133 | 0,116 |
| M2 | Wall U | 0,159 | 0,151 |
| P1 | G 40cm | 0,186 | 0,178 |
| S1 | Roof | 0,163 | 0,146 |
| S2 | Green Roof | 0,183 | 0,158 |

Thermal characteristics of opaque partitions and structures in non-air-conditioned rooms

| Code | Description | Average transmittance [W/m$^2$ K]. | Limit value [W/m$^2$ K]. | Verificatio n |
|---|---|---|---|---|

Hygrometric characteristics of opaque building envelope components

| Code | Description | Surface condensation | Interstitial condensation |
|---|---|---|---|
| M1 | Exterior Wall | Positive | Positive |
| M2 | Wall U | Positive | Positive |
| P1 | G 40cm | Positive | Positive |
| S1 | Roof | Positive | Positive |
| S2 | Green Roof | Positive | Positive |

Hygrometric characteristics of thermal bridges

| Code | Description | Critical temperature check |
|---|---|---|
| Z1 | GF - Wall - Floor to floor | Positive |
| Z2 | C - Angle between walls | Positive |
| Z3 | IF - Wall - Intermediate floor | Positive |
| Z4 | R - Wall - Roof | Positive |

Surface mass characteristics Ms and periodic transmittance YIE of opaque components

| Code | Description | Ms [kg/m ]$^2$ | YIE [W/m$^2$ K]. |
|---|---|---|---|

| | | | |
|---|---|---|---|
| M1 | Exterior Wall | 4 | 0,047 |
| S1 | Roof | 73 | 0,048 |
| S2 | Green Roof | 93 | 0,022 |

Thermal characteristics of glazed components

| Code | Description | Frame transmittance $U_w$ [W/m² K]. | Glass transmittance $U_g$ [W/m² K]. |
|---|---|---|---|
| W1 | Curtain Wall | 1,000 | 0,700 |
| W3 | 100x150 | 1,000 | 0,700 |
| W5 | 150x100 | 1,000 | 0,700 |
| W6 | 70x150 | 1,000 | 0,700 |
| W7 | 150x70 | 1,000 | 0,700 |
| W8 | 100x210 | 1,000 | 0,700 |

Number of air changes (24-hour average) - specify for different zones

| N. | Description | Design value [vol/h] | 24-hour average value [vol/h]. |
|---|---|---|---|
| 1 | Air-conditioned zone | 2,15 | 2,15 |

Replacement air flow rate (only in the case of controlled mechanical ventilation)

| Qty | Flow rate G [m³ /h]. | Flow rate $G_R$ [m /h]. ³ | $\eta_T$ [%]. |
|---|---|---|---|
| 1 | 383,8 | 383,8 | 90,0 |

G Air flow rate for controlled mechanical ventilation

$G_R$ Flow rate of circulating air through waste heat recovery equipment

$\eta_T$ Thermal efficiency of waste heat recovery equipment

b) Energy performance indices for winter and summer air conditioning, domestic hot water, ventilation and lighting

Determination of the following energy performance indices, expressed in kWh/m² per year, as defined in paragraph 3.3 of Annex 1 of the decree referred to in Article 4, paragraph 1 of Legislative Decree 192/2005, yields and parameters characterising energy efficiency

Method of calculation used (compulsory indication)

UNI/TS 11300 and related standards

Global average heat transfer coefficient for transmission per unit of dispersing surface area (UNI EN ISO 13789)

<u>Air-conditioned zone</u>

| | | |
|---|---|---|
| Dispersing surface S | 245,12 | m² |
| Design value $H'_T$ | 0,29 | W/m K² |
| Limit value (Table 10, Appendix A) $H'_{T,L}$ | 0,50 | W/m K² |
| Verification (positive/negative) | Positive | |

Summer equivalent solar area per unit of useful surface area

<u>Air-conditioned zone</u>

Useful surface $A_{sup}$ | 53,05 m$^2$

| | | |
|---|---|---|
| Useful surface $_{Asup}$ | 53,05 | m$^2$ |
| Project value $_{Asol,}$est/Asup $_{useful}$ | 0,02 | |
| Limit value (Tab. 11, Appendix A) ($_{Asol,}$est/Asup $_{useful}$)$_{limit}$ | 0,030 | |
| Verification (positive/negative) | Positive | |

Useful thermal performance index for winter air conditioning of the building

| | | |
|---|---|---|
| Project value $EP_{H,nd}$ | 36,81 | kWh/m$^2$ |
| EPH,$_{nd,limit}$ value | 82,88 | kWh/m$^2$ |
| Verification (positive/negative) | Positive | |

Useful thermal performance index for summer air conditioning of the building

| | | |
|---|---|---|
| Project value $EP_{C,nd}$ | 78,9 | kWh/m$^2$ |
| EPC $_{limit}$ value,$_{nd,limit}$ | 86,70 | kWh/m$^2$ |
| Verification (positive/negative) | Positive | |

Overall building energy performance index (Primary energy)

| | | |
|---|---|---|
| Energy performance for heating $EP_H$ | 146,17 | kWh/m$^2$ |
| Energy performance for domestic water $EP_W$ | 41,03 | kWh/m$^2$ |
| Energy performance for cooling $EP_C$ | 146,37 | kWh/m$^2$ |
| Energy performance per ventilation $EP_V$ | 0,00 | kWh/m$^2$ |
| Energy performance for lighting $EP_L$ | 0,00 | kWh/m$^2$ |
| Energy performance for services $EP_T$ | 0,00 | kWh/m$^2$ |
| Design value EPgl,$_{tot}$ | 333,57 | kWh/m$^2$ |
| Limit value EPgl,$_{tot,limit}$ | 539,36 | kWh/m$^2$ |
| Verification (positive/negative) | Positive | |

Overall building energy performance index (Primary non-renewable energy)

| | | |
|---|---|---|
| Project value $EP_{gl,nr}$ | 177,58 | kWh/m$^2$ |

›.1) Average seasonal plant efficiencies

| Description | Services | $\eta_g$ [%]. | $\eta_{g,amm}$ [%]. | Verification |
|---|---|---|---|---|
| Centralised | Heating | 35,7 | 33,3 | Positive |
| Centralised | Domestic hot water | 72,1 | 60,4 | Positive |
| Centralised | Cooling | 85,3 | 79,7 | Positive |

c) Renewable source installations for hot water production

| | | |
|---|---|---|
| Percentage coverage of annual requirements | 70,28 | % |

| | | |
|---|---|---|
| Minimum percentage of expected coverage | 60,00 | % |
| Verification (positive/negative) | Positive | |

(verification according to Legislative Decree No. 199 of 8 November 2021 - Annex 3)

d) Photovoltaic systems

| | | |
|---|---|---|
| Percentage coverage of annual requirements | 0,0 | % |
| Electricity demand from the grid | 4831 | $kWh_e$ |
| Electricity from local production | 0 | $kWh_e$ |
| Installed electrical power | 0,90 | kW |
| Required electrical power | 0,00 | kW |
| Verification (positive/negative) | Positive | |

(verification according to Legislative Decree No. 199 of 8 November 2021 - Annex 3)

Energy balance

| | | |
|---|---|---|
| Energy delivered or supplied $(E)_{del}$ | 3330 | kWh |
| Renewable energy $(Egl_{,ren})$ | 156,00 | $kWh/m^2$ |
| Exported energy $(E)_{exp}$ | 0 | kWh |
| Global annual primary energy demand $(Egl_{,tot})$ | 333,57 | $kWh/m^2$ |
| On-site renewable energy (electricity) | 0 | $kWh_e$ |
| On-site renewable energy (thermal) | 1092 | kWh |

e) Coverage from renewable sources

| | | |
|---|---|---|
| Percentage from renewable sources | 94 | % |
| Minimum percentage of expected coverage | 60,0 | % |
| Verification (positive/negative) | Positive | |

(verification according to Legislative Decree No. 199 of 8 November 2021 - Annex 3)

# 19 Statutory verifications

This chapter reports the verifications required for NZEB classification done on the envelope and system.

## 19.1 Boundary characteristics

To verify the building characteristics and their compliance with what are the characteristics a building that is considered NZEB (which have been reported in the chapter on NZEBs), we must first consider some boundary characteristics.

First and foremost, the climatic parameters of the location. Those are

| | | |
|---|---|---|
| Day Degrees (of the settlement area, determined according to Presidential Decree 412/93) | 2617 | GG |
| Minimum design outdoor temperature (according to UNI 5364 and subsequent updates) | -8,0 | °C |
| Maximum summer design outdoor air temperature according to standard | 31,0 | °C |

Then we have to consider the technical and construction data of the building and its structures.

a) Winter conditioning

| Description | V $[m]^3$ | S $[m]^2$ | S/V [1/m] | On $[m]^2$ | $\theta_{int}$ [°C] | $\varphi_{int}$ [%] |
|---|---|---|---|---|---|---|
| Air-conditioned zone | 254,23 | 245,12 | 0,96 | 53,05 | 20,0 | 65,0 |
| Housing Unit | 254,23 | 245,12 | 0,96 | 53,05 | 20,0 | 65,0 |

Presence of heat metering system: [x]

b) Summer air conditioning

| Description | V $[m]^3$ | S $[m]^2$ | S/V [1/m] | On $[m]^2$ | $\theta_{int}$ [°C] | $\varphi_{int}$ [%] |
|---|---|---|---|---|---|---|
| Air-conditioned zone | 254,23 | 245,12 | - | 53,05 | 26,0 | 51,3 |
| Housing Unit | 254,23 | 245,12 | - | 53,05 | 26,0 | 51,3 |

Presence of heat metering system: [x]

| | |
|---|---|
| V | Volume of the habitable or habitable parts of the building gross of the enclosing structures |
| S | External surface delimiting the volume |
| S/V | Building form ratio |
| At | Useful building surface |
| $\theta_{int}$ | Internal temperature design value |
| $\varphi_{int}$ | Indoor relative humidity design value |

For the characteristics of the envelope components we already saw them in the chapter of the envelope and so they will not be reported here.

## 5. PLANT DATA

5.1 Thermal Installations

Technological system intended for winter and/or summer air-conditioning services and/or domestic hot water production, regardless of the energy vector used.

a) Plant description

Type

Heat exchangers, supplied by the hot and chilled fluids produced in the existing thermal power plant

Generation systems

Heat pump

Temperature control systems

Adjustment adapted to experimental needs (basic, maintenance of "standard" comfort conditions is ensured by means of thermostats , room probes servo-assisted valves acting on the supply temperature of radiant circuits

Thermal energy metering systems

Direct metering by means of direct-reading flow meters, probes, and calculation unit

Heat carrier distribution systems

multilayer piping

Forced ventilation systems: types

Air handling unit q,max=800m3/h

Thermal storage systems: types

No.2 tanks for energy storage and higher inertia

Hot water production and distribution systems

Heat pump

Chemical conditioning treatment for water, standard UNI 8065: [x]

Presence of a safety filter: [x]

b) Power generator specifications

Installation of a domestic hot water volume meter: [x]

Installation of a water make-up volume meter: [x]

| | | | |
|---|---|---|---|
| Zone | Housing Unit | Quantity | 1 |
| Service | Heating, ventilation and hot water | Heat transfer fluid | Water |
| Generator type | Heat pump | Fuel | Electricity |
| Make - model | DAIKIN/ALTHERMA 3 H/EPGA11 | | |
| Cold source type | Outside air | | |

Useful heat output in heating mode 14,6 kW

Coefficient of Performance (COP) 4,73

Reference temperatures:

Cold source 7,0 °C Hot source 35,0 °C

| | | | |
|---|---|---|---|
| Zone | Housing Unit | Quantity | 1 |
| Service | Cooling | Heat transfer fluid | Water |
| Generator type | Heat pump | Fuel | Electricity |
| Make - model | DAIKIN/ALTHERMA 3 H/EPGA11 | | |
| Cold source type | Water | | |

Useful heat output in cooling 10,7 kW

Energy Efficiency Index (EER) 2,74

Reference temperatures:

Cold source 7,0 °C Hot source 31,0 °C

For thermal systems with or without domestic hot water production, which use, in whole or in part, machines other than those described above, the performance of these machines is provided using the physical characteristics of the specific equipment, and applying, where applicable, the technical standards in force.

c) Specifications for heating system regulation systems

Type of conduct envisaged [X] continuous with night-time dimming [] intermittent

More according to experimental needs

Type of summer management planned:

Presence of remote management system

Remote management system of the heating system, if any (summary description of functions)

Local network, for remote control and measurement acquisition in the experimental area

d) Heat metering devices in individual building units (only for centralised systems)

Air conditioning use

| | |
|---|---|
| Make - model | Meter |
| Number of luminaires | 1 |
| Brief description of the device | Volumeter meter with electronic integrator and probes on flow and return. |

Domestic hot water use

| | |
|---|---|
| Make - model | Meter |
| Number of luminaires | 1 |
| Brief description of the device | Volumeter meter with electronic integrator and probes on flow and return. |

Summer air-conditioning use

| | |
|---|---|
| Make - model | Meter |
| Number of luminaires | 1 |
| Brief description of the device | Volumeter meter with electronic integrator and probes on flow and return. |

e) Thermal energy supply terminals

| Type of terminals | Number of luminaires | Nominal heat output [W] |
|---|---|---|
| Radiant panels | 1 | 5000 |

g) Water treatment systems (type of treatment)

Safety filter and chemical conditioning for both plant water and domestic water

h) Thermal insulation specifications of the distribution network

| Network Description | Type of insulation | $\lambda_{is}$ [W/mK] | $Sp_{is}$ [mm] |
|---|---|---|---|
| multilayer pipe | Closed cell organic foam materials | 0.040 | 40 |

$\lambda_{is}$ Thermal conductivity of insulation material

$Sp_{is}$ Thickness of insulation material

i) Specifications of the circulation pump(s)

| | | | WORKING POINT | | |
|---|---|---|---|---|---|
| Qty | Circuit | Make - model – speed | G [kg/h] | ΔP [daPa] | $W_{aux}$ [W] |
| 0 | Main | Circulation pump with inverter | 10000 | 3920 | 250 |

G Circulation pump flow rate

ΔP Circulation pump head

$W_{aux}$ Circulation pump power consumption

5.2 Photovoltaic systems

Description and technical features

There is a 3kWp photovoltaic system serving the unit's heating and air conditioning consumers.

5.3 Solar thermal systems

Description and technical features

There is a solar panel serving the unit for domestic hot water utility

## 19.2 Envelope verifications

| Building: | Housing Unit |
|---|---|

[] It is hereby declared that the building that is the subject of this report can be defined as a 'nearly zero-energy building' as the following are simultaneously fulfilled
- All the requirements set out in letter b), paragraph 2, of paragraph 3.3 of the decree referred to in Article 4, paragraph 1 of Legislative Decree 192/2005, according to the values in force from 1 January 2019 for public buildings and from 1 January 2021 for all other buildings;
- Obligations to integrate renewable sources in compliance with the minimum principles of Annex 3, paragraph 2 of Legislative Decree No. 199 of 8 November 2021.

a) Building envelope and air exchange

Thermal characteristics of opaque building envelope components

| Code | Description | U transmittance [W/m² K]. | Average transmittance [W/m² K]. |
|---|---|---|---|
| M1 | Exterior Wall | 0,133 | 0,116 |
| M2 | Wall U | 0,159 | 0,151 |
| P1 | G 40cm | 0,186 | 0,178 |
| S1 | Roof | 0,163 | 0,146 |
| S2 | Green Roof | 0,183 | 0,158 |

Thermal characteristics of opaque partitions and structures in non-air-conditioned rooms

| Code | Description | Average transmittance [W/m² K]. | Limit value [W/m² K]. | Verification |
|---|---|---|---|---|

Hygrometric characteristics of opaque building envelope components

| Code | Description | Surface condensation | Interstitial condensation |
|---|---|---|---|
| M1 | Exterior Wall | Positive | Positive |
| M2 | Wall U | Positive | Positive |
| P1 | G 40cm | Positive | Positive |
| S1 | Roof | Positive | Positive |
| S2 | Green Roof | Positive | Positive |

Hygrometric characteristics of thermal bridges

| Code | Description | Critical temperature check |
|---|---|---|
| Z1 | GF - Wall - Floor to floor | Positive |
| Z2 | C - Angle between walls | Positive |
| Z3 | IF - Wall - Intermediate floor | Positive |
| Z4 | R - Wall - Roof | Positive |

Surface mass characteristics Ms and periodic transmittance YIE of opaque components

| Code | Description | Ms [kg/m ]² | YIE [W/m² K]. |
|---|---|---|---|

| | | | |
|---|---|---|---|
| M1 | Exterior Wall | 4 | 0,047 |
| S1 | Roof | 73 | 0,048 |
| S2 | Green Roof | 93 | 0,022 |

Thermal characteristics of glazed components

| Code | Description | Frame transmittance $U_w$ [W/m$^2$ K]. | Glass transmittance $U_g$ [W/m$^2$ K]. |
|---|---|---|---|
| W1 | Curtain Wall | 1,000 | 0,700 |
| W3 | 100x150 | 1,000 | 0,700 |
| W5 | 150x100 | 1,000 | 0,700 |
| W6 | 70x150 | 1,000 | 0,700 |
| W7 | 150x70 | 1,000 | 0,700 |
| W8 | 100x210 | 1,000 | 0,700 |

Number of air changes (24-hour average) - specify for different zones

| N. | Description | Design value [vol/h] | 24-hour average value [vol/h]. |
|---|---|---|---|
| 1 | Air-conditioned zone | 2,15 | 2,15 |

Replacement air flow rate (only in the case of controlled mechanical ventilation)

| Qty | Flow rate G [m$^3$ /h]. | Flow rate $G_R$ [m /h]. $^3$ | $\eta_T$ [%]. |
|---|---|---|---|
| 1 | 383,8 | 383,8 | 90,0 |

G Air flow rate for controlled mechanical ventilation

$G_R$ Flow rate of circulating air through waste heat recovery equipment

$\eta_T$ Thermal efficiency of waste heat recovery equipment

## 19.3 Plants verifications

b) Energy performance indices for winter and summer air conditioning, domestic hot water, ventilation and lighting

Determination of the following energy performance indices, expressed in kWh/m$^2$ per year, as defined in paragraph 3.3 of Annex 1 of the decree referred to in Article 4, paragraph 1 of Legislative Decree 192/2005, yields and parameters characterising energy efficiency

Method of calculation used (compulsory indication)

UNI/TS 11300 and related standards

---

Global average heat transfer coefficient for transmission per unit of dispersing surface area (UNI EN ISO 13789)

<u>Air-conditioned zone</u>

| | | |
|---|---|---|
| Dispersing surface S | 245,12 | m$^2$ |
| Design value $H'_T$ | 0,29 | W/m K$^2$ |
| Limit value (Table 10, Appendix A) $H'_{T,L}$ | 0,50 | W/m K$^2$ |
| Verification (positive/negative) | Positive | |

Summer equivalent solar area per unit of useful surface area

<u>Air-conditioned zone</u>

Useful surface $_{Asup}$ | 53,05 | $m^2$

| | | |
|---|---|---|
| Useful surface $_{Asup}$ | 53,05 | $m^2$ |
| Project value $_{Asol,}$est/Asup $_{useful}$ | 0,02 | |
| Limit value (Tab. 11, Appendix A) ($_{Asol,}$est/Asup $_{useful}$)$_{limit}$ | 0,030 | |
| Verification (positive/negative) | Positive | |

Useful thermal performance index for winter air conditioning of the building

| | | |
|---|---|---|
| Project value $EP_{H,nd}$ | 36,81 | $kWh/m^2$ |
| $EPH_{,nd,limit}$ value | 82,88 | $kWh/m^2$ |
| Verification (positive/negative) | Positive | |

Useful thermal performance index for summer air conditioning of the building

| | | |
|---|---|---|
| Project value $EP_{C,nd}$ | 78,9 | $kWh/m^2$ |
| EPC $_{limit}$ value$_{,nd,limit}$ | 86,70 | $kWh/m^2$ |
| Verification (positive/negative) | Positive | |

Overall building energy performance index (Primary energy)

| | | |
|---|---|---|
| Energy performance for heating $EP_H$ | 146,17 | $kWh/m^2$ |
| Energy performance for domestic water $EP_W$ | 41,03 | $kWh/m^2$ |
| Energy performance for cooling $EP_C$ | 146,37 | $kWh/m^2$ |
| Energy performance per ventilation $EP_V$ | 0,00 | $kWh/m^2$ |
| Energy performance for lighting $EP_L$ | 0,00 | $kWh/m^2$ |
| Energy performance for services $EP_T$ | 0,00 | $kWh/m^2$ |
| Design value $EPgl_{,tot}$ | 333,57 | $kWh/m^2$ |
| Limit value $EPgl_{,tot,limit}$ | 539,36 | $kWh/m^2$ |
| Verification (positive/negative) | Positive | |

Overall building energy performance index (Primary non-renewable energy)

| | | |
|---|---|---|
| Project value $EP_{gl,nr}$ | 177,58 | $kWh/m^2$ |

).1) Average seasonal plant efficiencies

| Description | Services | $\eta_g$ [%]. | $\eta_{g,amm}$ [%]. | Verification |
|---|---|---|---|---|
| Centralised | Heating | 35,7 | 33,3 | Positive |
| Centralised | Domestic hot water | 72,1 | 60,4 | Positive |
| Centralised | Cooling | 85,3 | 79,7 | Positive |

c) Renewable source installations for hot water production

| | | |
|---|---|---|
| Percentage coverage of annual requirements | 70,28 | % |

| | | |
|---|---|---|
| Minimum percentage of expected coverage | 60,00 | % |
| Verification (positive/negative) | Positive | |

(verification according to Legislative Decree No. 199 of 8 November 2021 - Annex 3)

d) Photovoltaic systems

| | | |
|---|---|---|
| Percentage coverage of annual requirements | 0,0 | % |
| Electricity demand from the grid | 4831 | $kWh_e$ |
| Electricity from local production | 0 | $kWh_e$ |
| Installed electrical power | 0,90 | kW |
| Required electrical power | 0,00 | kW |
| Verification (positive/negative) | Positive | |

(verification according to Legislative Decree No. 199 of 8 November 2021 - Annex 3)

Energy balance

| | | |
|---|---|---|
| Energy delivered or supplied $(E)_{del}$ | 3330 | kWh |
| Renewable energy $(Egl_{,ren})$ | 156,00 | $kWh/m^2$ |
| Exported energy $(E)_{exp}$ | 0 | kWh |
| Global annual primary energy demand $(Egl_{,tot})$ | 333,57 | $kWh/m^2$ |
| On-site renewable energy (electricity) | 0 | $kWh_e$ |
| On-site renewable energy (thermal) | 1092 | kWh |

e) Coverage from renewable sources

| | | |
|---|---|---|
| Percentage from renewable sources | 94 | % |
| Minimum percentage of expected coverage | 60,0 | % |
| Verification (positive/negative) | Positive | |

(verification according to Legislative Decree No. 199 of 8 November 2021 - Annex 3)

# 20 Thesis conclusions

At this point we came at the conclusion of the research and design work done as part of this thesis.
This paper started from a need: to study a new and better way of building that could fit within the landscape of climate change and energy crisis in which we are pouring with increasing urgency.

We started, as mentioned above, from the conceptual impetus given by the design for the ReGen Village, modeled as self-sufficient both energy and food-wise.
We then entered the Reinventing Cities competition, going to locate ourselves in a real and existing space, that of Bovisasca, on the outskirts of Milan.

In doing so, we were able not only to carry out a more accurate design, allowing us to create something that could blend with the existing context, but we also inserted ourselves in a context that was in full development, in an area where innovation and attention to the energy aspect of design are increasingly relevant.
We designed what turned out to be a minimal village that met the desired requirements and criteria, coming to define a small district that could be repurposed, hrough specific calibrations, in other locations, paying attention to the context of insertion and respectfully grasping the resources offered by the area.

We have seen what is the state of research regarding both self-sufficient villages and regarding materials and techniques that are more attentive to environmental sustainability, such as dry or prefabricated tencologies.
We have seen what are the legislations that control new constructions in Italy and Europe, and then we went to refer precisely to these when we carried out the verifications on the designed building.
We looked at the different energy certifications that a building can meet and when they can be awarded and why.

We studied the ReGen project, which was the driving force behind the idea for this thesis, saw how it worked and why it is innovative, what the underlying principles are and what the ultimate goals are, and made them our own, going on to reproduce them carefully calibrated for our case.

Different types of food production were studied, trying to understand the advantages and disadvantages of the different types in order to be able to consistently choose the ones to be applied in our project and also to give the possibility to anyone who wants to try to repropose such a solution, to adapt the choices to their own context.
We then went on to identify the site in which we have inserted ourselves and the development it is undergoing.
The Bovisa site in Milan is in fact undergoing strong redevelopment at the moment, which is precisely why it turned out to be the optimal site in which to develop the project in question.
Given the attention that the community is developing towards environmental sustainability in the area developing something green turns out to be the perfect stimulus for the site.

The designed buildings feature different attentions, from the facilities management part, developed according to the Smart Building concept, to the envelope design part, which follows the concepts of passive house, modularity and prefabrication, making use of the BIM methodology.

The last part of the work done involved managing the verification of the developed building, both from an energy and architectural point of view, going to verify the consistency of the building with the NZEB certification.

The work carried out therefore was very careful and developed, going to touch and develop almost all aspects of the design of a space such as a small self-sufficient district.
Going to study in detail the design of a housing unit both from the architecural and thermal point of view, developing a building that could best integrate into the context while responding to the increasingly pressing demand for a building modeling more attentive to the demands of a struggling environment.

With the work done, the goals set were thus achieved, going on to demonstrate how careful and conscious design can enable the development of the idea of NZEB, NZECB and smart buildings in the real world.
Allowing for the creation of a connected community based on the circular economy that can, on its own, be self-sufficient, and that can, if repeated and taken up and developed on a large scale, help the climate issue we find ourselves in.

URBAN PLANNING FRAMEWORK

General Framework - Scale 1:100.000
Bovisa District - Scale 1:5.000
General Plan of the Project - 1:2.000
Project Masterplan - Scale 1:200
Framing within MoLeCoLa's Masterplan - Out of Scale
3D view of the project - Out of Scale

Regenerating the urban outskirts
A self-sufficient ecovillage in Milan's Bovisasca area


Politecnico di Torino

Department of Structural,
Geotechnical and Building Engineering

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Marta Durantini

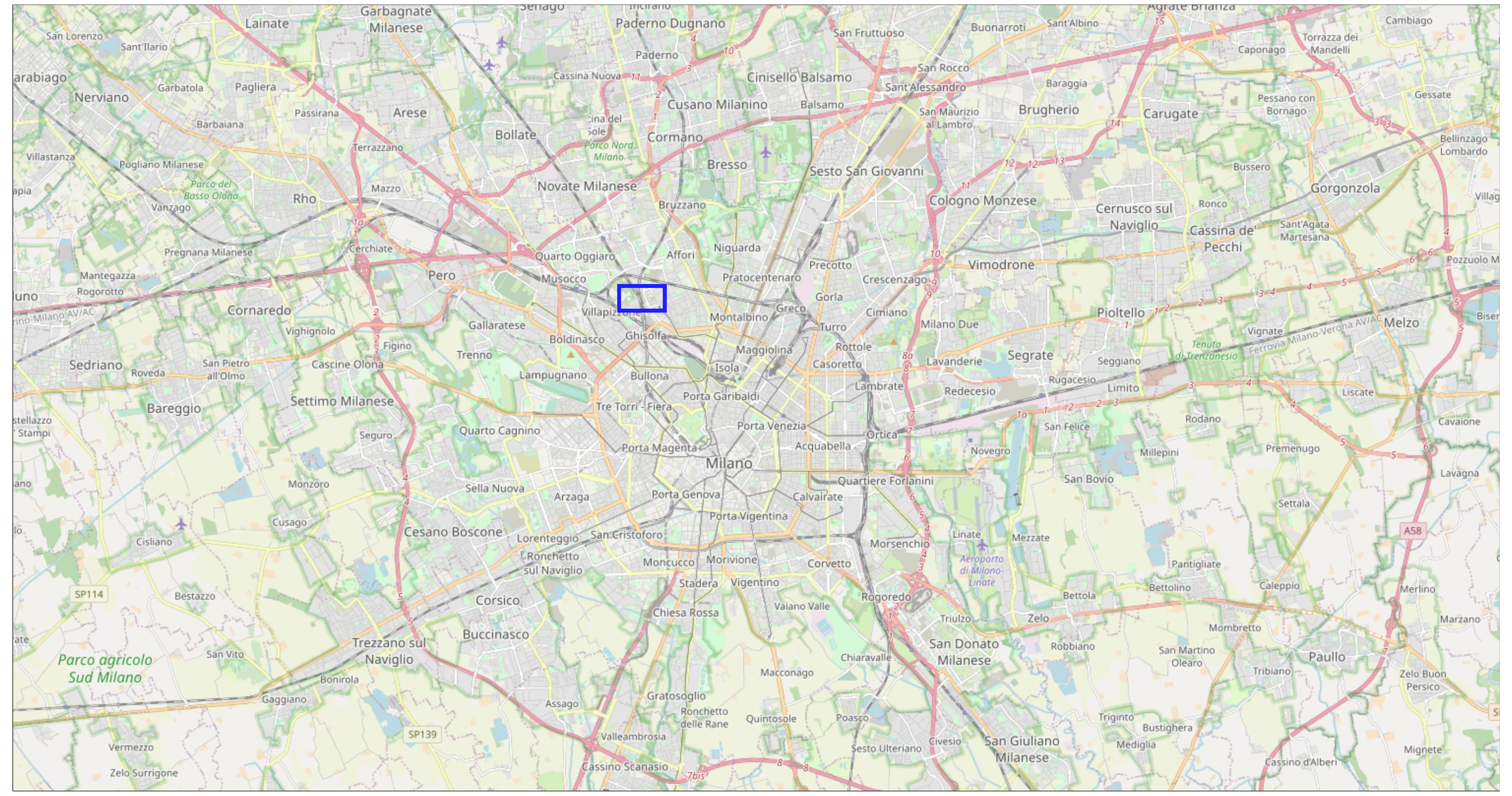
*Thesis Advisor:*
Marika Mangosio


*Date:*
05/04/2023

AA 2022/2023

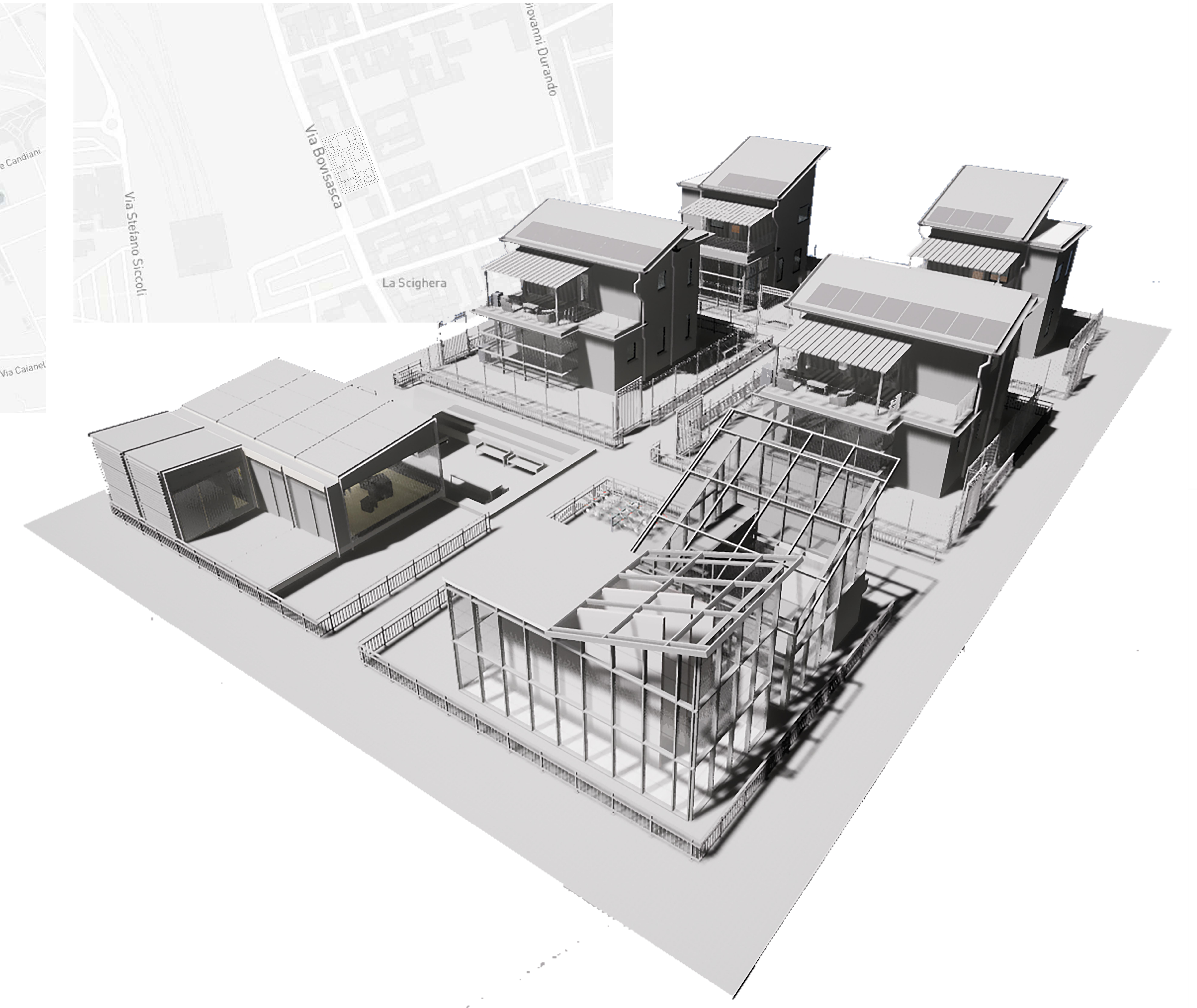
GENERAL FRAMEWORK

Scale 1:100.000



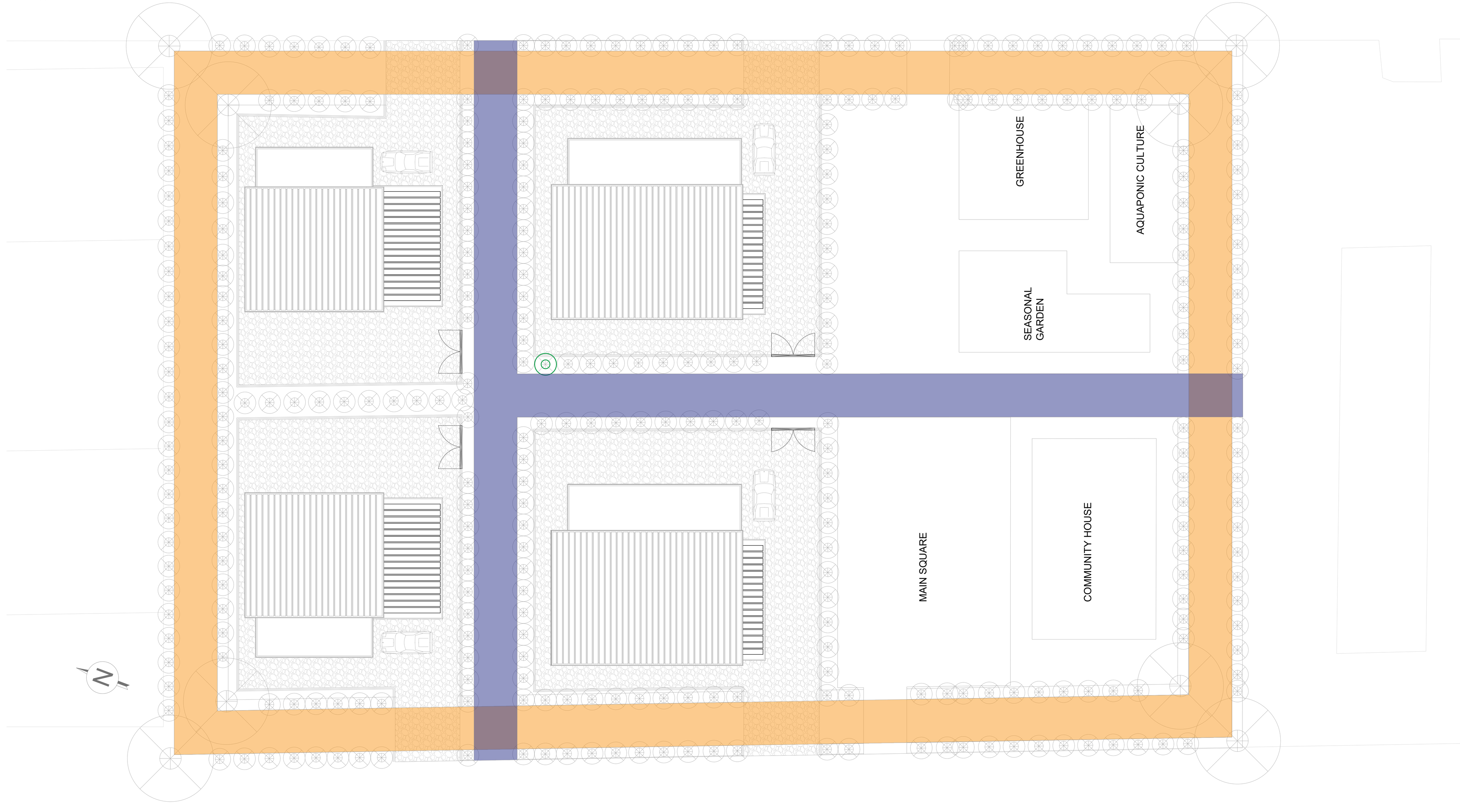

BOVISA DISTRICT

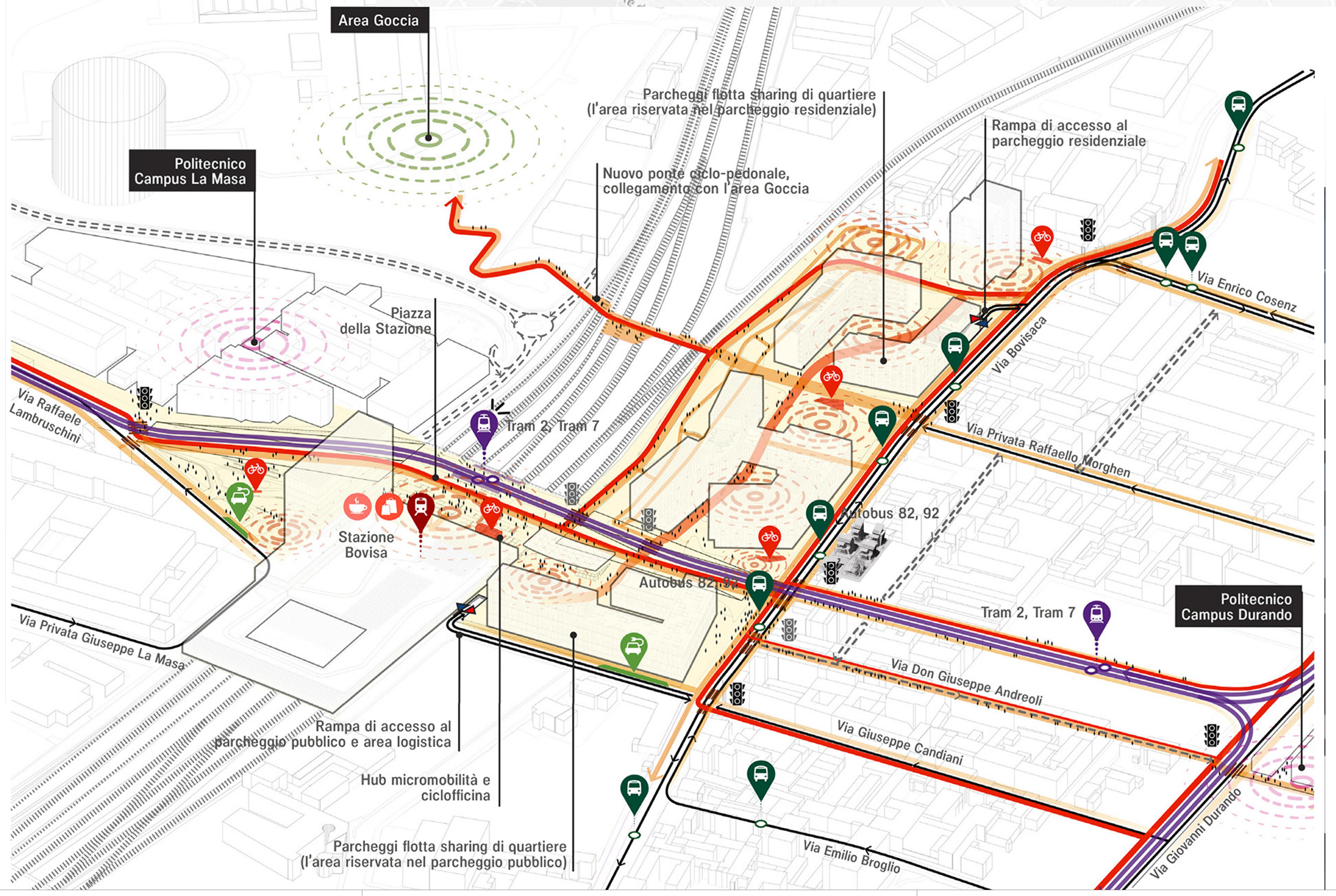

GENERAL PLAN OF THE PROJECT




PROJECT MASTERPLAN

Scale 1:200



# FLOOR PLANS

Scale 1:50
Ground Floor
First Floor
Roofing Floor

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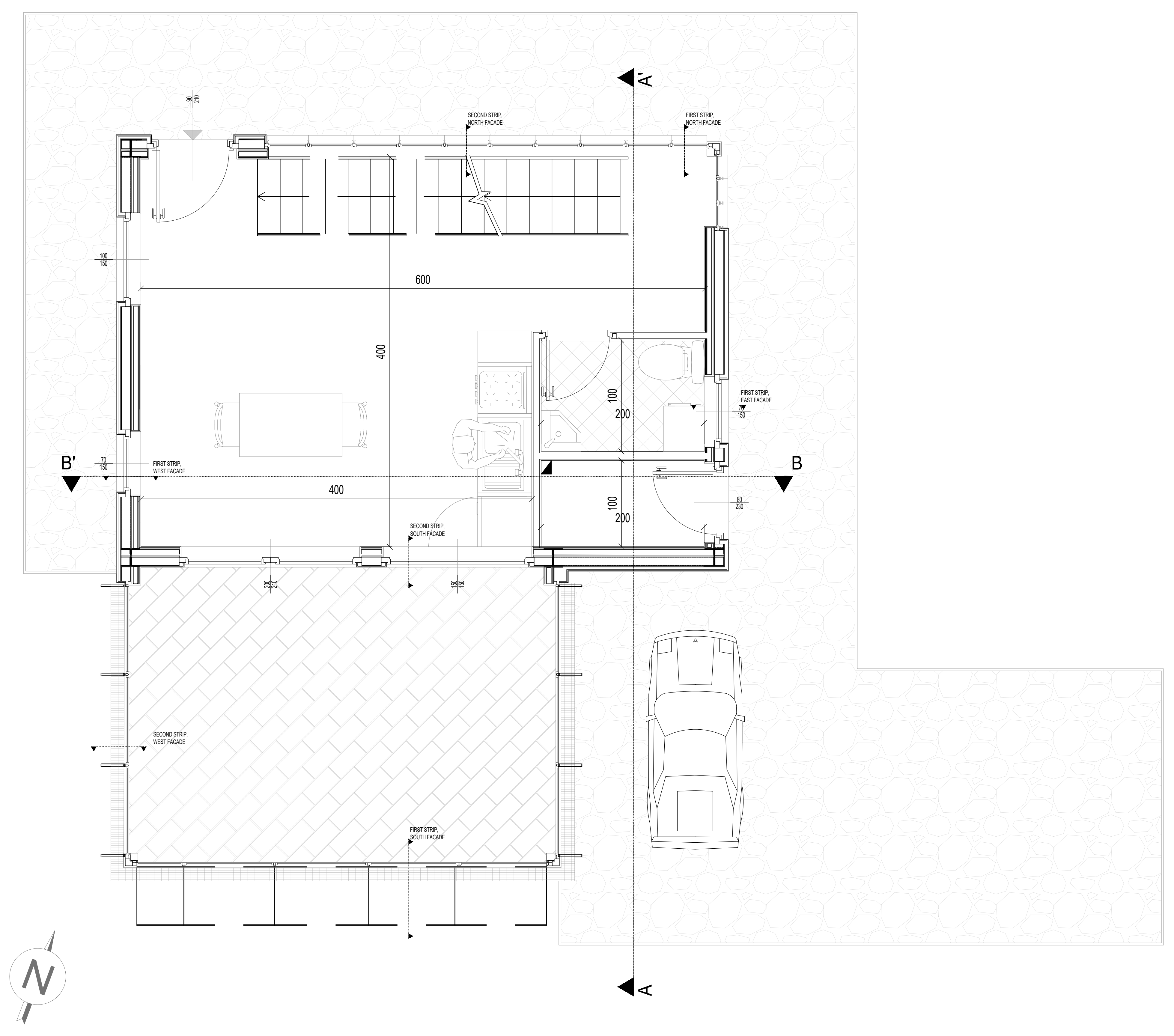
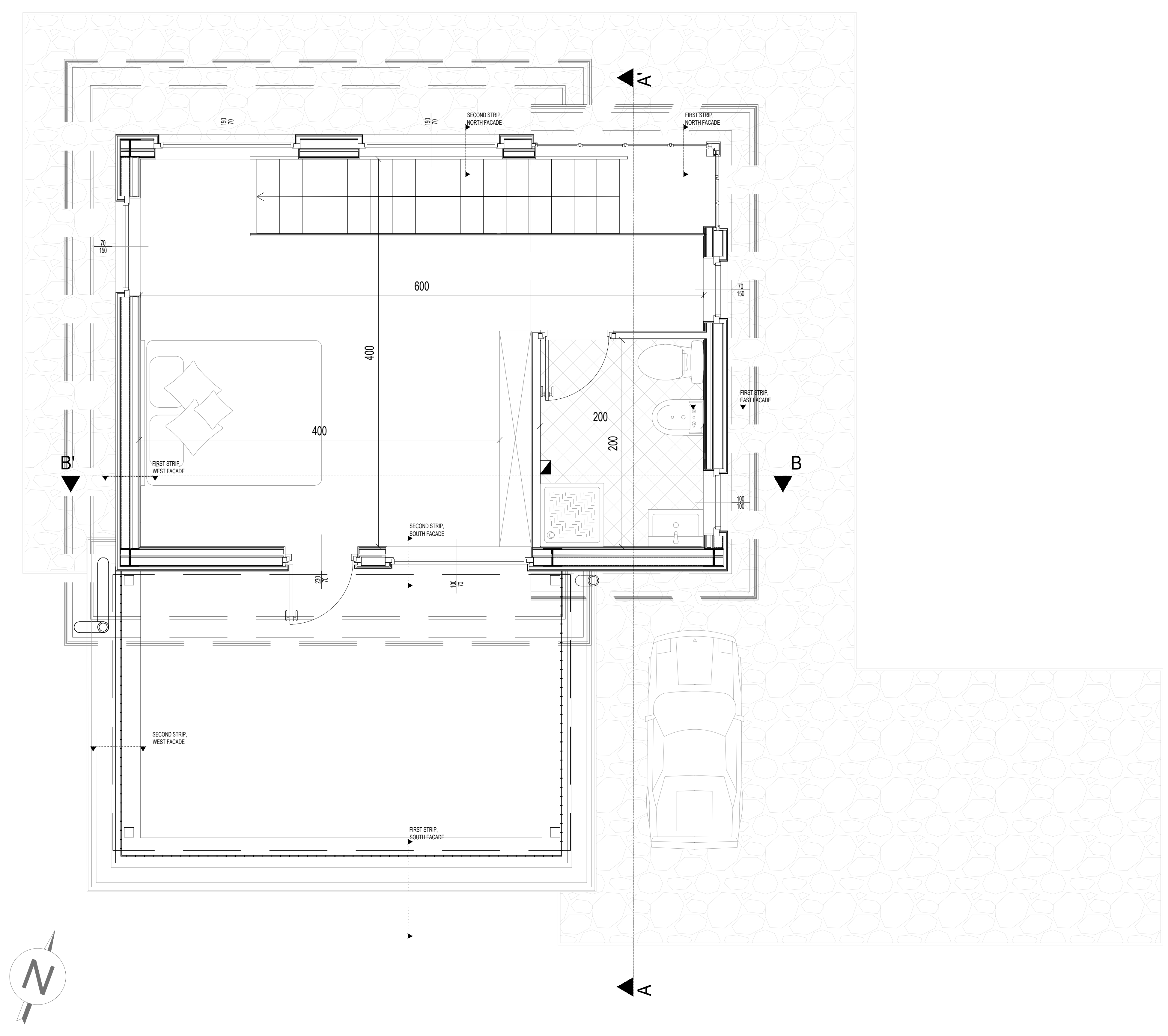
## GROUND FLOOR PLAN

Scale 1:50



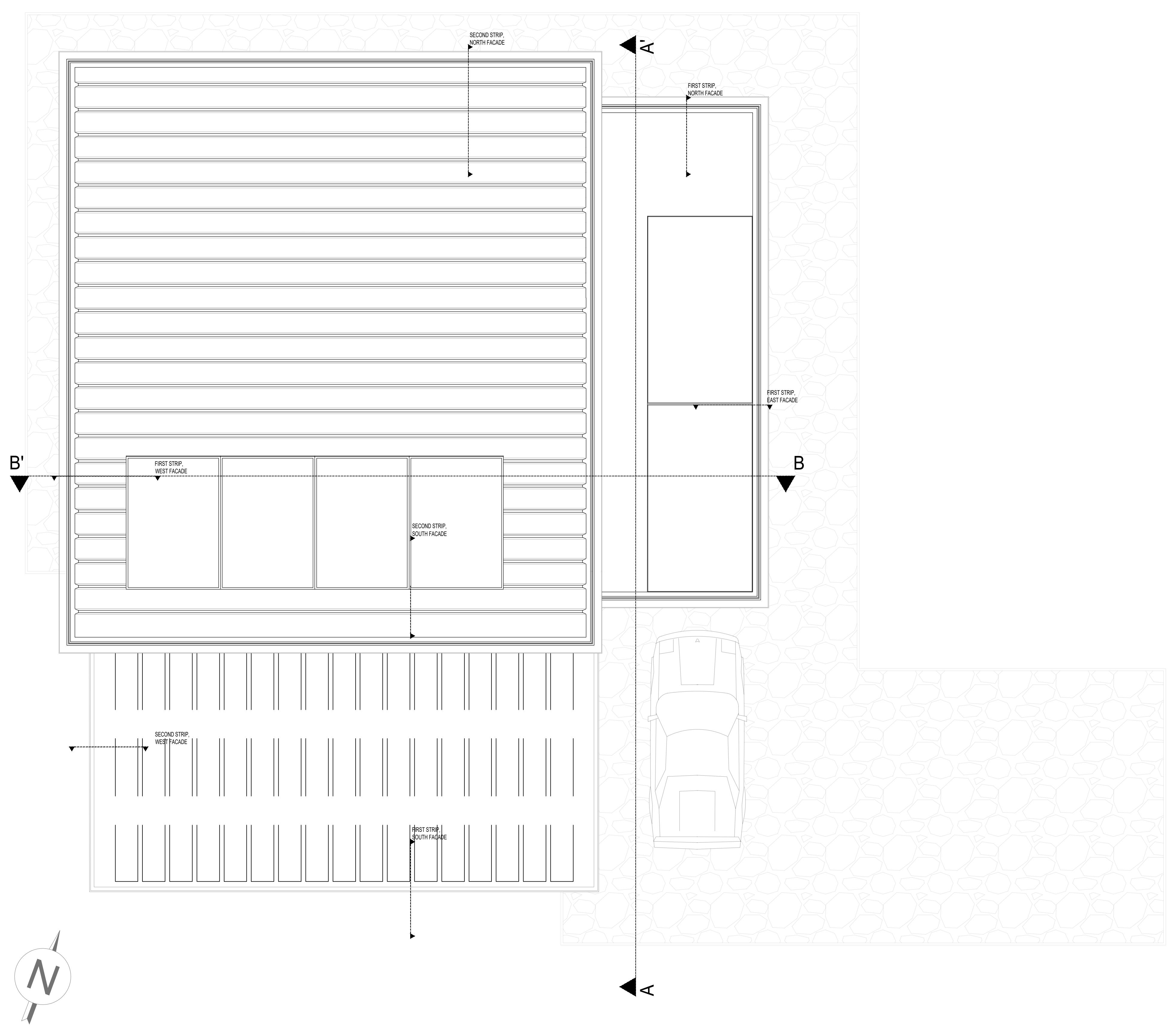

## FIRST FLOOR PLAN

Scale 1:50




## ROOFING FLOOR PLAN

Scale 1:50



# ELEVATIONS

Scale 1:50
East Elevation
North Elevation
West Elevation
South Elevation

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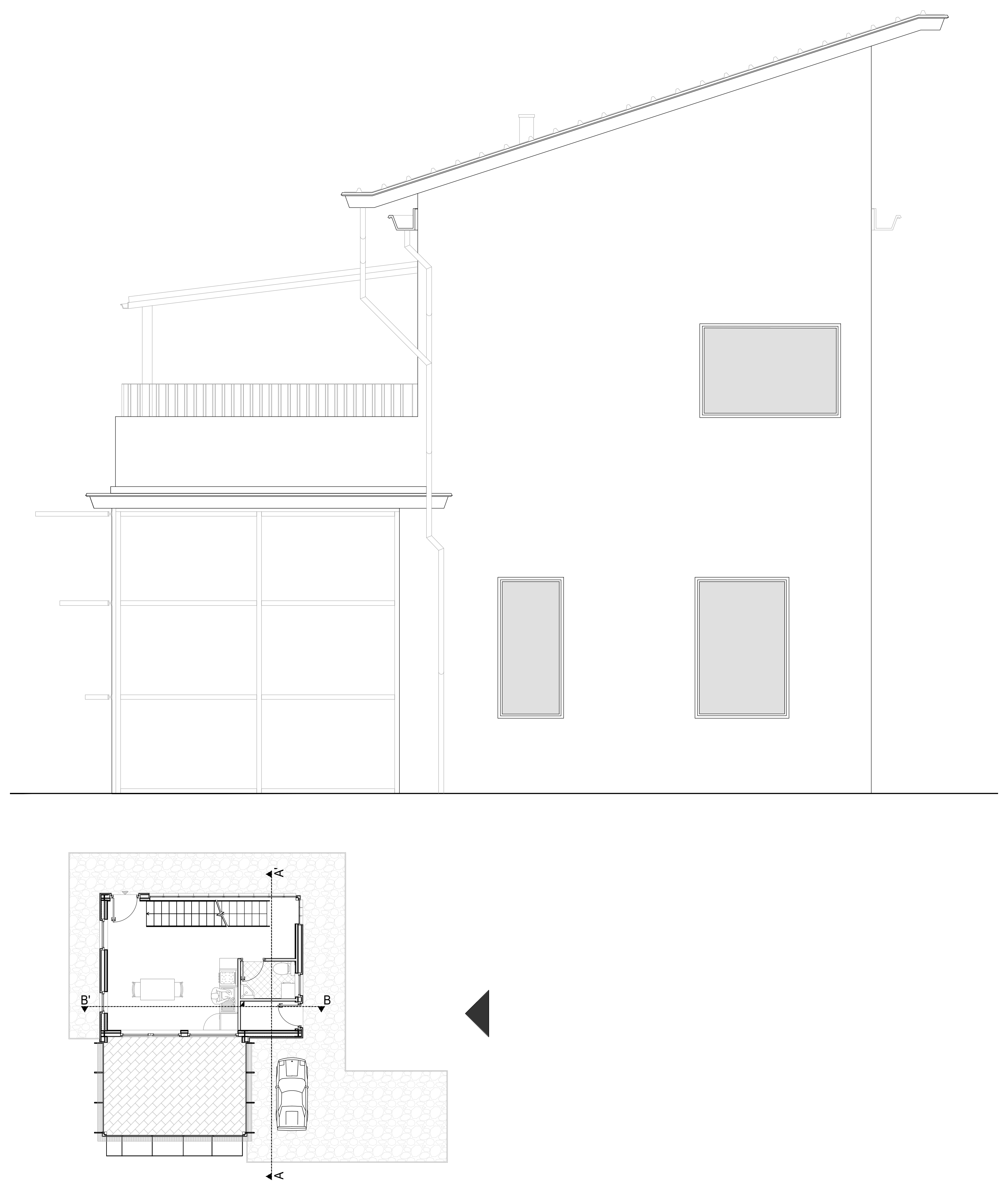
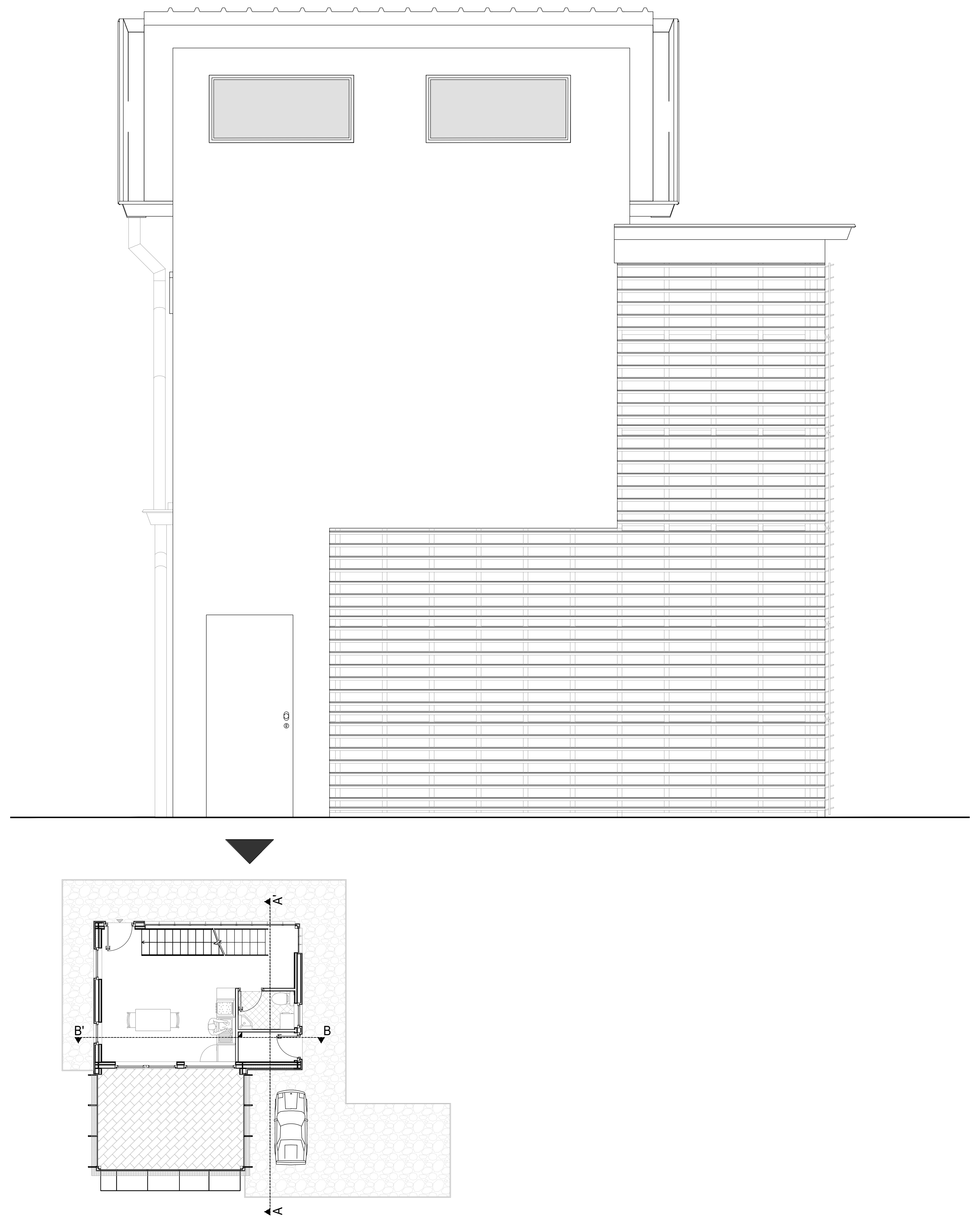
## EAST ELEVATION

Scale 1:50



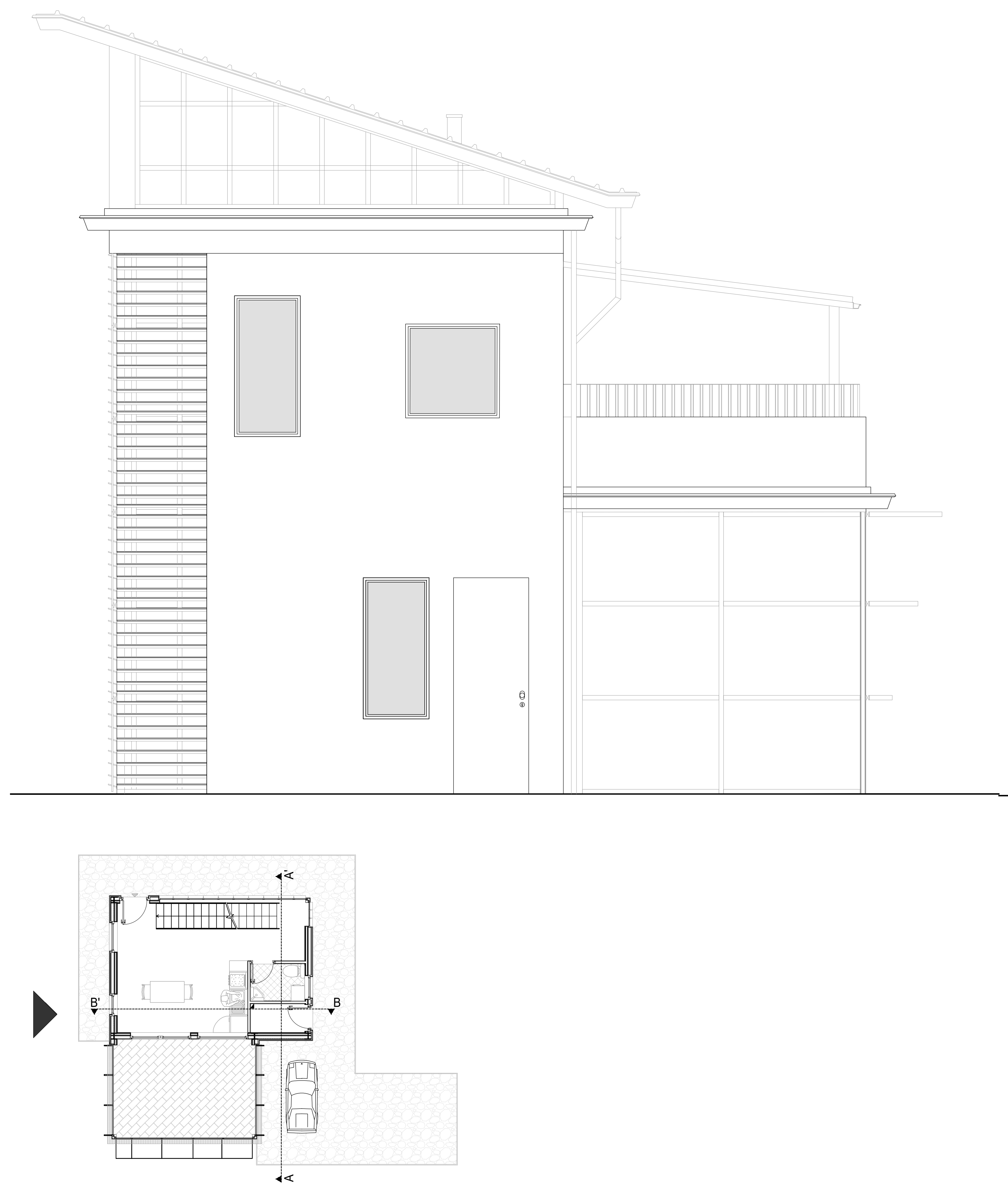
## NORTH ELEVATION

Scale 1:50



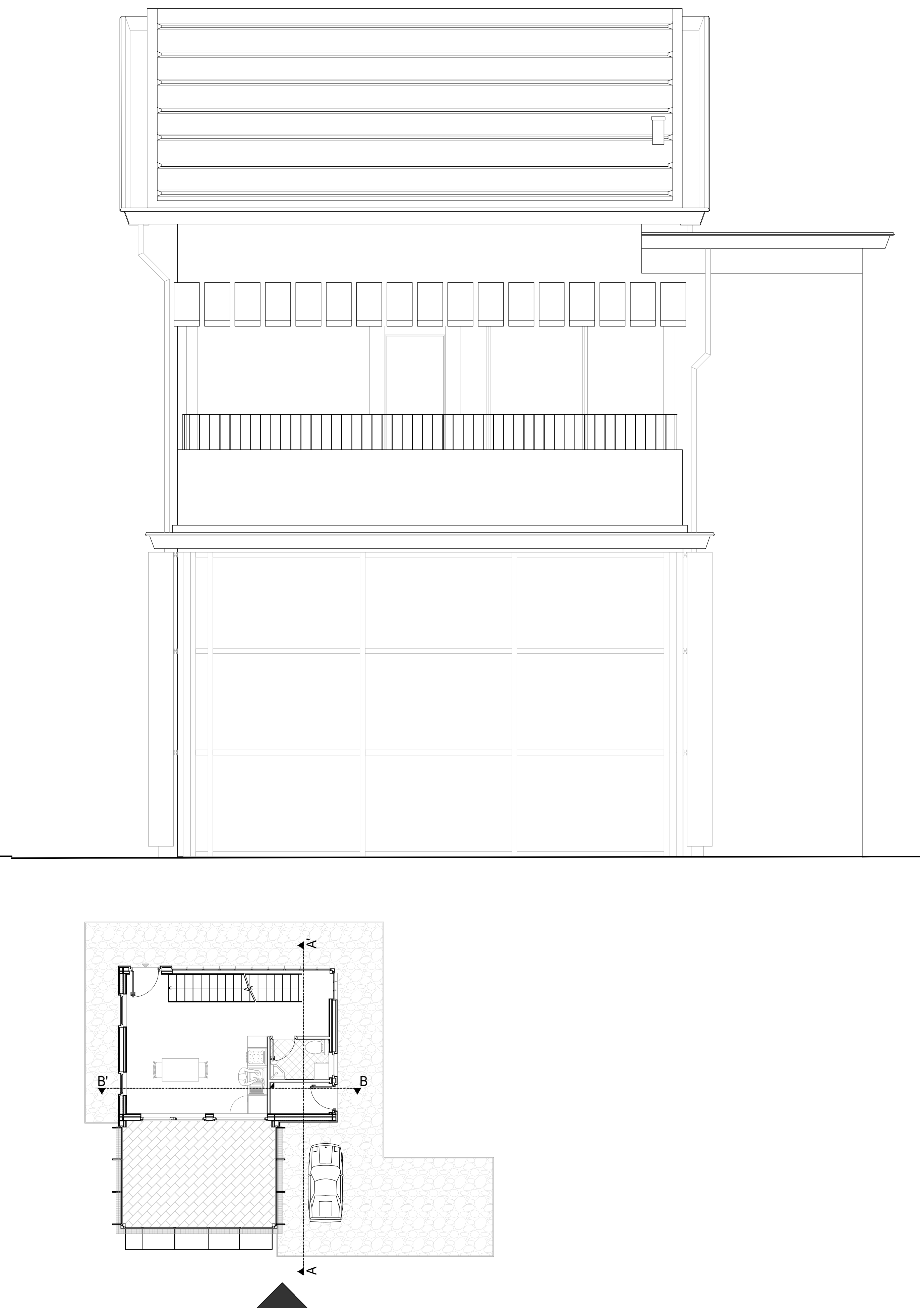
## WEST ELEVATION

Scale 1:50



## SOUTH ELEVATION

Scale 1:50



# SECTIONS

Scale 1:50
Section A-A'
Section B-B'

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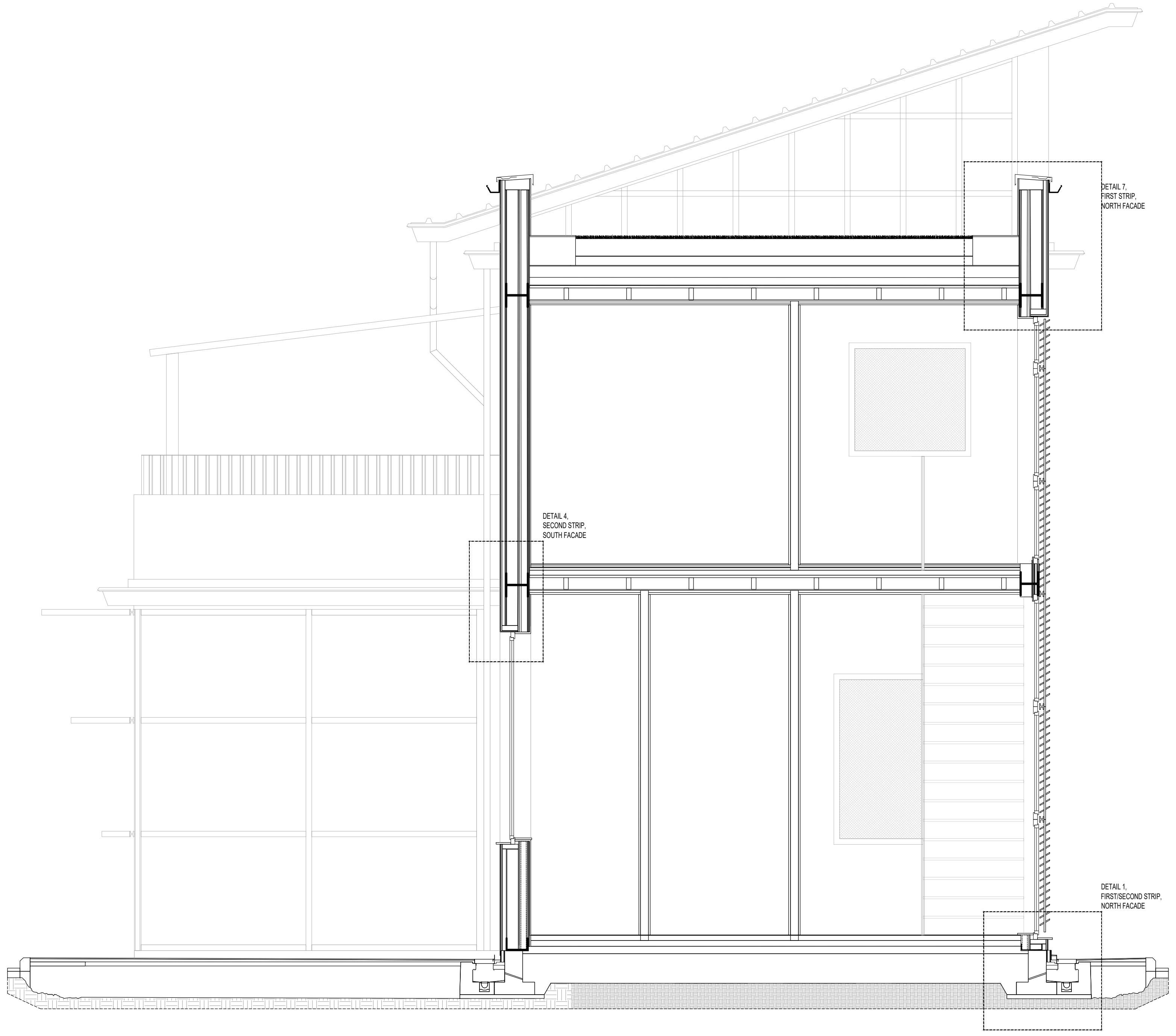
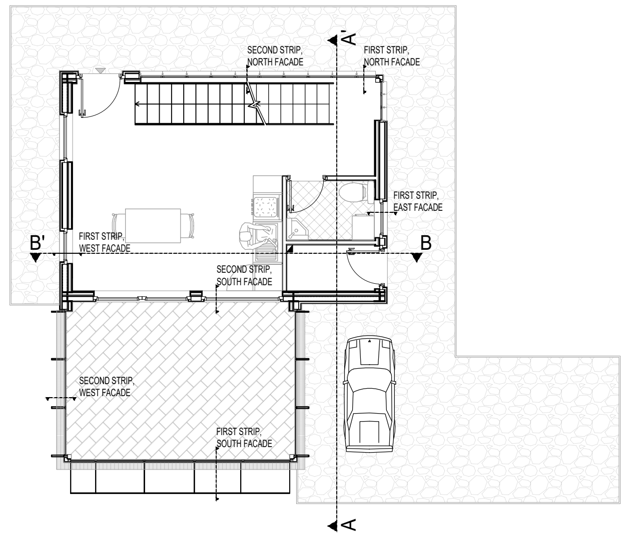
## SECTION A-A'

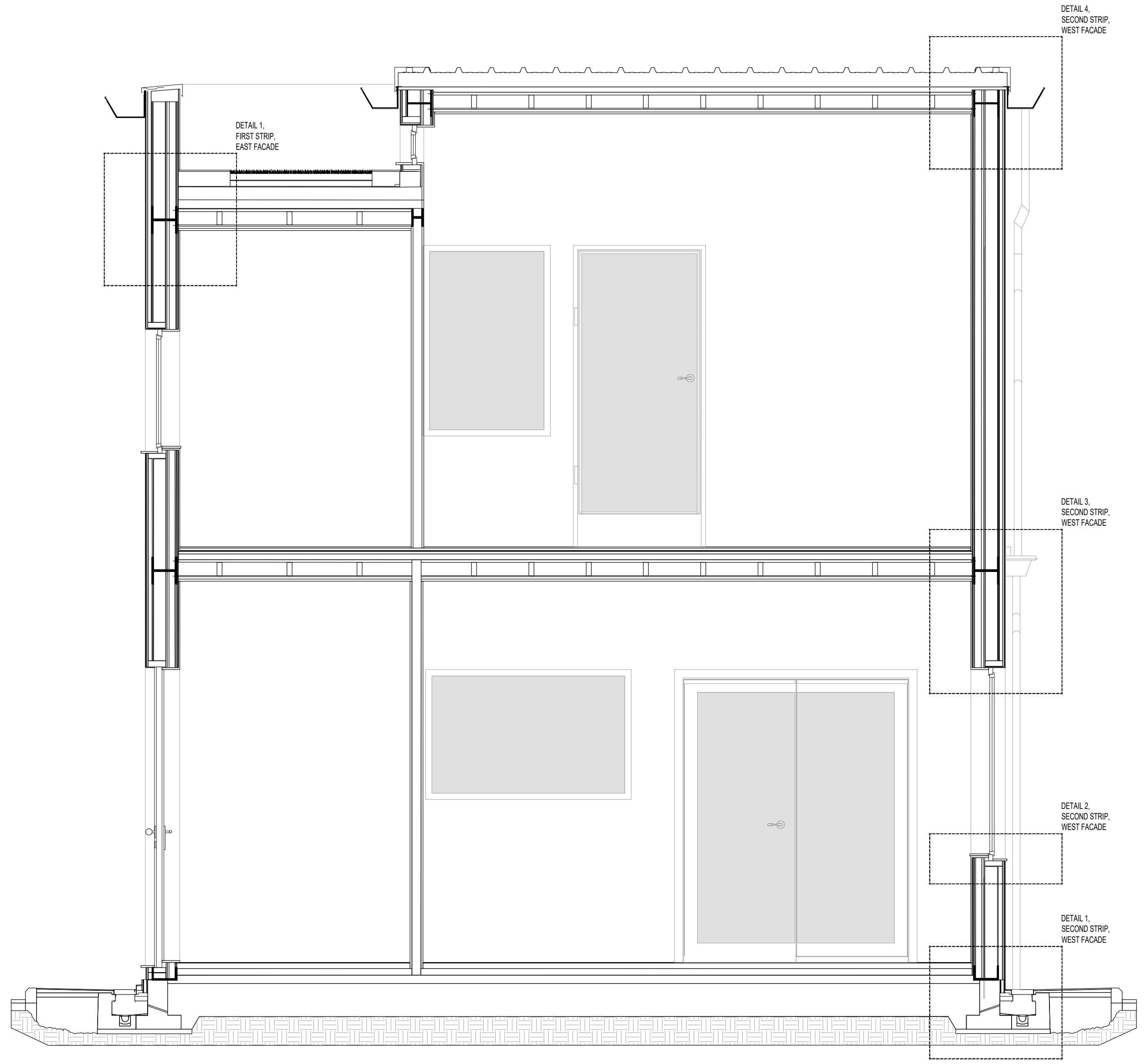
Scale 1:50

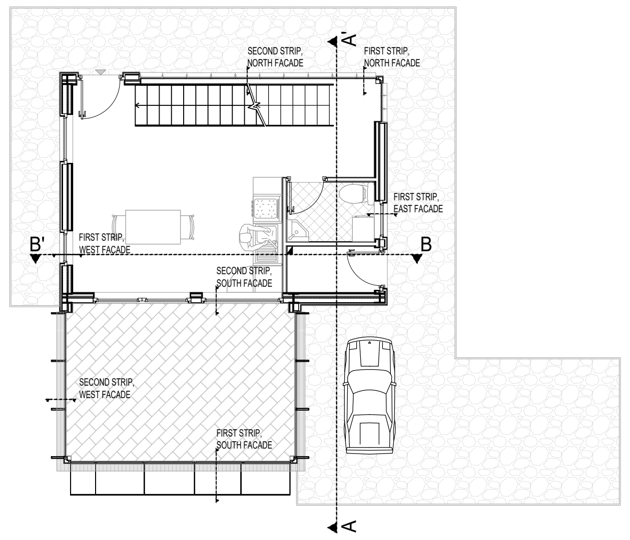





## SECTION B-B'

Scale 1:50





# NORTH FACADE DETAILS

Scale 1:5
First strip - Detail 7
First strip - Detail 6
First strip - Detail 1
Second strip - Detail 6
Second strip - Detail 5
Second strip - Detail 4
Second strip - Detail 3
Second strip - Detail 1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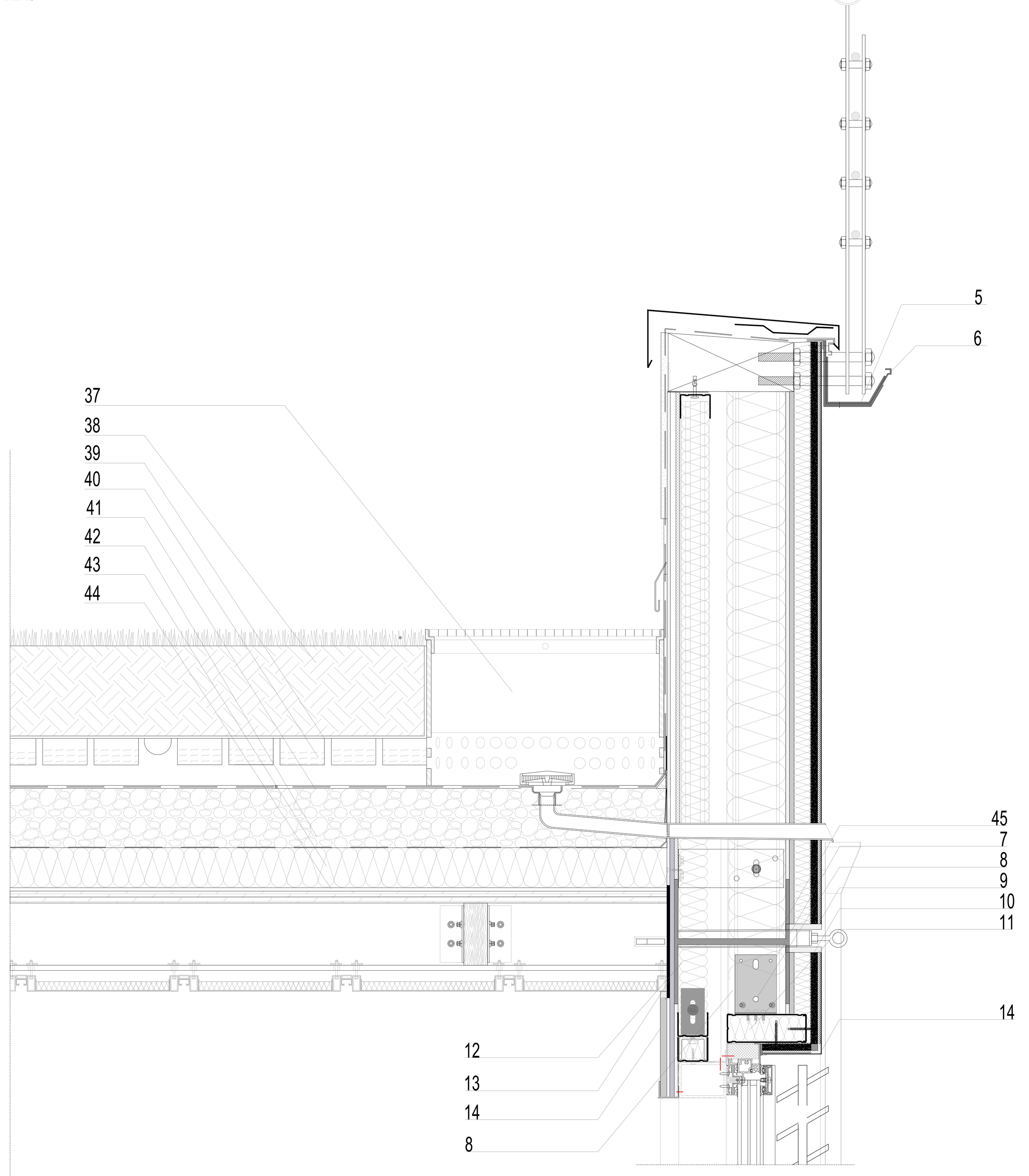
LEGENDA

1. Fixing screw
2. External steel flashing
3. Roof sandwich panel
4. Gasket
5. Eaves
6. Eaves support
7. Connection element
8. CW stud
9. Render system
10. Water barrier
11. Sealing tape
12. Connection profile
13. Vapour barrier
14. Corner protection
15. Setting block
16. Gypsum board
17. Insulation
18. Pavement layer
19. Fibre-reinforced radiant screed with high thermal conductivity
20. Floor heating system
21. Footfall acoustic mat
22. Slabs/Panels for dry subfloors
23. Dry subfloor
24. Boarding
25. Wood joist
26. Waterproof case
27. Reinforced concrete slab
28. Separator layer in non-woven fabric
29. Thermal insulation in expanded clay
30. Ground
31. Finishing element
32. Substrate
33. Prefabricated channel for water removal
34. Structural element (CLS)
35. Gravel for draining
36. Granite curb for protection and finishing
37. Gully in galvanized steel for water drainage
38. Potting soil with high water retention capacity
39. Sheet of non-woven propylene fabric, selective passage of roots
40. Pre-printed expanded polystirene panel
41. Double breathable sheath in high density polyethilene, waterproofing
42. Lightened concrete with polystyrene beads and electro-welded mesh
43. Panels of extruded polystyrene, insulation
44. Multilayer film with aluminium, vapour barrier
45. Scaffolding anchor, removable

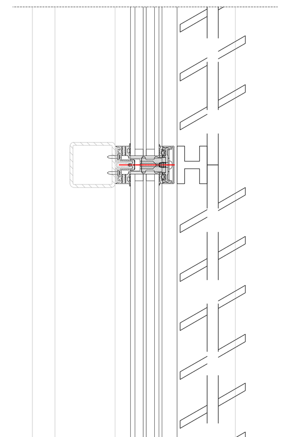
FIRST STRIP - DETAIL 7

Scale 1:5



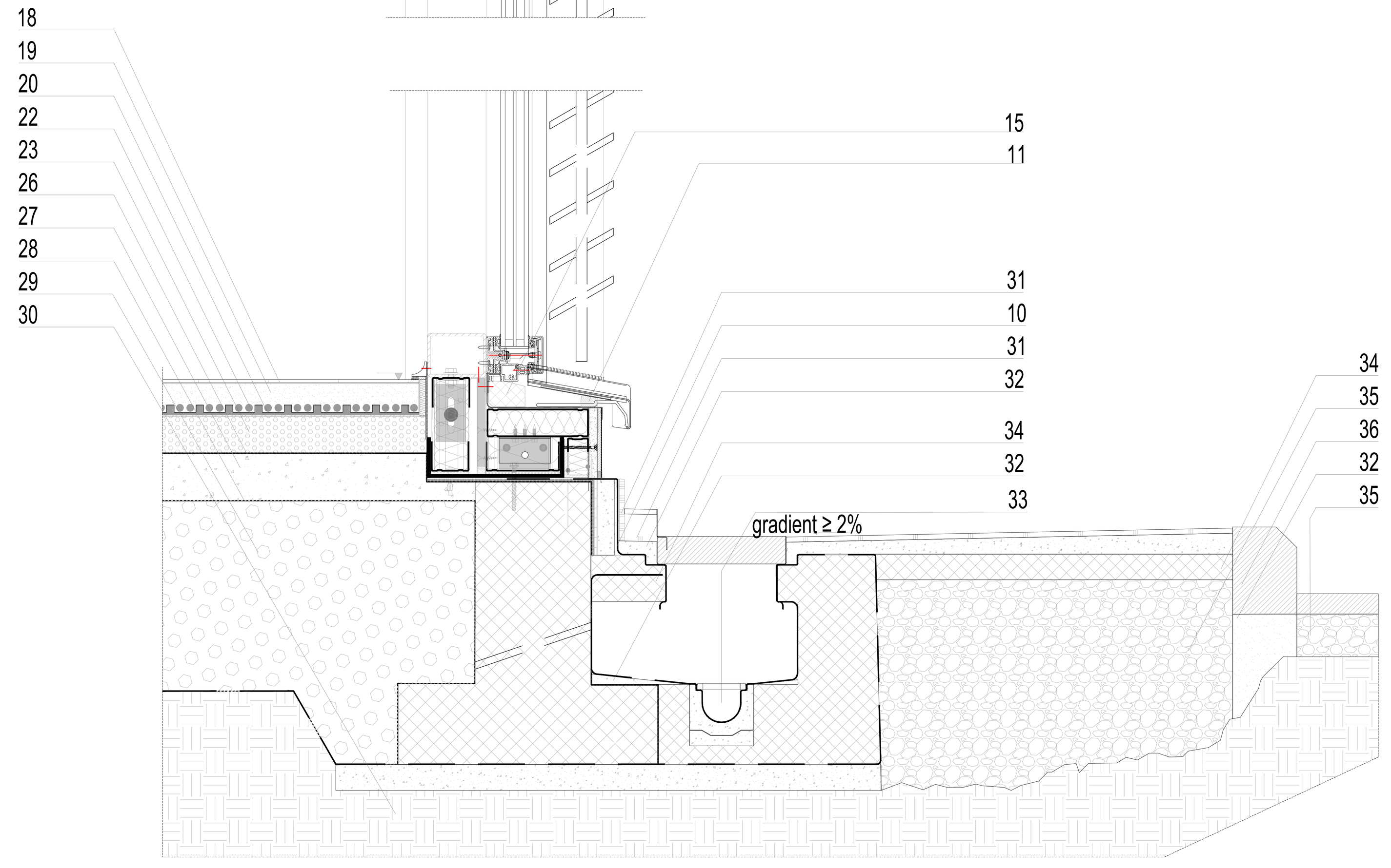

FIRST STRIP - DETAIL 6

Scale 1:5



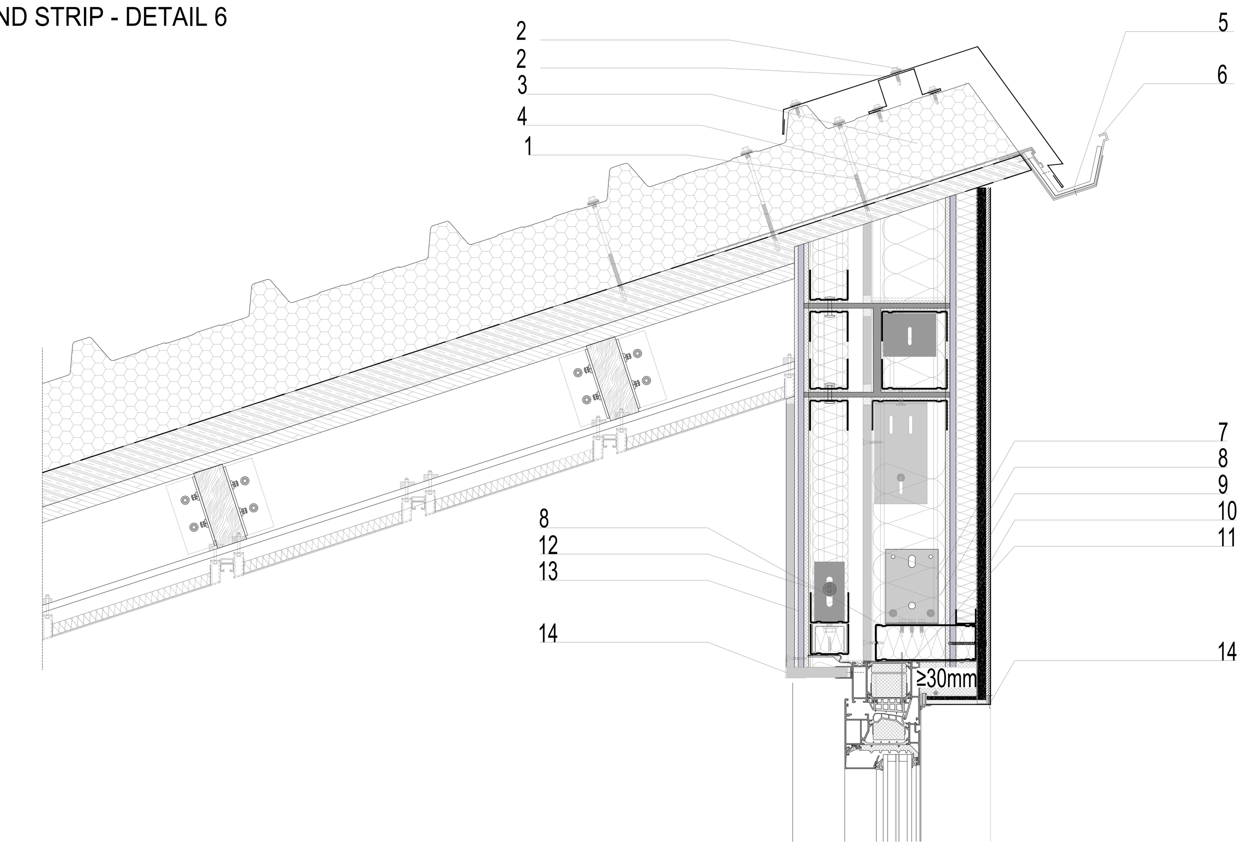
FIRST STRIP - DETAIL 1

Scale 1:5



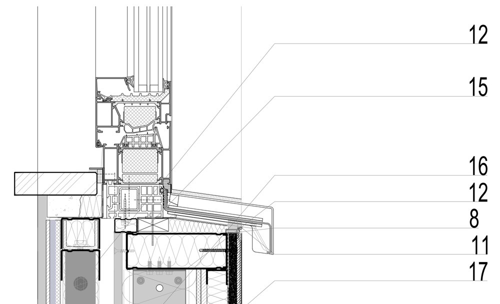

SECOND STRIP - DETAIL 6

Scale 1:5



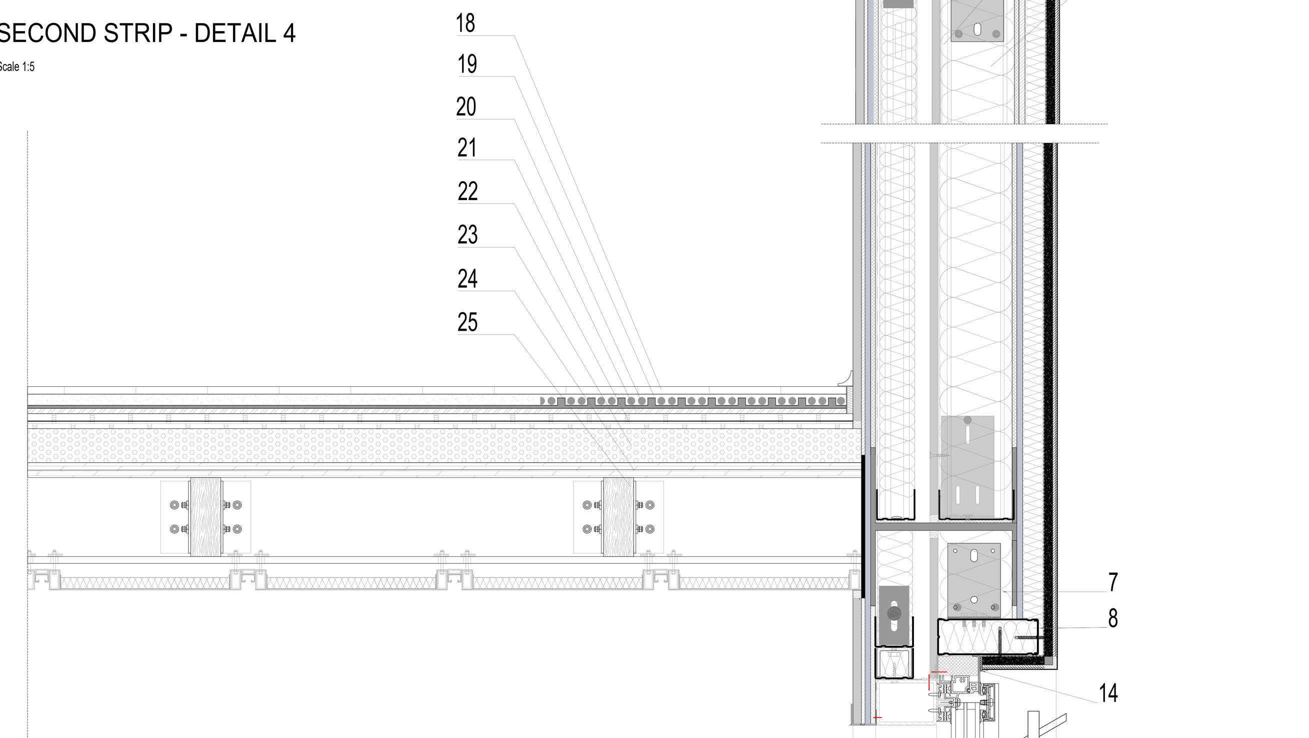

SECOND STRIP - DETAIL 5

Scale 1:5



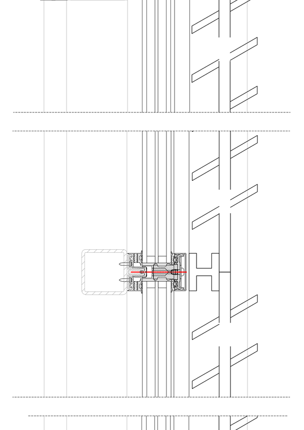

SECOND STRIP - DETAIL 4

Scale 1:5



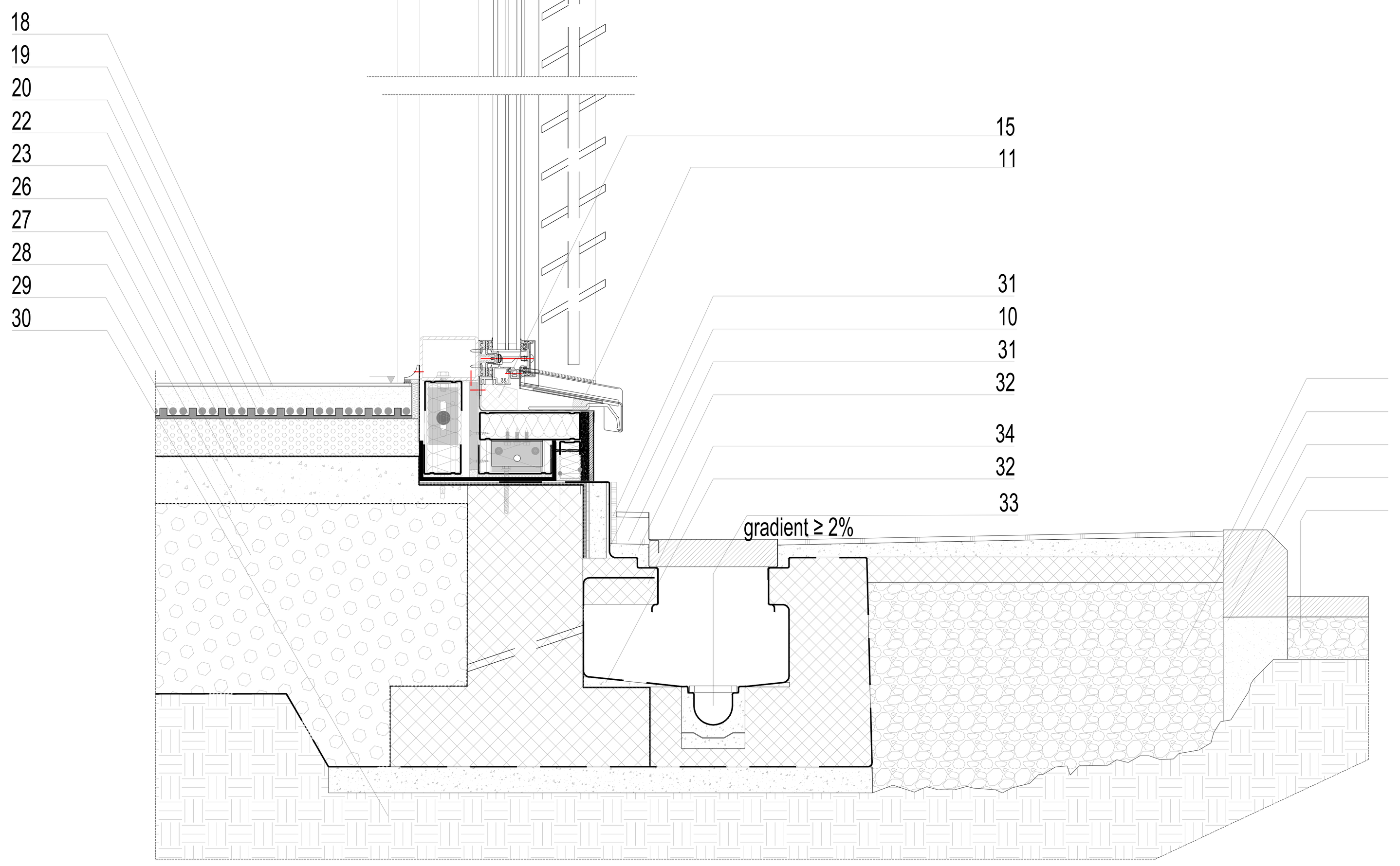

SECOND STRIP - DETAIL 3

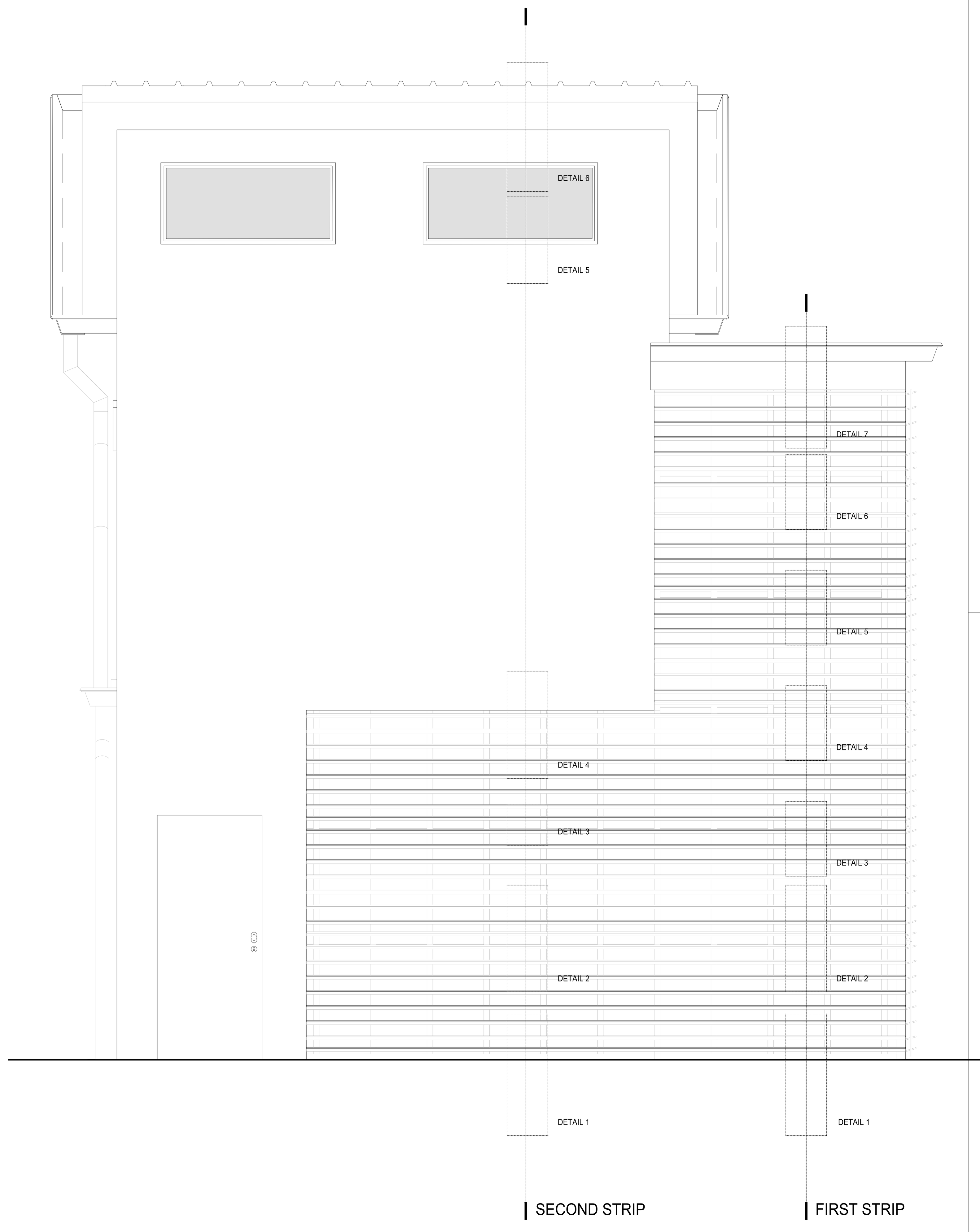
Scale 1:5

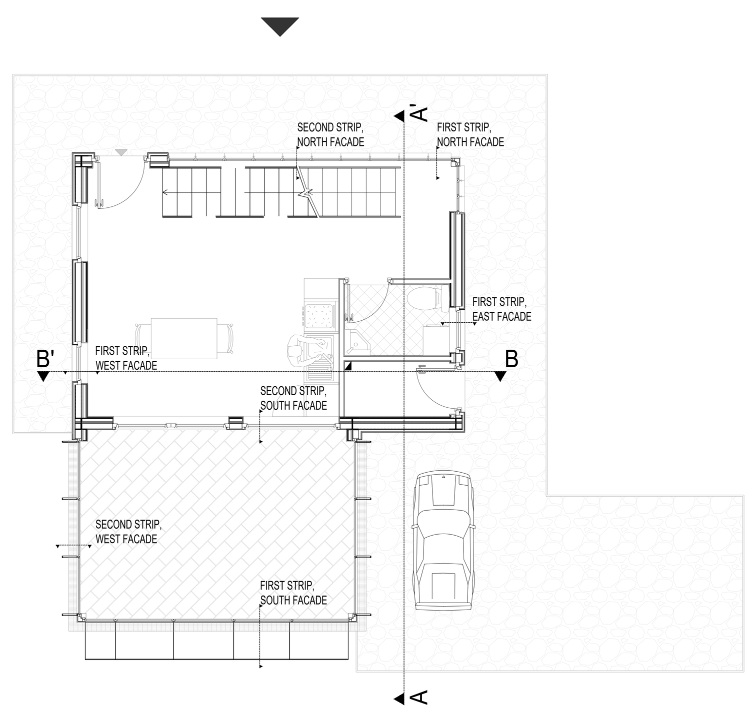


SECOND STRIP - DETAIL 1

Scale 1:5



# EAST FACADE DETAILS

Scale 1:5
First strip - Detail 3
First strip - Detail 2
First strip - Detail 1

Regenerating the urban outskirts
A self-sufficient ecovillage in Milan's Bovisasca area


Politecnico di Torino
Building engineering
Department

*Author:*
Marta Durantini

*Thesis Advisor:*
Marika Mangosio

*Date:*
05/04/2023

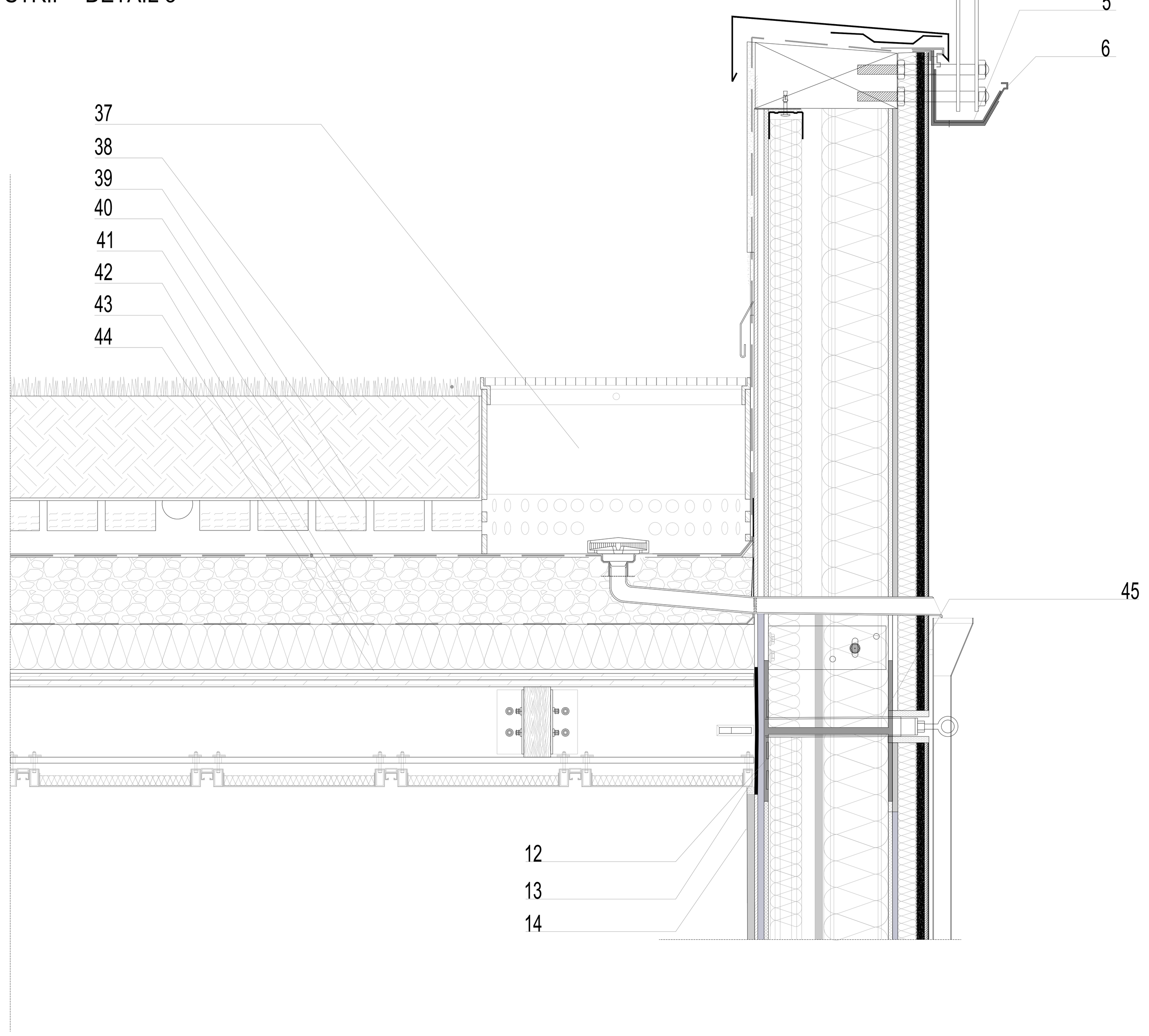

AA 2022/2023

LEGENDA

1. Fixing screw
2. External steel flashing
3. Roof sandwich panel
4. Gasket
5. Eaves
6. Eaves support
7. Connection element
8. CW stud
9. Render system
10. Water barrier
11. Sealing tape
12. Connection profile
13. Vapour barrier
14. Corner protection
15. Setting block
16. Gypsum board
17. Insulation
18. Pavement layer
19. Fibre-reinforced radiant screed with high thermal conductivity
20. Floor heating system
21. Footfall acoustic mat
22. Slabs/Panels for dry subfloors
23. Dry subfloor
24. Boarding
25. Wood joist
26. Waterproof case
27. Reinforced concrete slab
28. Separator layer in non-woven fabric
29. Thermal insulation in expanded clay
30. Ground
31. Finishing element
32. Substrate
33. Prefabricated channel for water removal
34. Structural element (CLS)
35. Gravel for draining
36. Granite curb for protection and finishing
37. Gully in galvanized steel for water drainage
38. Potting soil with high water retention capacity
39. Sheet of non-woven propylene fabric, selective passage of roots
40. Pre-printed expanded polystirene panel
41. Double breathable sheath in high density polyethilene, waterproofing
42. Lightened concrete with polystyrene beads and electro-welded mesh
43. Panels of extruded polystiyrene, insulation
44. Multilayer film with aluminium, vapour barrier
45. Scaffolding anchor, removable

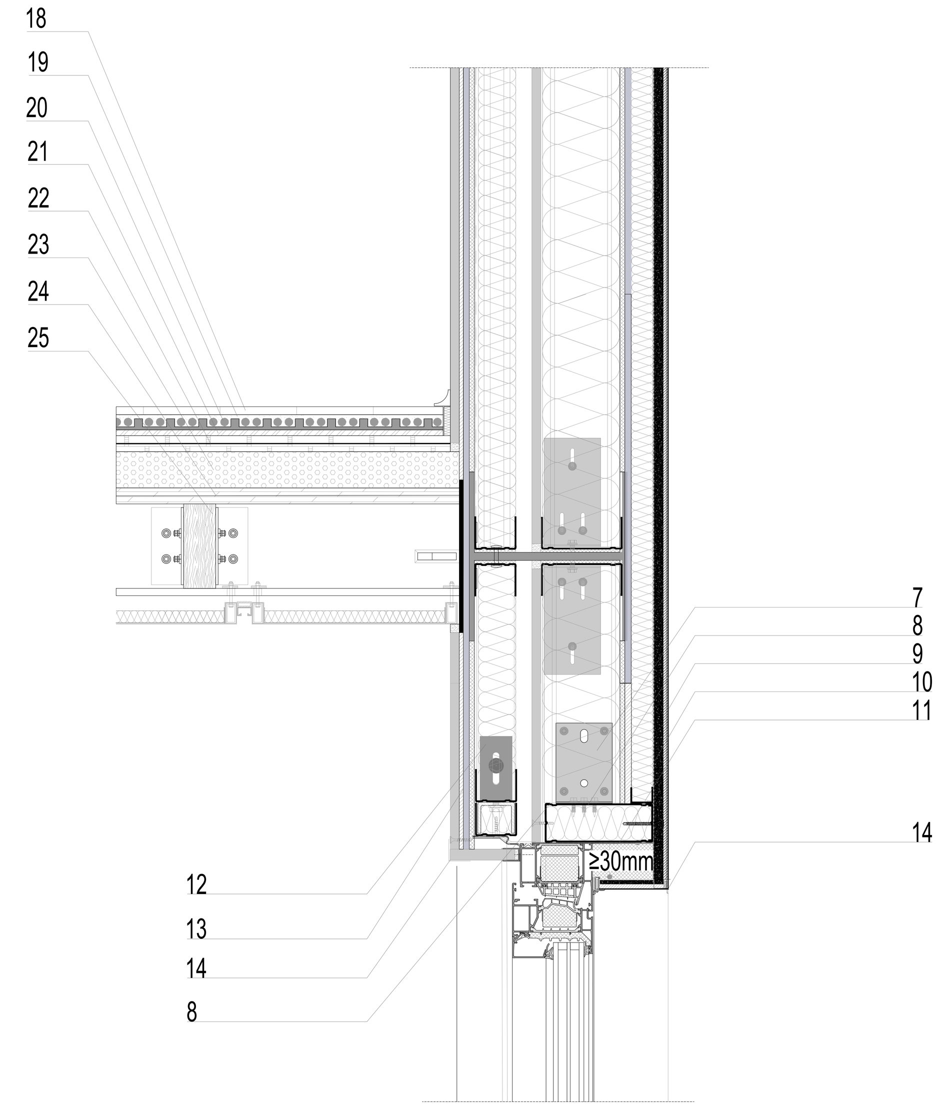
FIRST STRIP - DETAIL 3

Scale 1:5



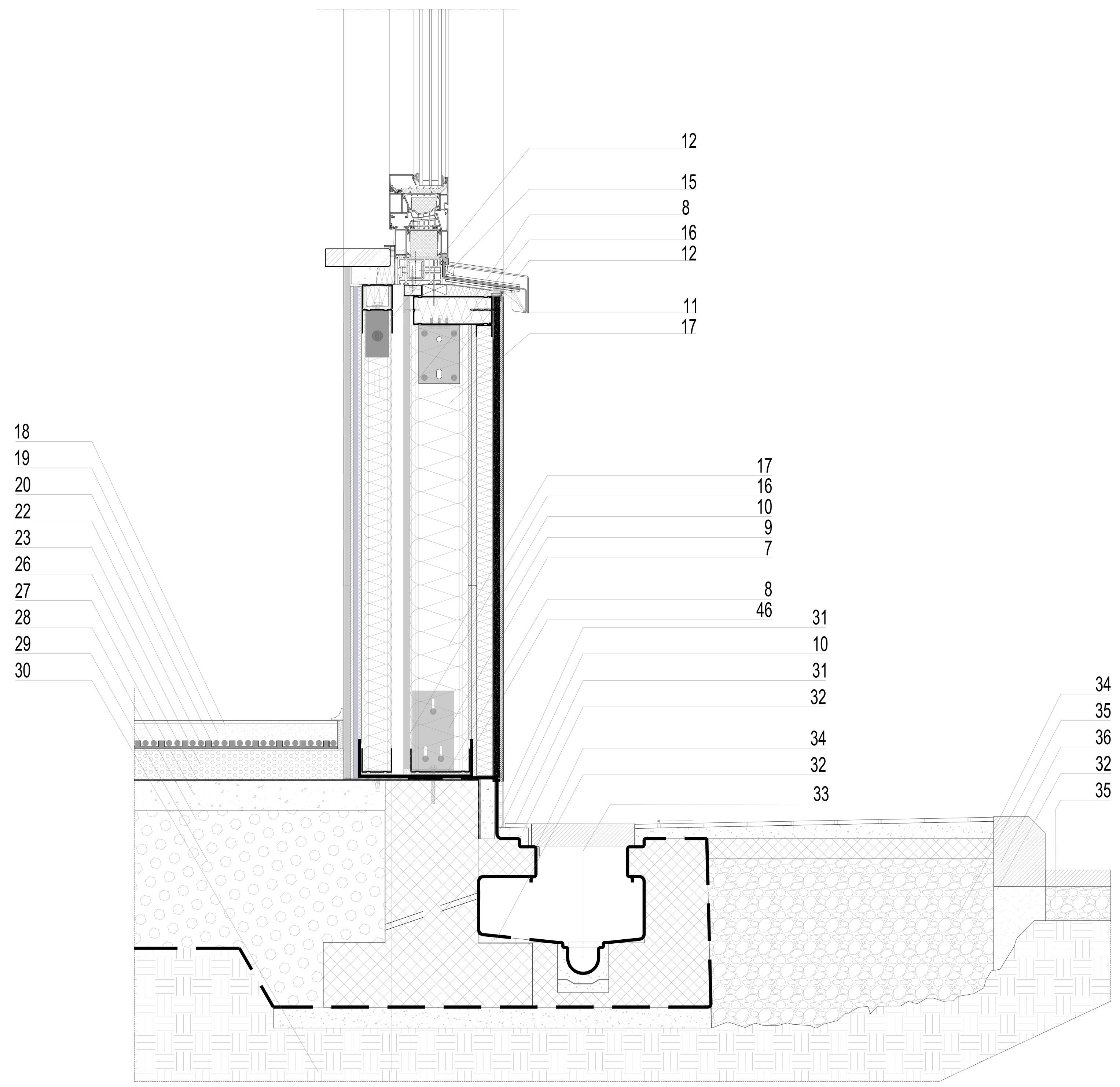

FIRST STRIP - DETAIL 2

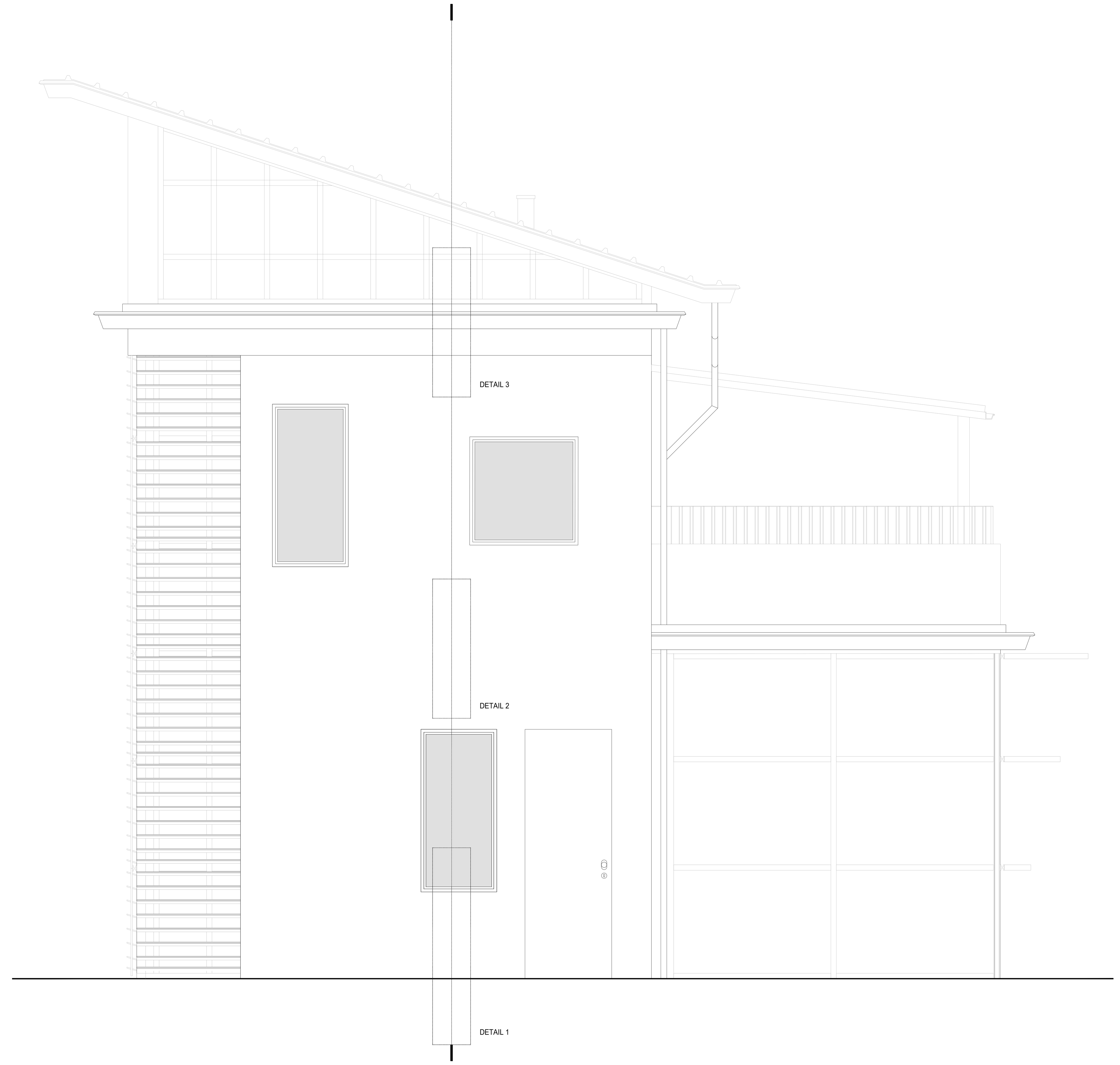
Scale 1:5



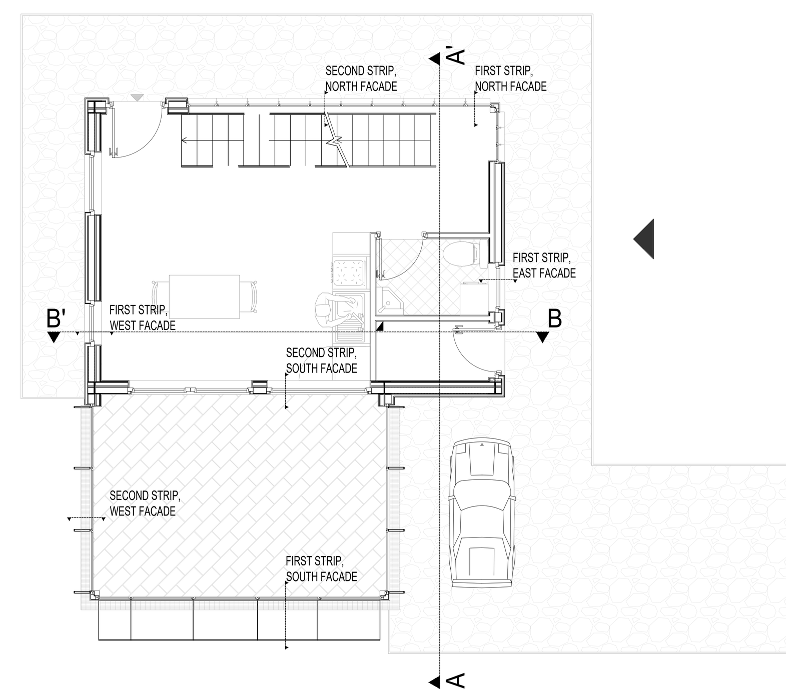

FIRST STRIP - DETAIL 1

Scale 1:5




FIRST STRIP



# SOUTH FACADE DETAILS

Scale 1:5
First strip - Detail 7
First strip - Detail 6
First strip - Detail 5
Second strip - Detail 4
Second strip - Detail 1
First strip - Detail 4
First strip - Detail 3
First strip - Detail 1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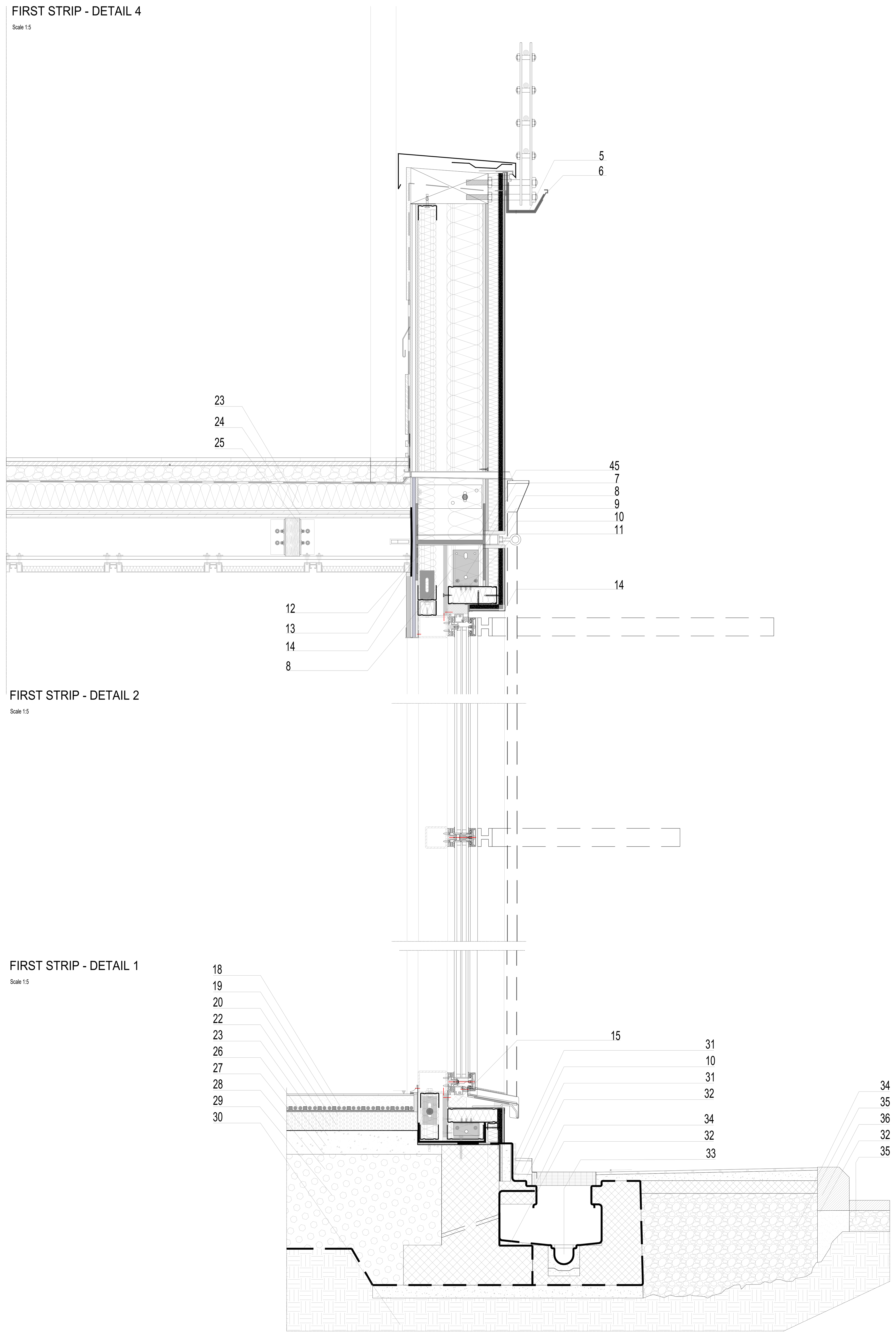


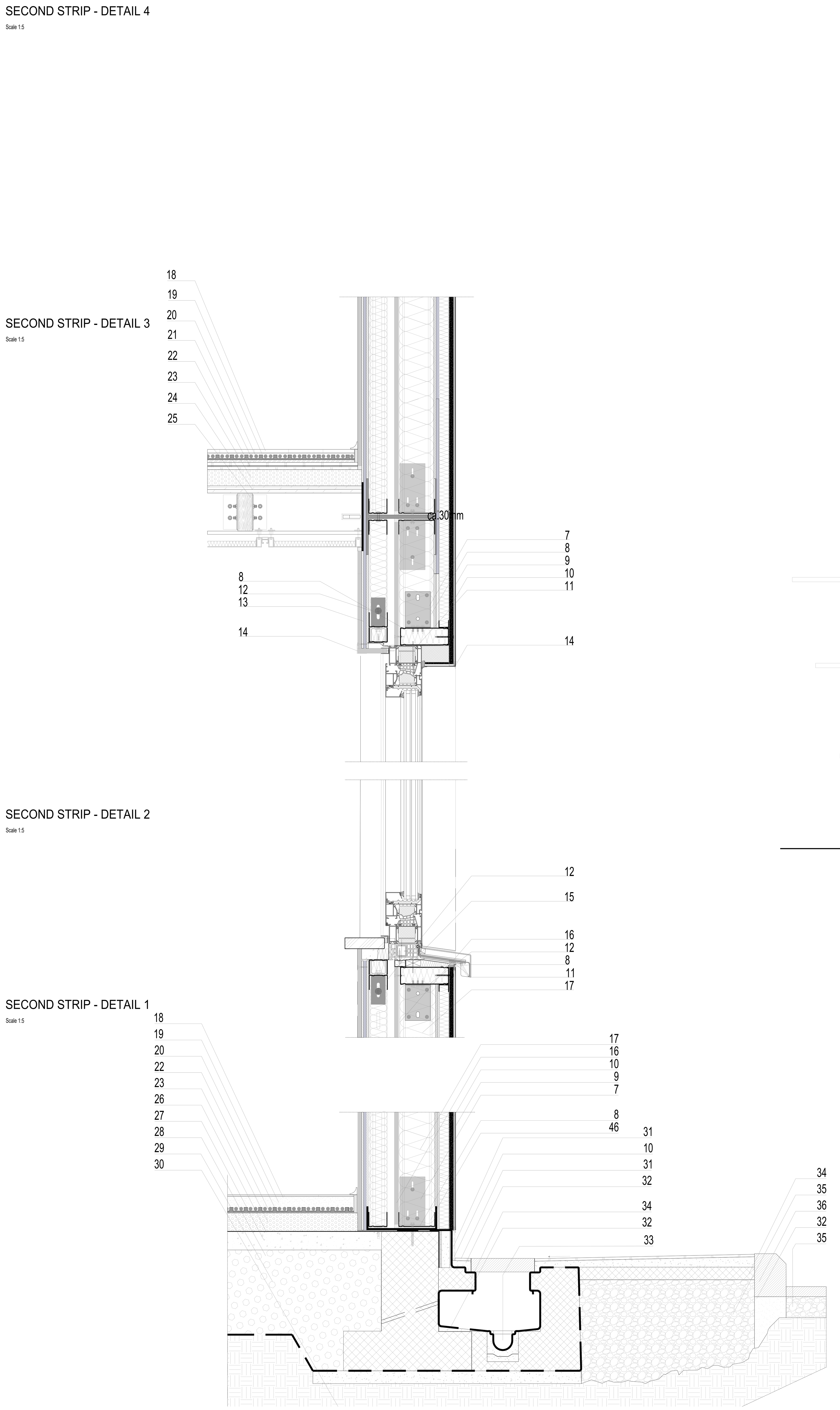


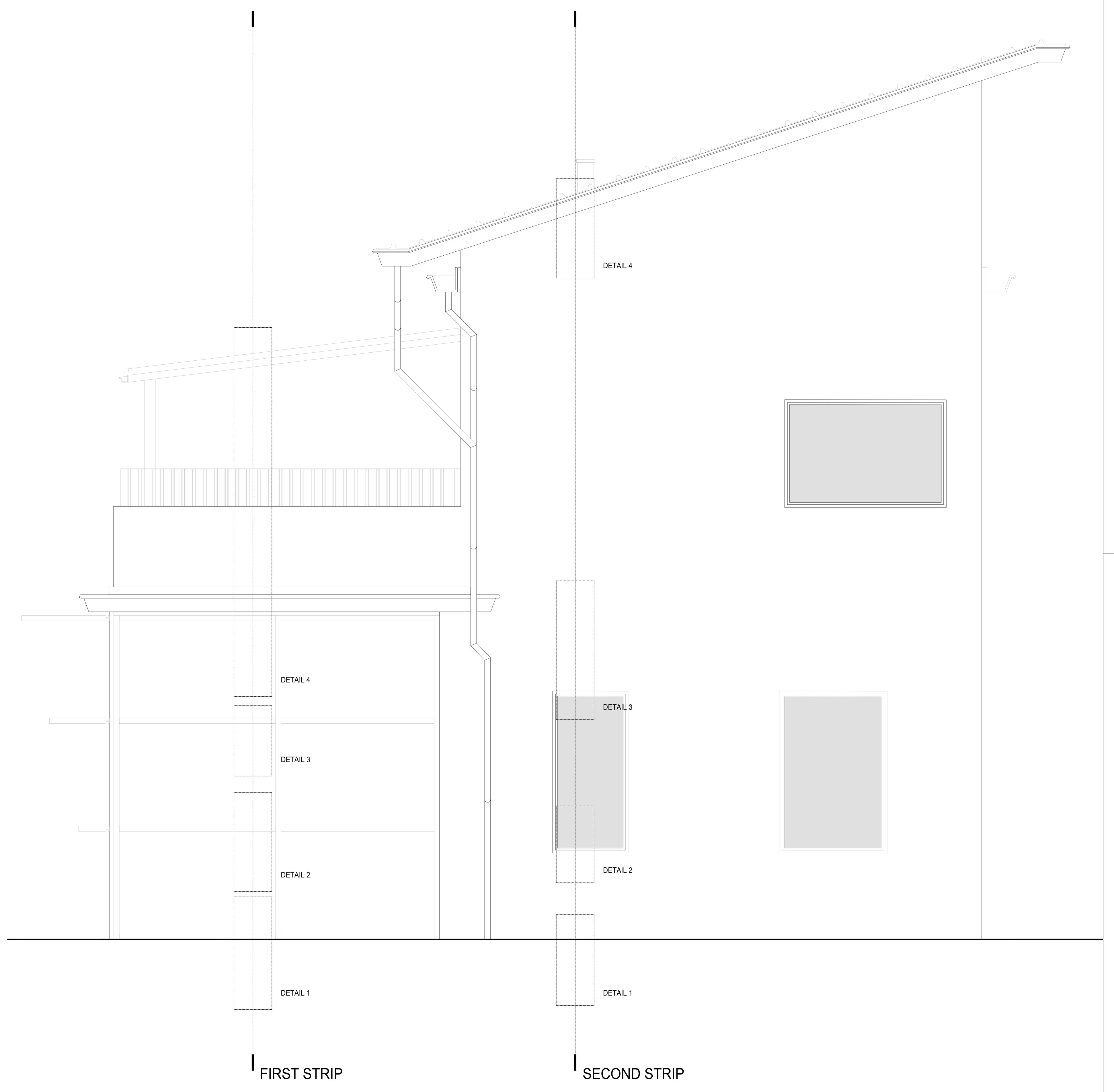


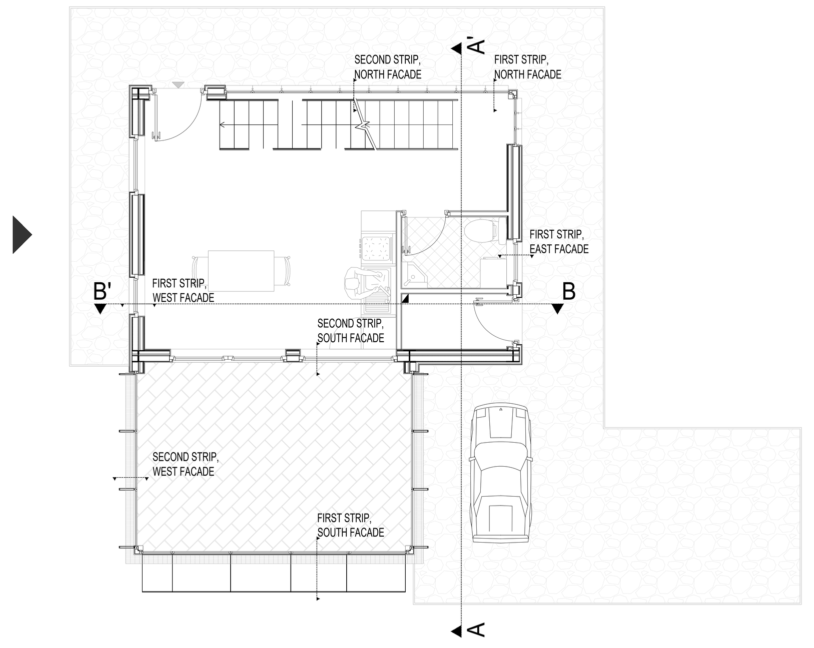

# SOUTH FACADE DETAILS

Scale 1:5
First strip - Detail 7
First strip - Detail 6
First strip - Detail 5
Second strip - Detail 4
Second strip - Detail 1
First strip - Detail 4
First strip - Detail 3
First strip - Detail 1


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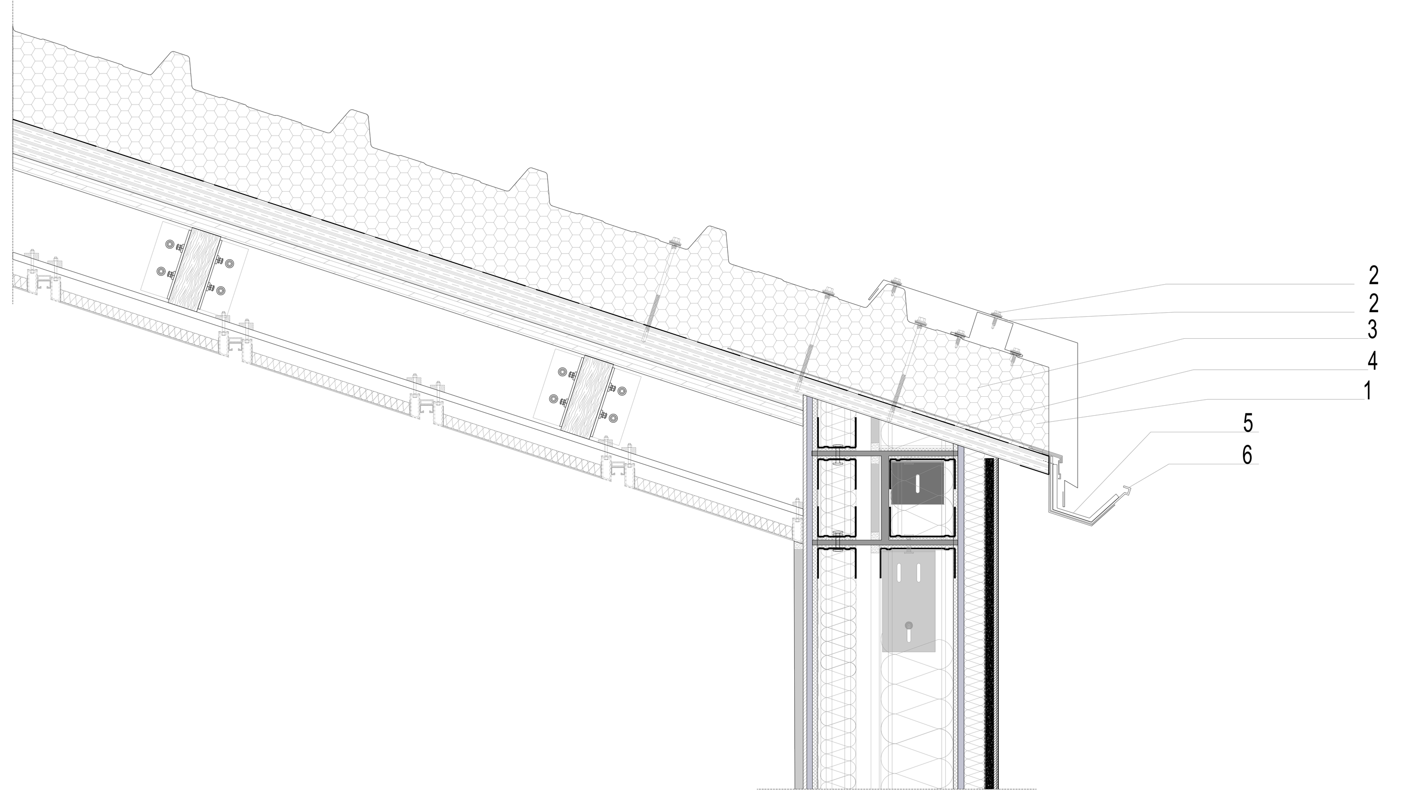
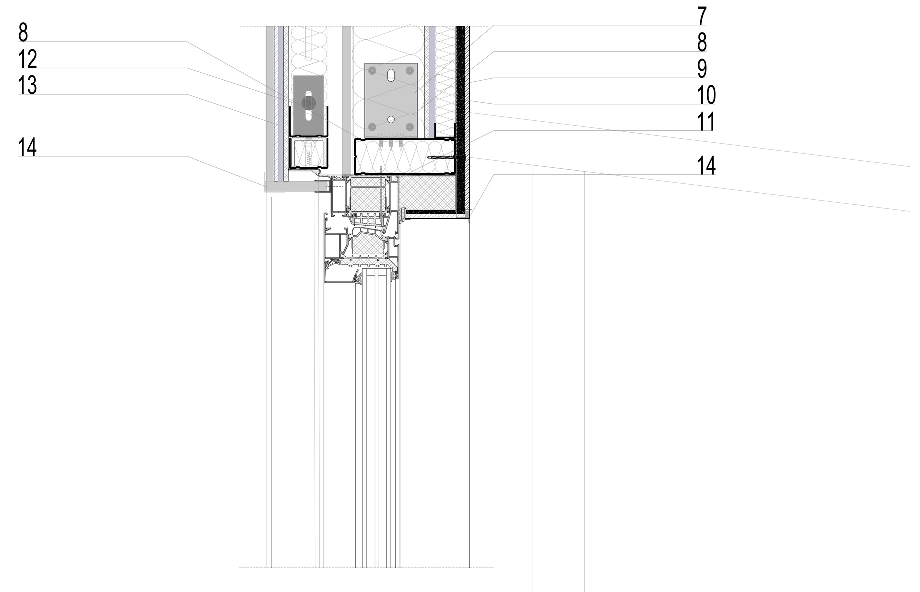
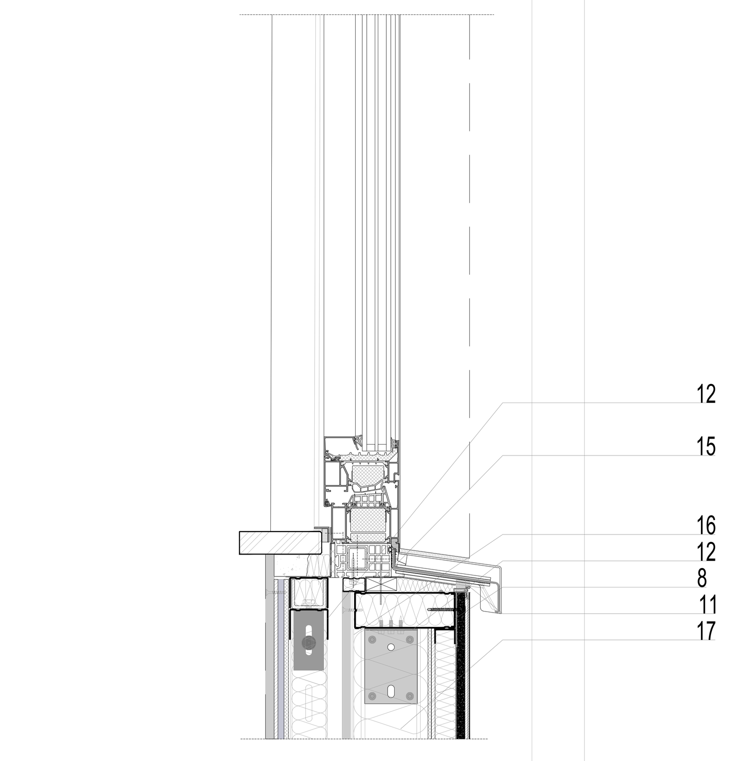
FIRST STRIP - DETAIL 7
Scale 1:5



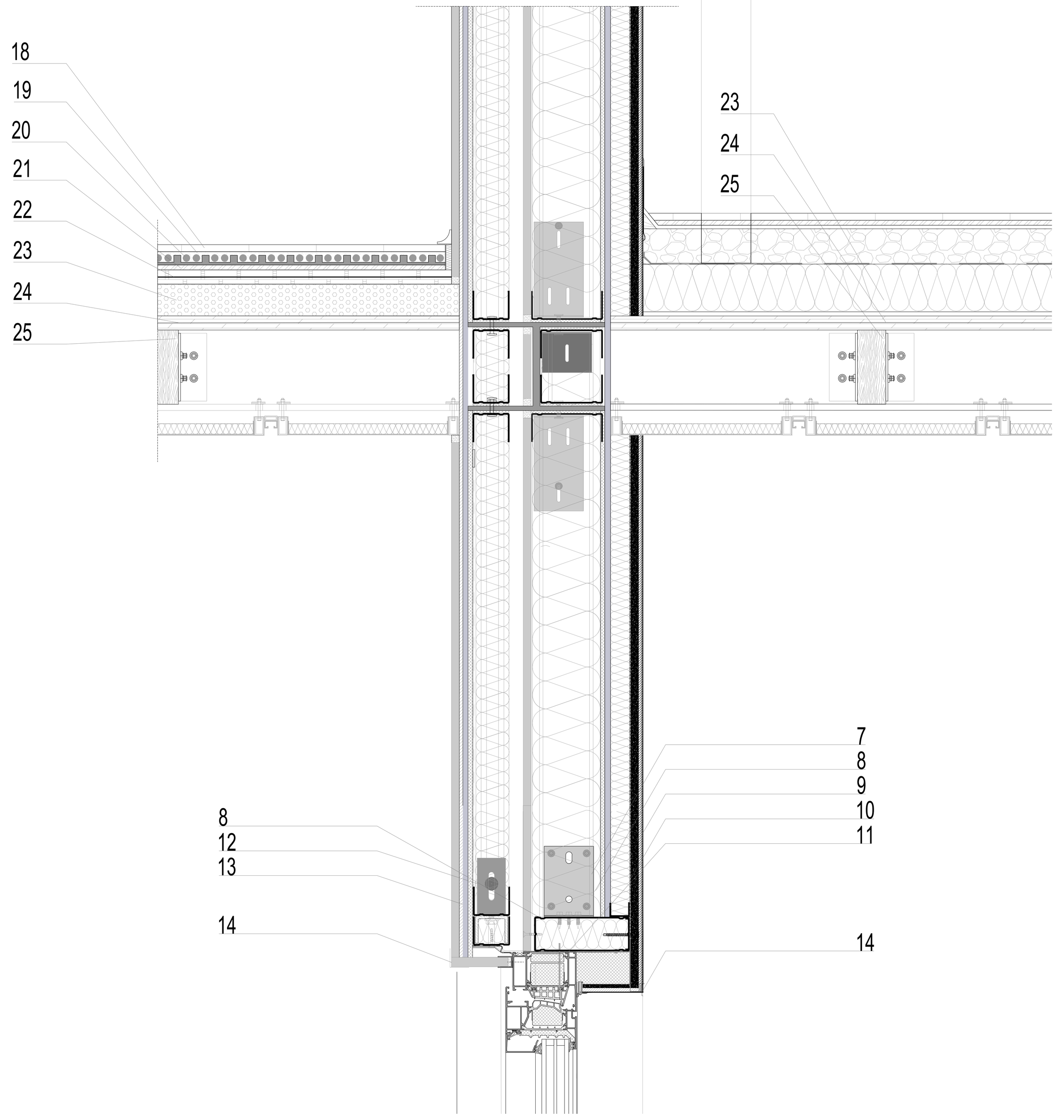

FIRST STRIP - DETAIL 6
Scale 1:5



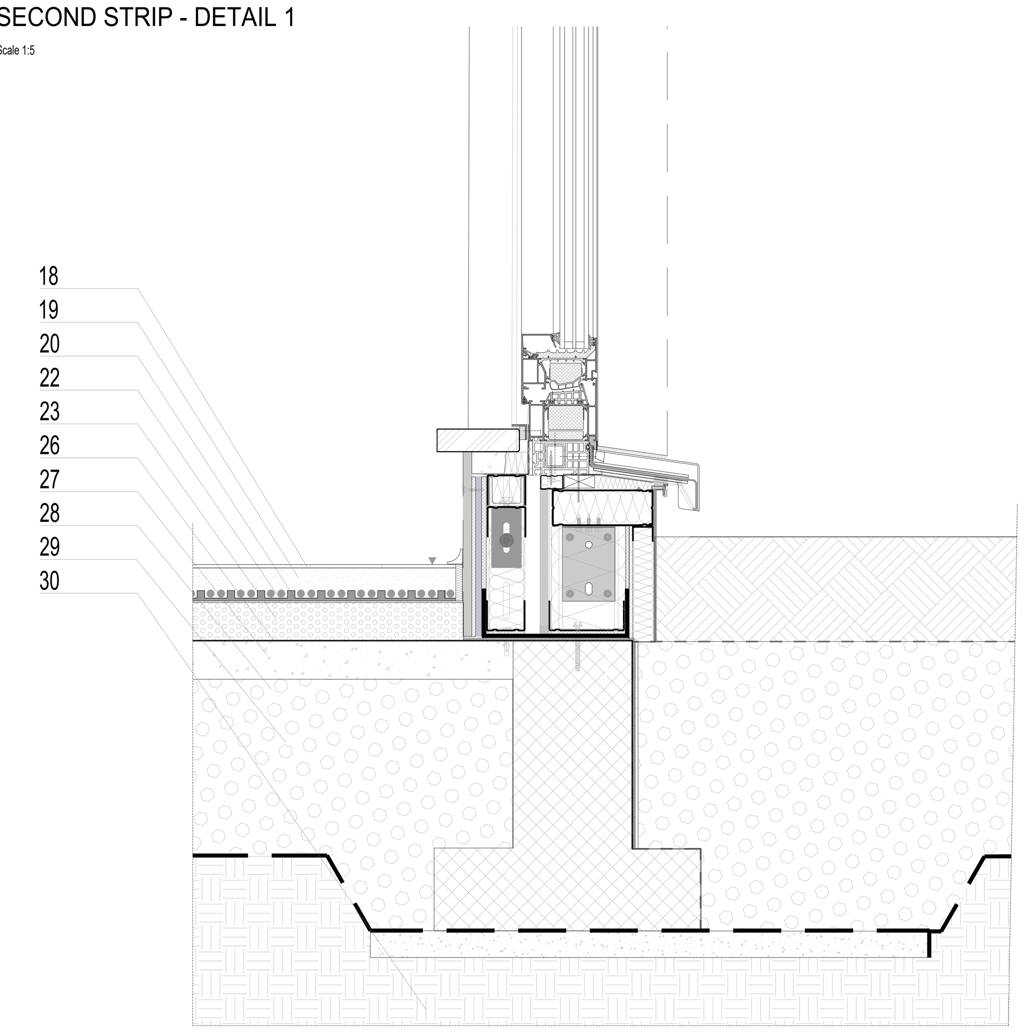

FIRST STRIP - DETAIL 5
Scale 1:5



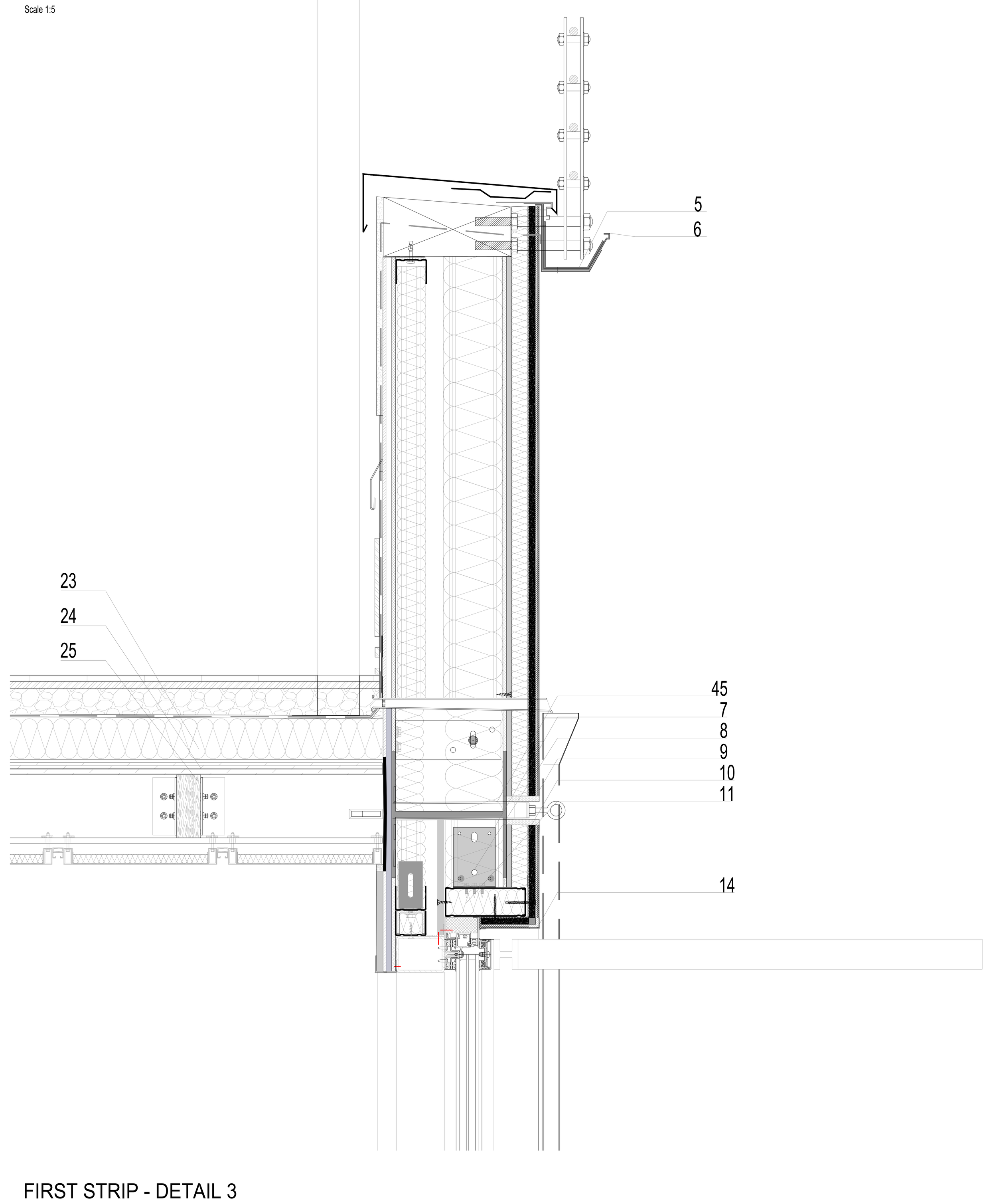

SECOND STRIP - DETAIL 4
Scale 1:5



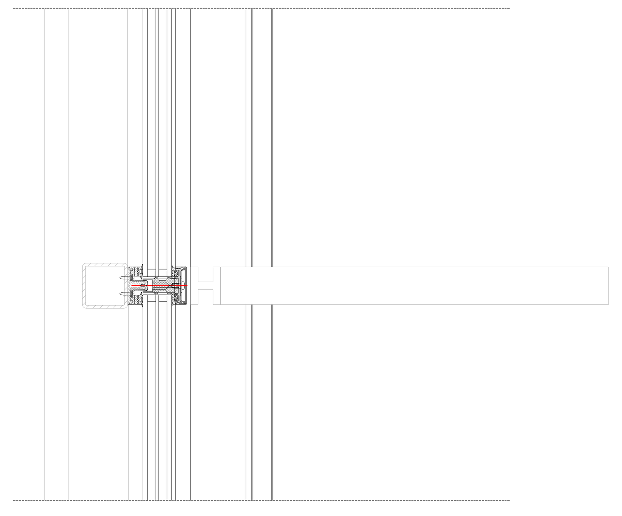

SECOND STRIP - DETAIL 1
Scale 1:5



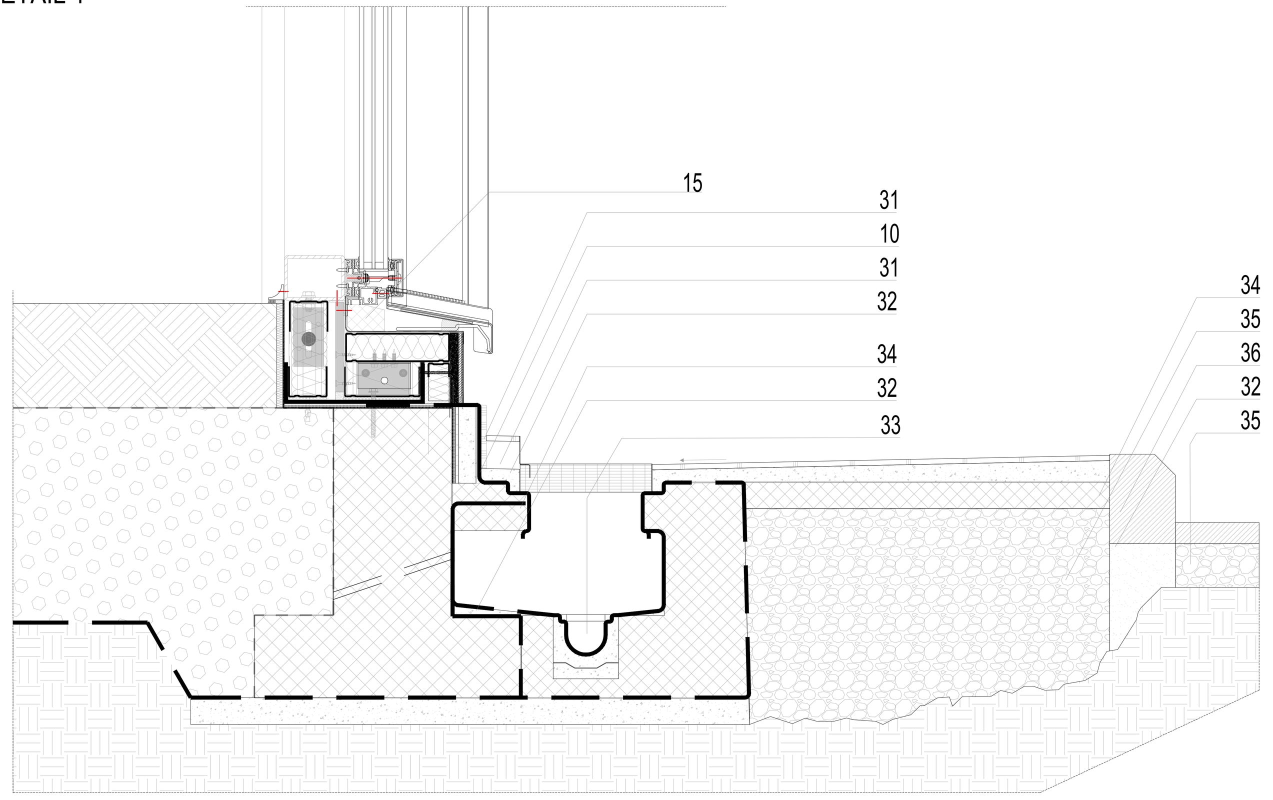

FIRST STRIP - DETAIL 4"
Scale 1:5

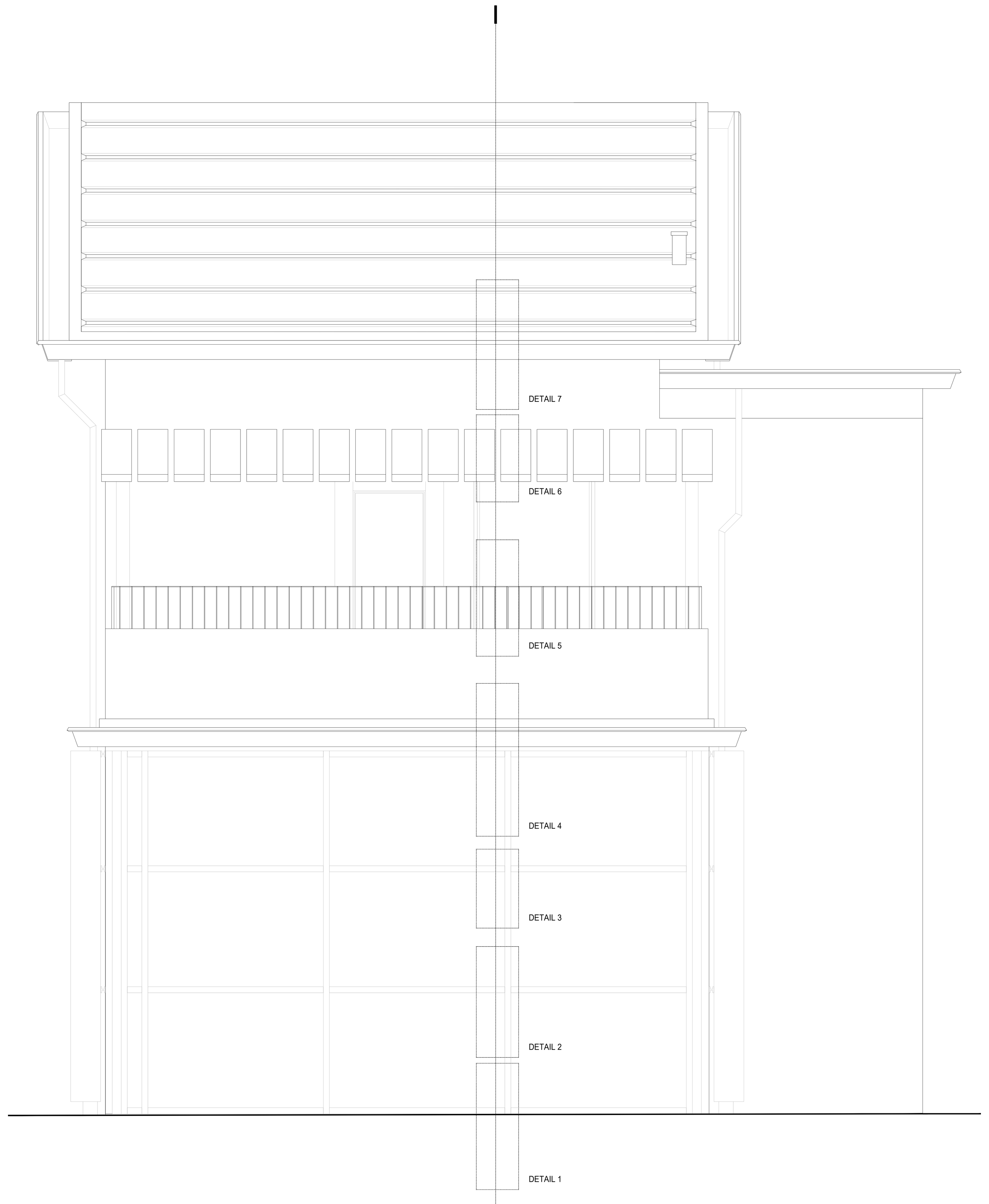



FIRST STRIP - DETAIL 3
Scale 1:5

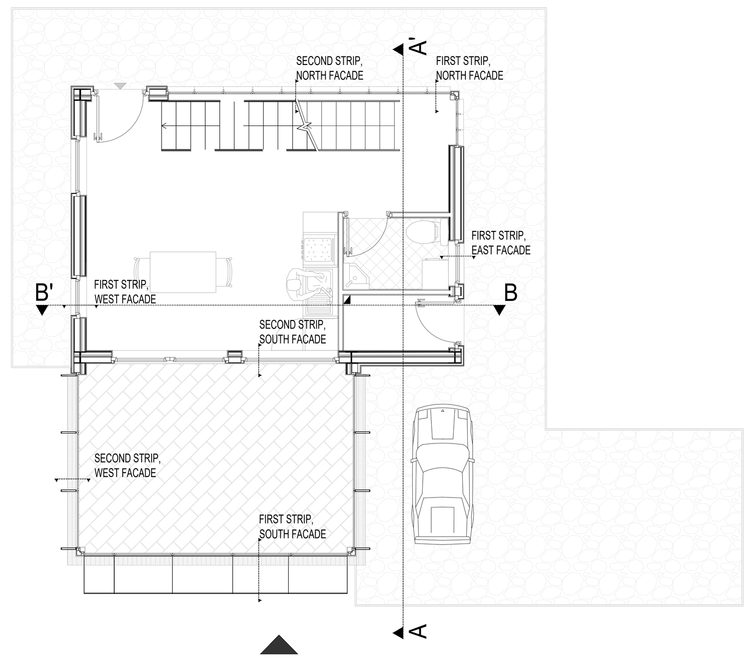


FIRST STRIP - DETAIL 1"
Scale 1:5




FIRST AND SECOND STRIP



# PLANAR DETAILS

Scale 1:5
Detail 1
Detail 2
Detail 3
Detail 4
Detail 5
Detail 6

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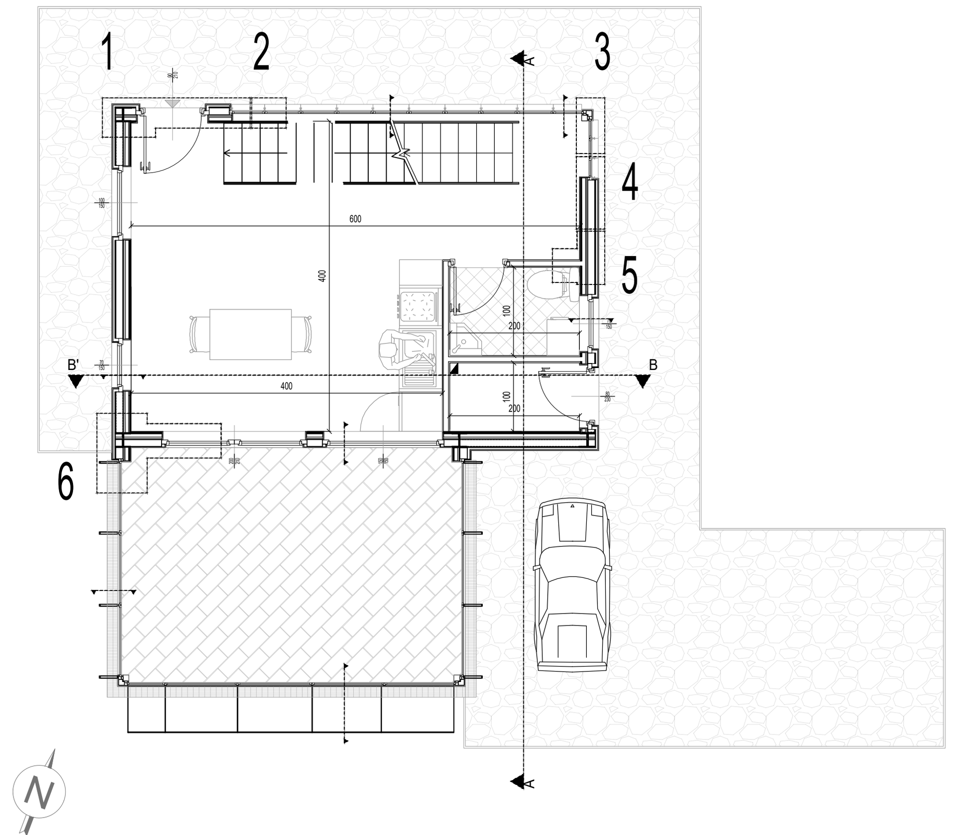
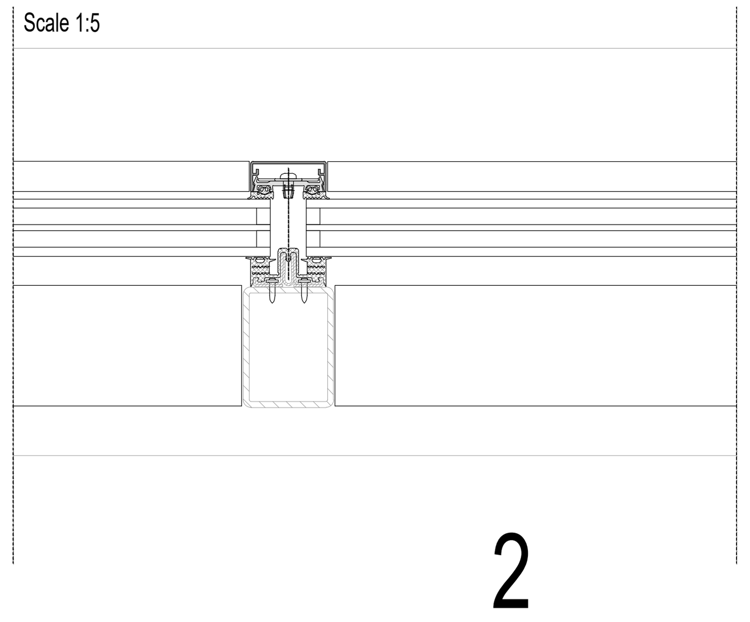



## DETAIL 1

Scale 1:5

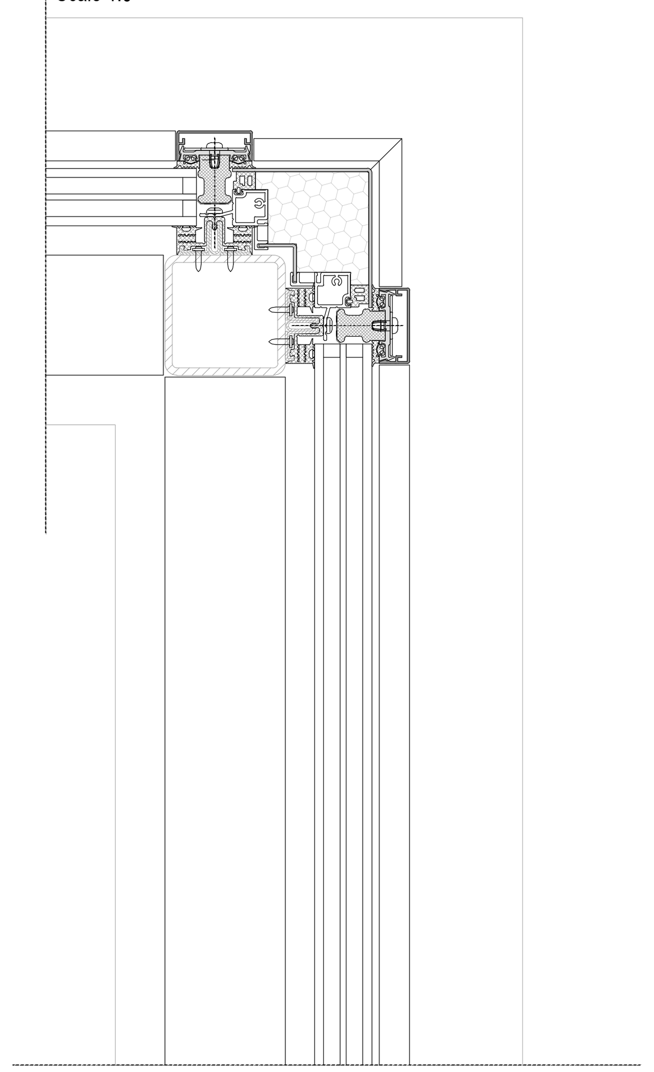
## DETAIL 2

Scale 1:5



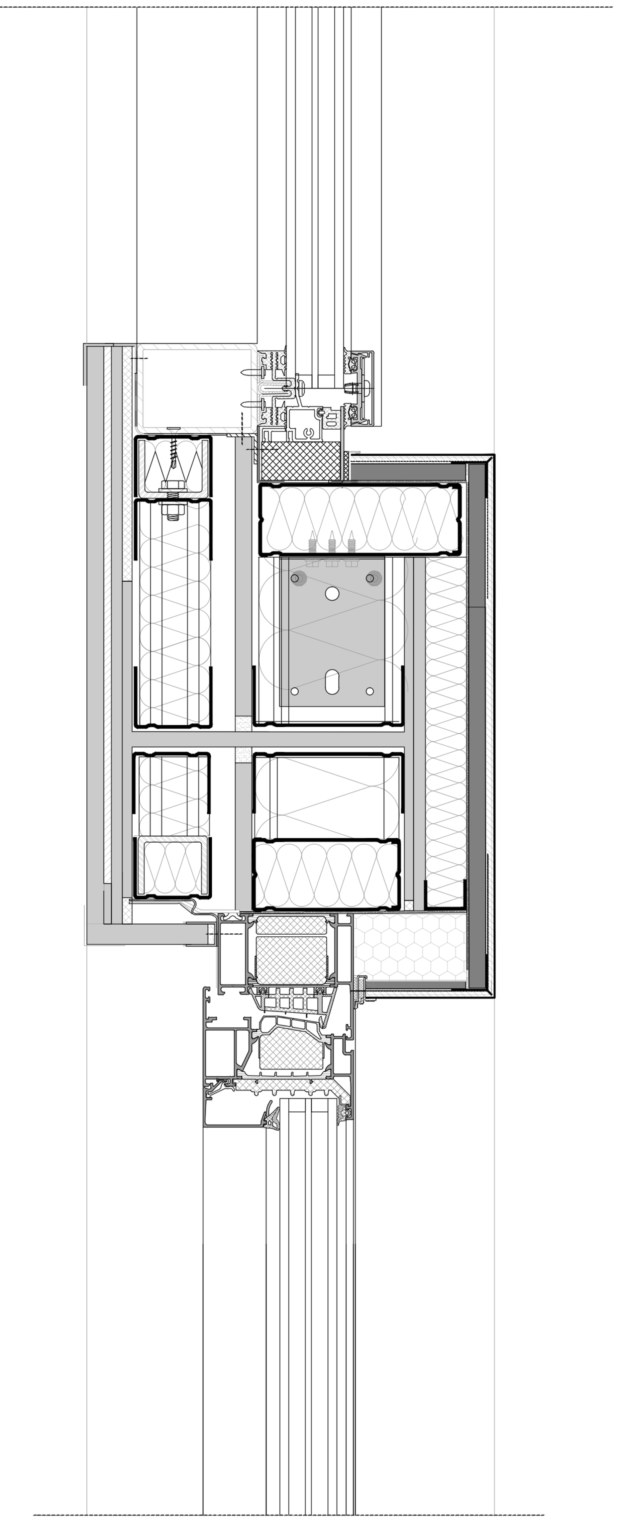

## DETAIL 3

Scale 1:5



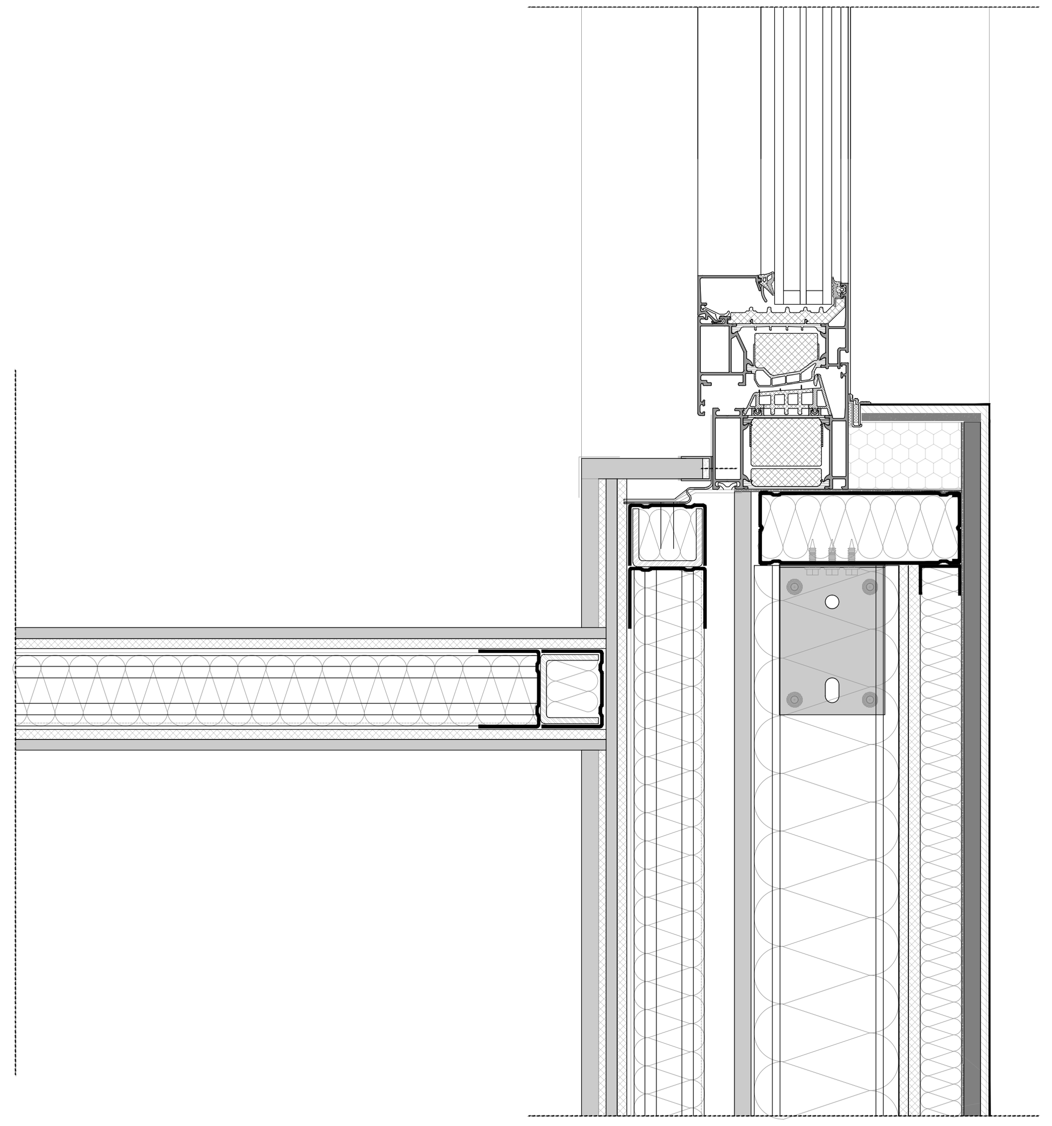
## DETAIL 4

Scale 1:5



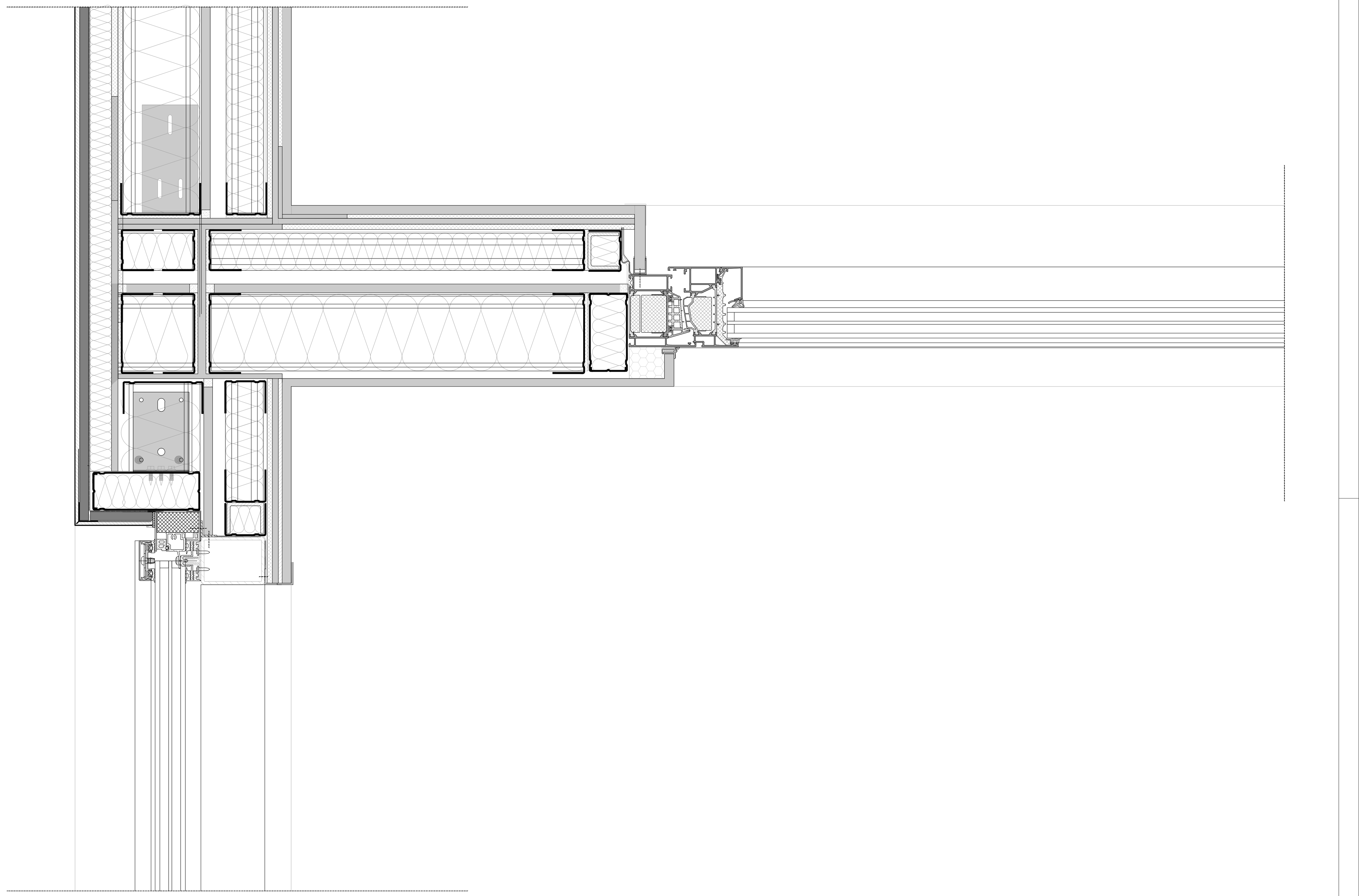
## DETAIL 5

Scale 1:5



## DETAIL 6

Scale 1:5



# SECOND HOUSING UNIT

Ground Floor Plan - Scale 1:100
First Floor Plan - Scale 1:100
Roofing Floor Plan - Scale 1:100
East Elevation - Scale 1:100
North Elevation - Scale 1:100
Section A-A' - Scale 1:100

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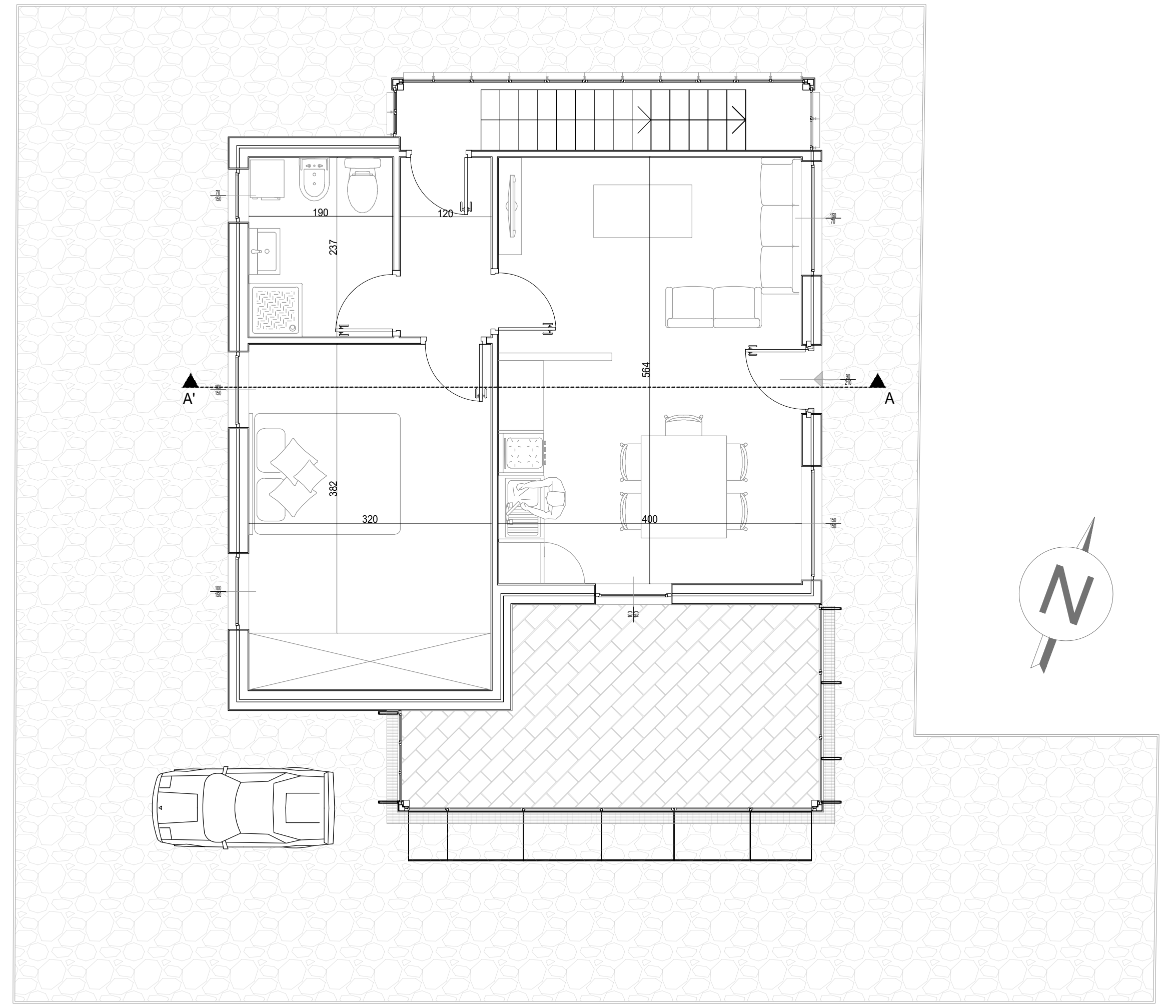
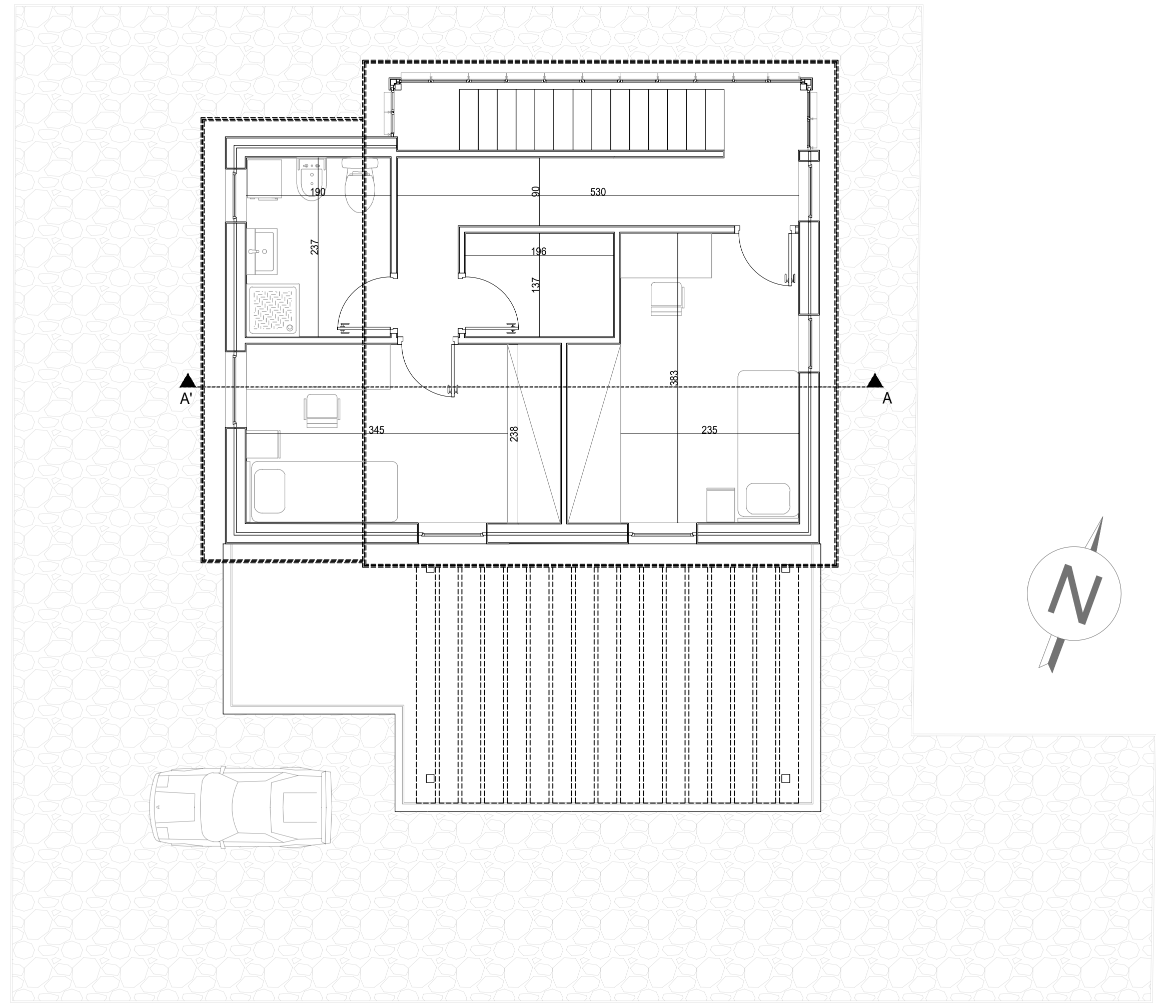
## GROUND FLOOR PLAN

Scale 1:100



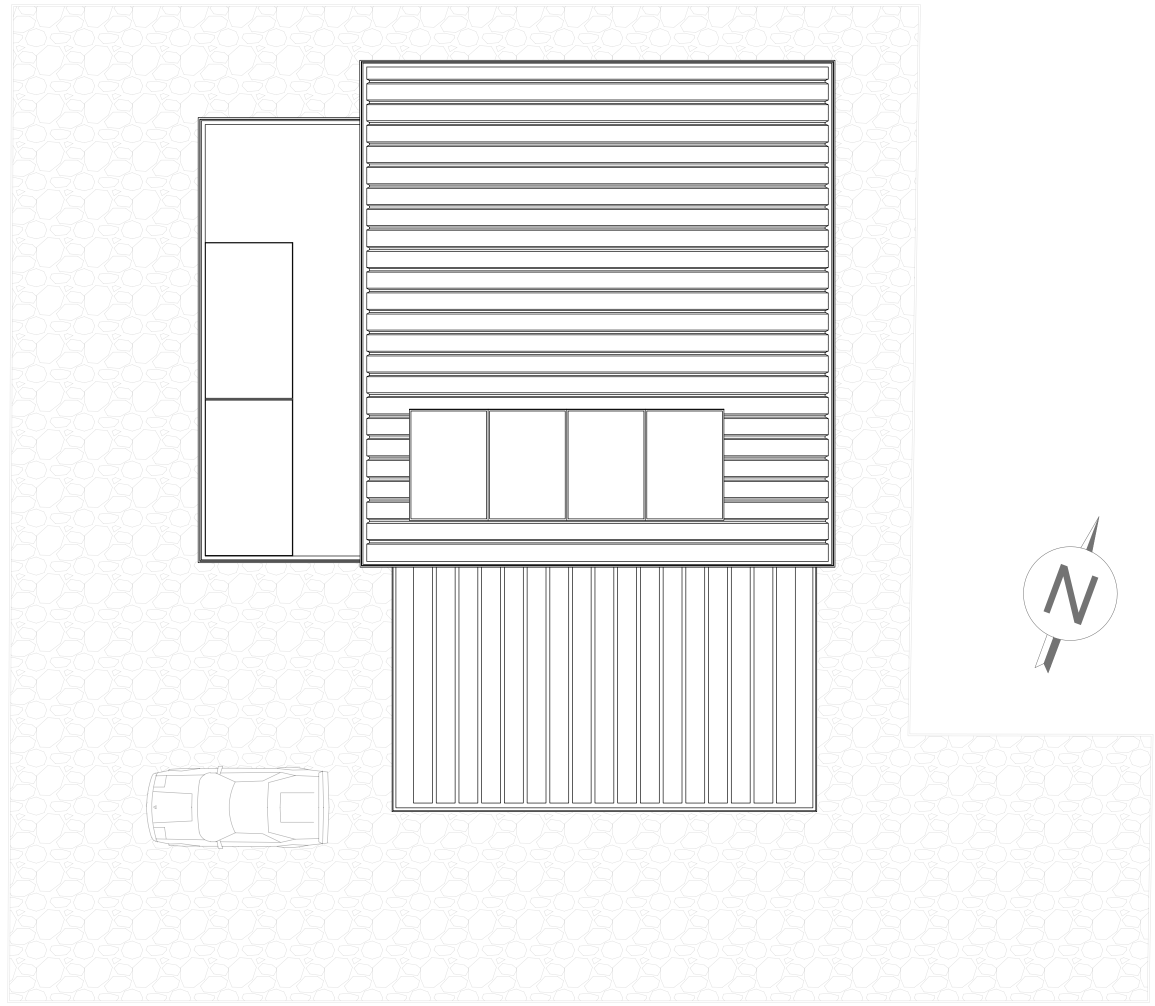
## FIRST FLOOR PLAN

Scale 1:100



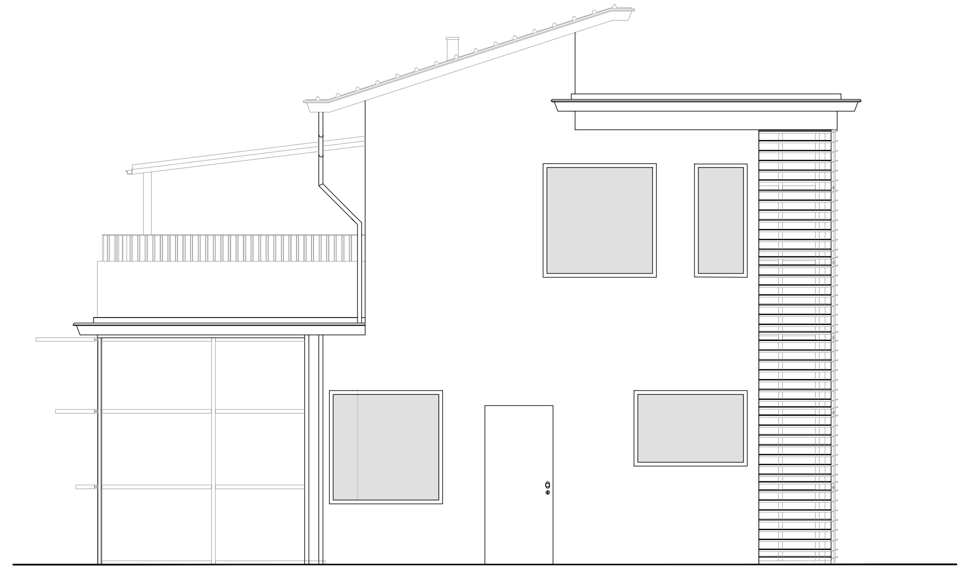
## ROOFING FLOOR PLAN

Scale 1:100



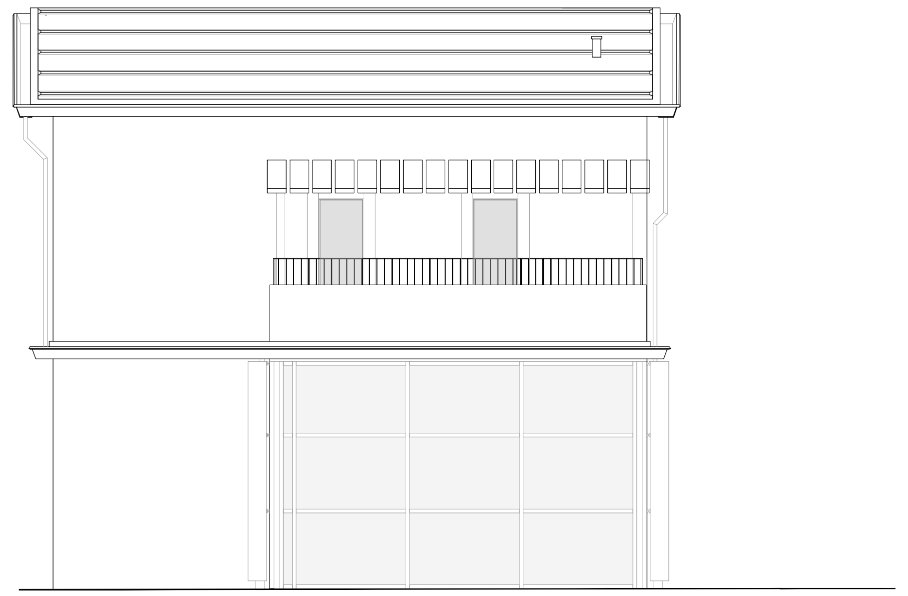
## EAST ELEVATION

Scale 1:100



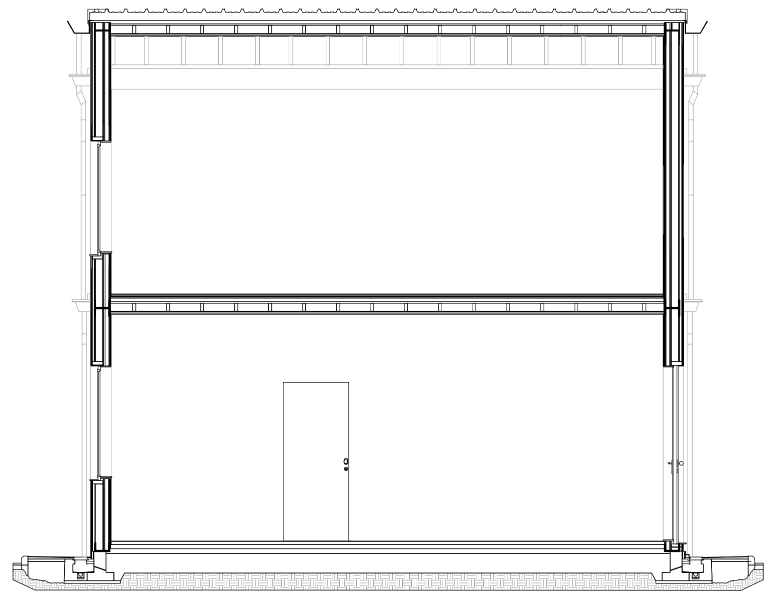
## SOUTH FLOOR PLAN

Scale 1:100



## SECTION A-A'

Scale 1:100



# 3D RENDERS OF THE PROJECT

Placement in the context
External views of the masterplan
External views of the first housing unit
Internal views of the first housing unit
External views of the second housing unit
Section A-A' - Scale 1:100

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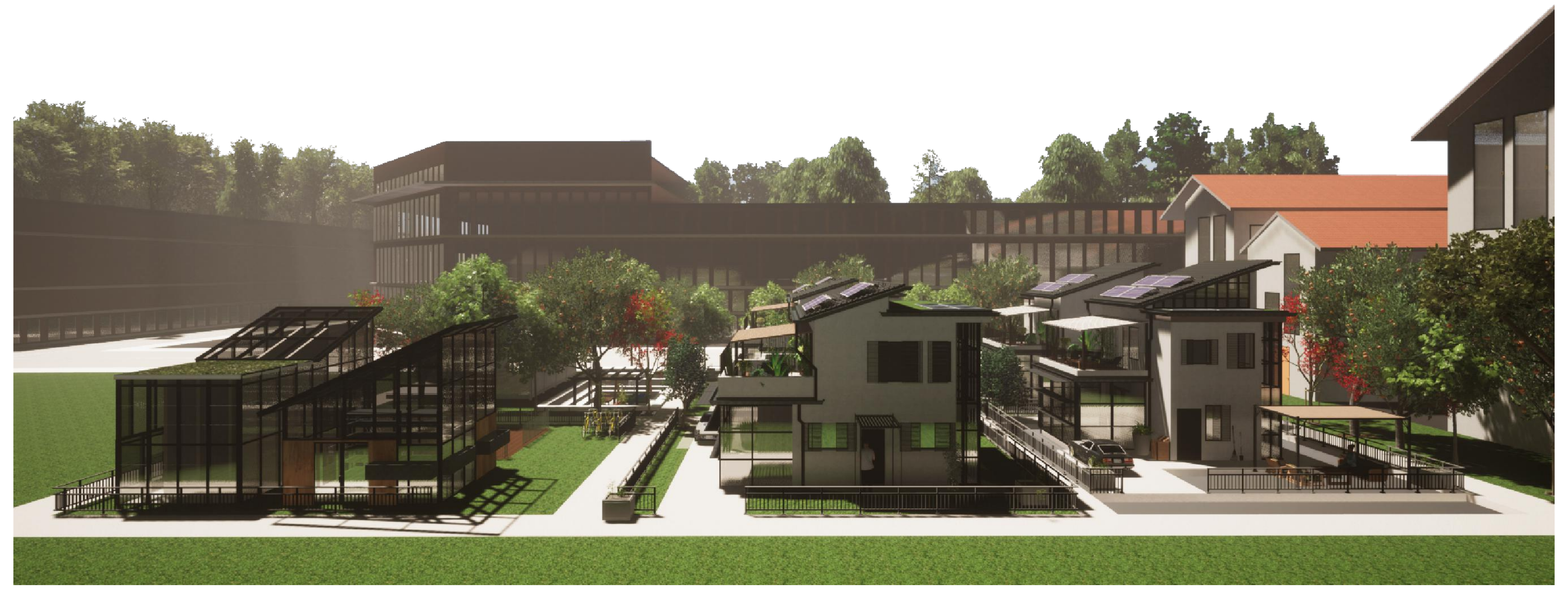

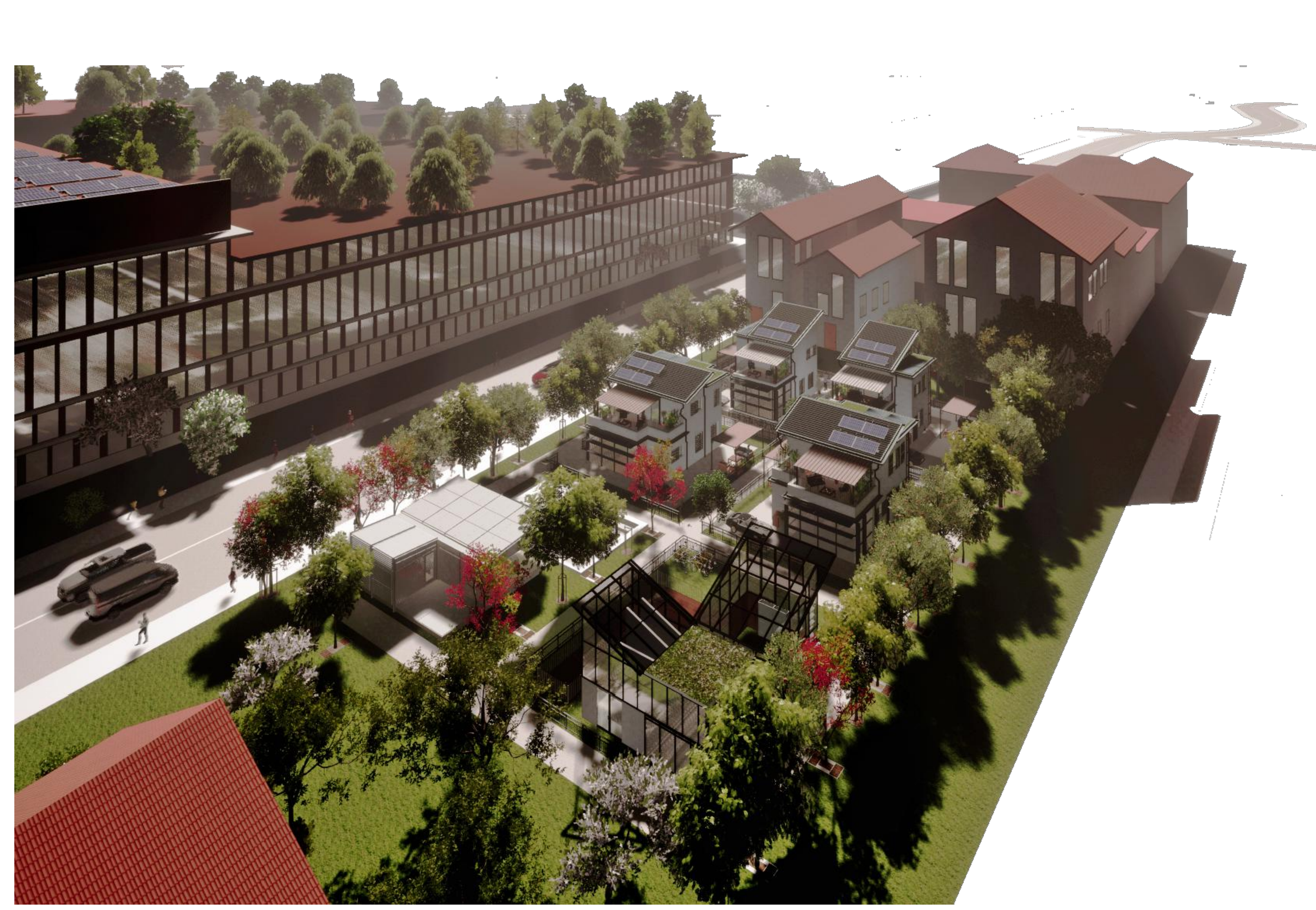

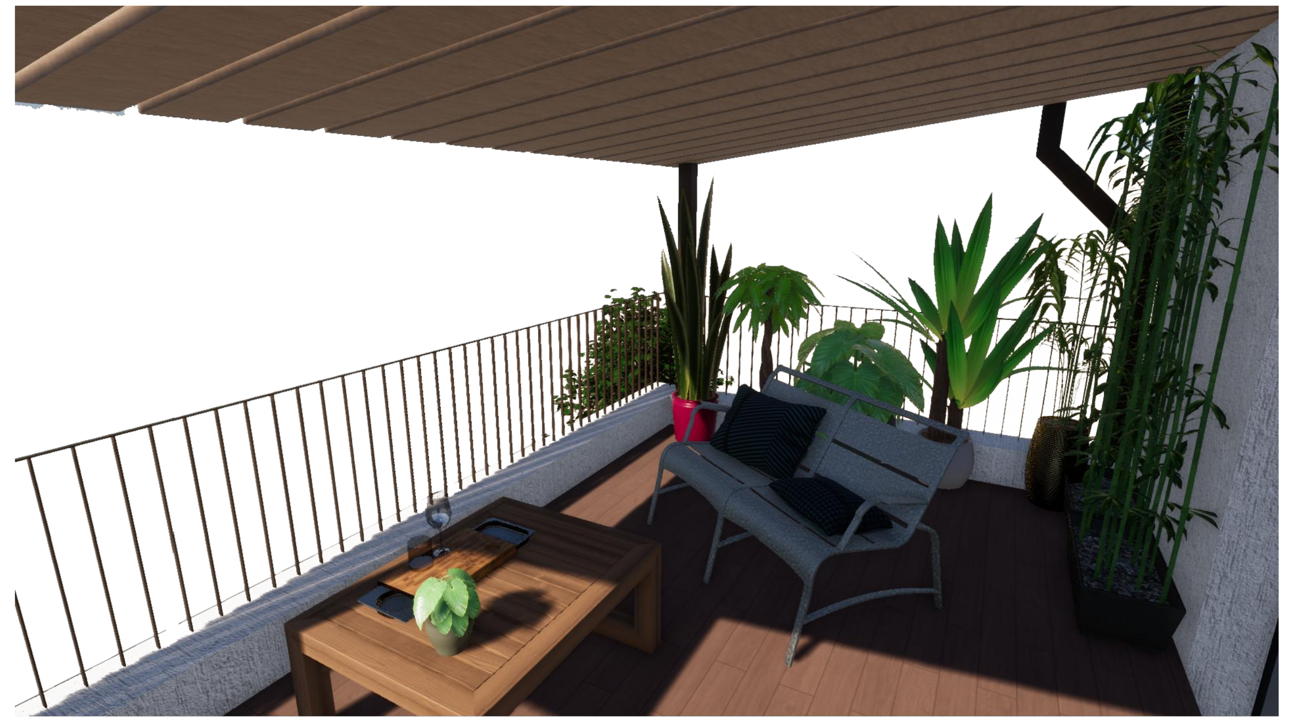

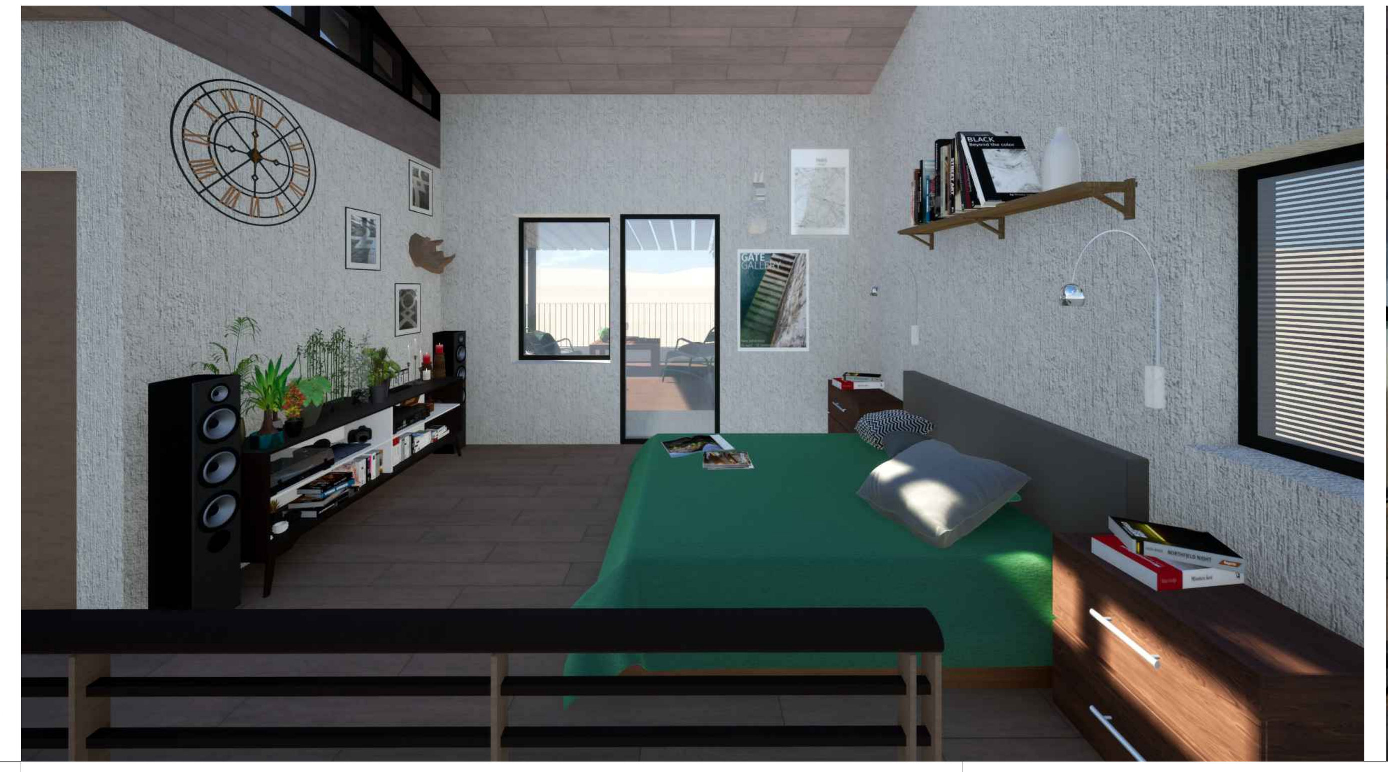

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