SynEnergy District

Study of the effect of the implementation of electric mobility on the energy behaviour of a newly built district including a performing arts centre

Politecnico di Milano

Polo Territoriale di Lecco
Scuola di Architettura Urbanistica Ingegneria delle Costruzioni
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Global and European overview on CO_2 emissions, construction and transport field impact, and official policies

Understanding the main trends in the overall scenario of energy consumption and CO_2 emissions is fundamental to better understand the reasons behind the ambitious energy targets defining the base of our research.

Buildings

A big percentage of the global greenhouse gas emission is due to the building sector. According to the International Energy Agency (IEA), buildings consume 32% of global final energy. Moreover, consumption exceeds 50% if also production of materials and construction process are considered. The European panorama substantially mirrors the global trends. Indeed, according to the European Commission buildings are responsible for the 40% of the European energy consumption and for the 36% of its CO_2 emissions.

Vehicles

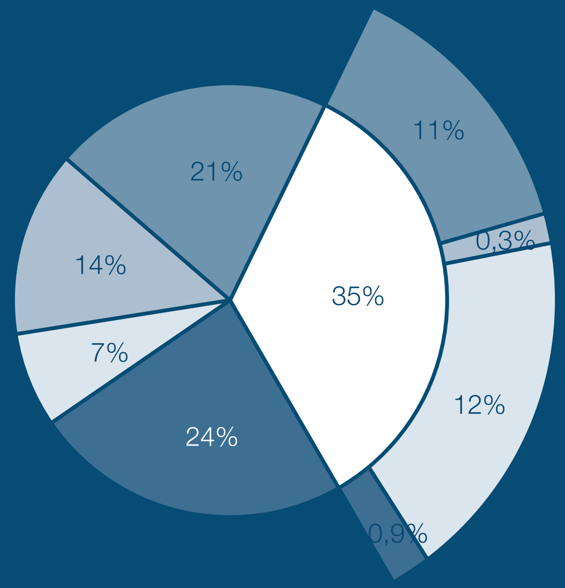
Transports sector produces almost a quarter of the total European greenhouse gas emissions and it is the main responsible of cities air pollution. While the other sectors, thanks to a low carbon circular economy underway, registered a gradual decline of CO_2 emissions, those due to transports only started to decrease during 2007, remaining higher compared to 1990. Road mobility is by far the biggest emitter accounting for more than 70% of all the greenhouse gas emissions coming from transports, and the highest percentage is due to cars.

European policies

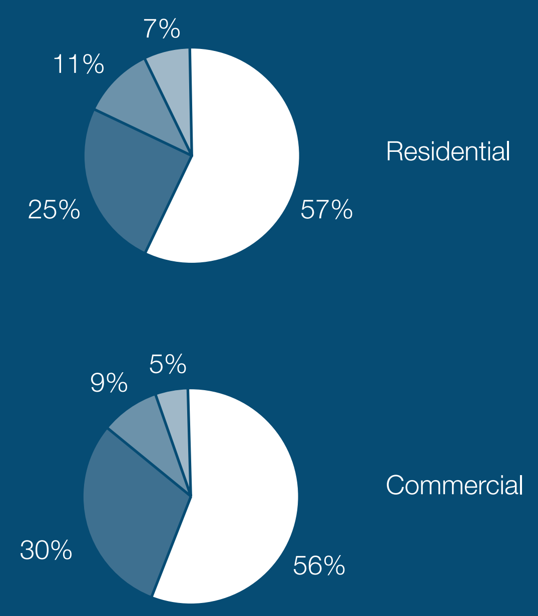
EU and its Member States' set of energy and climate policies will strongly impact its transformation up to and beyond 2030. For this purpose, European Community developed a "baseline scenario" in order to reflect in the current and future EU de-carbonization trajectory largely based on agreed EU policies and goals. According to the EC baseline previews, comparing primary energy consumption projections to 2005 levels, the EU energy supply levels evolve either in generic terms either in terms of energy mix. The baseline illustrates an overall reduction of 26% by 2030, in line with the 2030 EU target, and a 35% reduction by 2050; while, by 2070 no reductions are registered due to the counterbalancing effect of economic growth on energy consumption.

Strategies

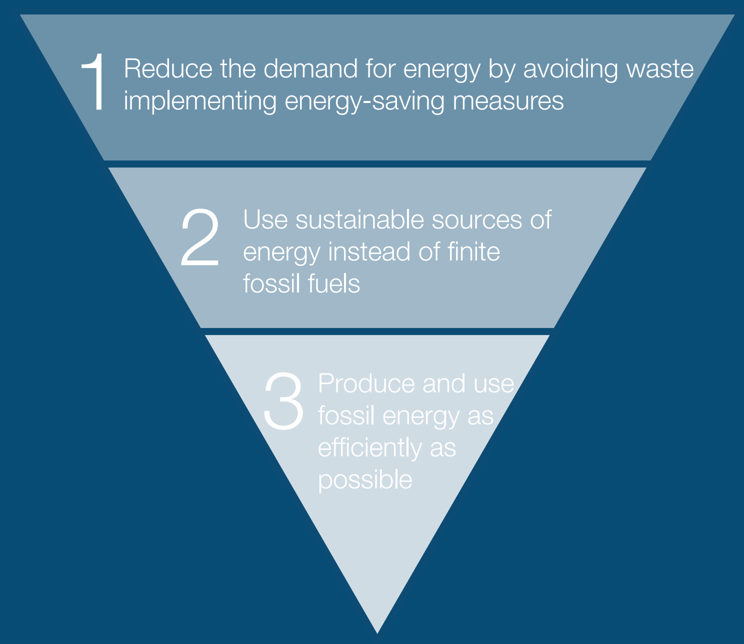
Approaching the topic of minimising the amount of energy consumed by a building in its lifetime is very complicated and multifaceted. The first thing to be considered is that the most environmentally friend way to build and run a building is with no energy at all, as energy production comes with pollution, even if in a small amount. This implies that we not only have to investigate the amount of energy that a building consumes to maintain a comfortable interior environment. We also have to be conscious about the energy embodied during the construction, the disposal, and the sources of all the energy used by a building during its lifespan.



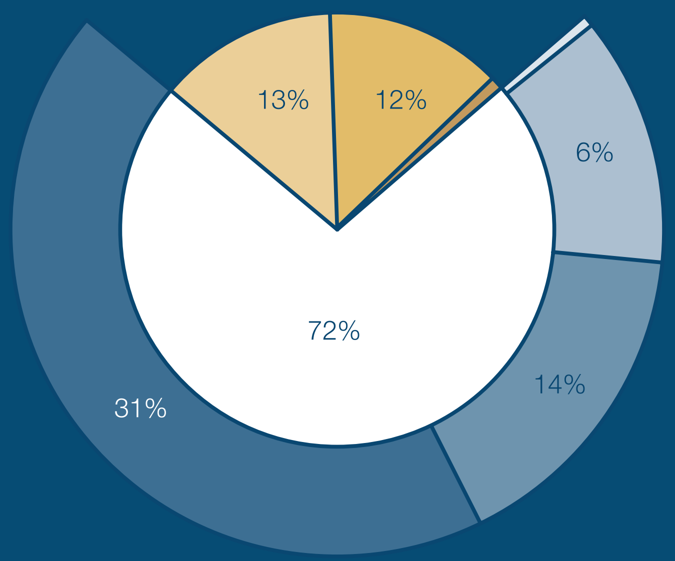
European carbon dioxide (CO_2) emissions by sector



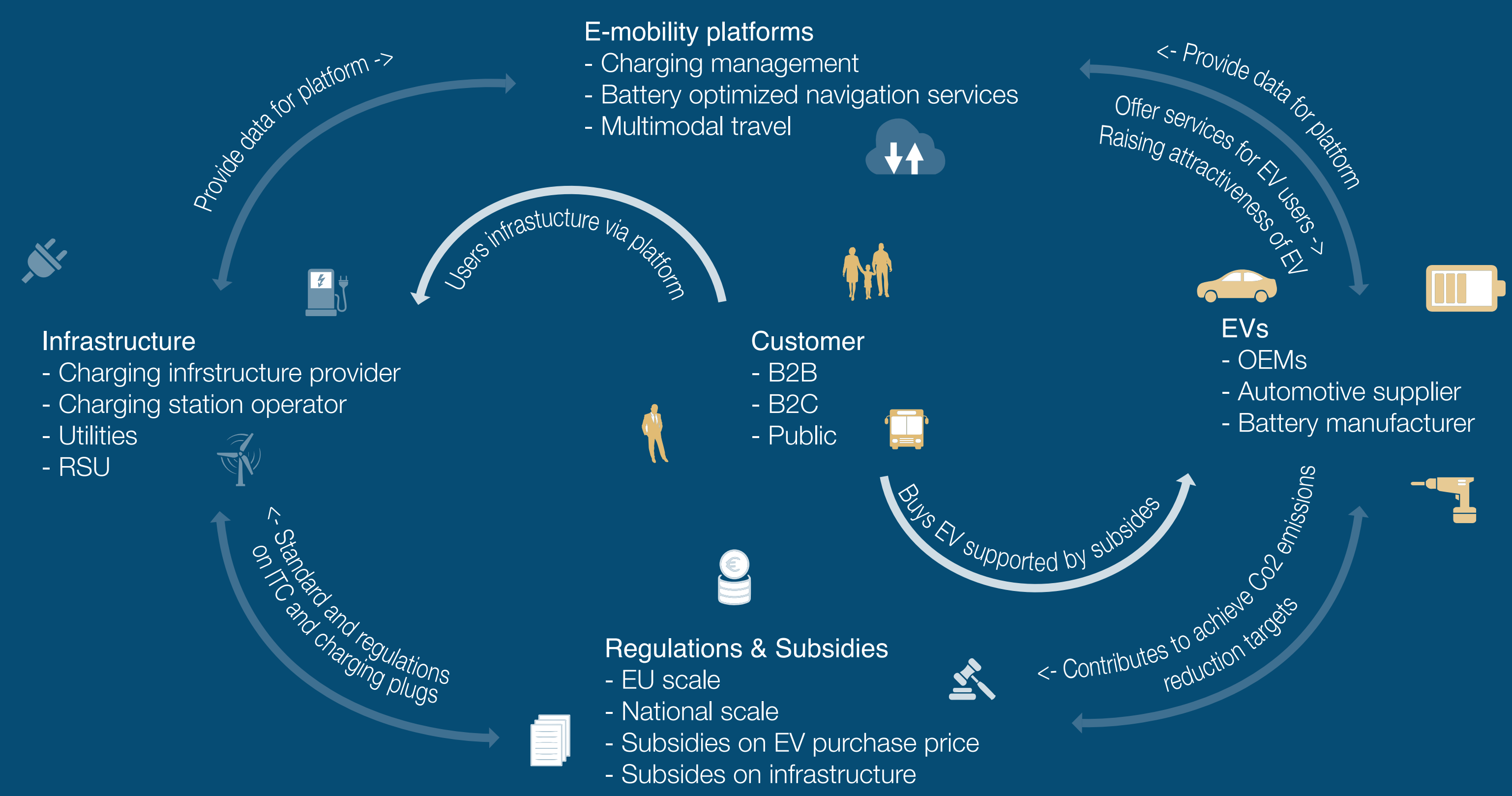
European carbon dioxide (CO_2) emissions



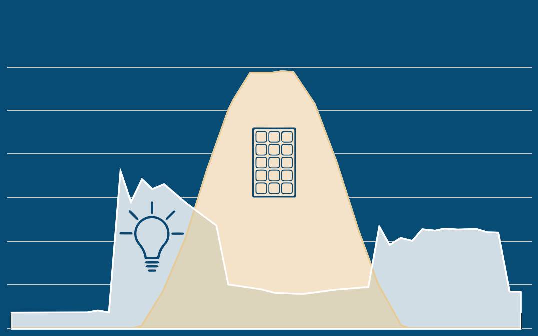
The trias energetica concept



European carbon dioxide (CO_2) emissions of vehicles

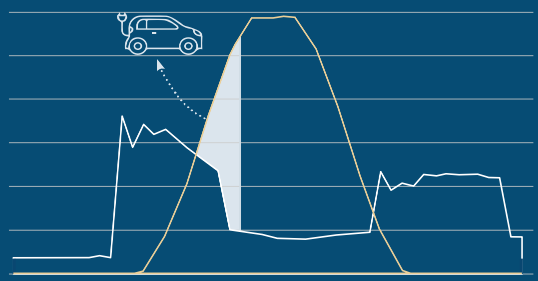


Strategies applied to daily energy simulations to reduce net consumption of buildings



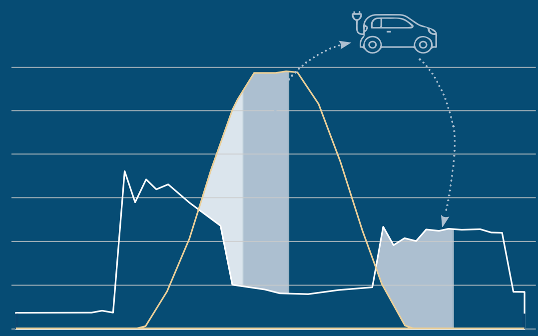
Consumption and generation schedules

The daily schedules are obtained through dynamic energy simulations. The consumption (white) and generation (beige) profiles depend on the season. Here average values, at equinoxes, are represented.



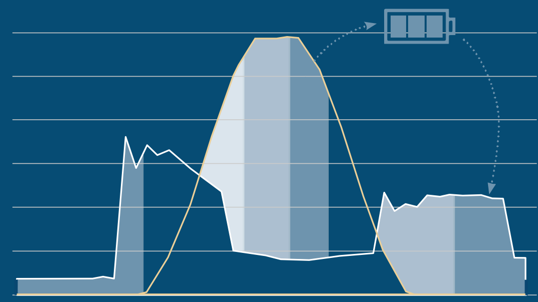
Electric vehicles consumption

Considering an average consumption of 2100 kWh per year, the daily energy needed by EVs is obtained from the first surplus available in the building.



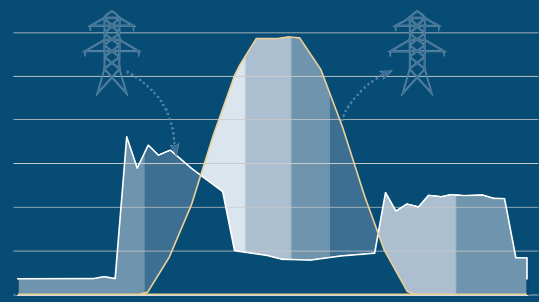
Electric vehicle storage and reuse

The remaining capacity of the battery (not used for everyday trips) is used as temporary energy storage, which is then reused in the first hours of the night as an energy source instead of the grid.



Power wall storage and reuse

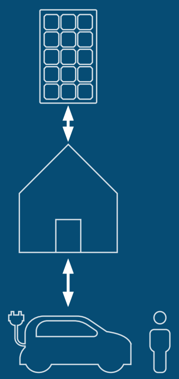
When the car battery is full, the power wall is used as a storage in order to increase the independence from the grid.



Net consumption and surplus

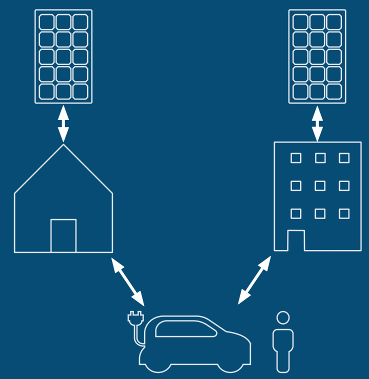
The grid is used as energy source during the first hours in the morning, when the stored energy is over. In case even the power walls will not be enough as storage, the exceeding generated energy is sent in the grid.

Strategies regarding the interaction between EVs and buildings



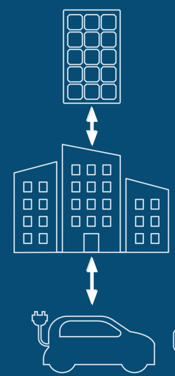
Localized production, private car

In this scenario the cars would be charged and discharged with the energy surplus produced by a single building (e.g. private houses) and would be private themselves.



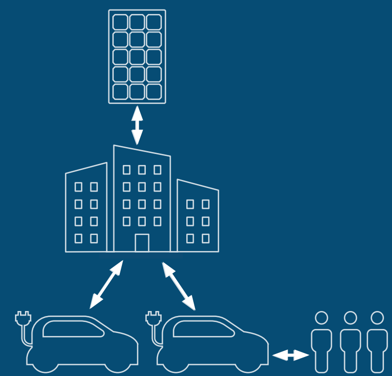
Shared production, private car

In this scenario the cars, again privately owned, would be charged and discharged with the energy surplus produced by a small set of buildings.



Diffused production, private car

In this scenario the cars, privately owned, would be charged and discharged with the energy surplus produced by buildings to which the car would be connected during the day.



Diffused production, shared cars.

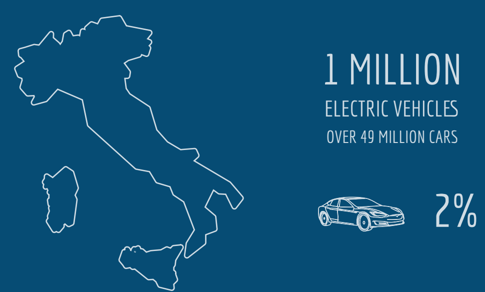
In this scenario cars would not be private anymore. Instead they would be shared, as the energy production would be. Private energy production or energy storage would not exist anymore.

Energy balances of different possible scenarios - EV diffusion

SCENARIO 0: ITALY 2019

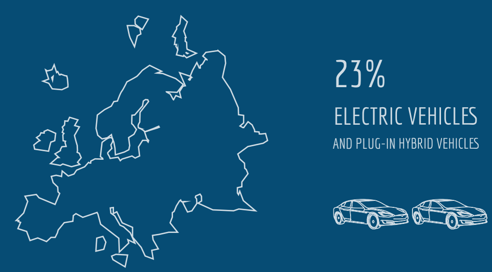
The first scenario, used as starting point, regards Italy nowadays with a number of EVs which is nearly zero. The city taken as example is Milano, with a share of workers using the car every day to go to work around 45%. *(Accordo di programma Comune di Milano e Ferrovie dello Stato)*

SCENARIO 1: ITALY 2030



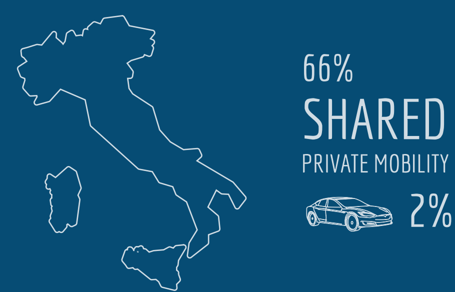
This scenario considers as location Italy but in ten years from now. In this scenario there will be around one million electric cars over a total amount of 49 million cars. This means that it will count roughly the 2% of cars. *(Urban Studies Department of Politecnico di Milano on the future deployment on EVs)*

SCENARIO 2: EU 2030



In this case the reference panorama was the perspective for the European Union in ten years from now, even if the location for the scenario simulations was still Milano. The amount of electric private vehicles was set to the 23% of the total amount of vehicles. *(Cambridge Analitica)*

SCENARIO 3: ITALY 2030
WITH SHARED MOBILITY



The last scenario still refers to an hypothetical Italian situation in 2030, however in this case the idea is that a certain amount of cars will be shared. The amount of cars shared in this scenario is assumed to be around 66%. *(EY mobility think tank 2018)*

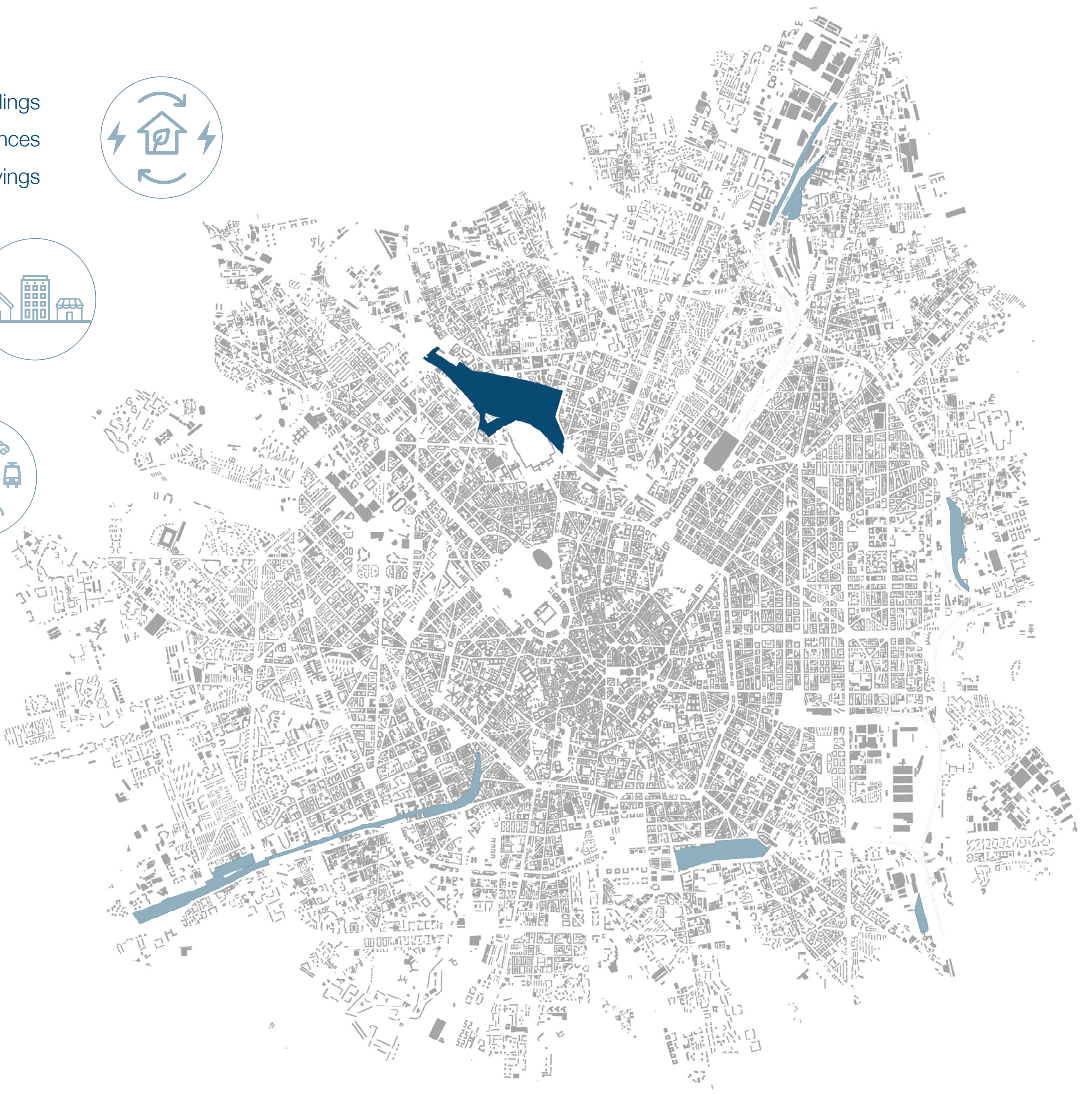
M01

Masterplan | Scalo Farini

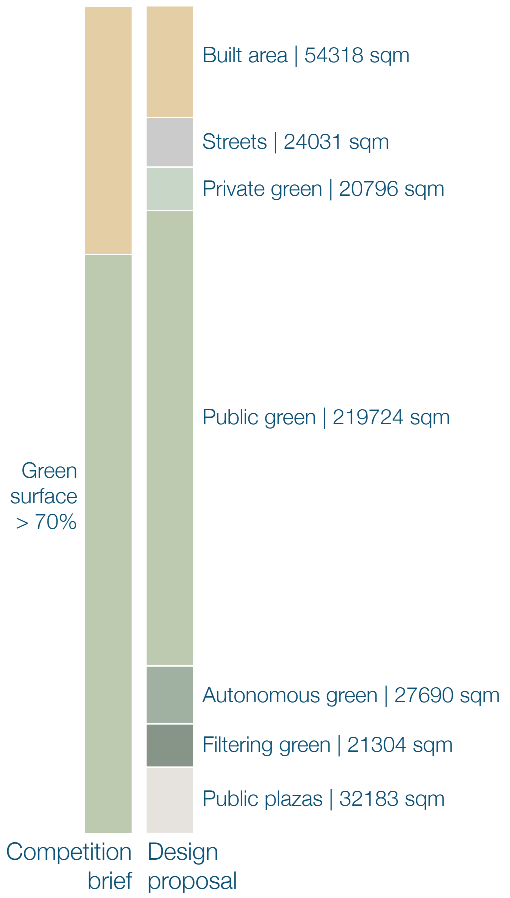
Possibility to design new buildings with maximum energy performances and savings

Adequate size in order to allocate proper functional mix (residential, offices, commercial)

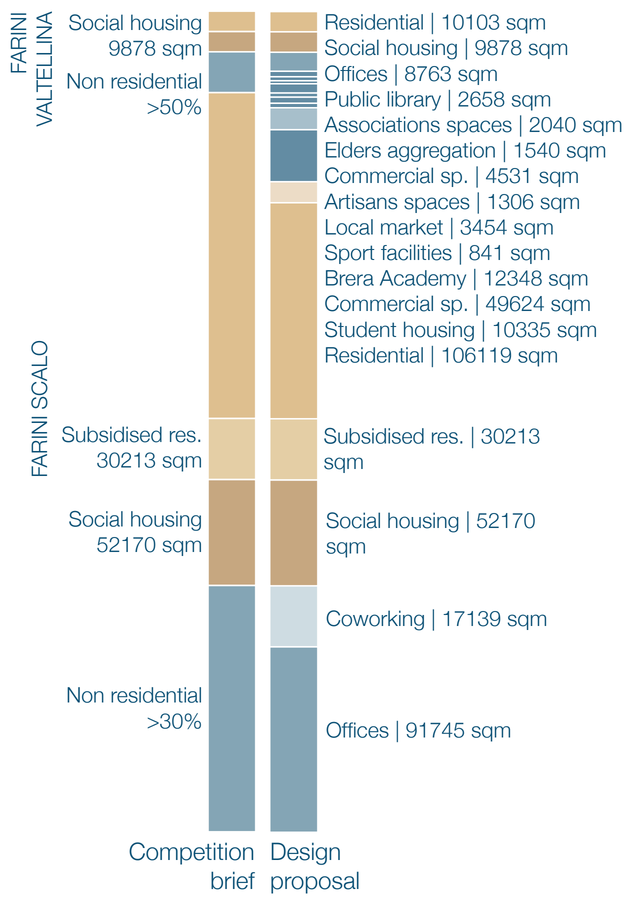
Well connected with the large road infrastructures and with a sufficiently high audience



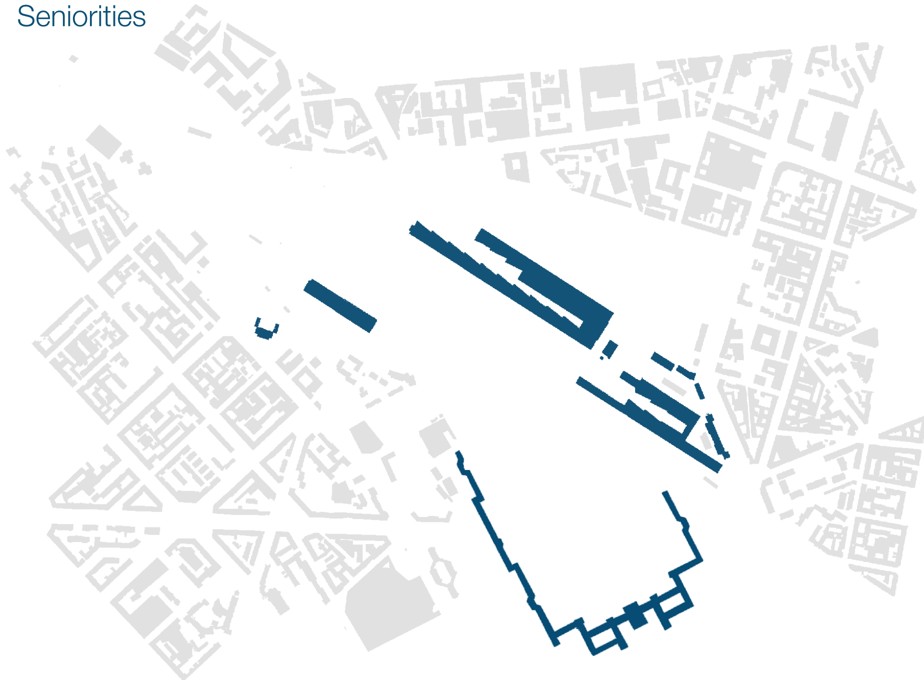
Total surface: 400062 sqm



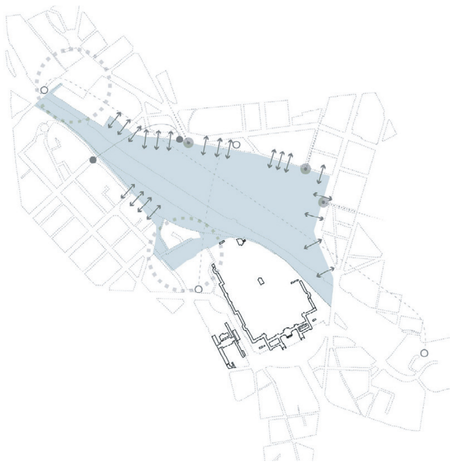
GFA: 402460 sqm



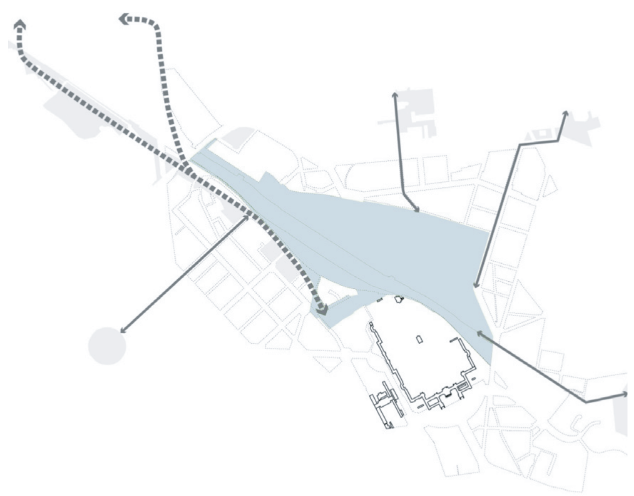
Seniorities



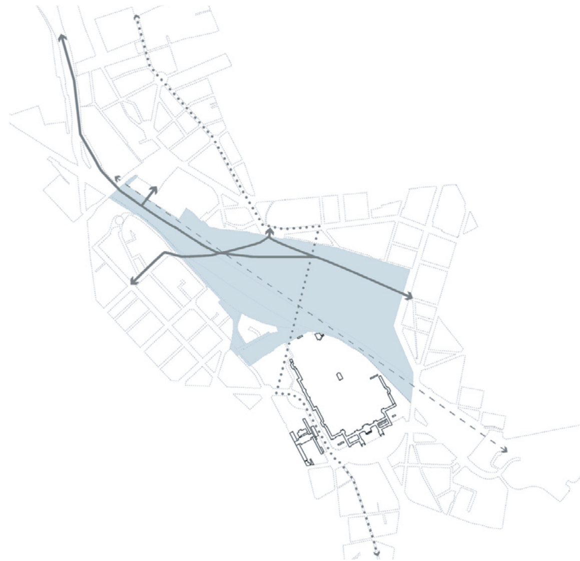
Competition requirements



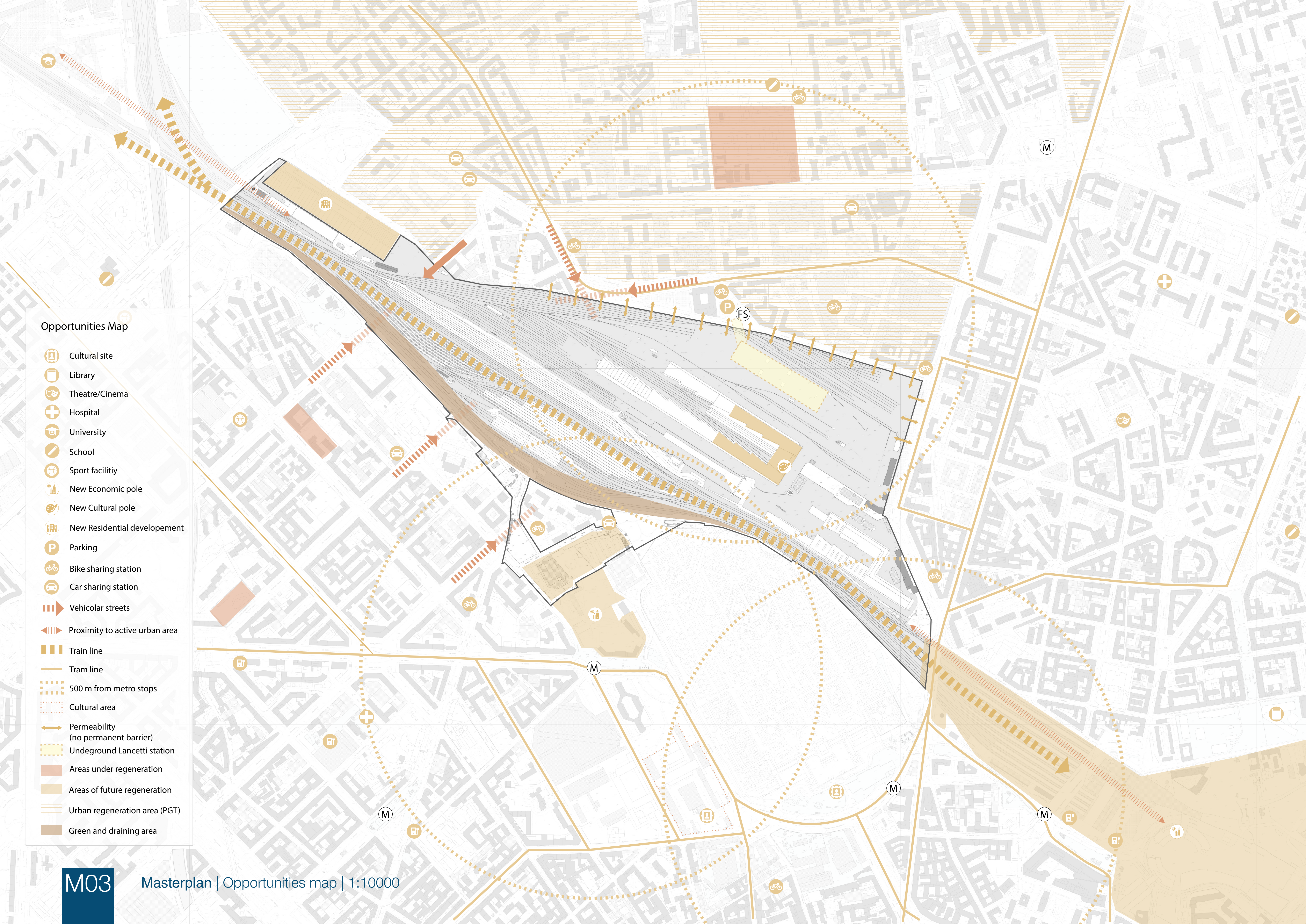
Create relationships with the surrounding area and the urban context



Connect with the surrounding areas and public spaces

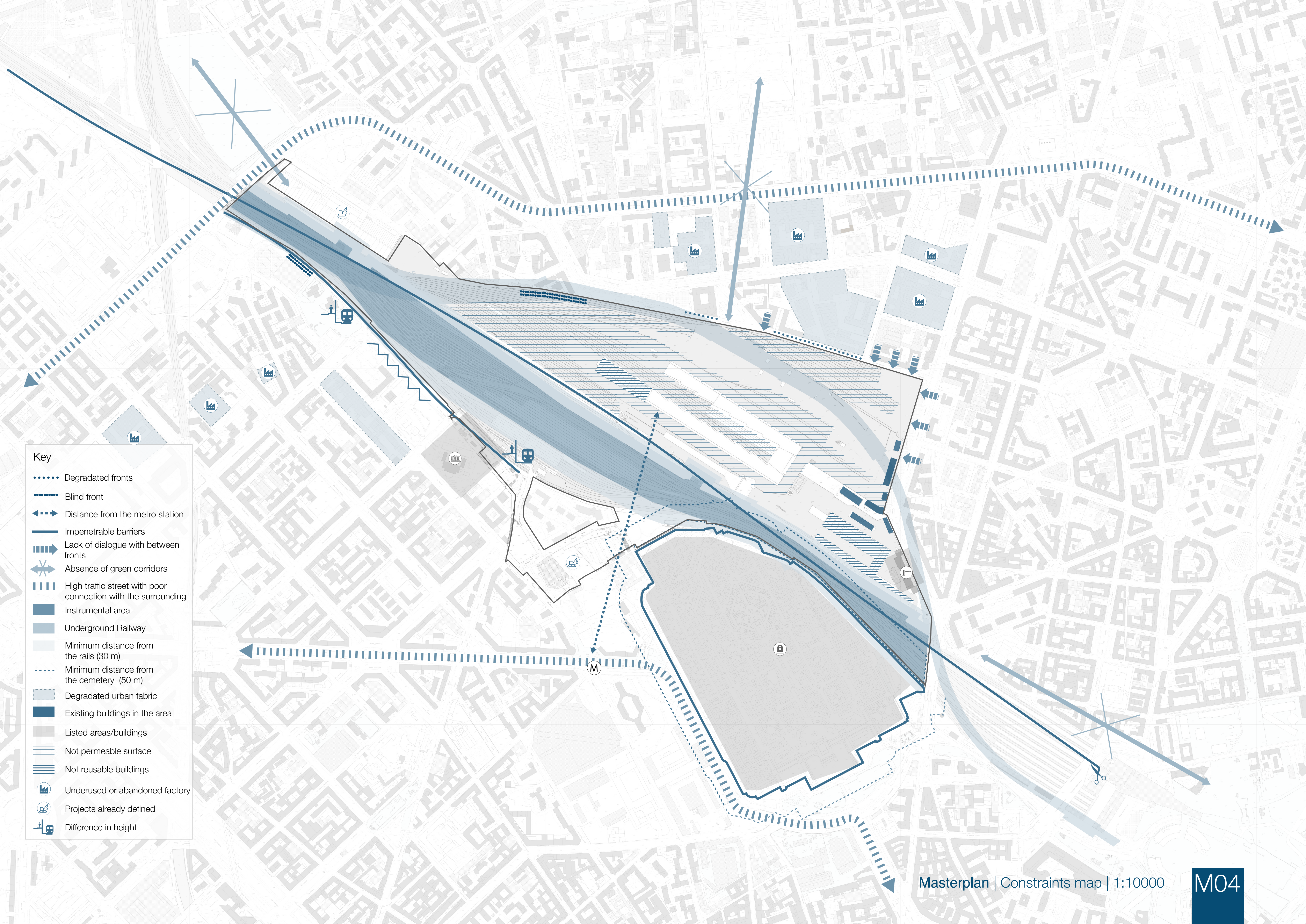


Reconnect the urban fabric allowing to cross the railways



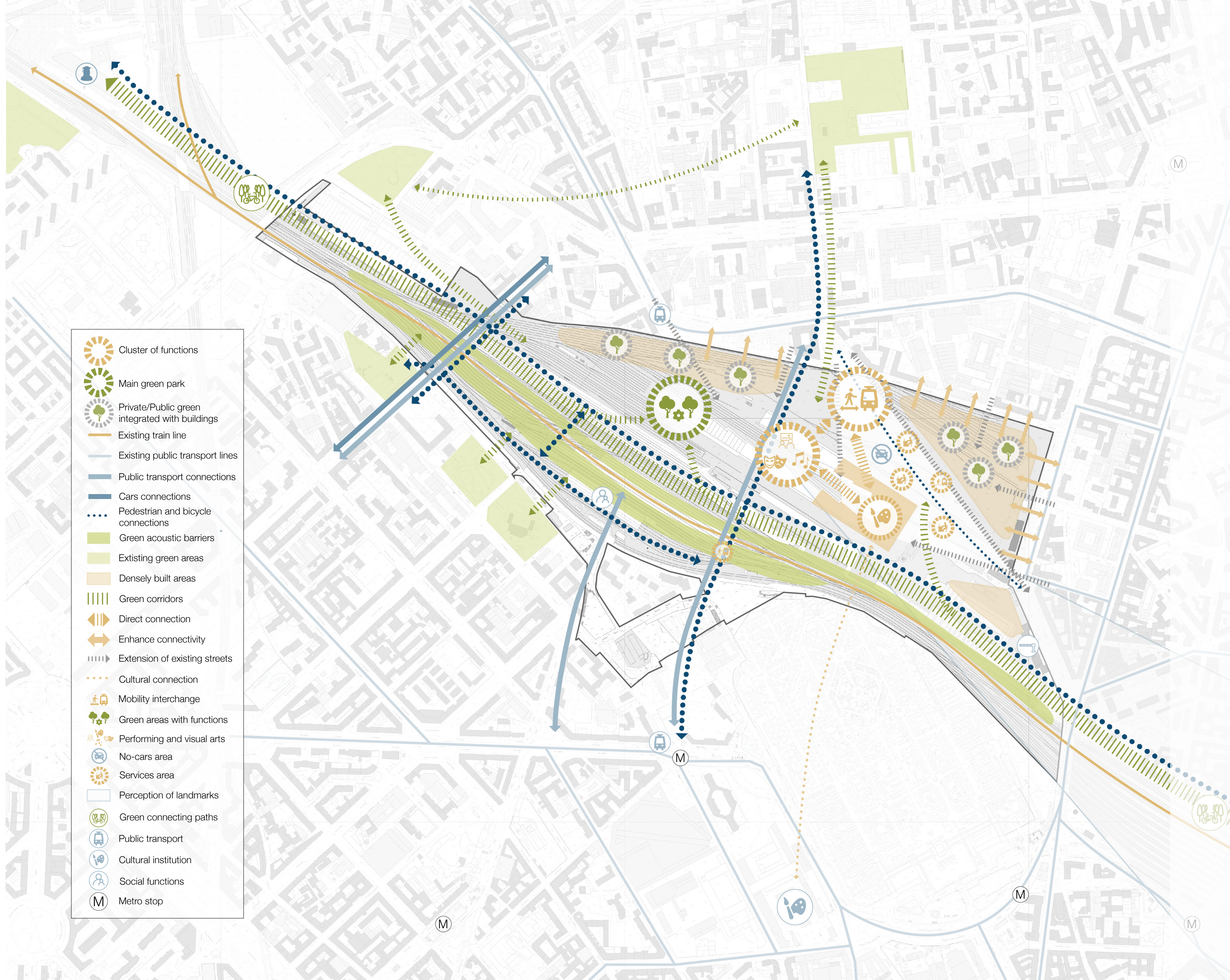
M03

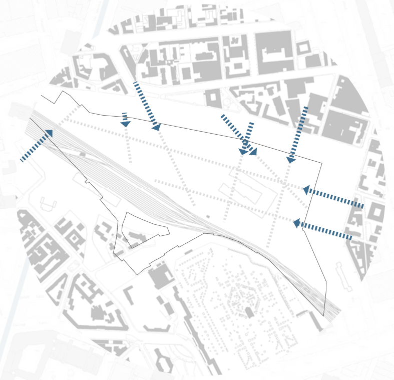
Masterplan | Opportunities map | 1:10000



Masterplan | Constraints map | 1:10000

M04

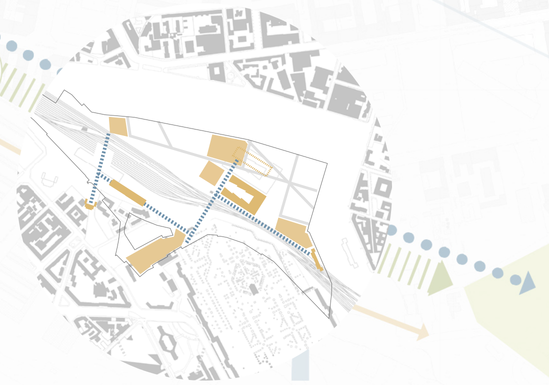




Extension of the existing streets to reconnect the urban fabric

Unitary green between the rails and the urban fabric, densification of the blocks confining with the existing

Valorisation of the existing elements with high social and cultural functions



Expansion of the existing functions with complementary urban services and infrastructural connections

M05 Masterplan | Concept | 1:10000

Masterplan | Design | 1:10000

M06

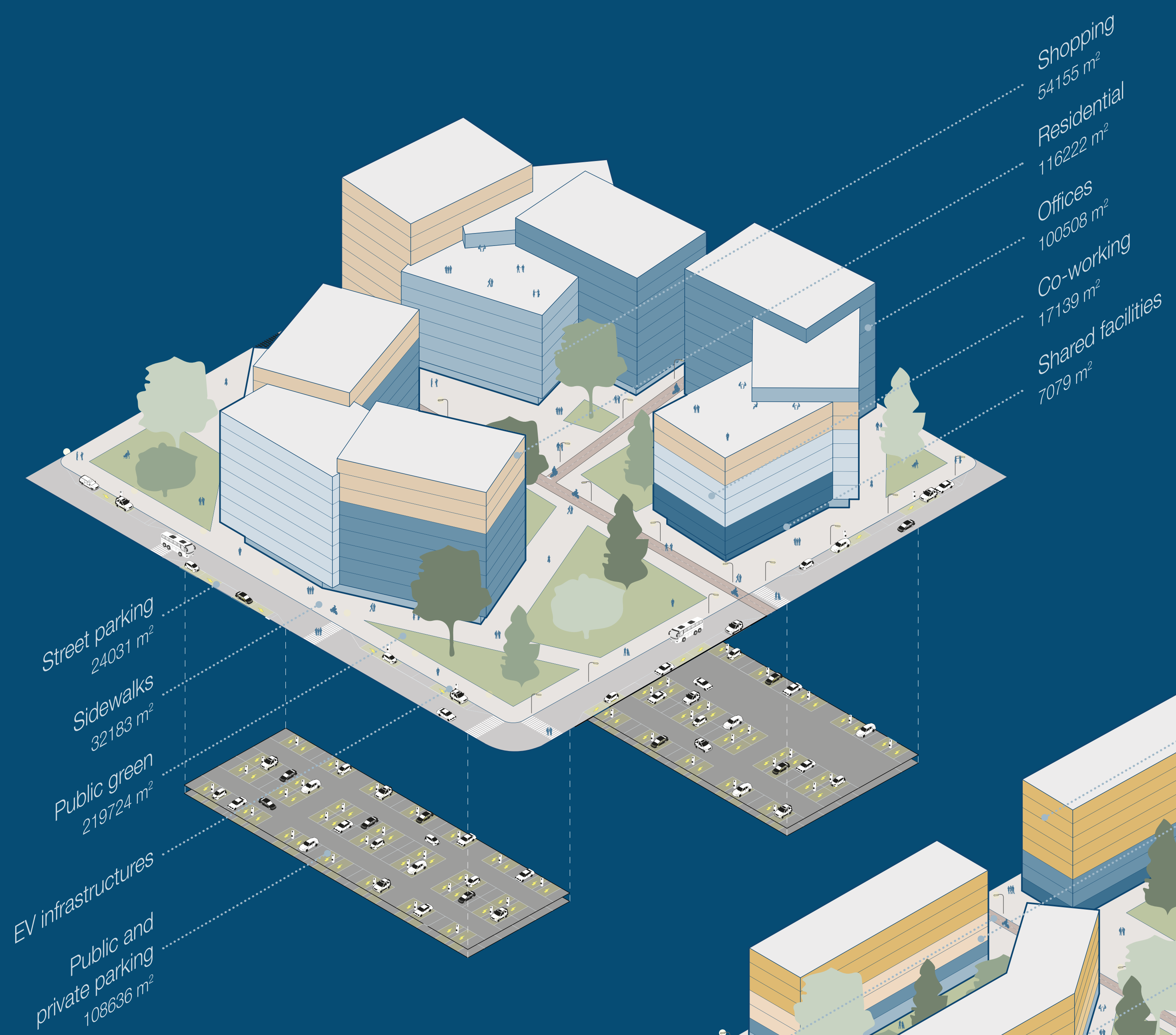
Multifunctional district energy balance

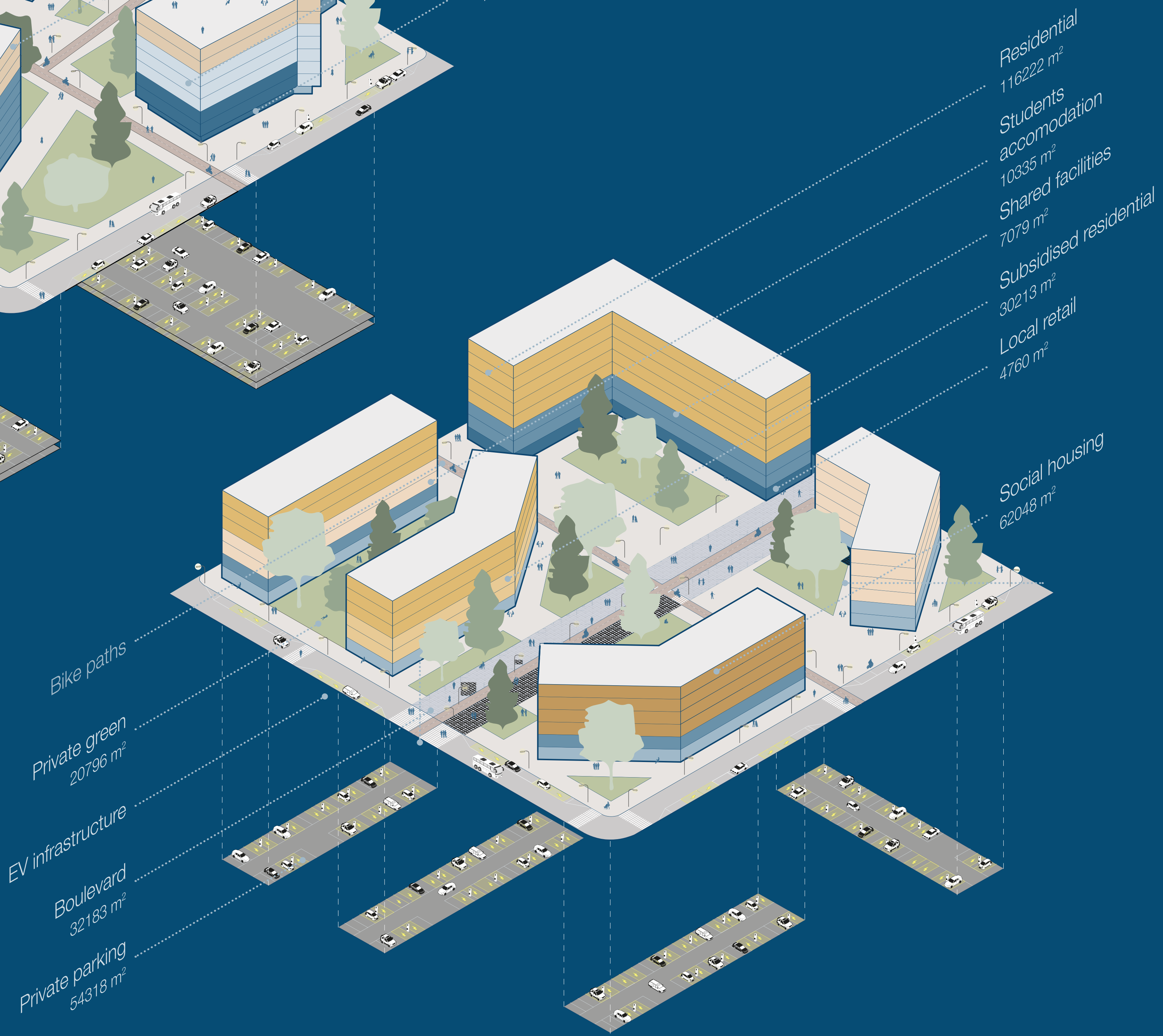
The buildinga shaping the masterplan of Scalo Farini are built in order to achieve high energy performances. This requirement has been fulfilled choosing, after proper analysis and simulations, high performance stratigraphies and HVAC system, using heat recovery and a ground source heat pump. The district was designed in order to avoid as much as possible the mutual shading and improve the PV panels efficiency during the day. This parameter is fundamental for the simulations because the energy produced by PV panels has to be maximised in order to achieve the best results possible.

The presence of different functions in the district allows a more uniform distribution of the consumptions during the day, which improve the effectiveness of the energy strategy. Both of the district typology are designed in order to provide the neighbourhood with different activities, in order to be active for most hours of the day and avoid energy demand peaks. The presence of multiple EV charging stations, both private and public, enhances the possibility of energy storage, increasing the energy performance of the whole district and stimulating the use of electric vehicles in the area.

The annual simulation of the whole district shows an important amount of produced energy, which is higher than the consumption for most of the time. The general results are very good, considering that the total consumption is only 27.6 kWh/m²y, which is an optimal value for mixed use buildings. Being the total production 40.2 kWh/m²y, the district can be considered as "active", meaning that the buildings generate more energy than they consume.
The summer peak of consumptions, due to the increasing use of energy for cooling, is offset by an important increase in production. On the other hand, the winter production can be enough for the consumption during the day, while during winter nights the energy will have to be taken from the grid.

During an average day, as represented in the chart on next page, the production reaches higher values than the consumption, providing an important surplus during daytime. This excessive energy needs to be stored in order to make it available during night hours. The storage should be enough to store as much energy as it is needed to fulfil the consumption not covered by production. Both electric vehicles and power walls can be good ways to store energy even though they both have problems in relationship to their availability and additional costs. The simulations showed an important amount of excessive energy, which can be useful to charge EVs or to provide passive buildings with renewable energy. In the last steps this possibility has been analysed, using EVs as storage and energy carrier in order to increase the grid independence of the district.





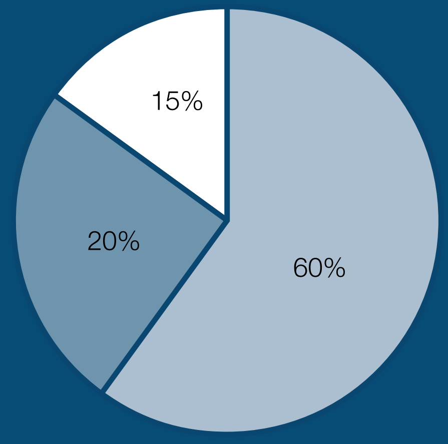
Energy balances of different possible scenarios - Masterplan

The surrounding district has been designed with high performances in terms of systems, lighting and thermal transmittance. This explains the low percentage of energy consumption relative to heating and cooling, as it happens to lighting. The appliances have the highest percentage of consumptions, which include office equipments, cooking and home appliances.

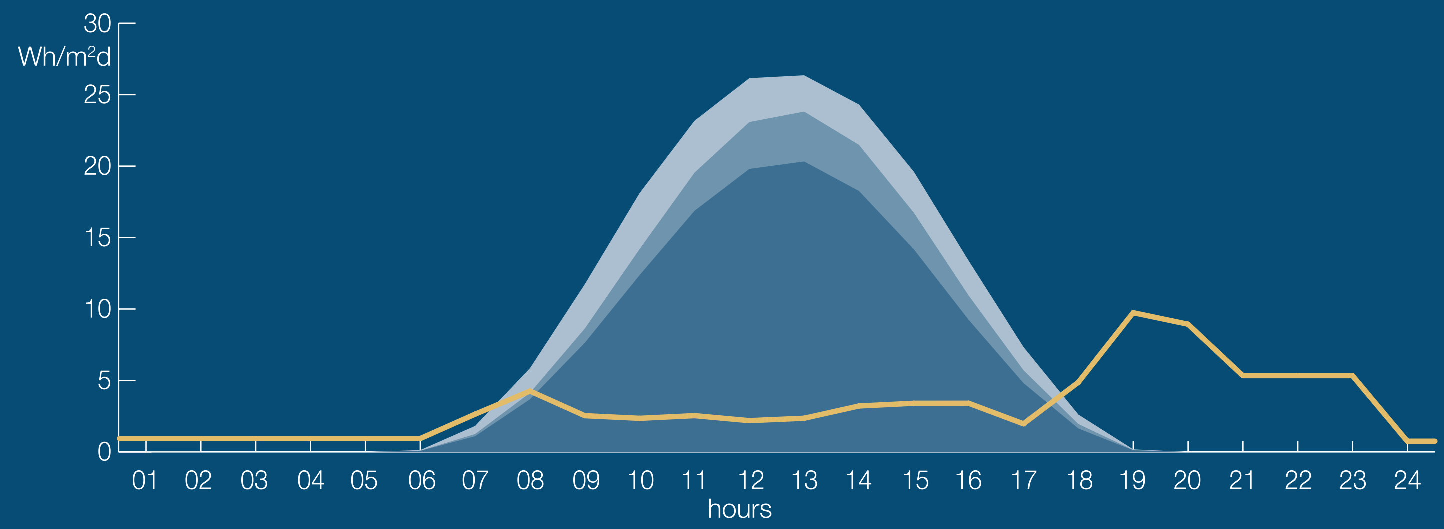
For the energy analysis, three different scenarios were considered, depending on the amount of photovoltaic panels installed on the buildings. Three different simulations were run, the first one with only PV panels on the roof, then adding them on the South façade and finally also on the East and West fronts. The simulations results show how the energy produced by the panels on the roof is considerably higher then the following steps.

The three options are introduced also on the energy balance of the EV scenarios, with results representing each combination. The performance indexes which can be used to compare the different results are:

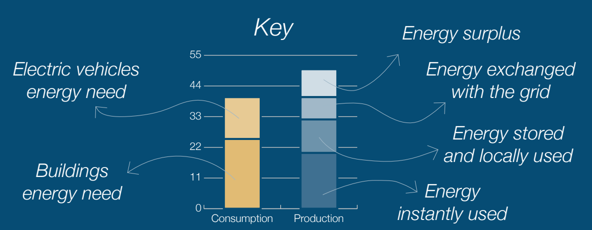
- GI (Grid Independence): it measures the percentage of the total consumption of annual energy which is locally produced and not taken from the grid.
- PS (Production Surplus): it measures the percentage of the total generation from PV panels which exceeds the need and is sold to the grid.



Consumptions in the high performance district



Energy analysis on the equinox of the high performance district



SCENARIO 0: ITALY 2019

45% PEOPLE GOING TO WORK BY CAR IN MILANO

SCENARIO 1: ITALY 2030

1 MILLION ELECTRIC VEHICLES OVER 49 MILLION CARS

2%

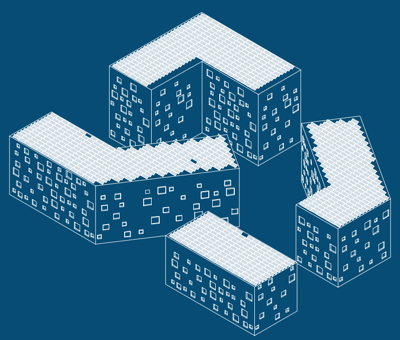
SCENARIO 2: EU 2030

23% ELECTRIC VEHICLES AND PLUG-IN HYBRID VEHICLES

SCENARIO 3: ITALY 2030 WITH SHARED MOBILITY

66% SHARED PRIVATE MOBILITY

2%



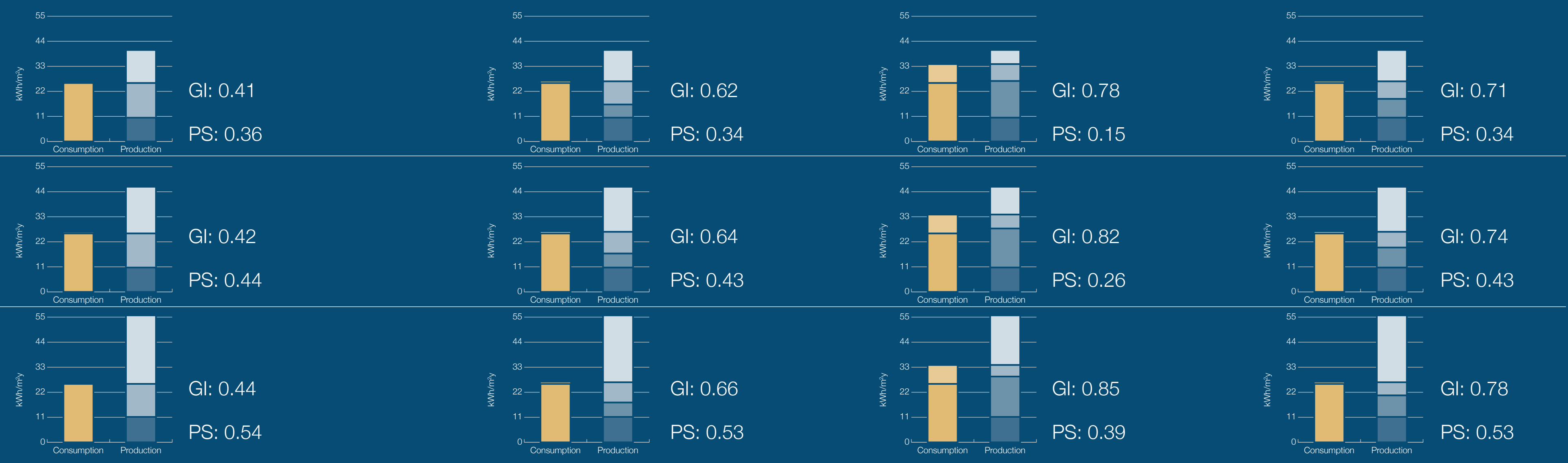
MIXED-USE URBAN BLOCK

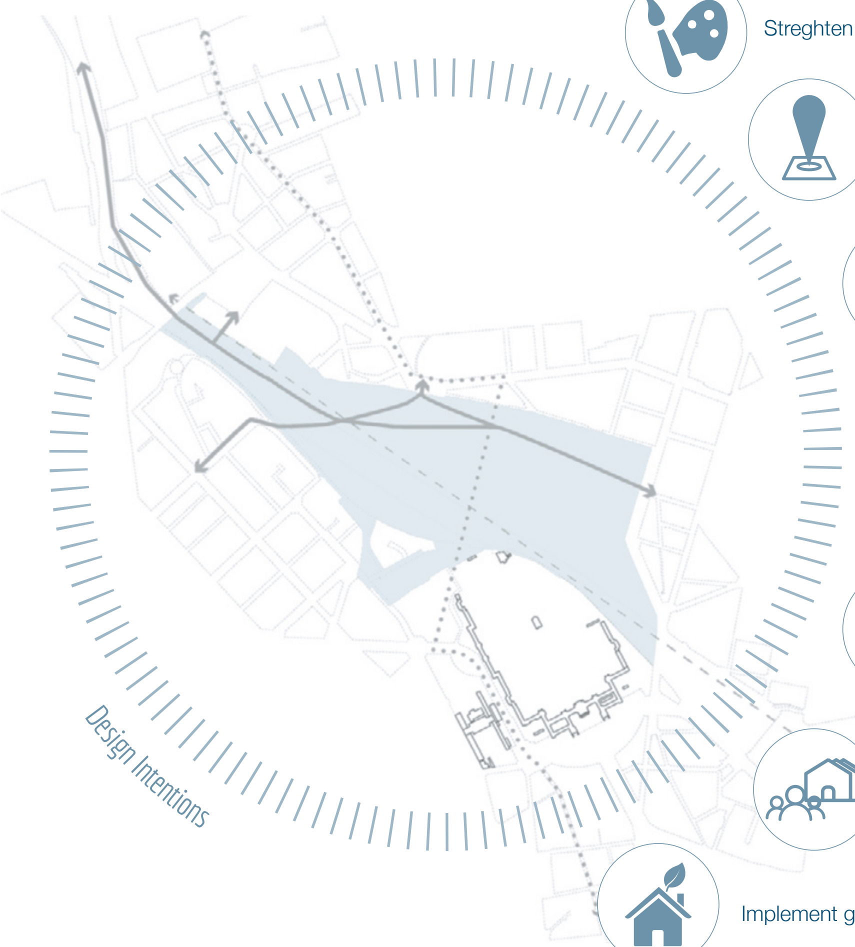
SURFACE: 19358 m²

OPTION 1: PV PANELS ON THE ROOF

OPTION 2: PV PANELS ON THE ROOF AND SOUTH FACADES

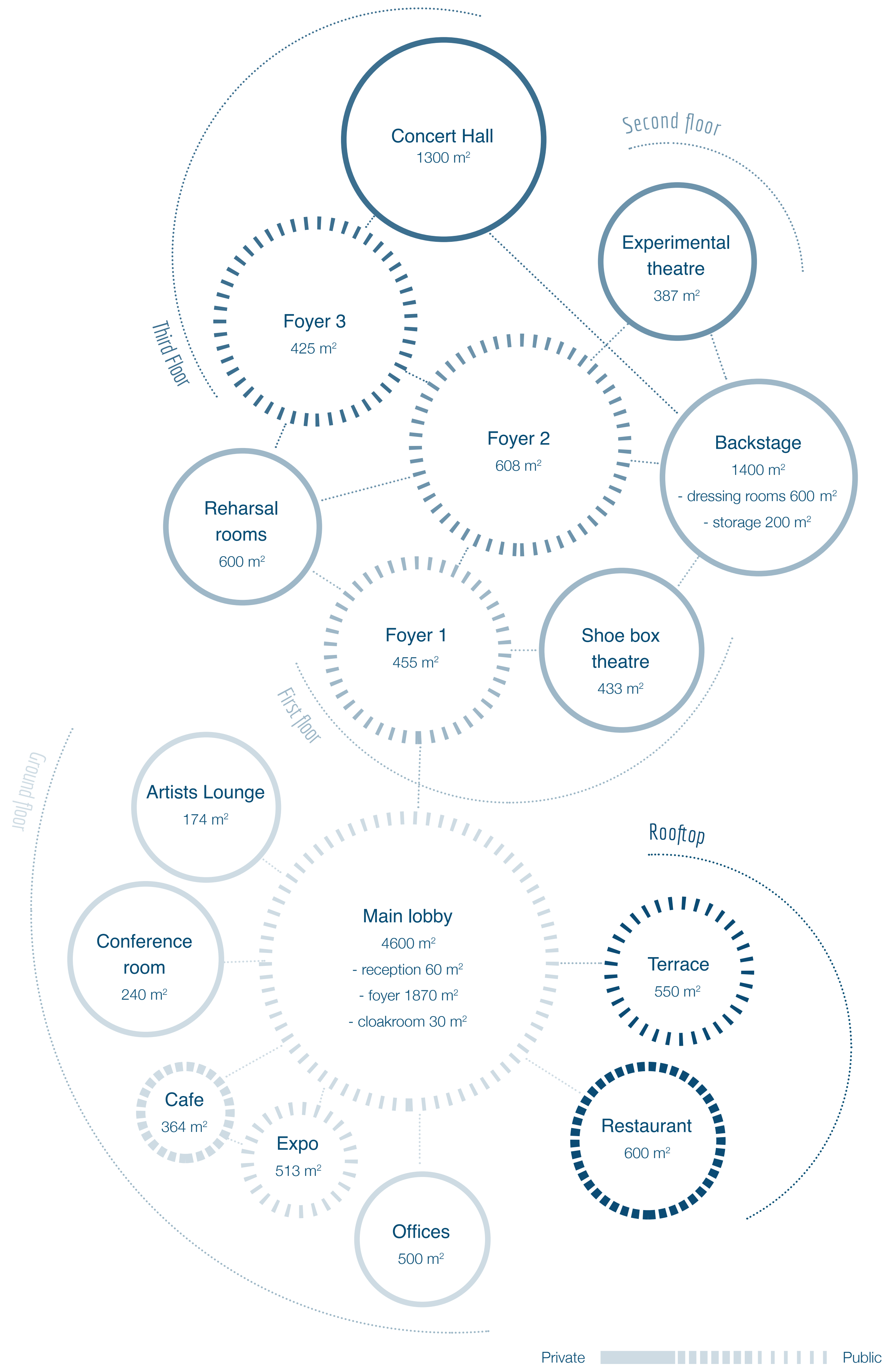
OPTION 3: PV PANELS ON THE ROOF AND SOUTH, EAST AND WEST FACADES

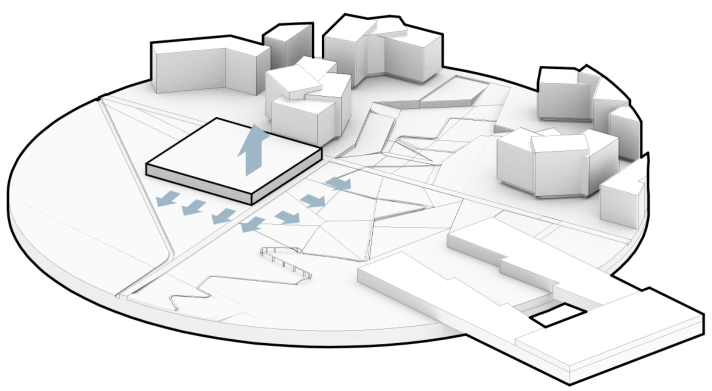




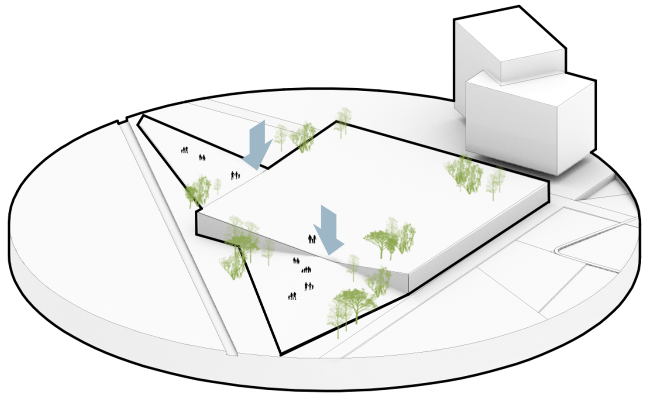
- Streghten the Cultural Path
- Define a new landmark highlighting the new developing district
- Enhance green areas and nearby infrastructures
- Exploit good infrastructures connection
- Offer a service identified as one of the main trend in big cities
- Define an object that well dialogues with the existing buildings coupling them to actract further users
- Implement green strategies to define a high performance public building

- Implement high performing systems
- Study the independence and the interdependence of a public building in relationship to a high performing neighborhood in a micro-grid
- Study the impact of electric mobility on the single building and on the interaction with the neighborhood and the city

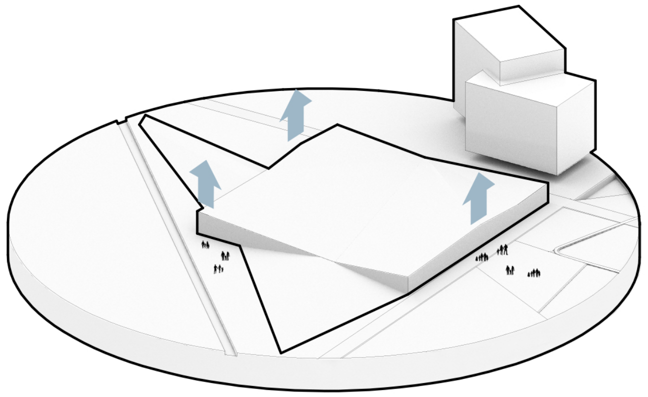




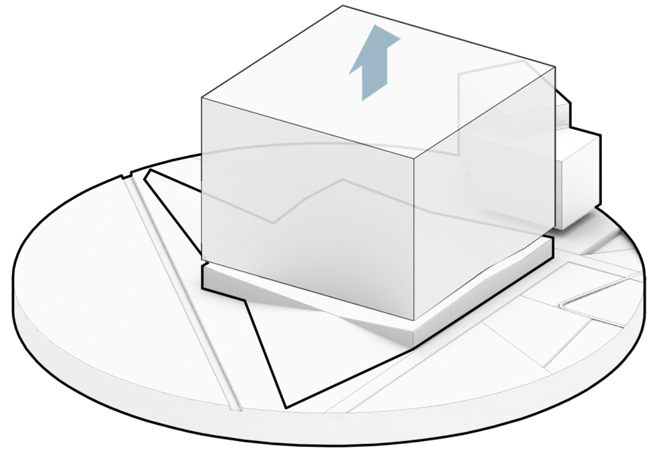
The lowest volume follows the streets and spreads horizontally in order to create a strong relation with the ground floor



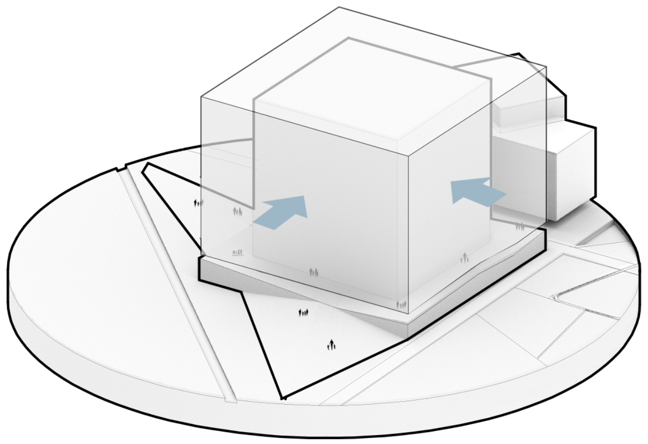
The roof is modified in order to allow the park and the flows to spead over the building



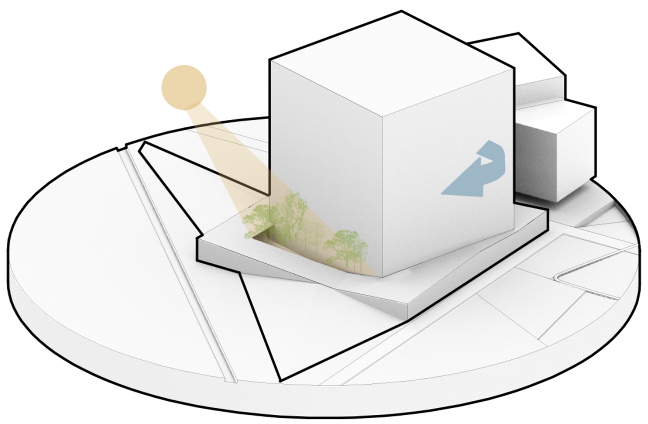
New vertexes are created and modified to enhance the entrances



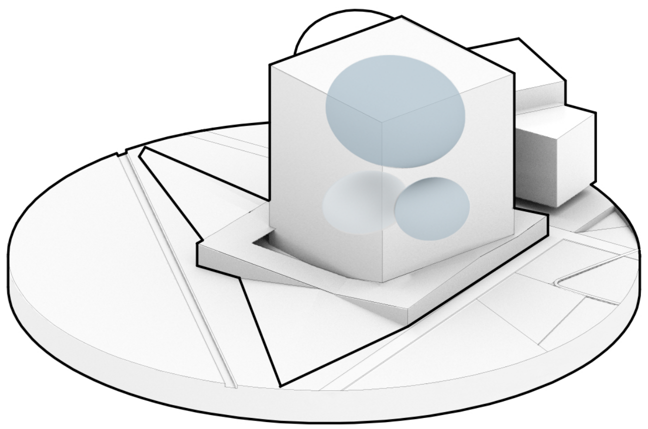
Extrusion of the footprint in order to generate a vertical volume where the funcions will take place



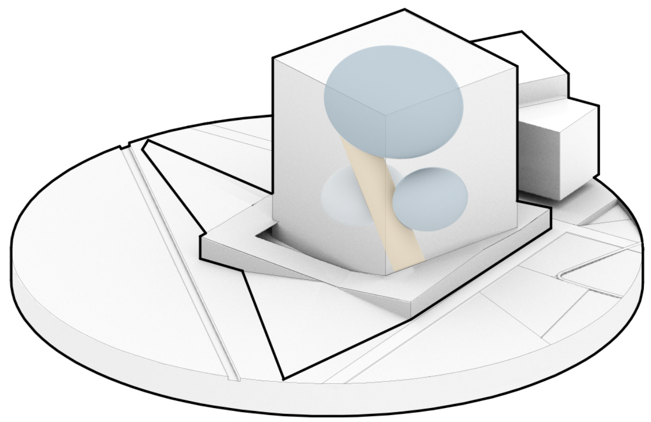
The vertical volume is pushed back from the outermost layer to allow green public spaces over the roof



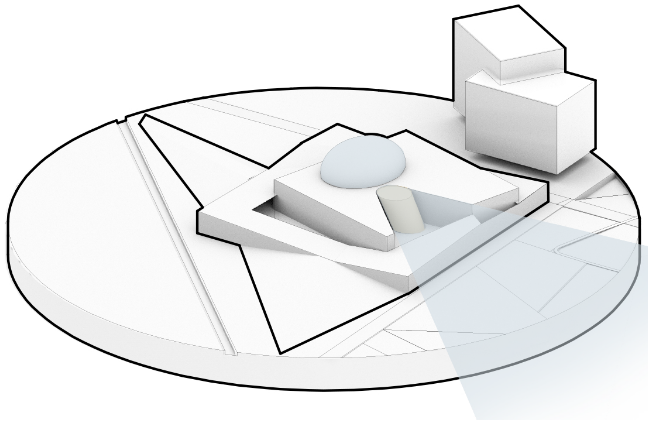
The vertical volume is rotated in order to create a visual connection with Brera and to allow natural light inside



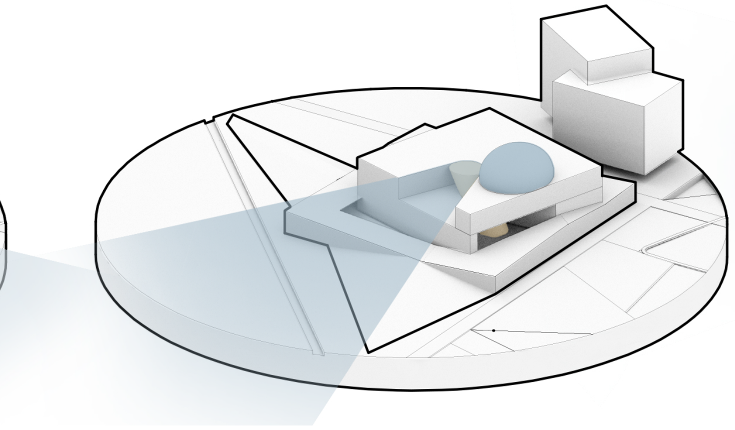
Disposal of the three main functions that occur vertically



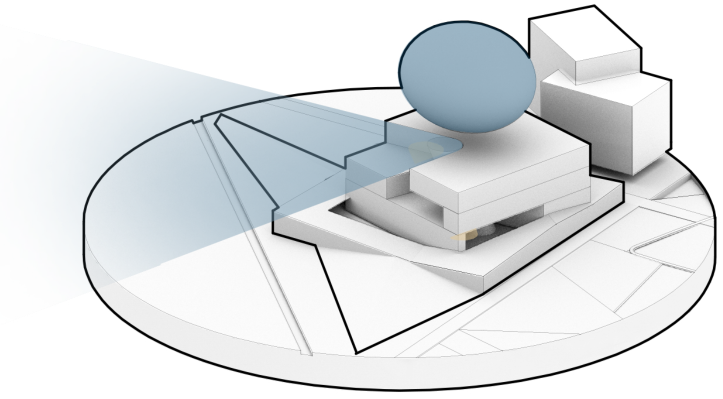
Connection of the three main functions through a suggestive path



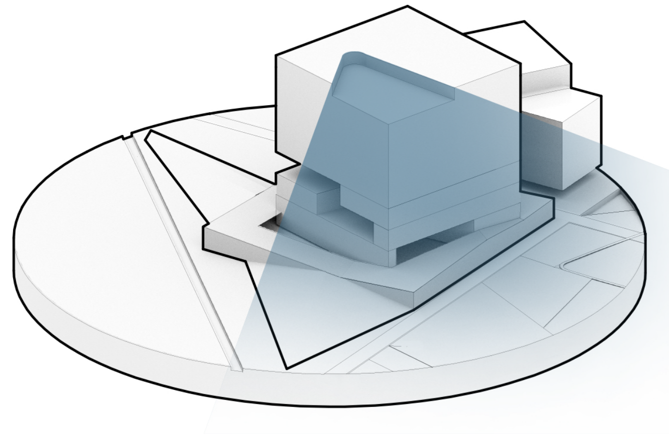
Views are generated in order to create a stronger relation between the inside and the outside: the first level opens up in the direction of the main entrance in front of Brera



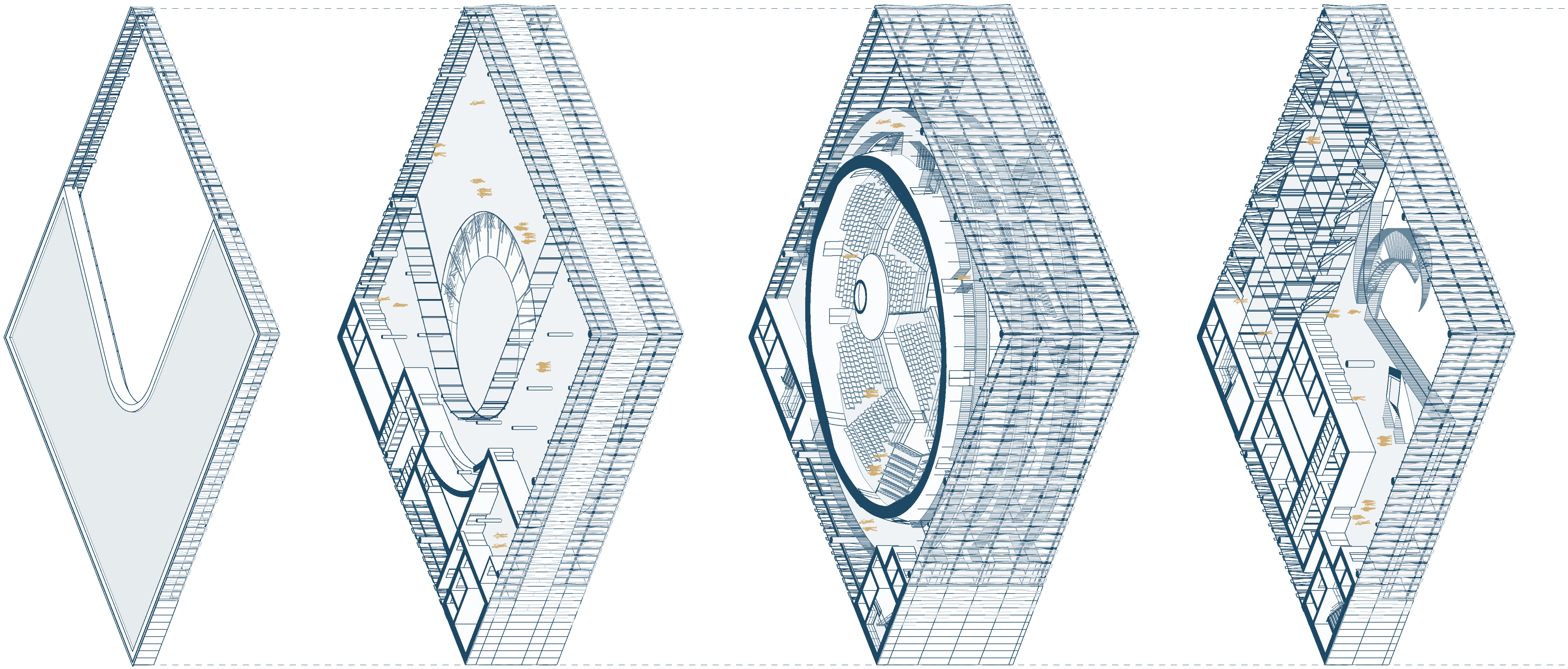
Views are generated in order to create a stronger relation between the inside and the outside: the second level looks at the new green bridge over the railway and the park



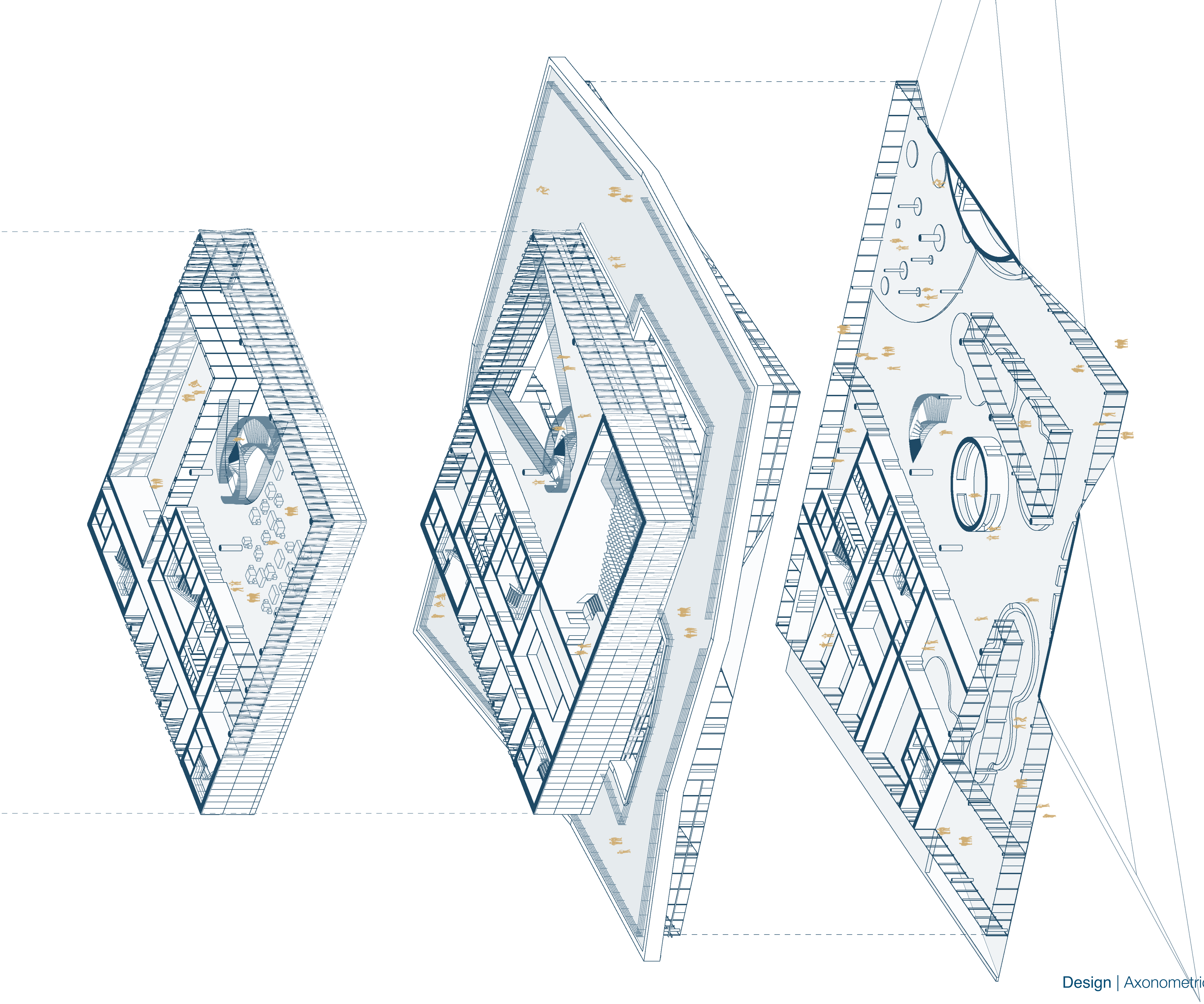
Views are generated in order to create a stronger relation between the inside and the outside: the thrird level opens up in the direction of the park



Views are generated in order to create a stronger relation between the inside and the outside: the roof offers a view towards the city and Porta Nuova

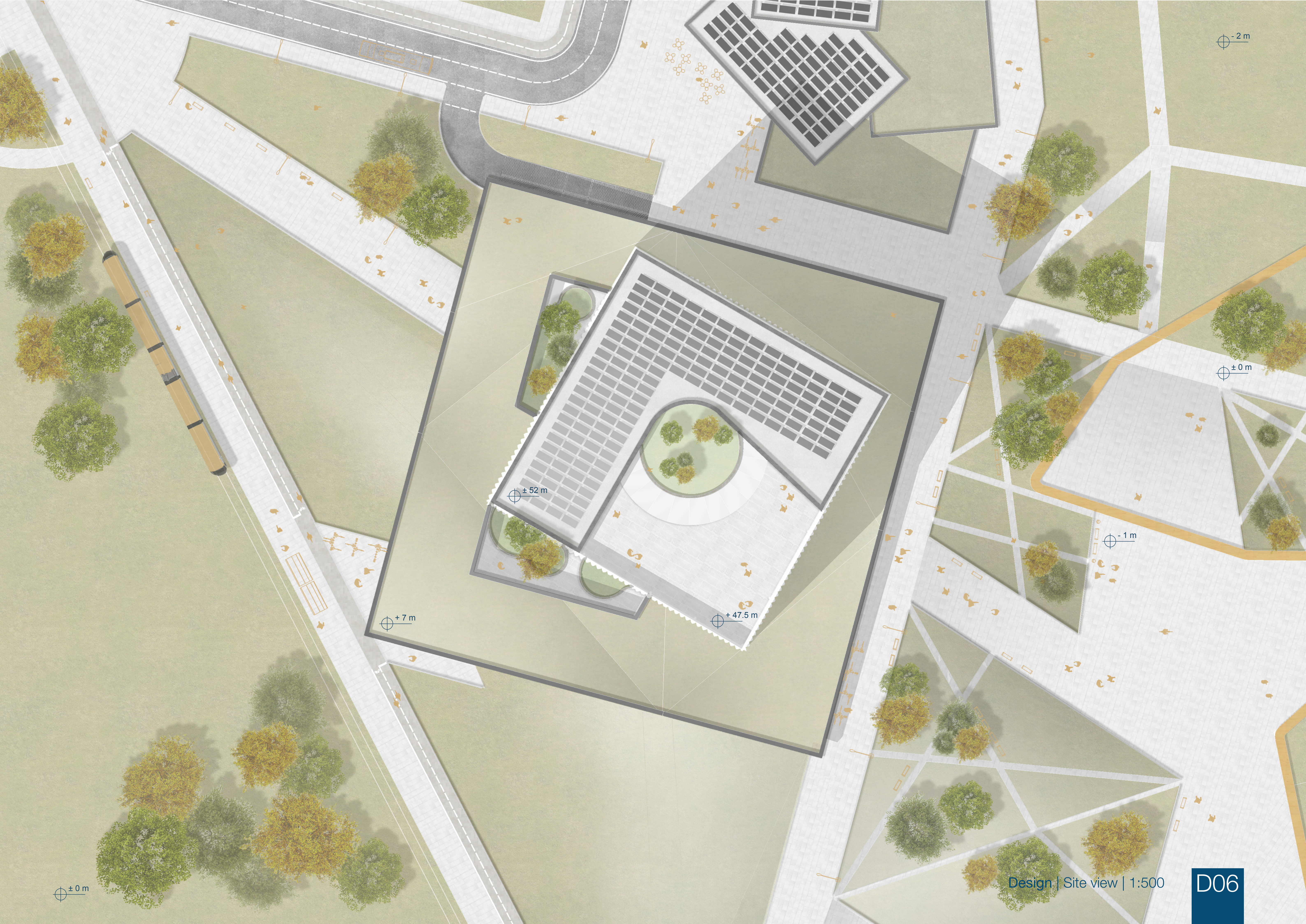


Design | Axonometric view | 1:300



Design | Axonometric view | 1:300

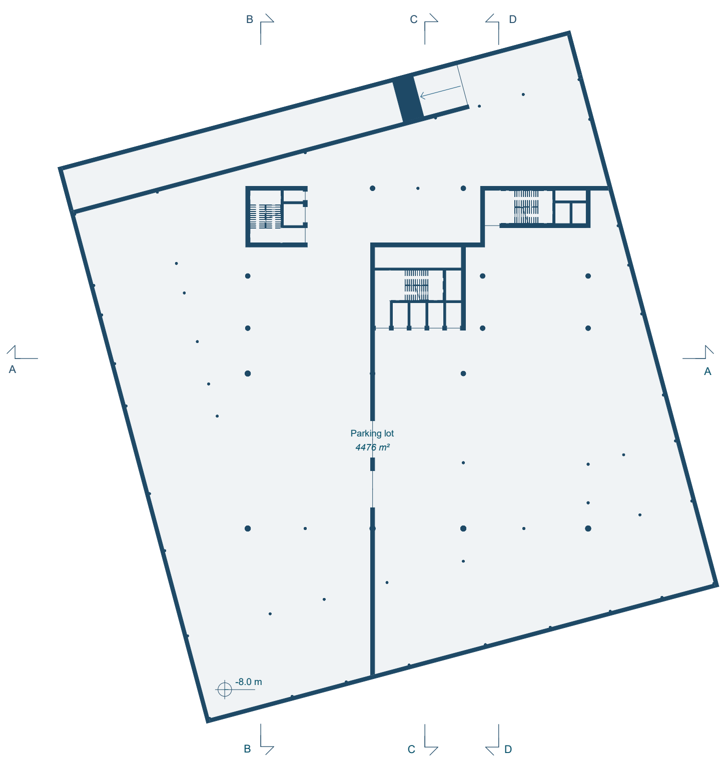
D05 Design



Design | Site view | 1:500

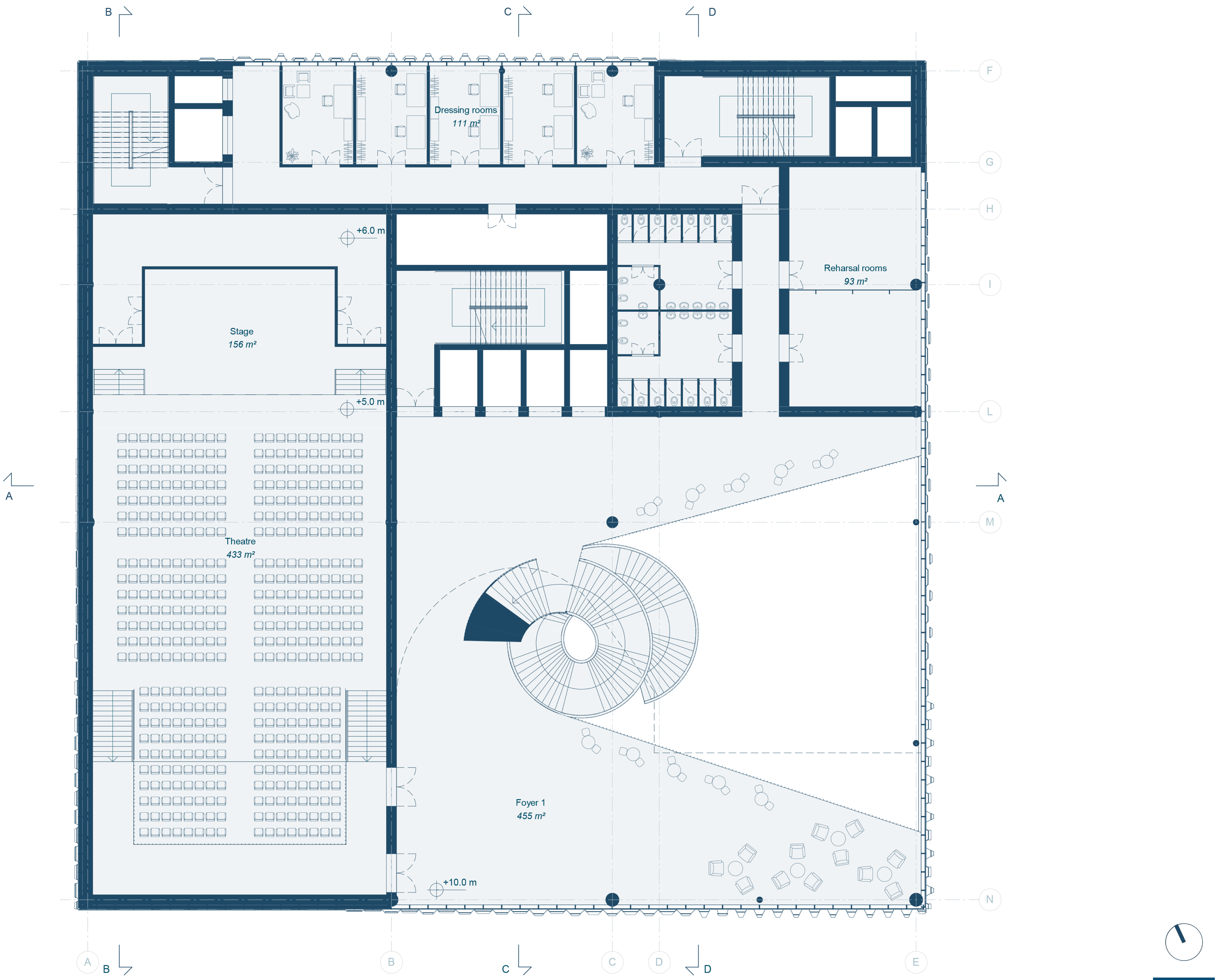
D06

Design | Groundfloor view

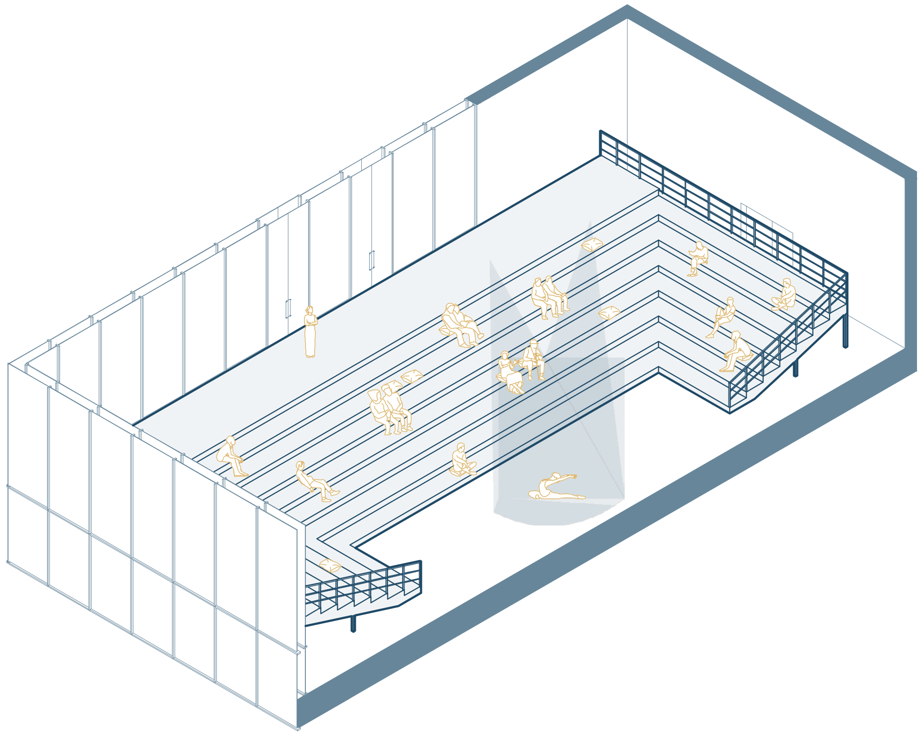


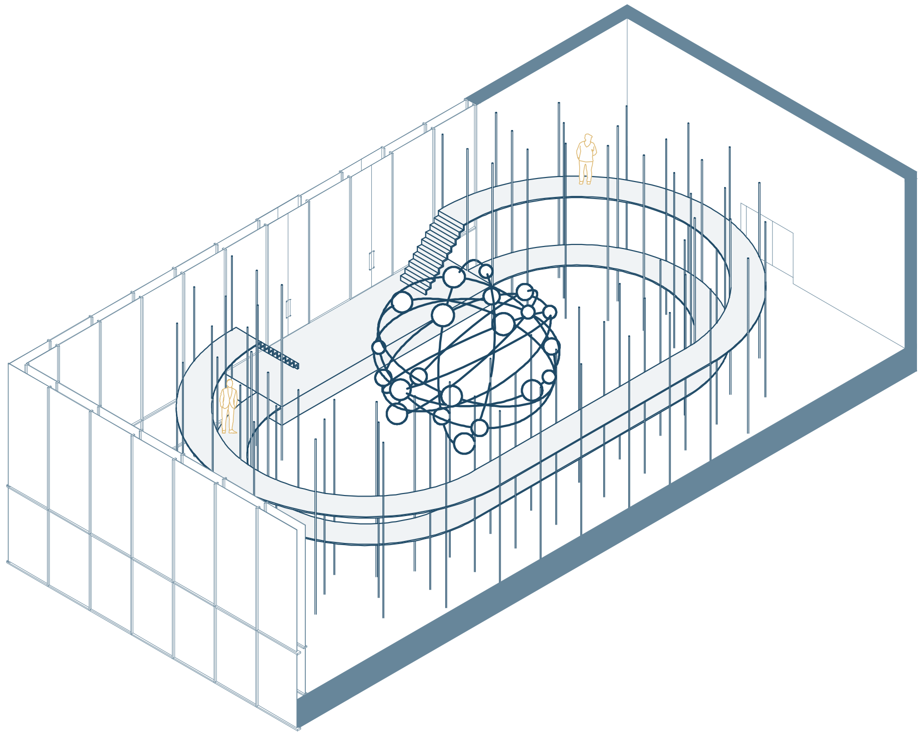
Design | Level 0 and underground levels | Groundfloor and parking lots | 1:350 / 1:1000

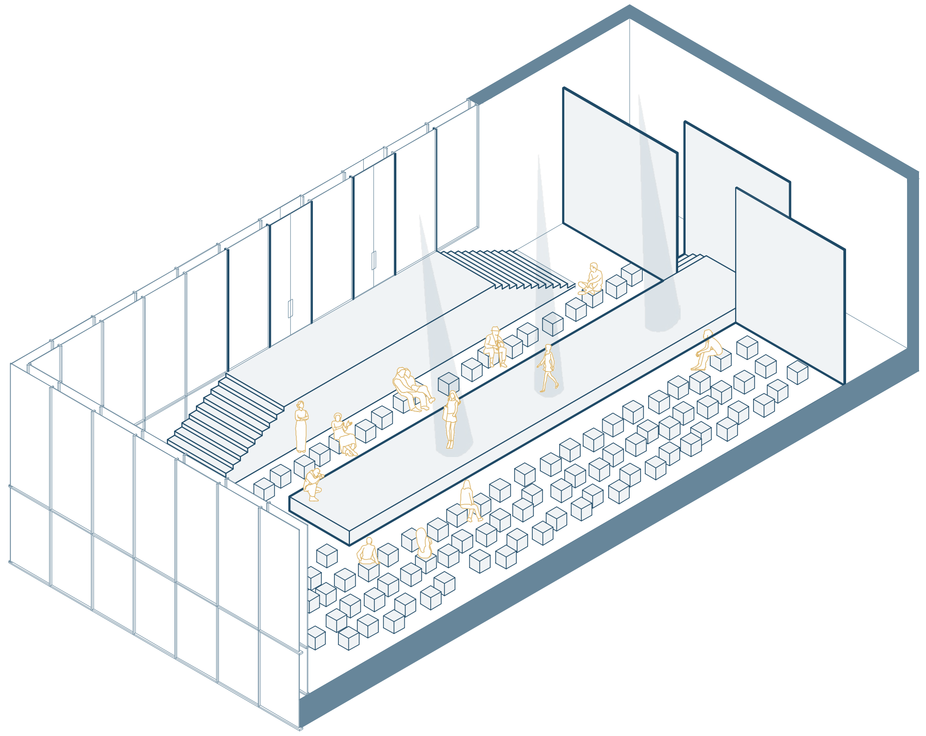
D09 Design | View from the experimental theatre

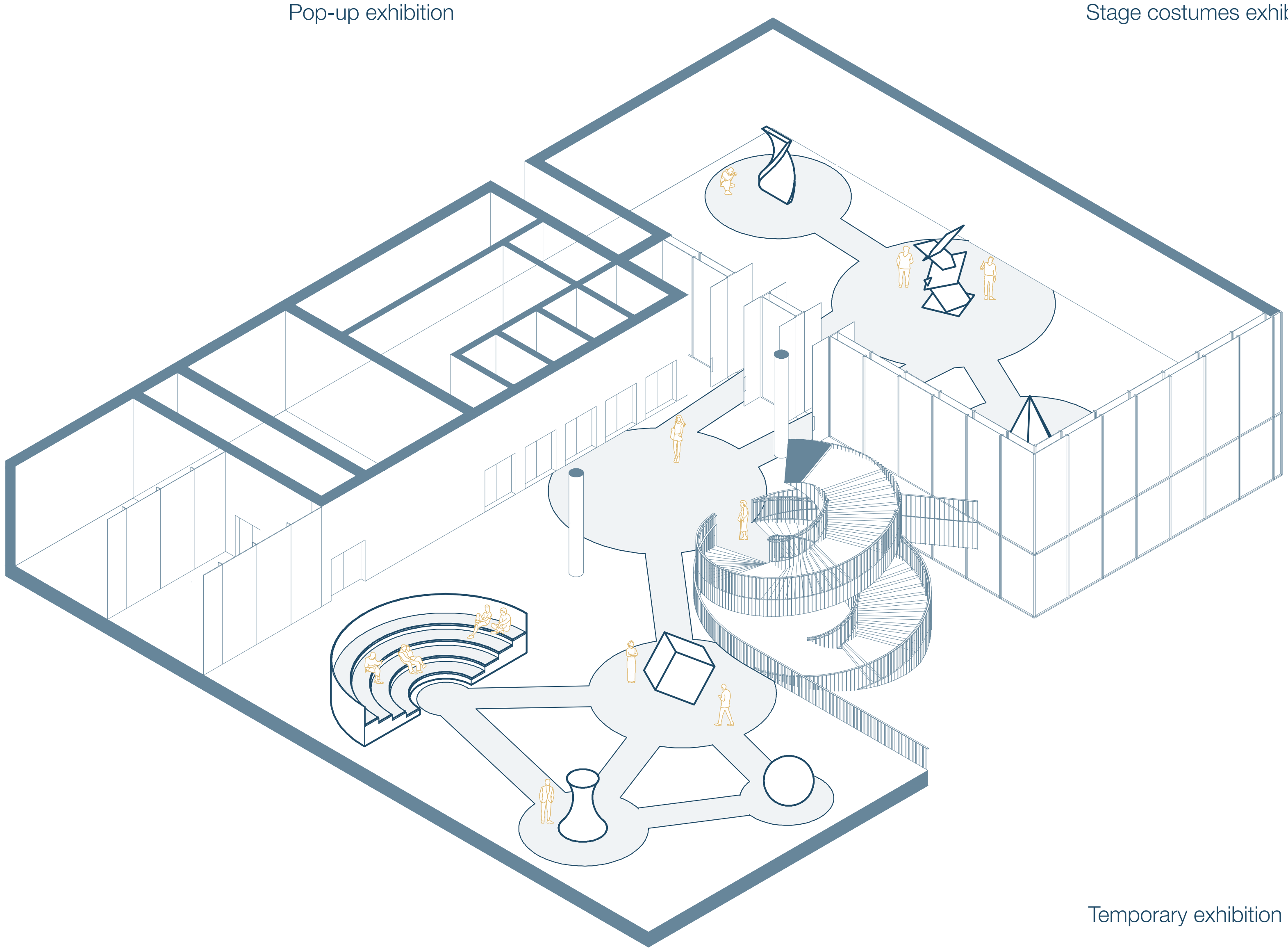


Dressing rooms
111 m²
Stage
156 m²
+6.0 m
+5.0 m
Reharsal rooms
93 m²
Theatre
433 m²
Foyer 1
455 m²
+10.0 m


Pop-up theatre

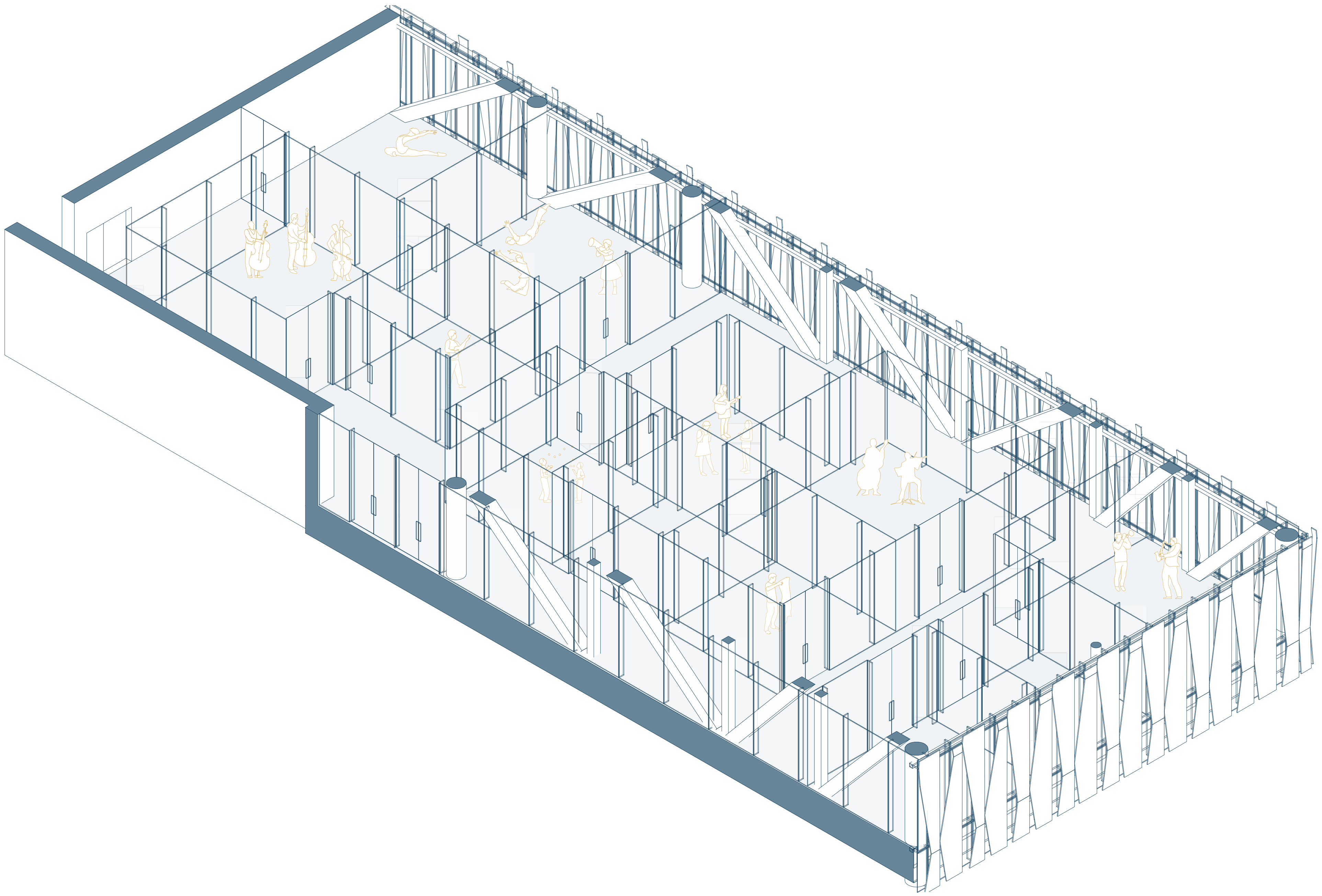

Pop-up exhibition


Stage costumes exhibition

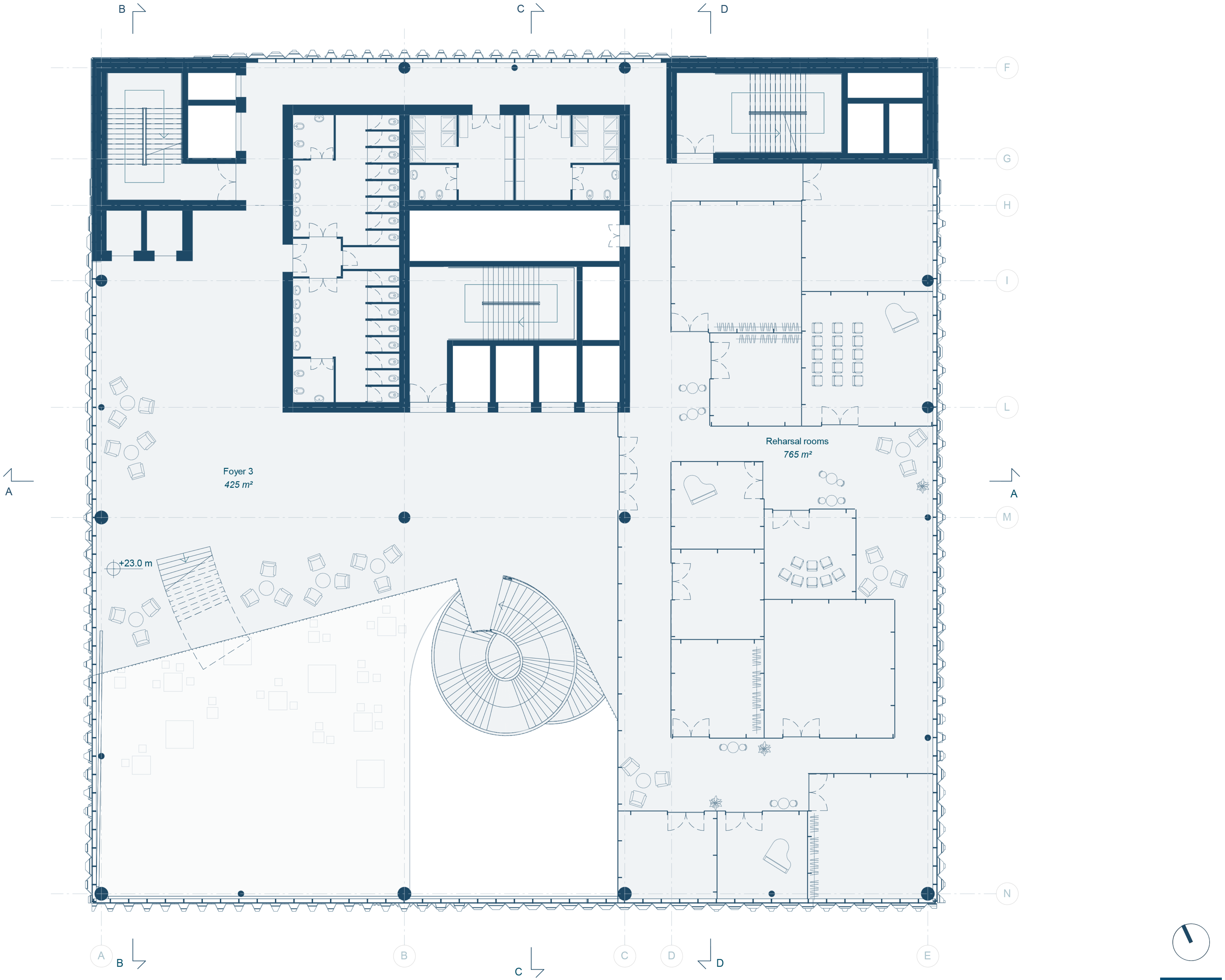

Temporary exhibition

D11 **Design** | Level 4 layout alternatives | 1:300

Design | Level 4 | Experimental theatre | 1:200



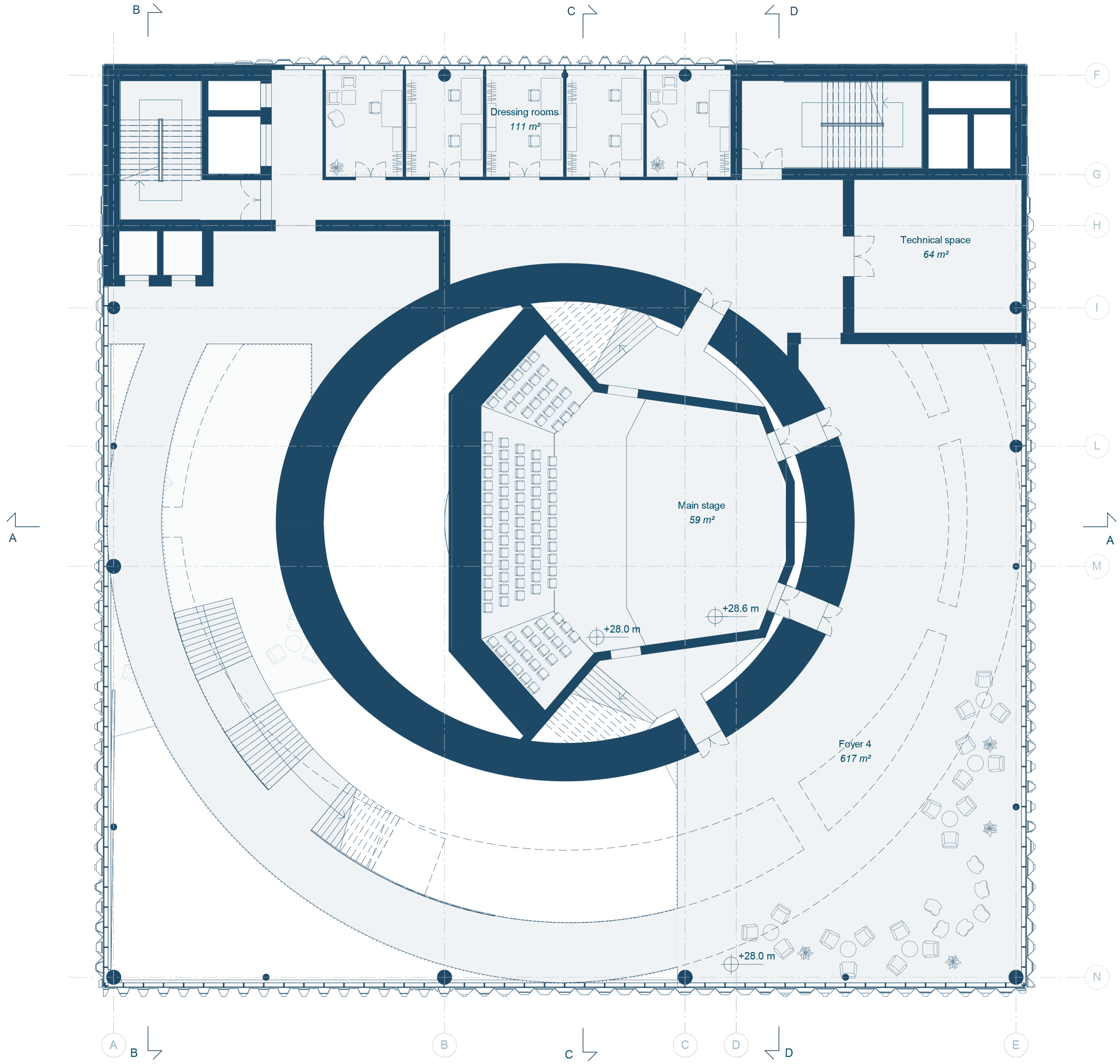
D13 **Design** | Level 5 layout alternatives | 1:200



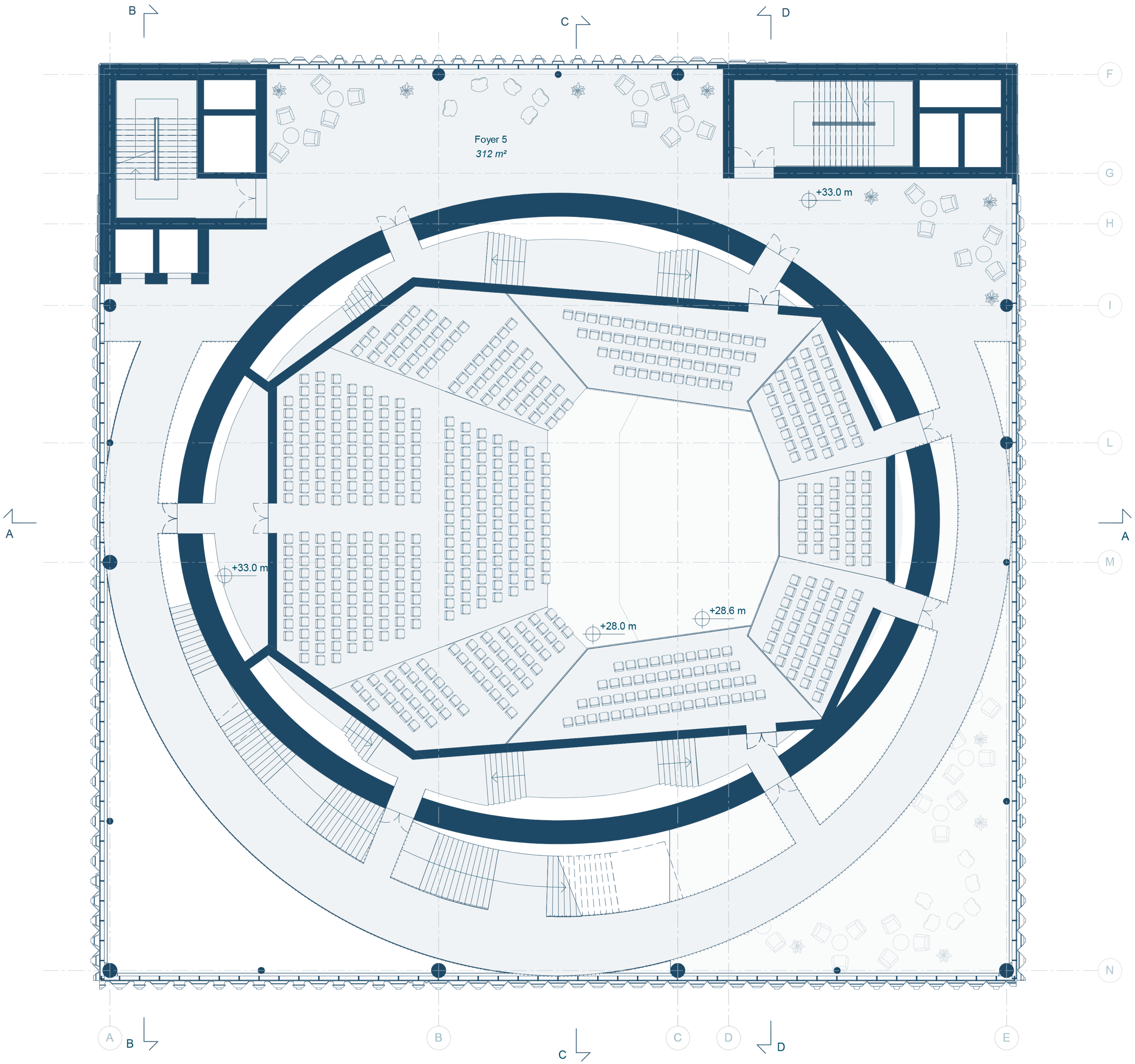
Design | Level 5 | Main hall foyer | 1:200

D14

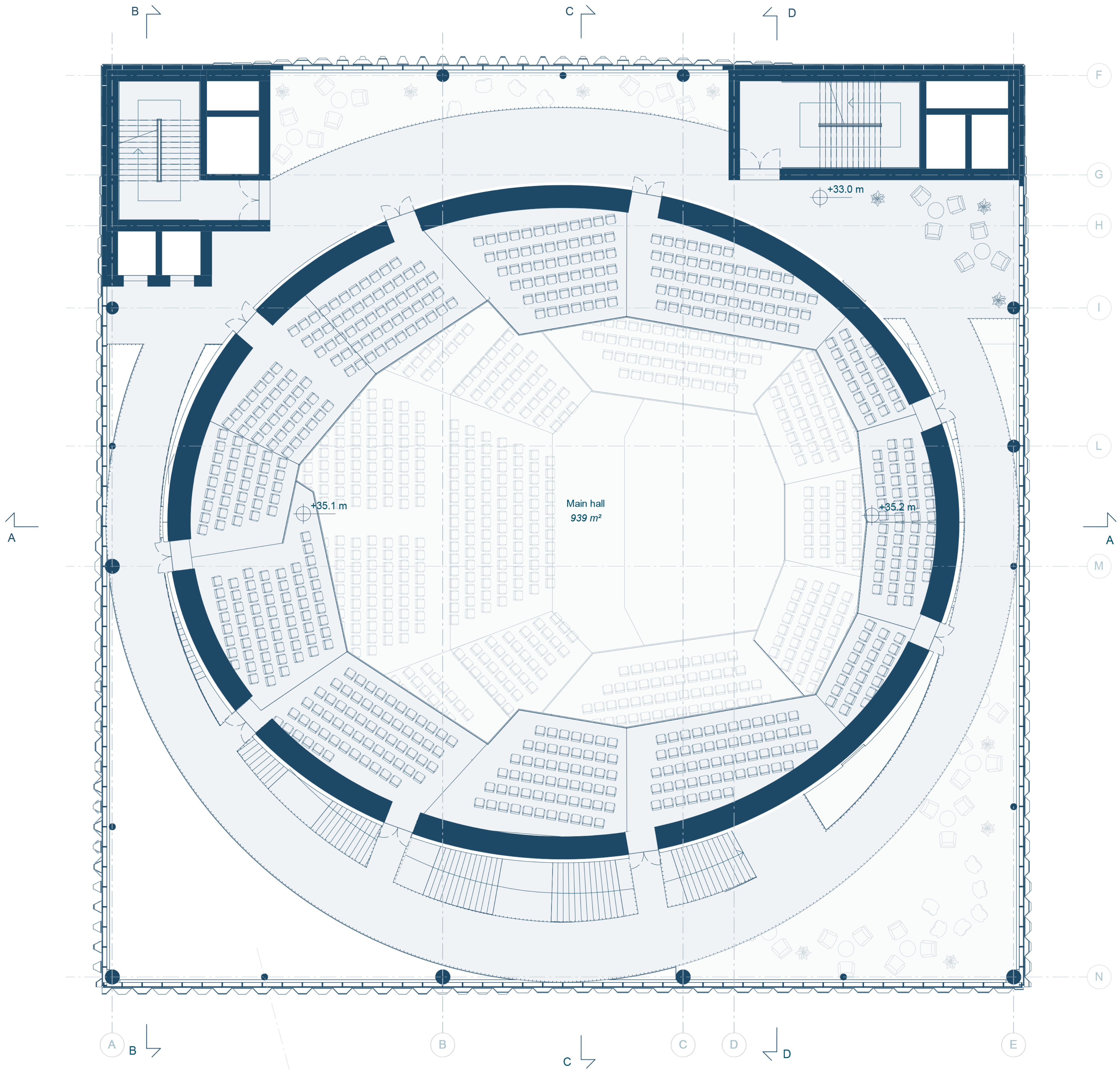
D15 Design | View of the main hall exterior



B
C
D
Dressing rooms
111 m²
Technical space
64 m²
Main stage
59 m²
+28.6 m
+28.0 m
Foyer 4
617 m²
+28.0 m
A
A
F
G
H
I
L
M
N
A
B
C
D
E

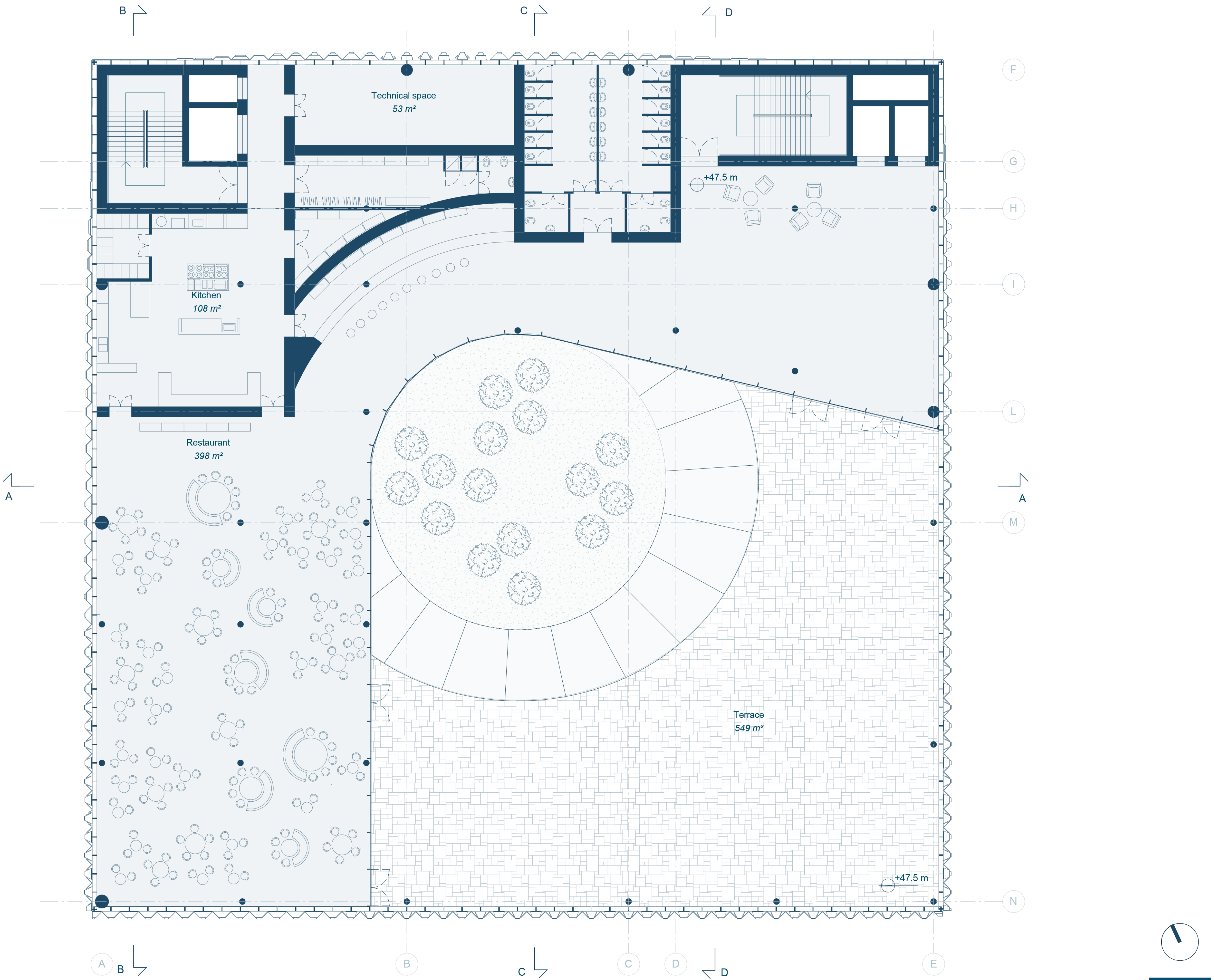


Design | Level 7 | Main Hall | 1:200



Main hall
939 m²
+35.1 m
+35.2 m
+33.0 m

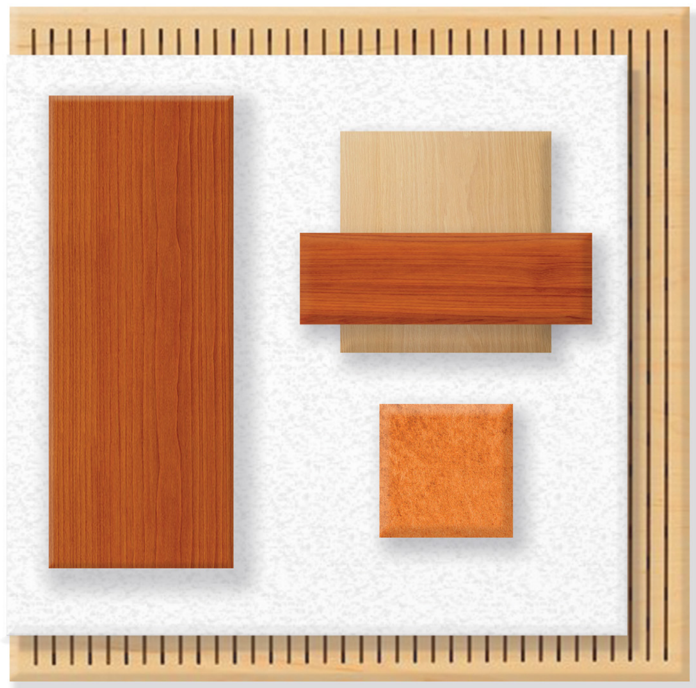
Design | Rooftop terrace


B
C
D
Technical space
53 m²
+47.5 m
Kitchen
108 m²
Restaurant
398 m²
A
A
Terrace
549 m²
+47.5 m
F
G
H
I
L
M
N
A
B
B
C
C
D
D
E

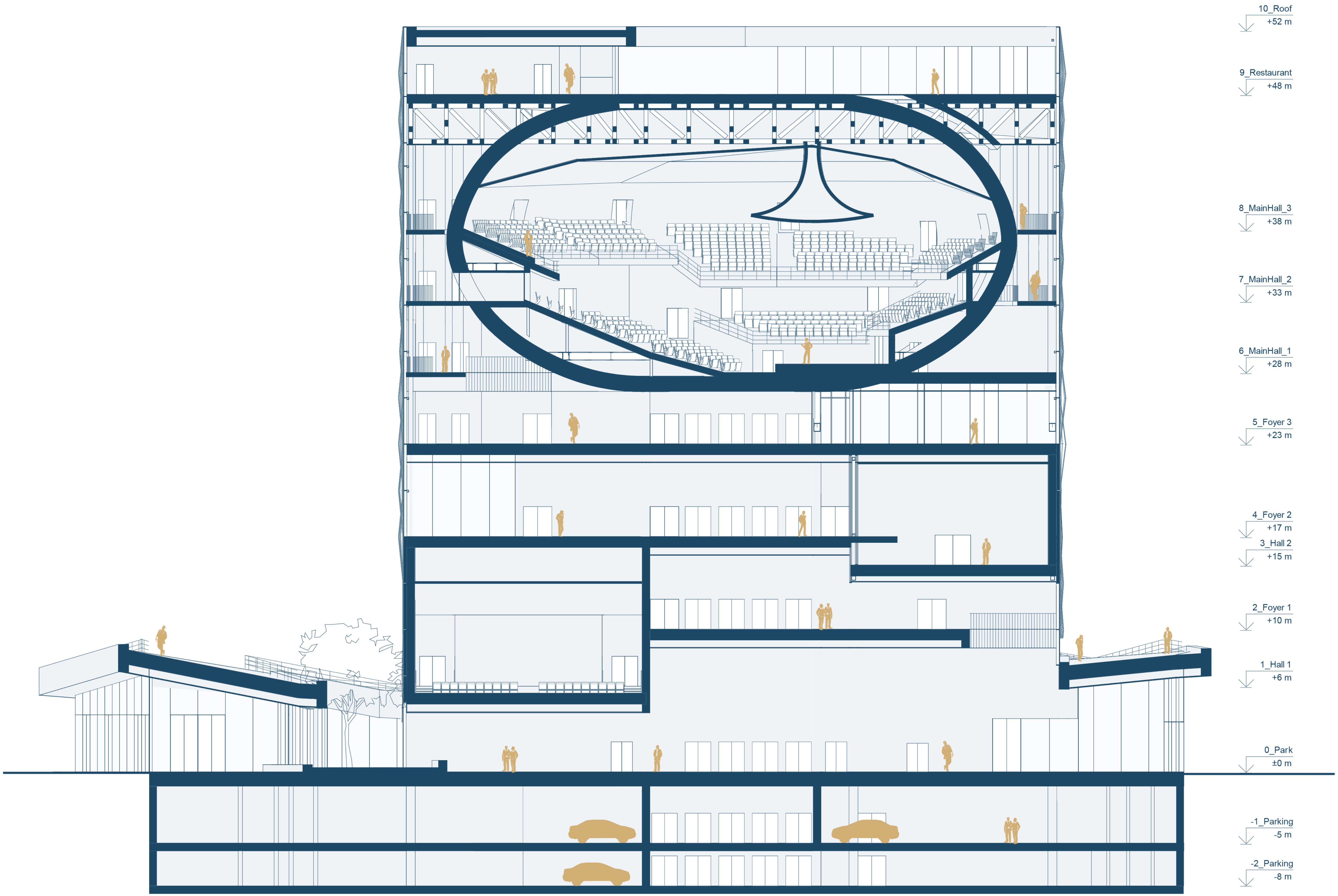
Foyers moodboard

Traditional theatre moodboard

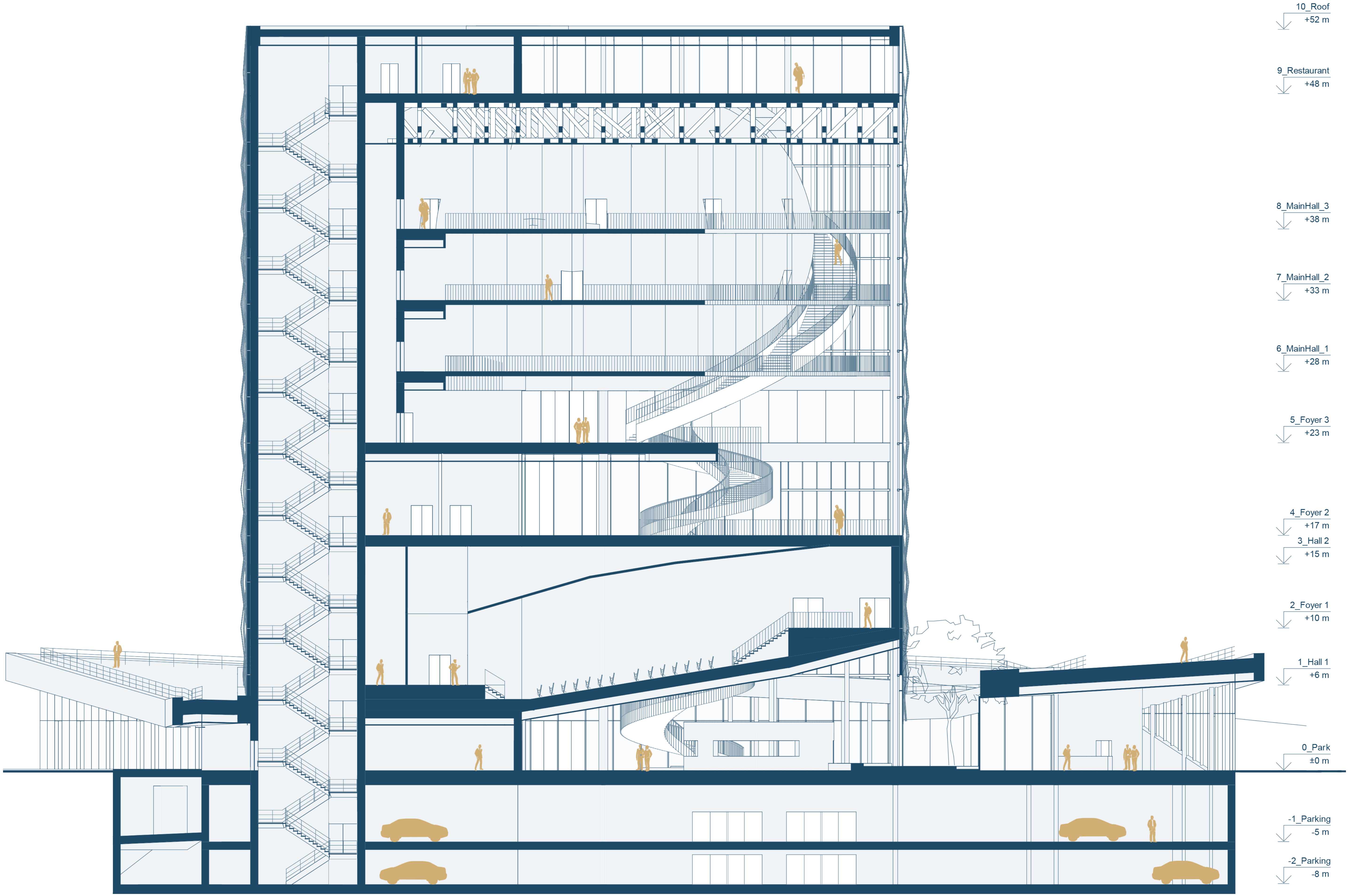
Experimental theatre moodboard



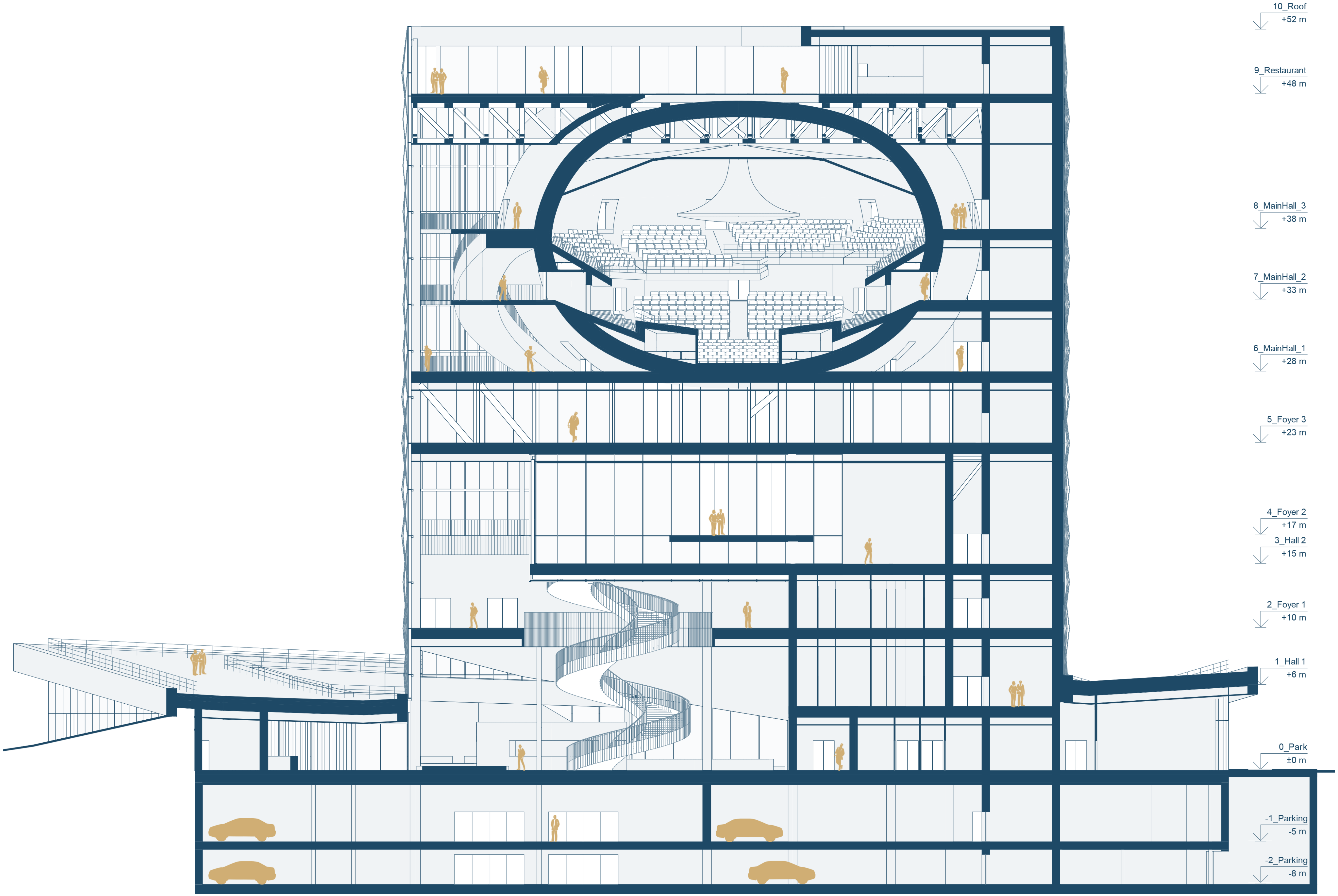
Main hall moodboard



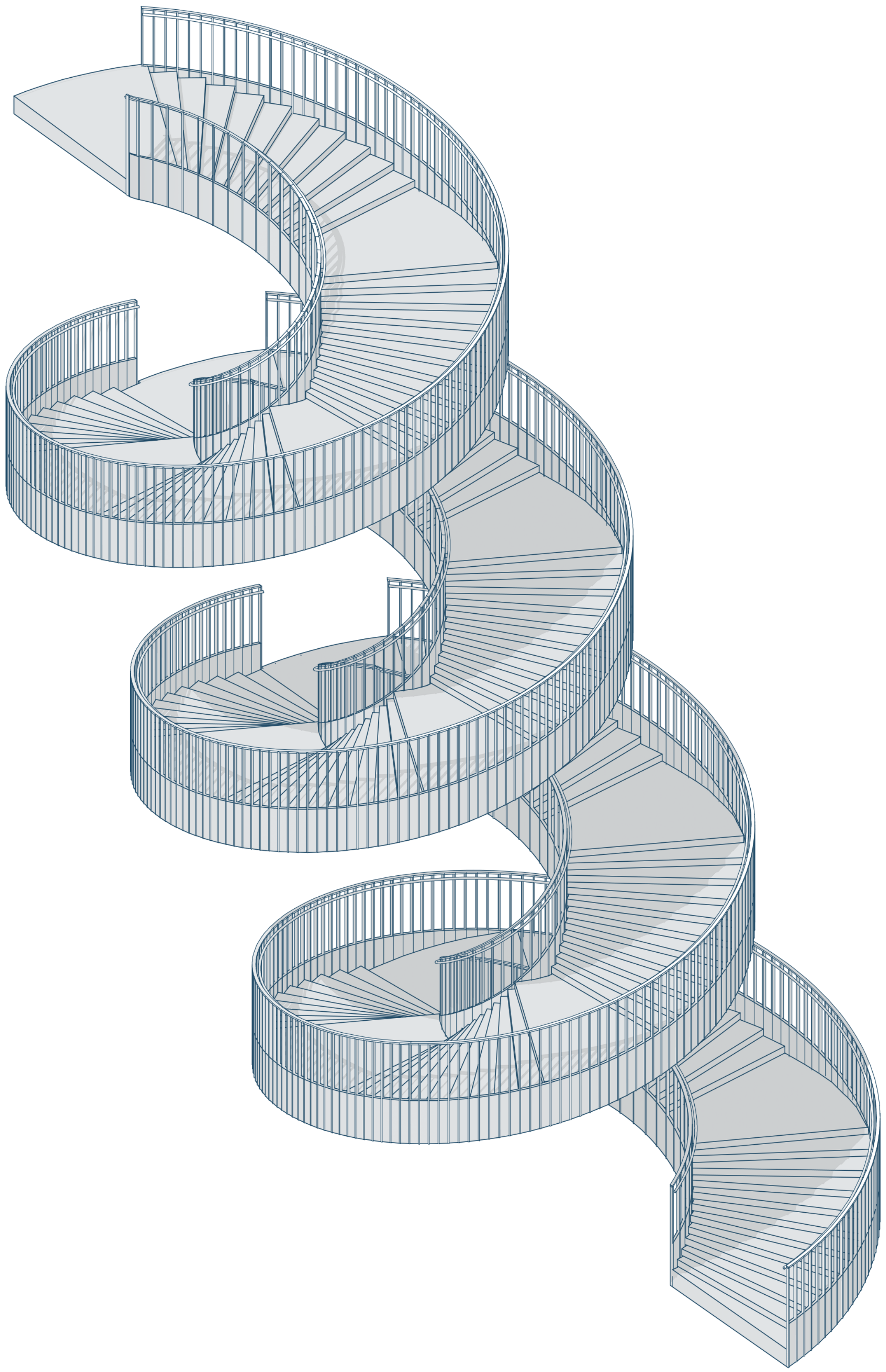
Design | Section A | 1:250

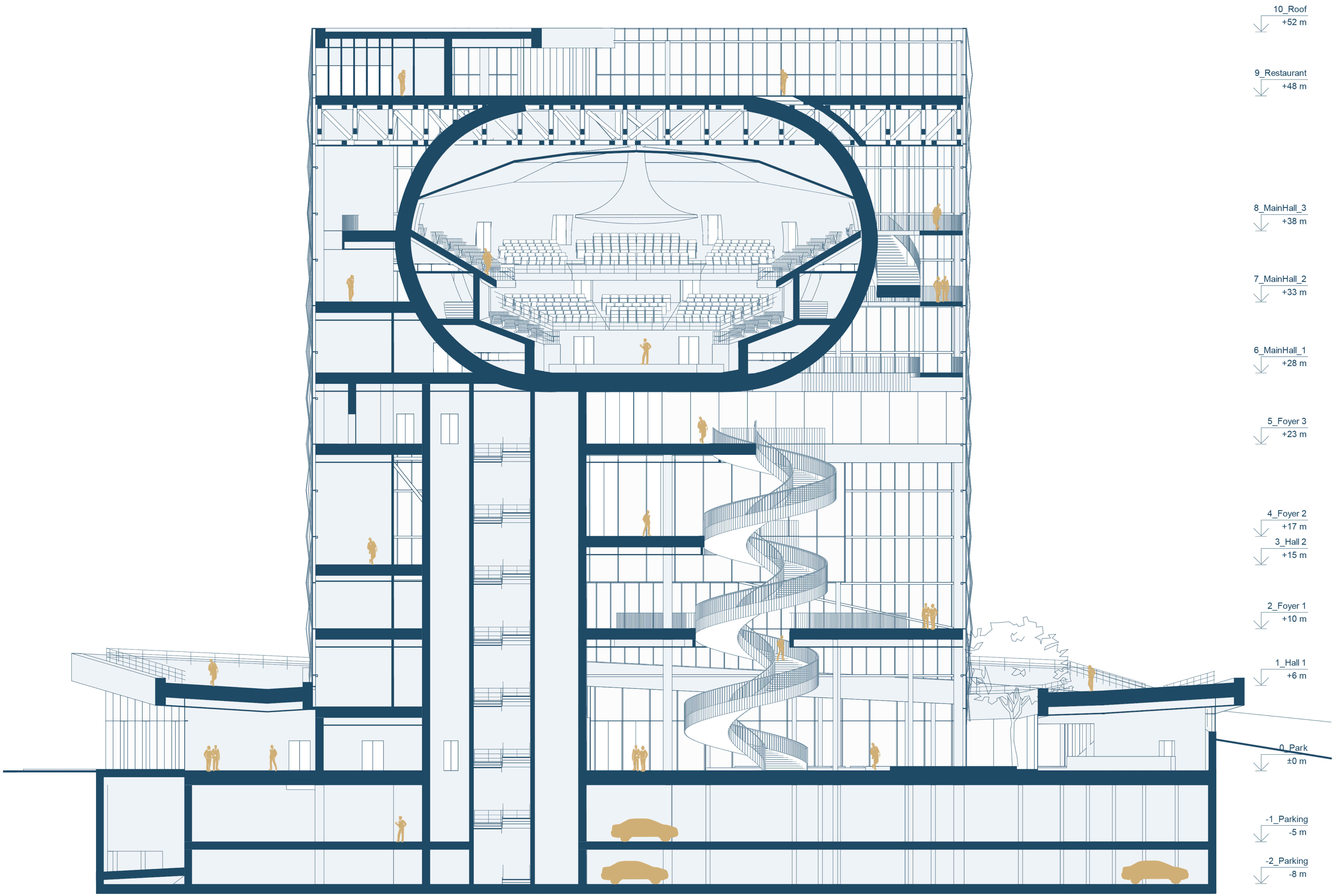


Design | Section B | 1:250



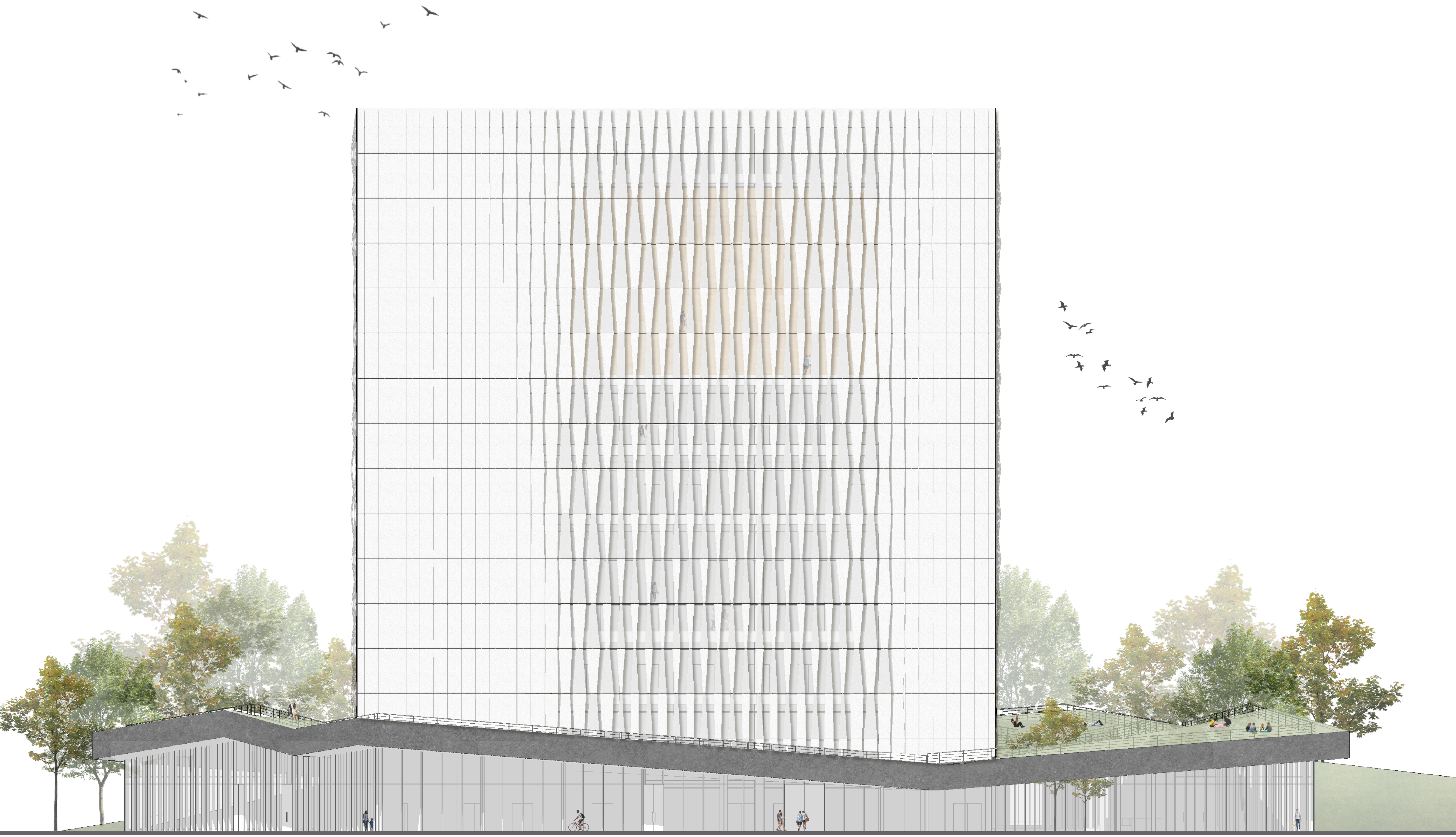
Design | Section D | 1:250

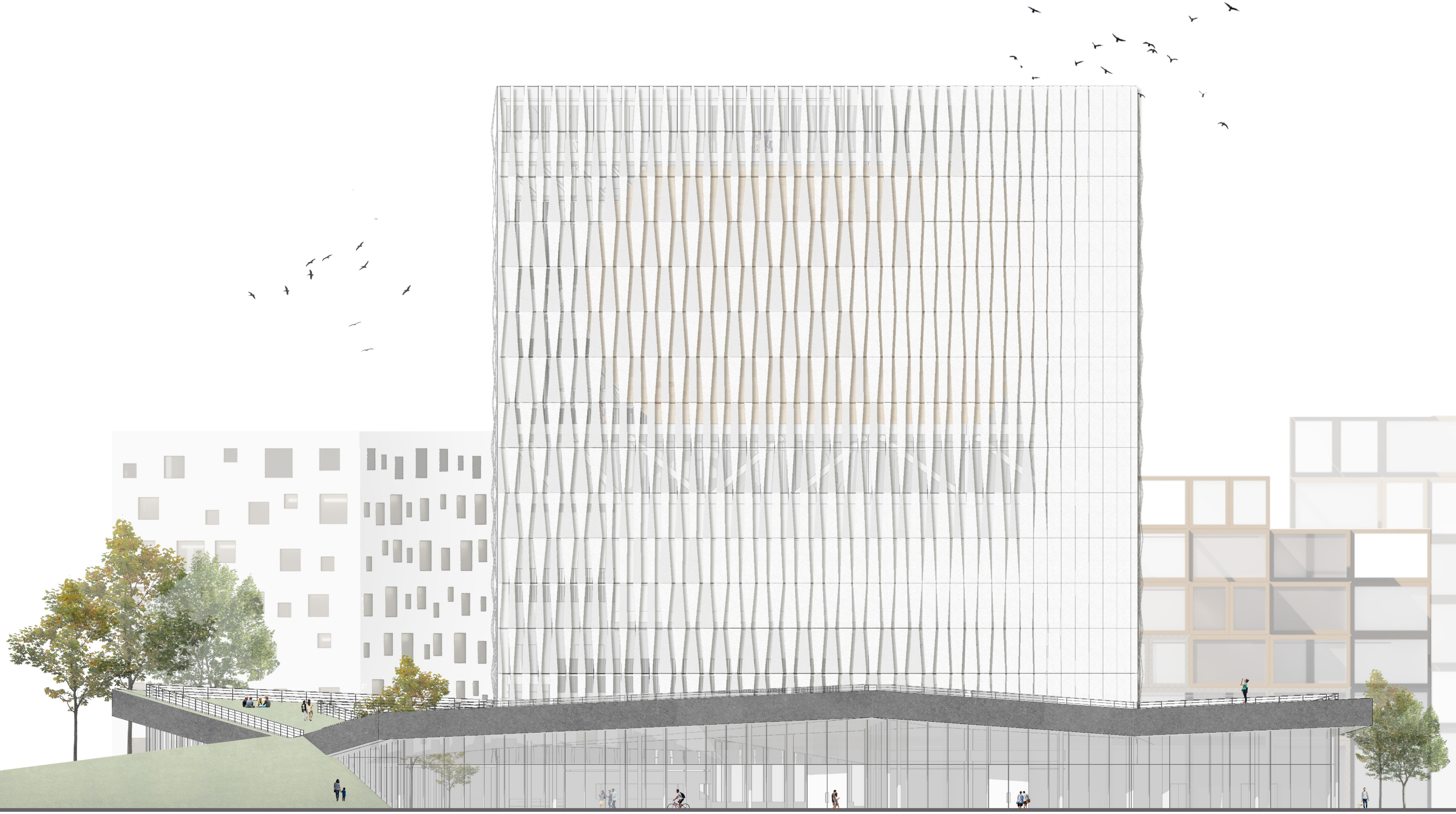




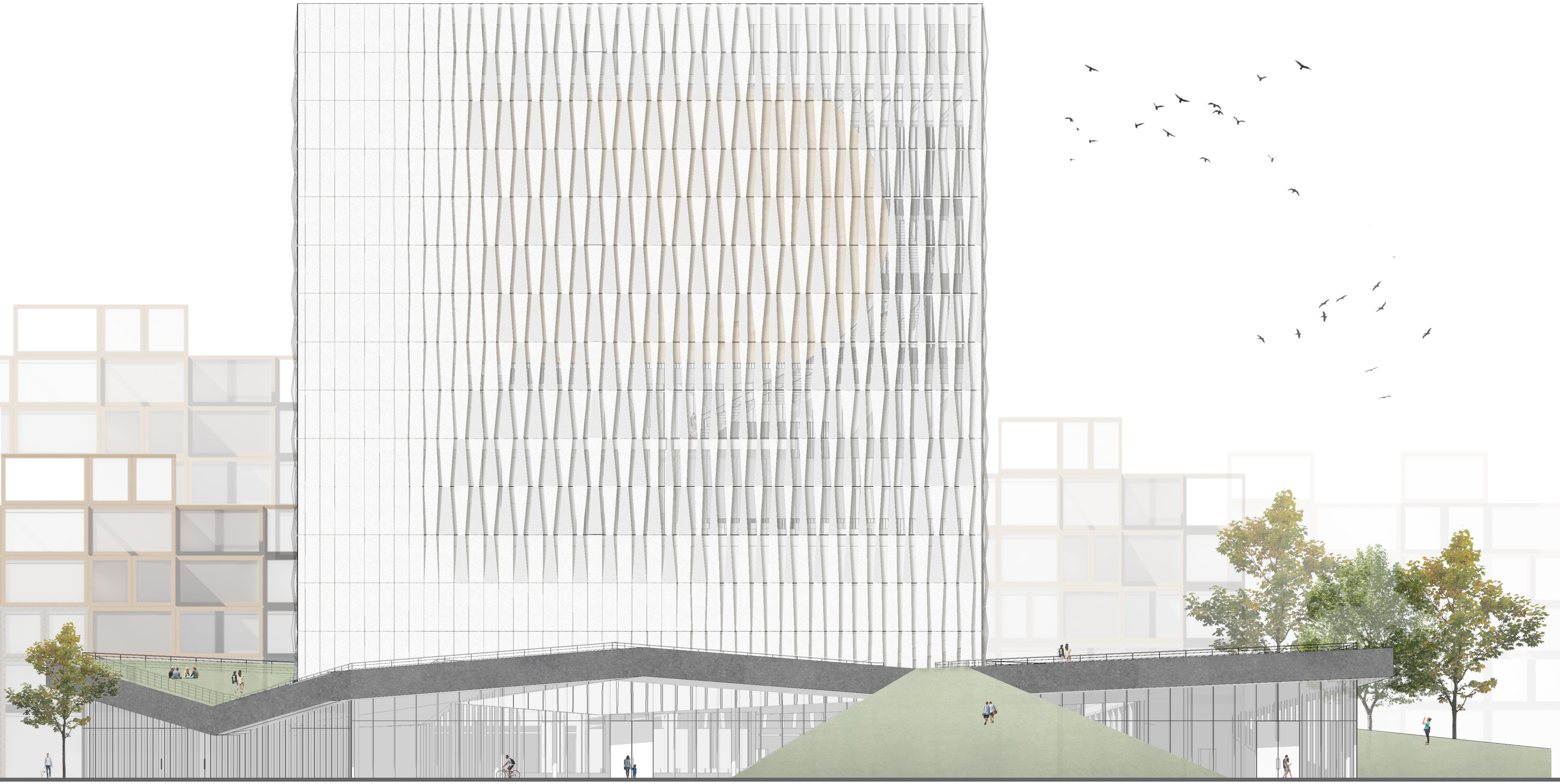
Design | Section C | 1:250

Design | South elevation | 1:250



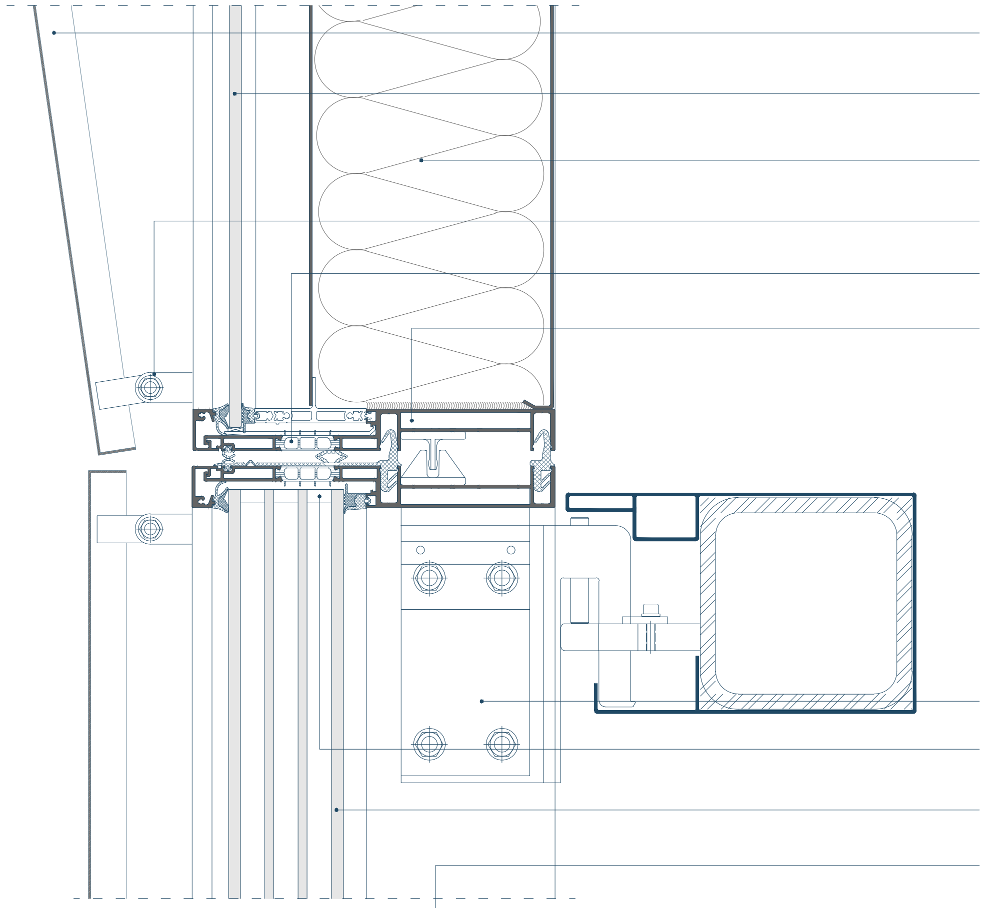


Design | East elevation | 1:250



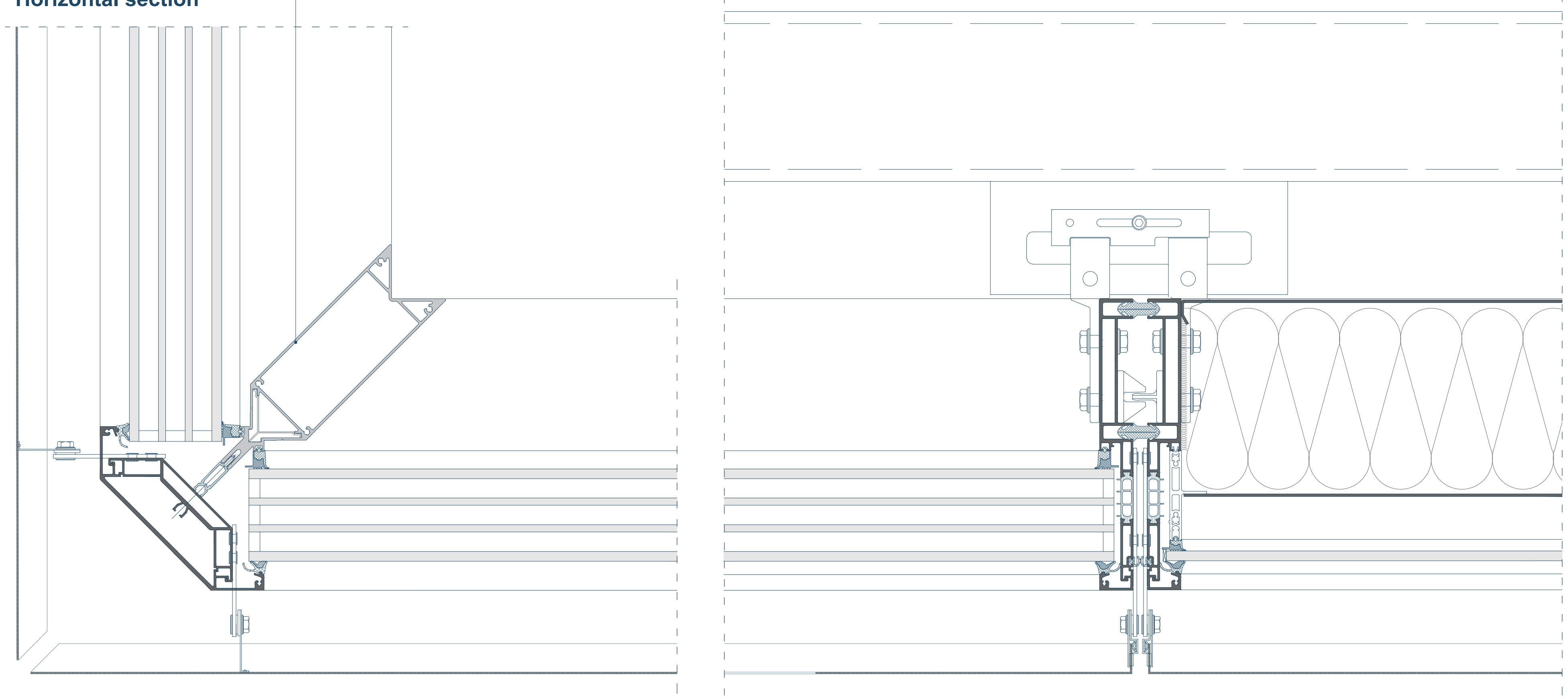
Design | West elevation | 1:250

Unitized system panels details: transparent (U = 0.64 W/m²k) and opaque (U = 0,199 W/m²k)

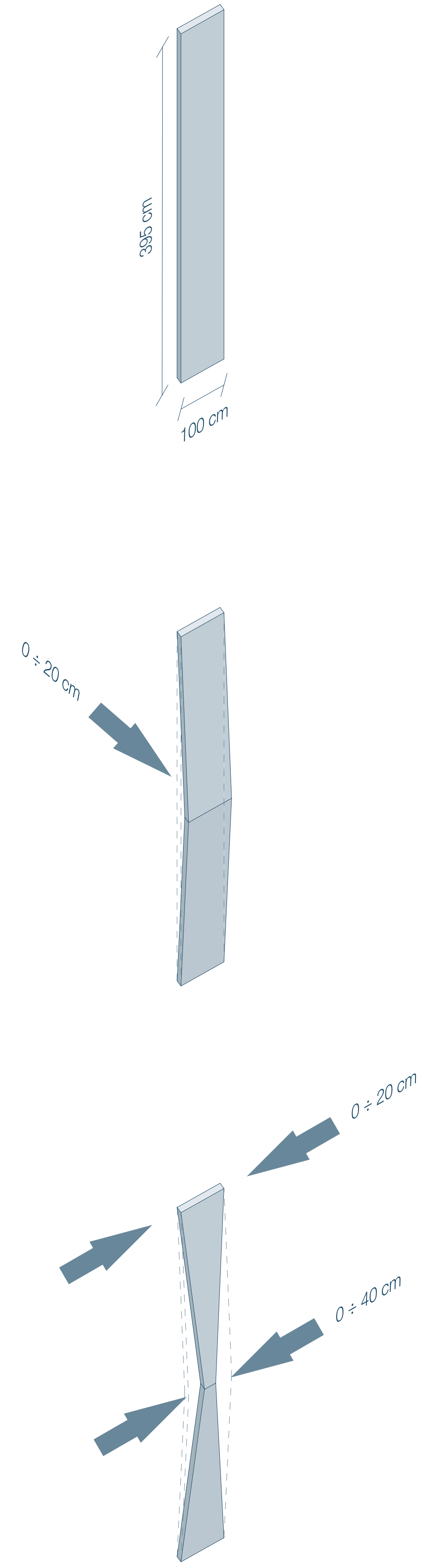


- Anodized aluminum panel with punctual fixing, th. 2 mm, variable dimensions
- Glass finishing panel with reflective film, th. 8 mm
- Sandwich spandrel panel, th. 150 mm, with rock wool panels infill, λ = 0.035 W / mK, ρ = 40 kg / m3, and outer aluminium layer
- Punctual fixing: variable length, th. 3 mm
- High resistance thermal cut
- Unitized system extruded aluminum frame profile, dim. 24x6.5 cm
- Steel plate with slotted holes
- Spacer filled with moisture absorbing desiccant
- Quadruple layered glass with air fill, th. 8/16/6/12/6/16/8 mm
- Special element for angular elements: extruded aluminium profile, dim. 26x6,5 cm

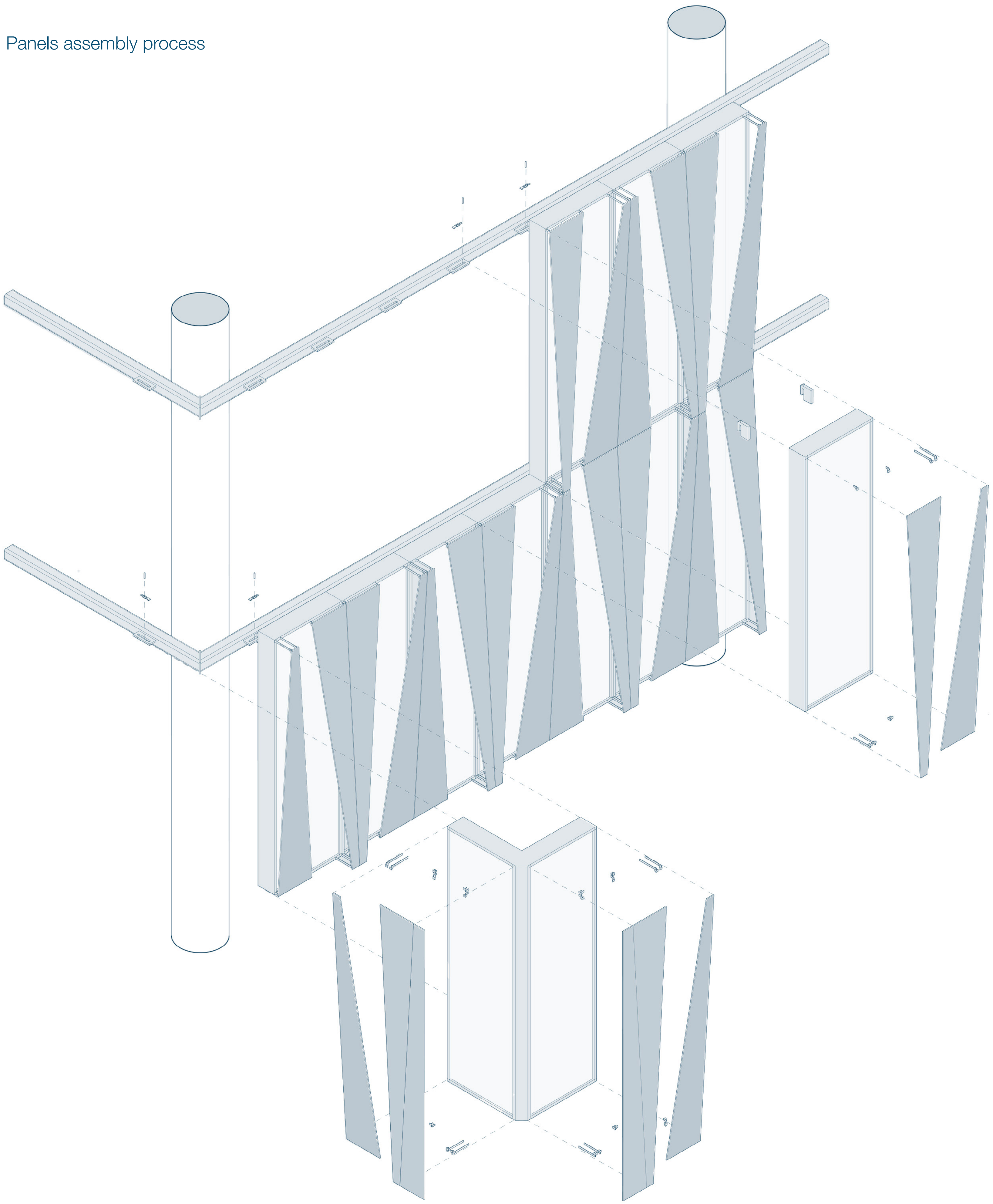
Horizontal section

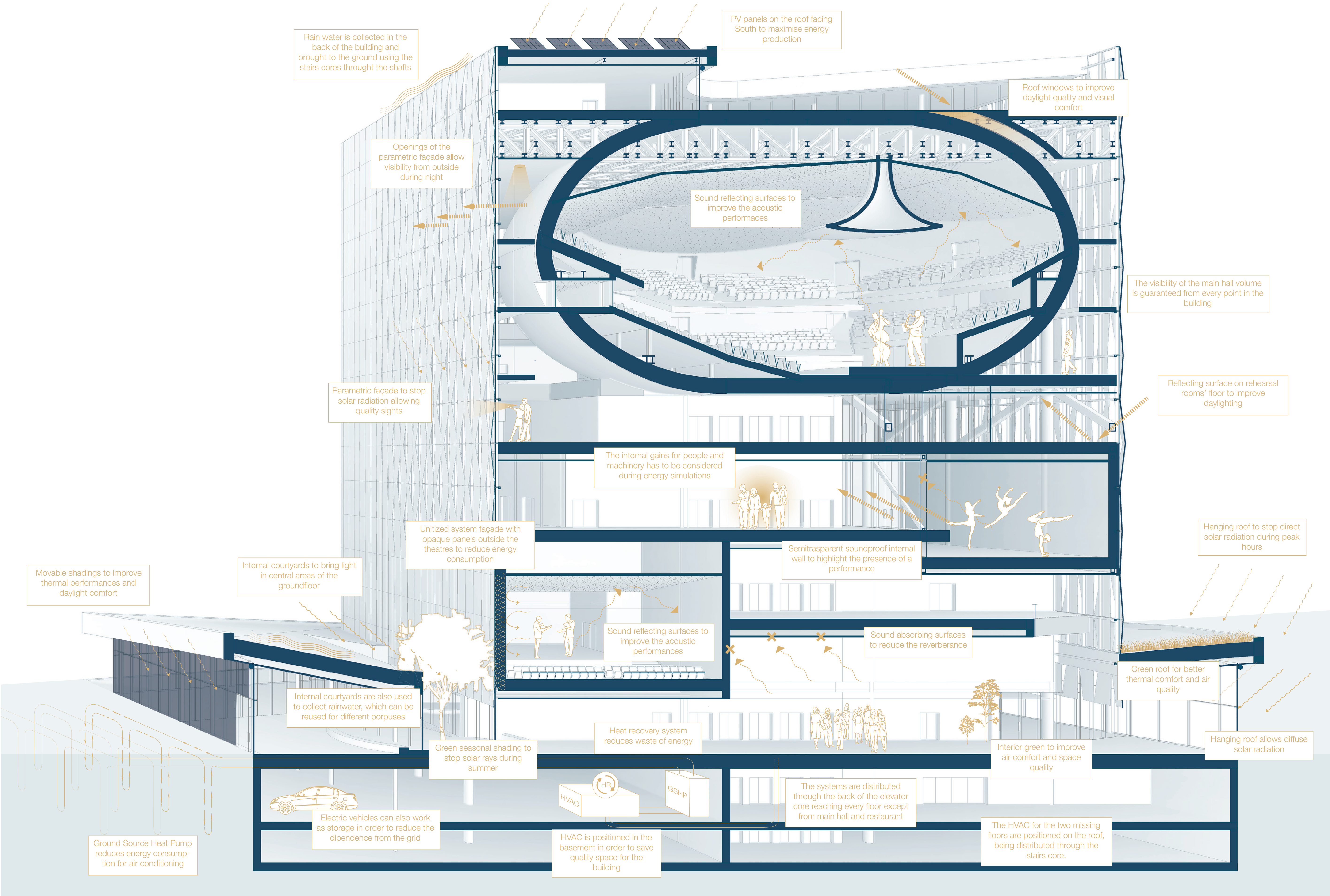


Parameters controlling the panels shape



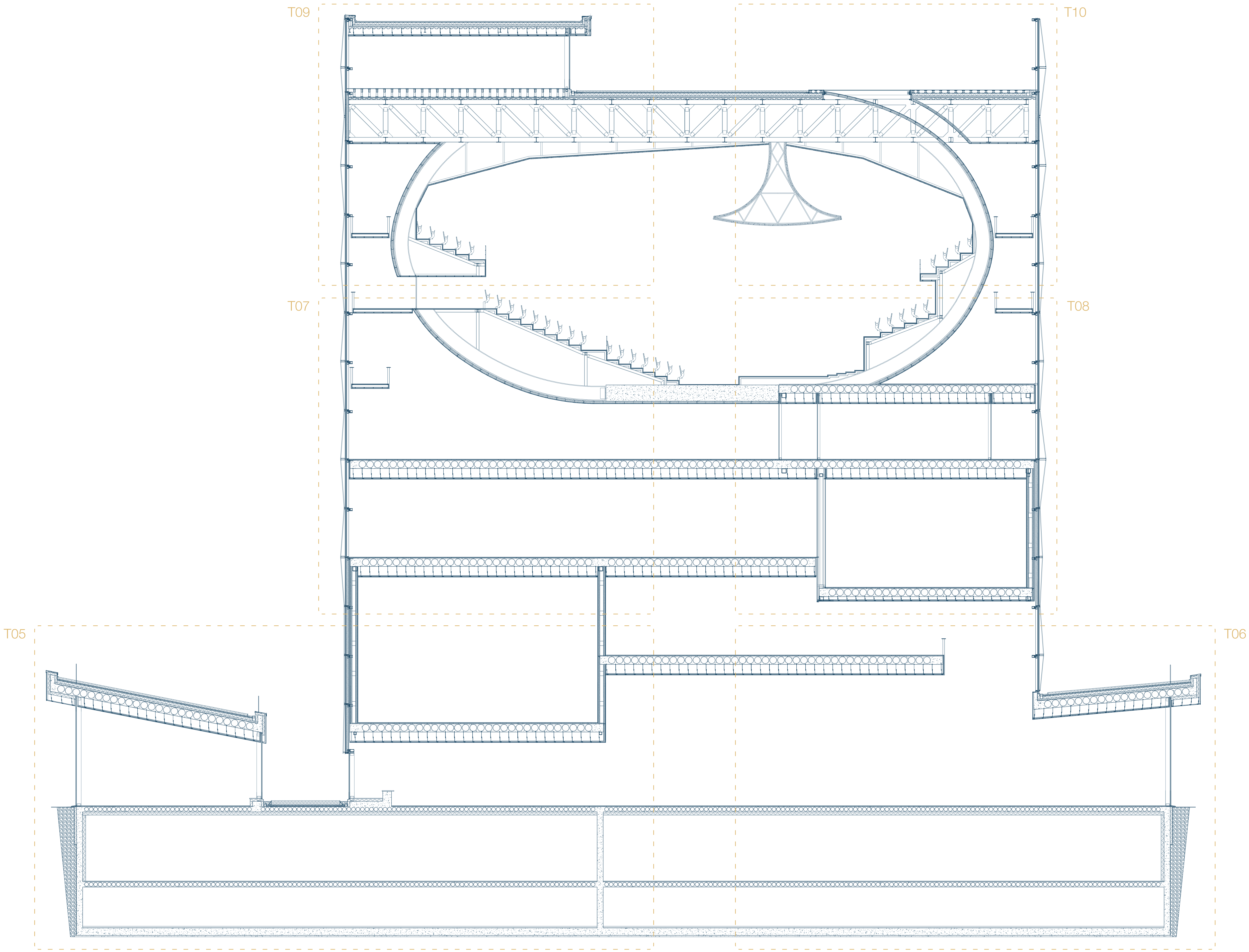
Panels assembly process

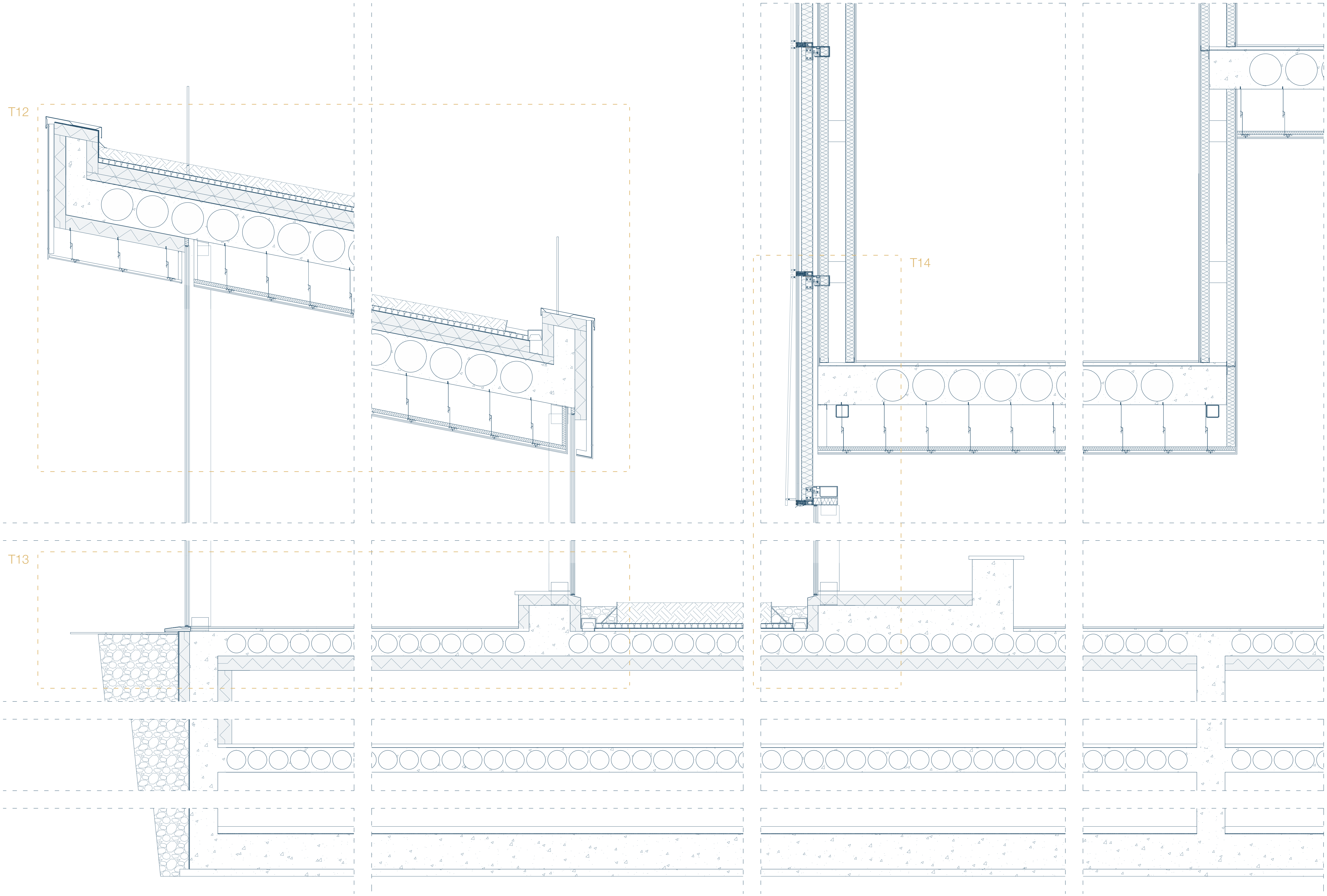




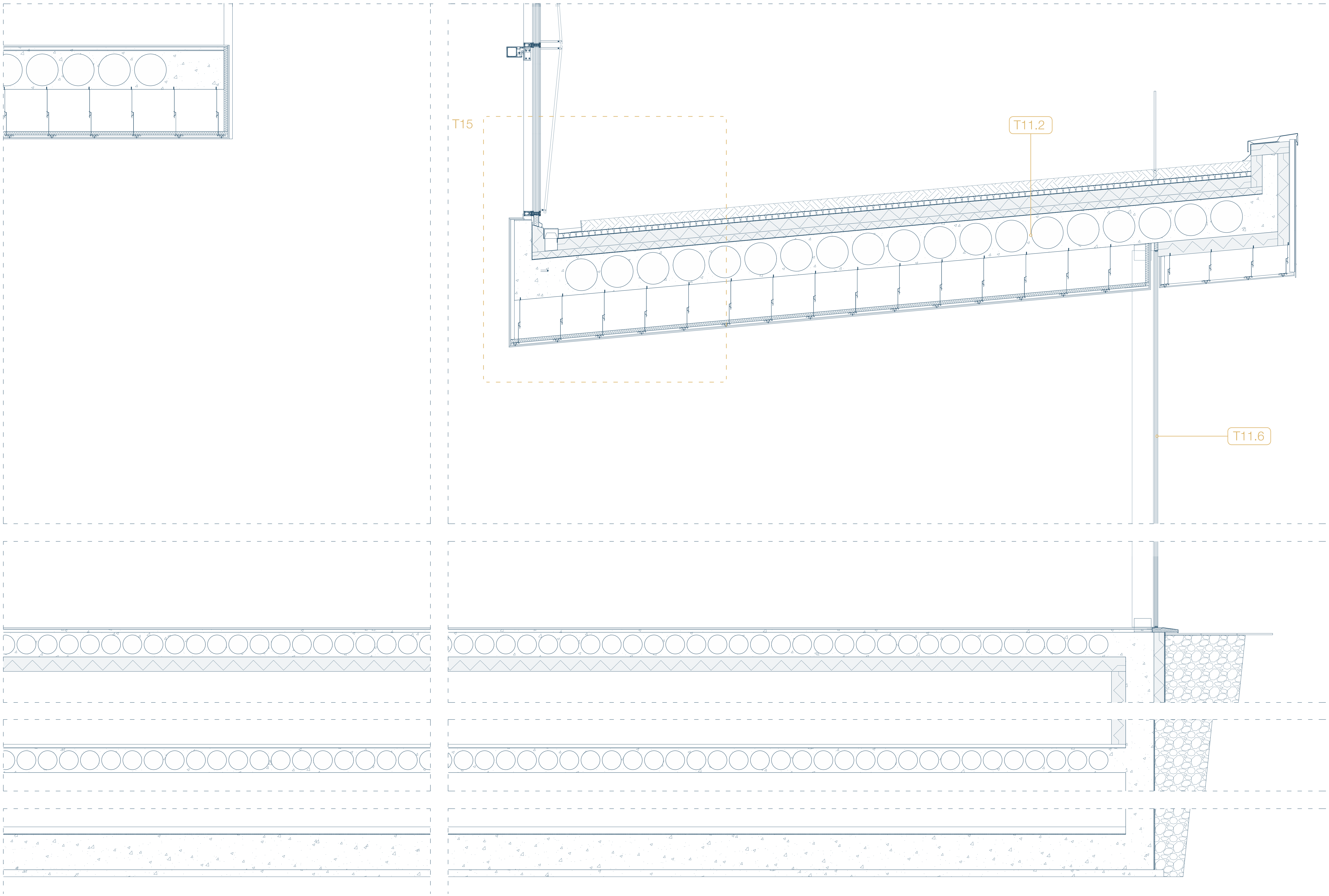
T03

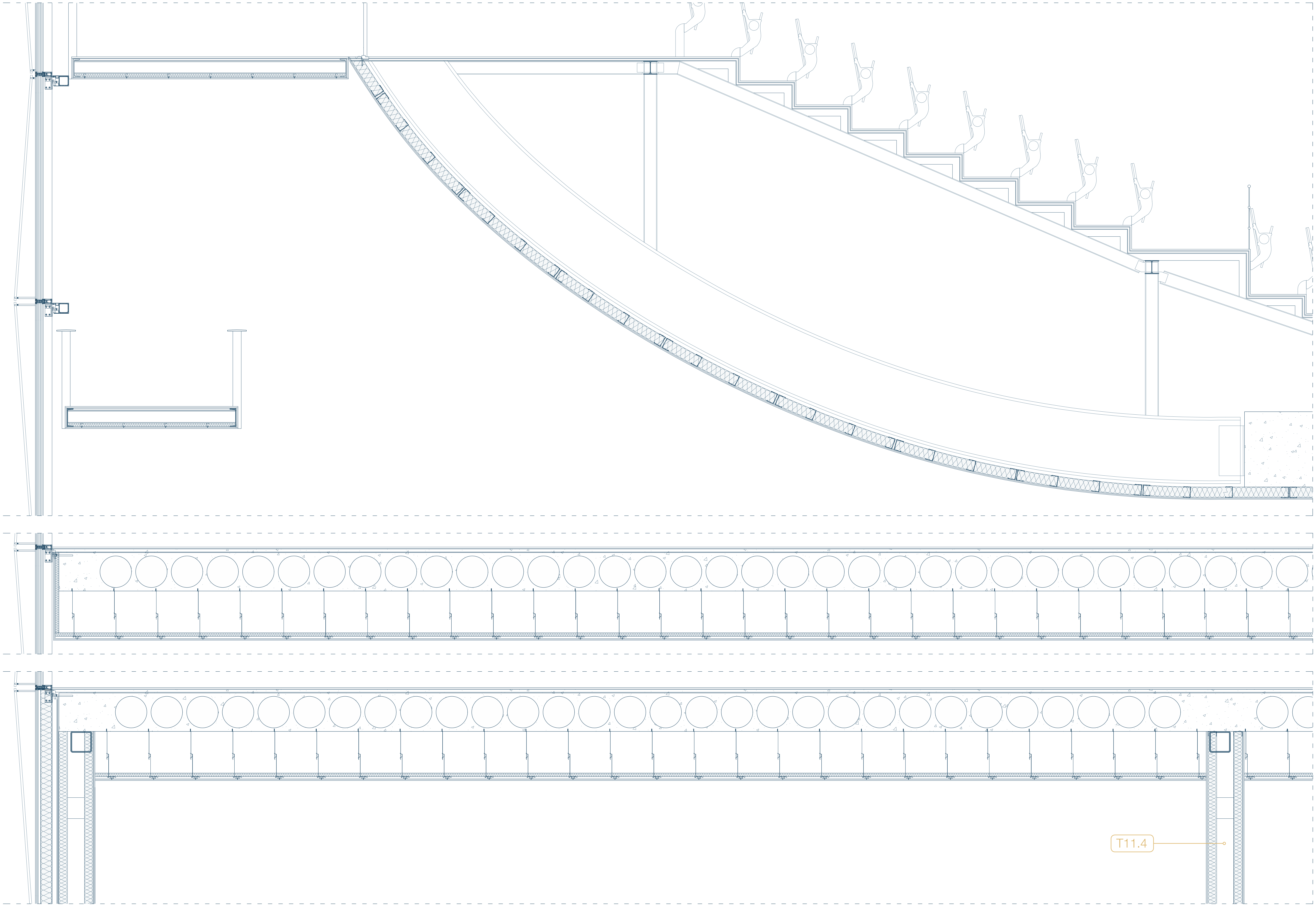
Detailing | Schematic design


T09
T10
T07
T08
T05
T06

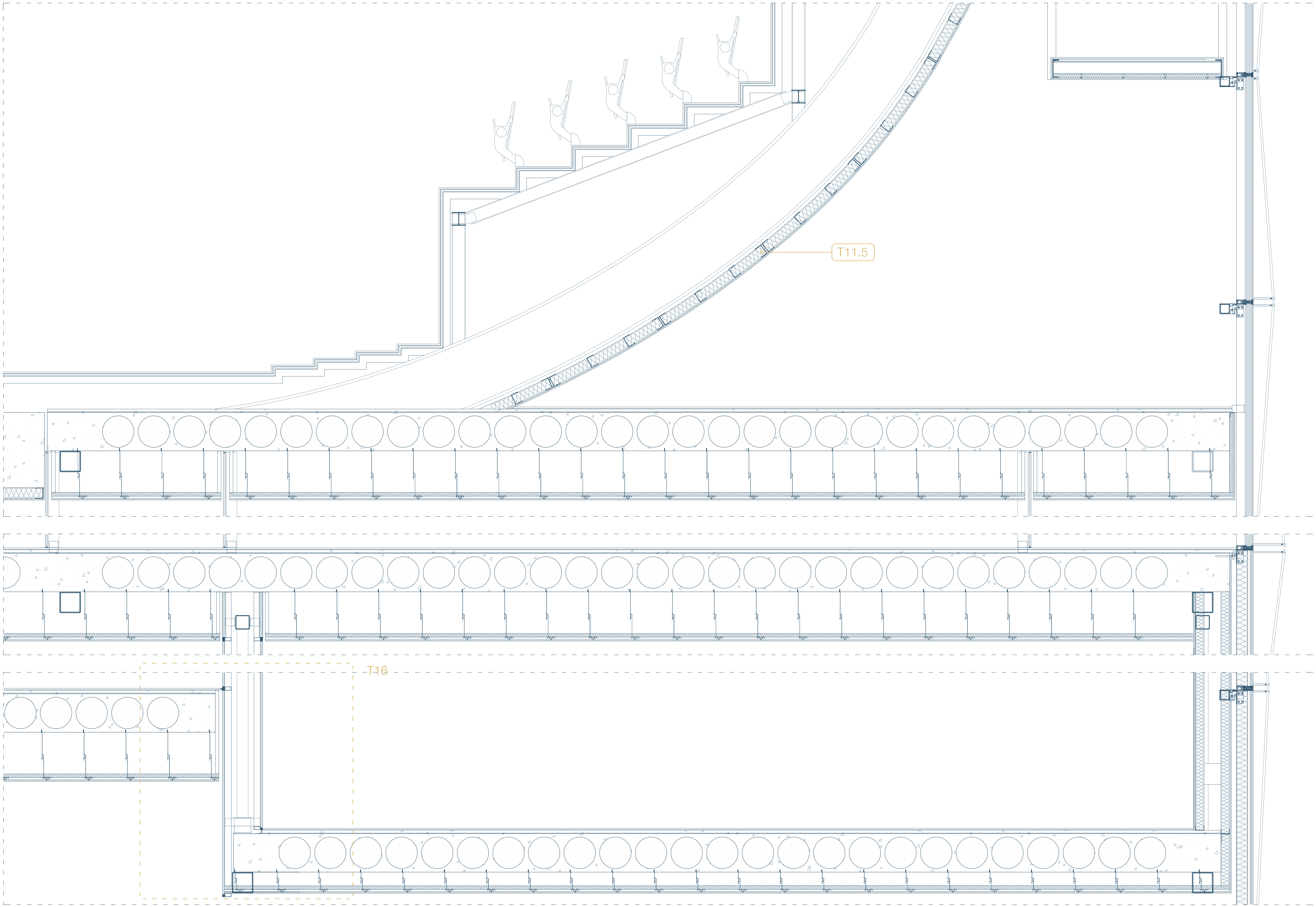


Detailing | Technological section | 1:50

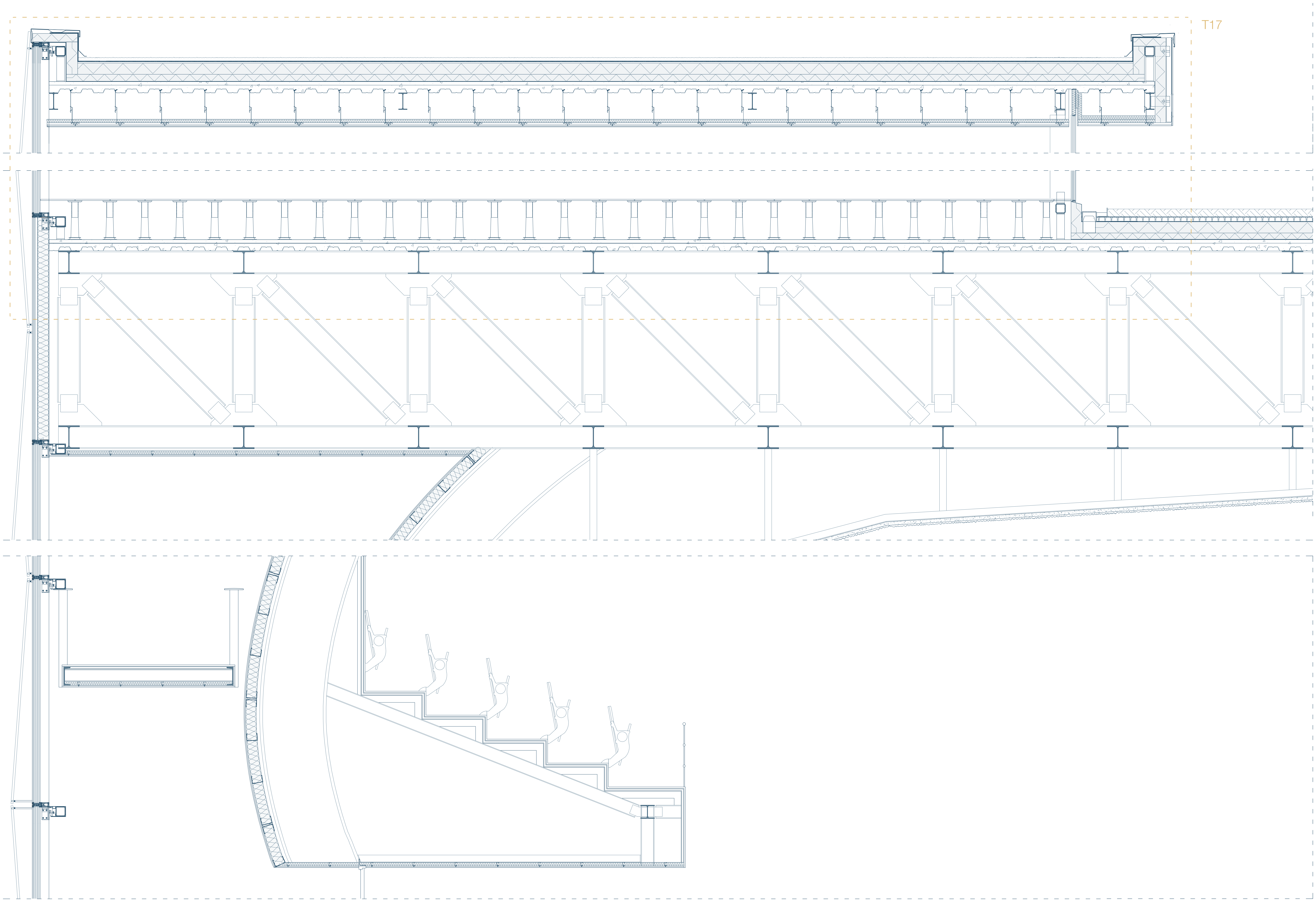

T15
T11.2
T11.6



Detailing | Technological section | 1:50

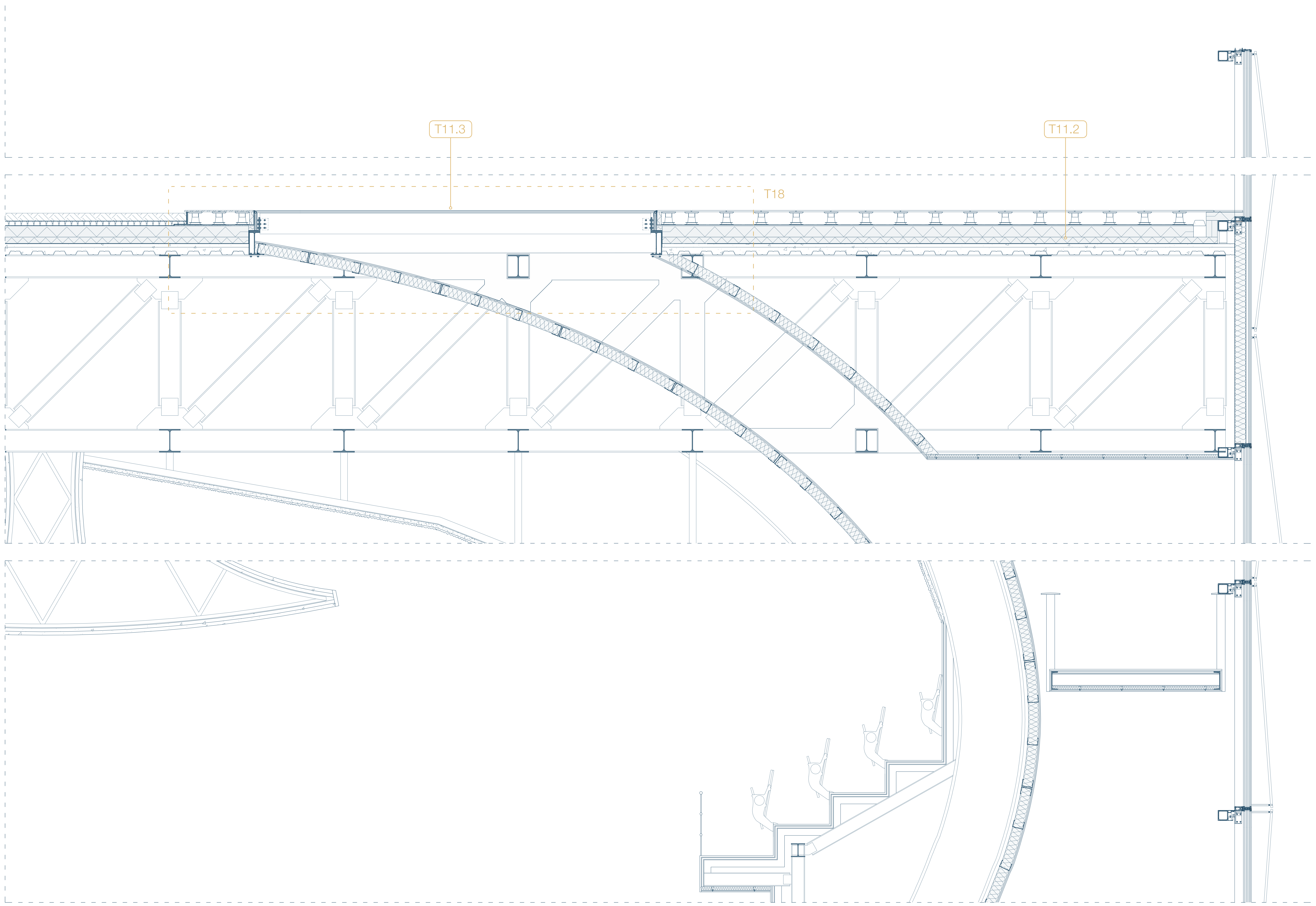


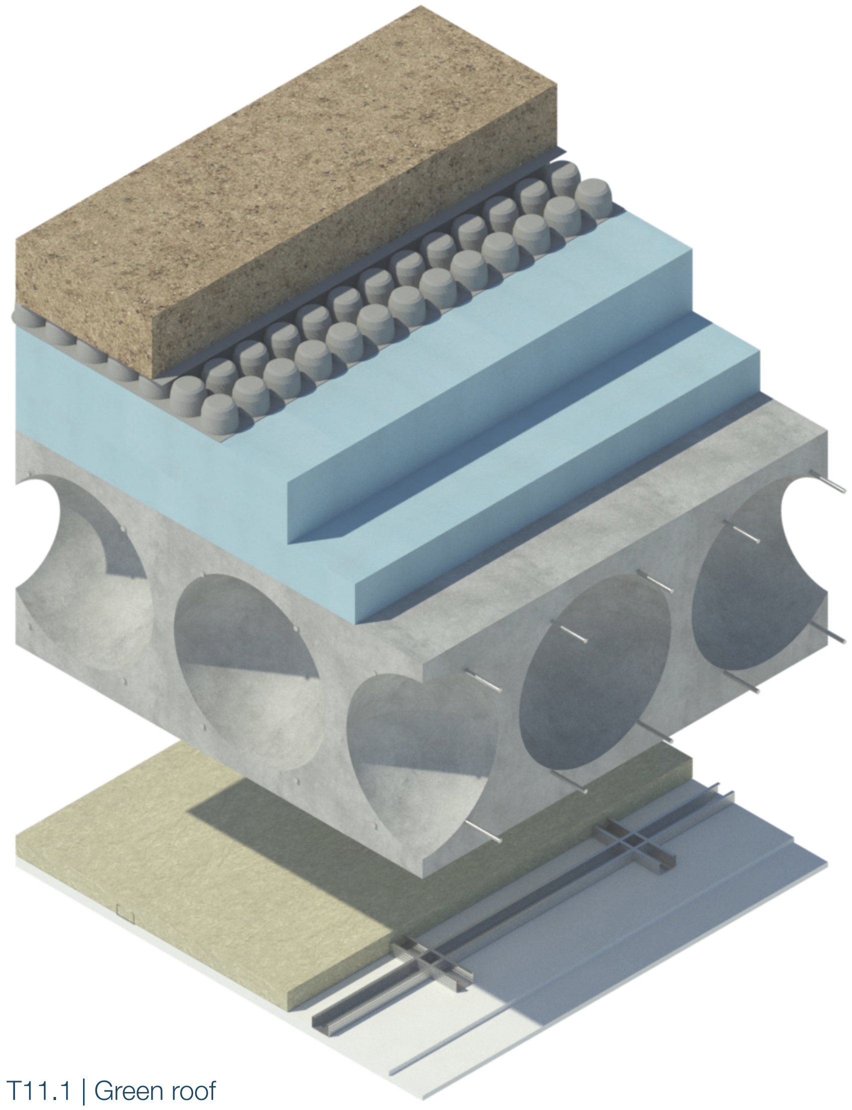
Detailing | Technological section | 1:50



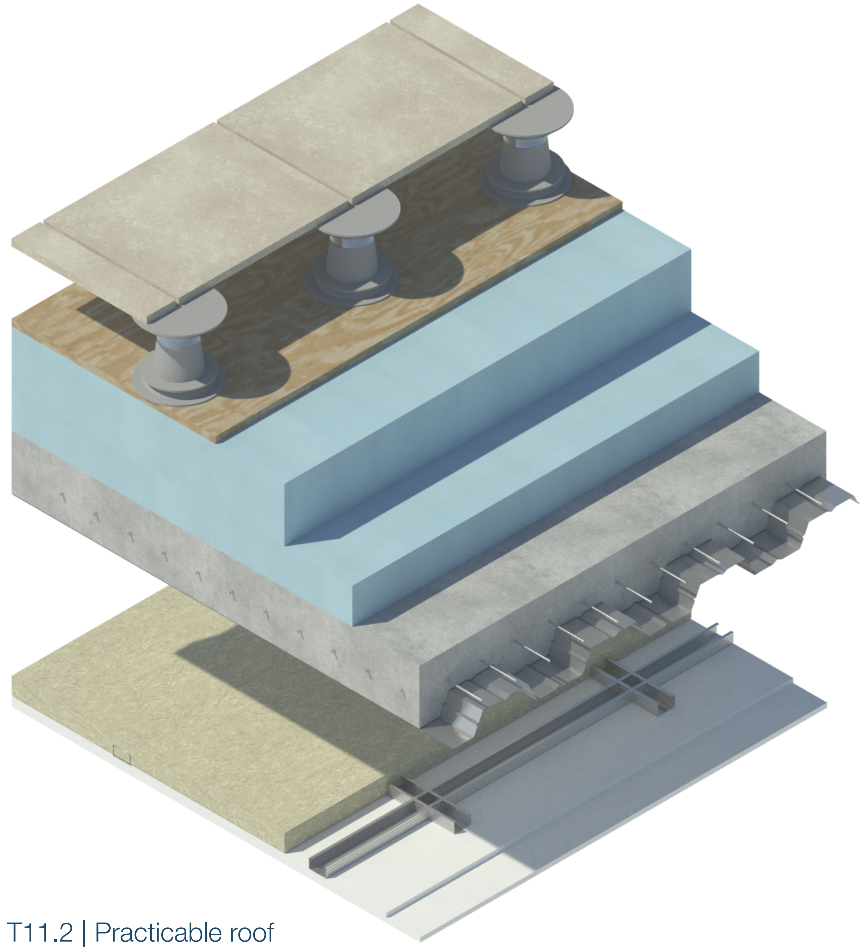
T09

Detailing | Technological section | 1:50

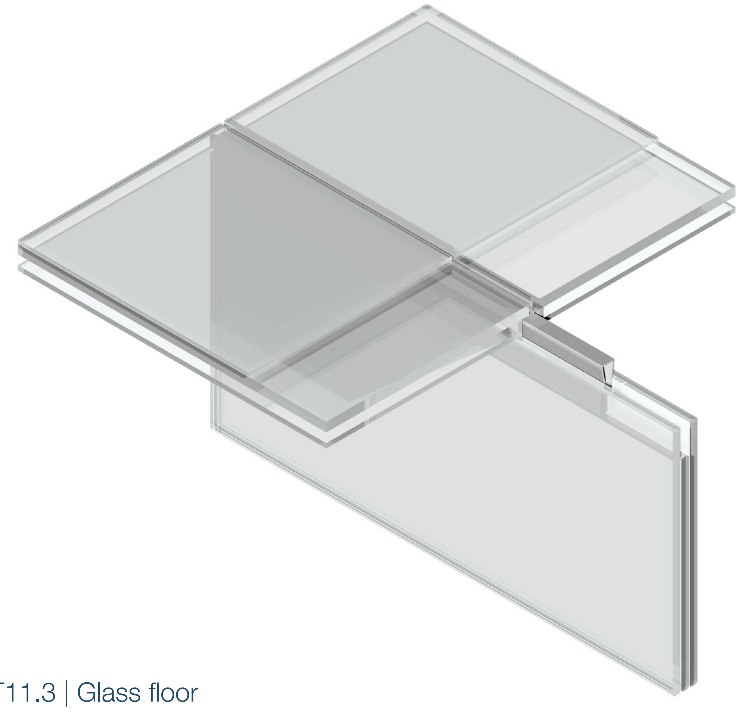

T11.3
T11.2
T18



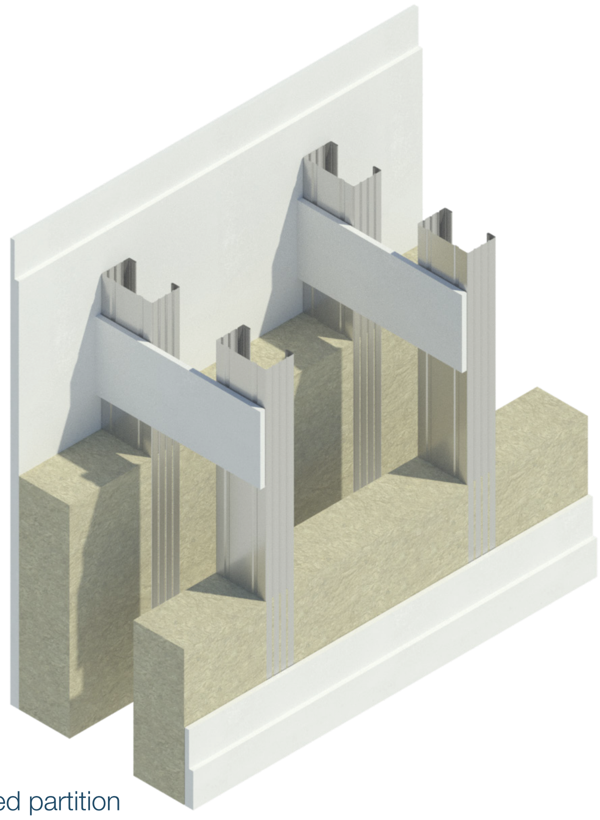
T11.1 | Green roof



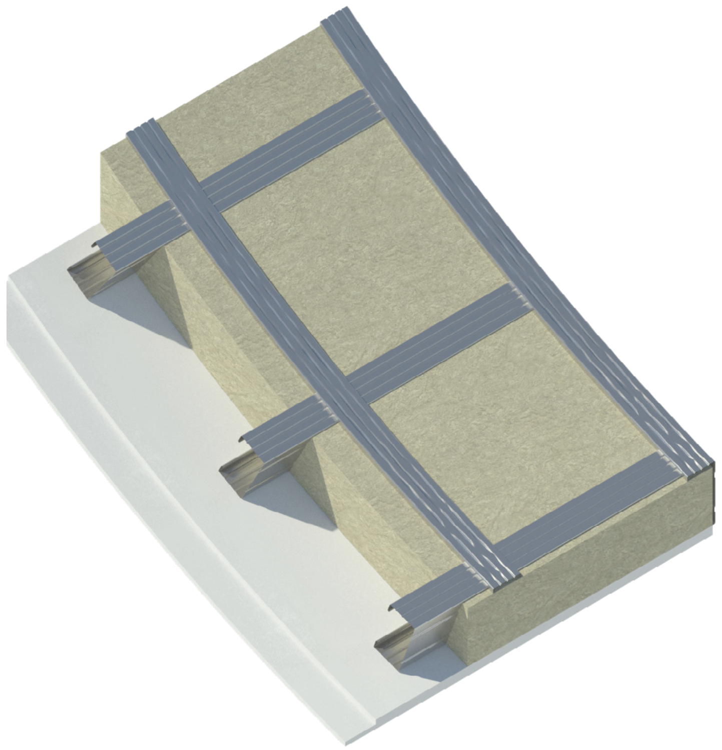
T11.2 | Practicable roof



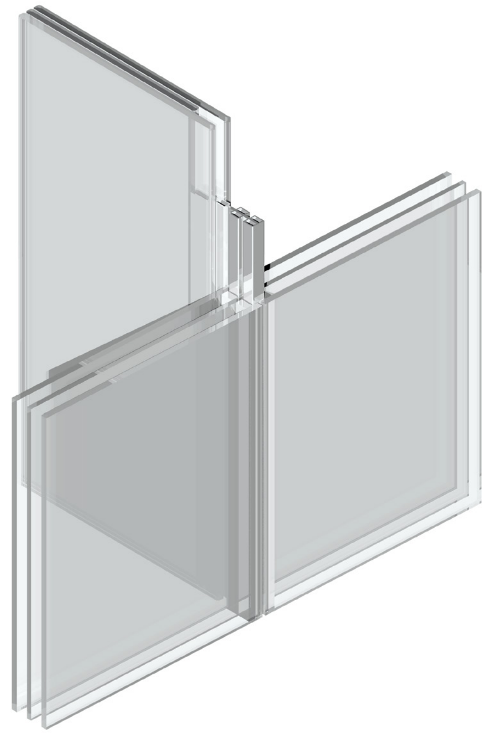
T11.3 | Glass floor



T11.4 | Isolated partition

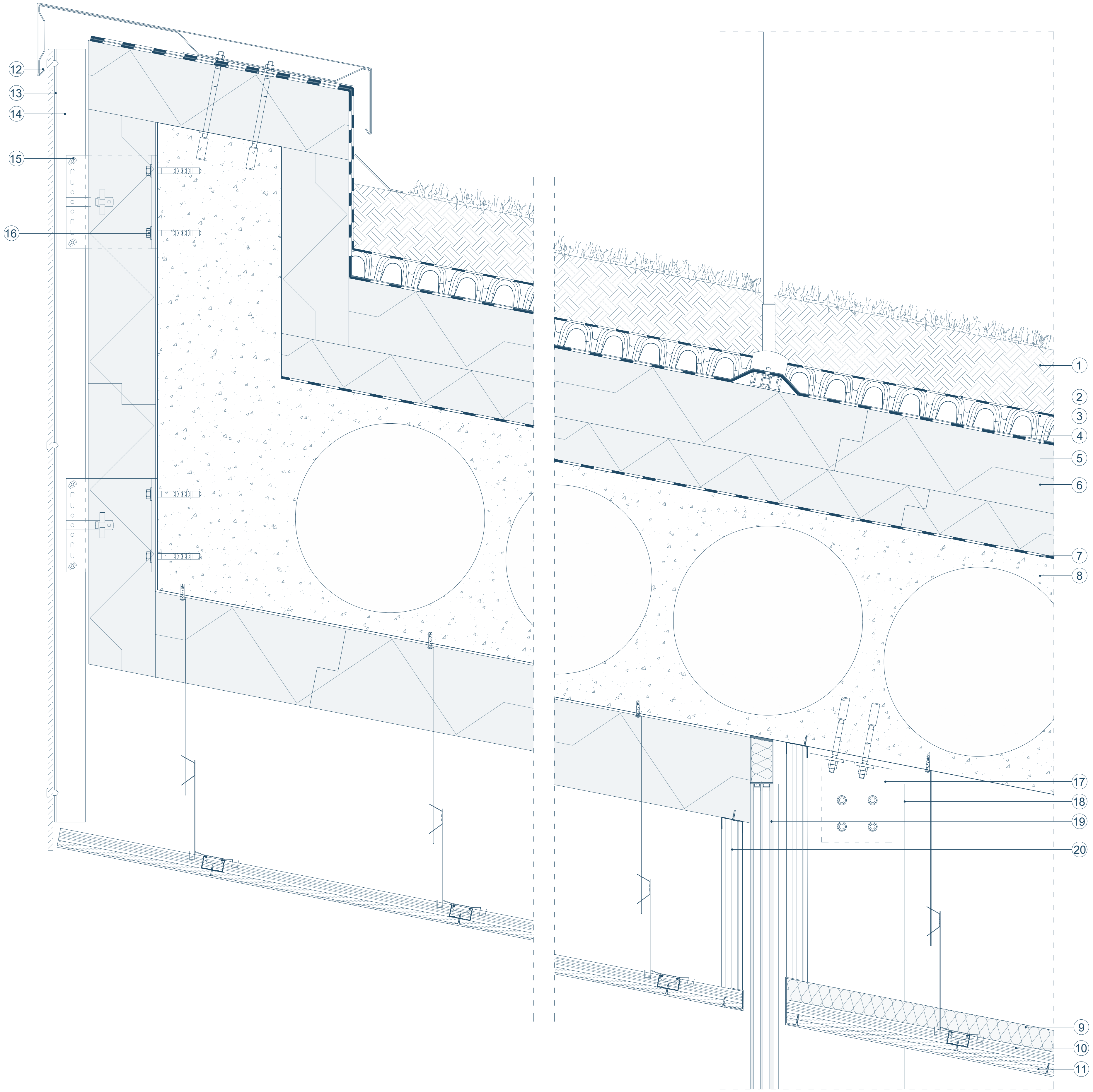


T11.5 | Main hall outer skin

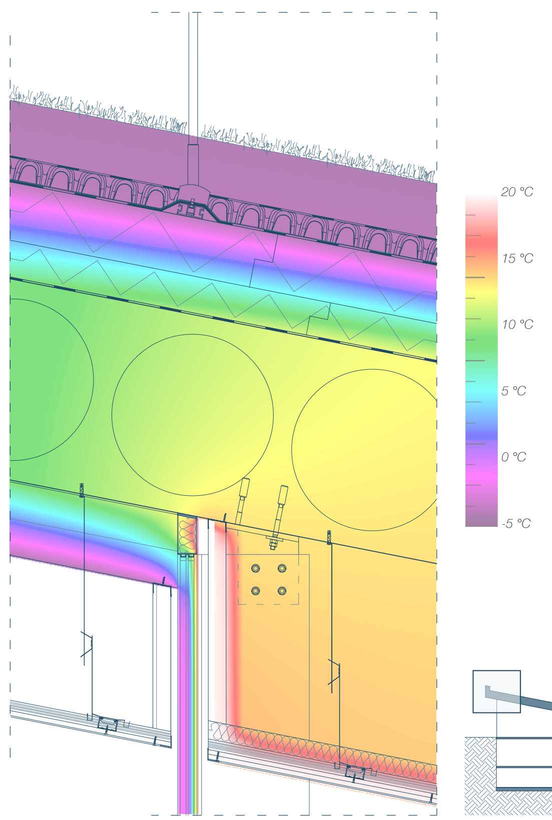


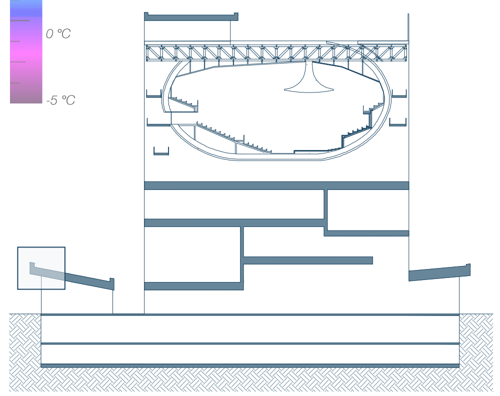
T11.6 | Transparent facade

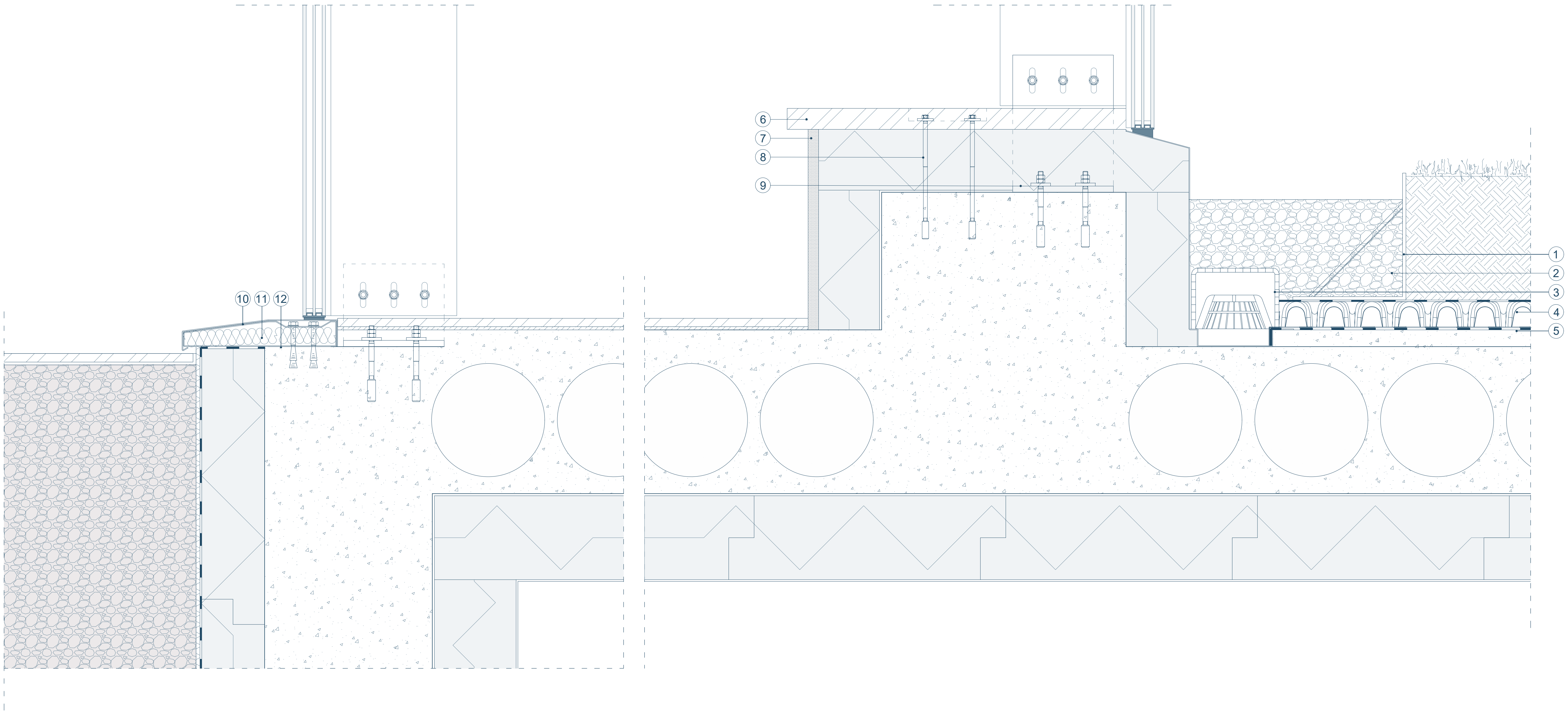
Detailing | Relevant stratigraphies | 1:20



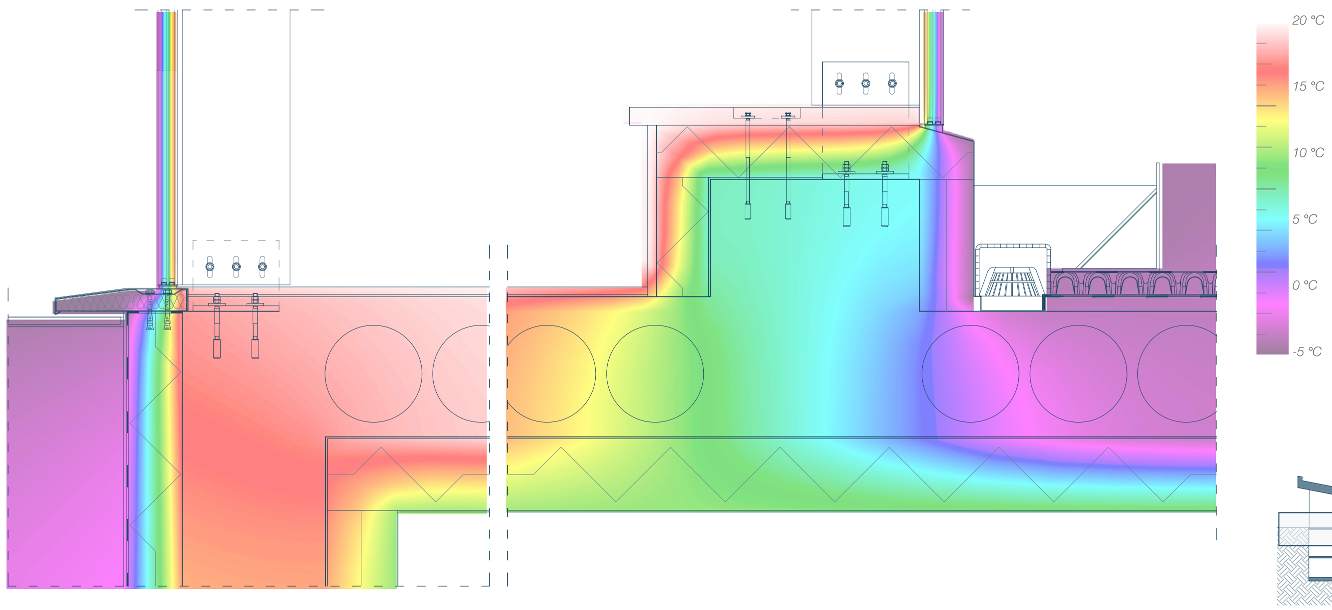
1. Soil layer for extensive cultivation th. 15 cm
2. Anti-root filtering layer, non-woven polyester fabric, th. 0.4 cm
3. Water collection layer: compression-resistant polyethylene storage elements, th. 6 cm
4. Protection layer: geotextile membrane with polypropylene fibers, th. 0.13 cm
5. Watertight layer: waterproof and desolidarizing sheet in PVC reinforced with glass fibers, th. 6 mm
6. Thermal insulation layer: XPS panel, th. 16+10 cm, λ = 0.033 W / mK, ρ = 33 kg / m3
7. Vapour barrier, aluminum foil with glass felt, th. 0.04 cm
8. Load bearing layer: prefabricated BubbleDeck slab, height 55 cm, spheres diameter 45 cm
9. Sound insulation layer: rock wool panels, sp. 5 cm, λ = 0.035 W / mK, ρ = 40 kg / m3
10. C-shaped load-bearing profiles crossed with orthogonal union hooks and fixed to the bearing layer by means of adjustable spring hooks and hangers, dimensions 50x27 mm, thickness 0.6 mm
11. Finishing layer: double plasterboard panel, th. 1.25 cm
12. Galvanized pre-painted aluminum flashing, th. 0,4 mm
13. Anodized aluminum panel with punctual fixing, th. 2 mm
14. Steel mullion supporting the aluminum panels and connected to the concrete slabs
15. Steel connecting element with slotted holes
16. Concrete screw fixed with epoxy resin
17. L- shaped steel plate, th. 15 mm , fixed with concrete screw fixed with epoxy resin
18. Triple layered high resistance tempered glass with PVB laye, th 1+1+1 cm, depth 30 cm
19. Triple layered glass with air fill, th. 8/16/6/16/8 mm
20. Cold-formed steel C-shaped and U-shaped profiles, th. 0,8 mm

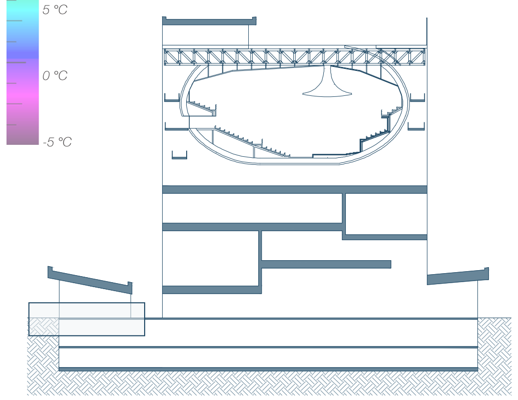


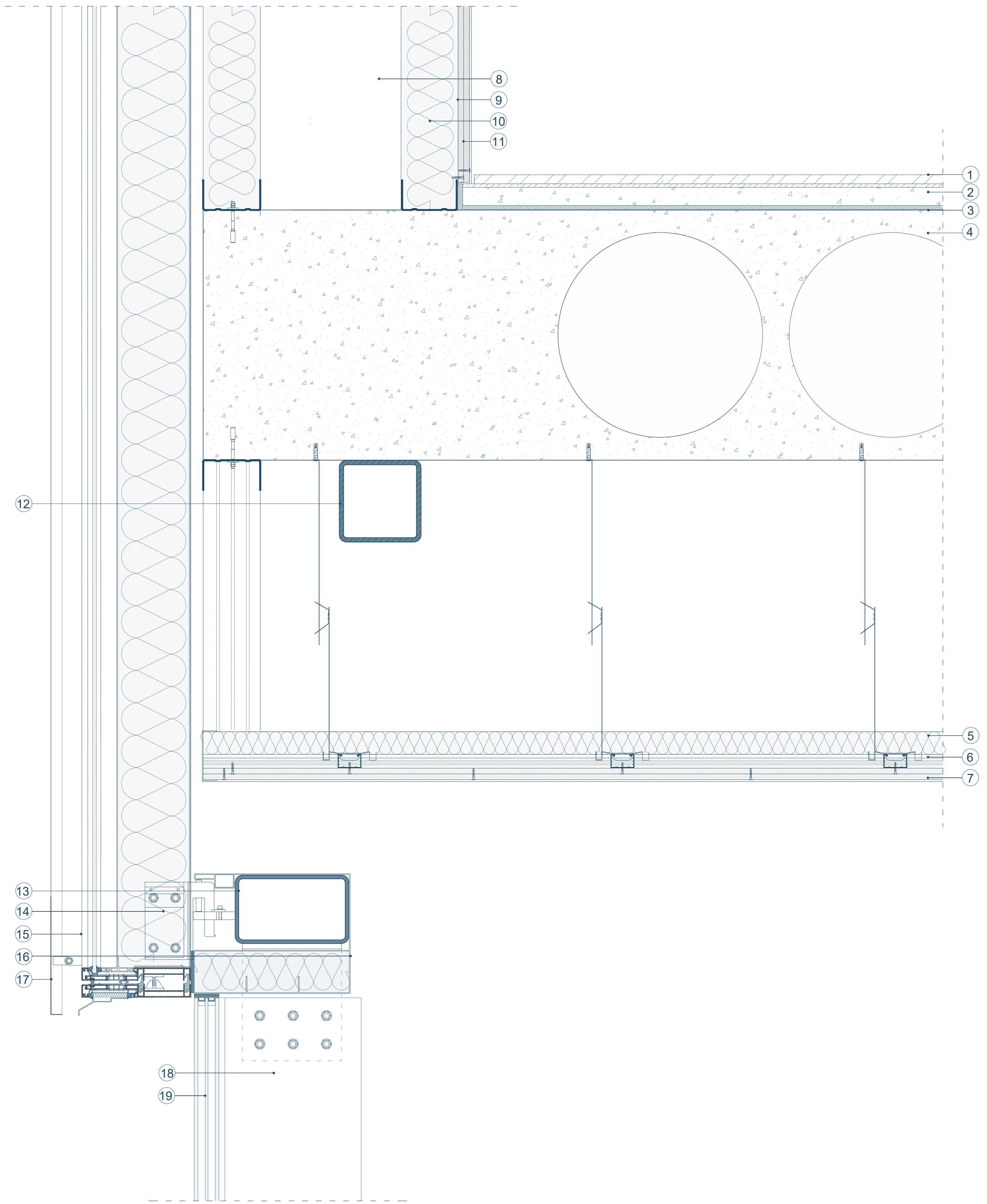




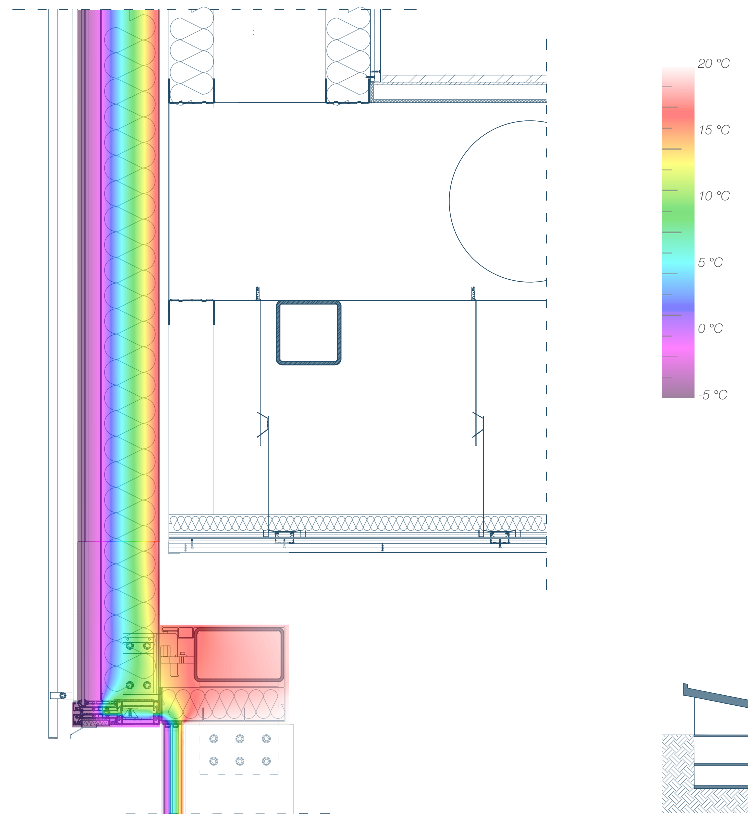
1. L-shaped profile retaining the soil layer
2. Ballasting layer: polished white gravel, th. 5 cm
3. Steel gutter
4. Water collection layer: compression-resistant polyethylene storage elements, th. 6 cm
5. Watertight layer: waterproof and desolidarizing sheet in PVC reinforced with glass fibers, th. 6 mm
6. Wooden element
7. Finishing layer: plasterboard panel, th. 1.25 cm
8. Concrete screw fixed with epoxy resin
9. L- shaped steel plate, th. 15 mm , fixed with concrete screw fixed with epoxy resin
10. Reinforced pre-painted aluminum flashing, th. 0,4 mm
11. Rock wool panel, sp. 5 cm, λ = 0.035 W / mK, ρ = 40 kg / m3/
12. Watertight layer: waterproof and desolidarizing sheet in PVC reinforced with glass fibers, th. 6 mmh

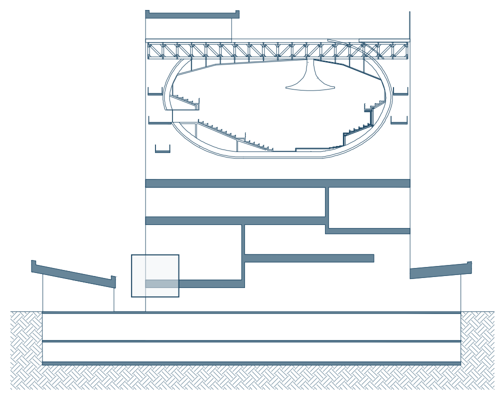


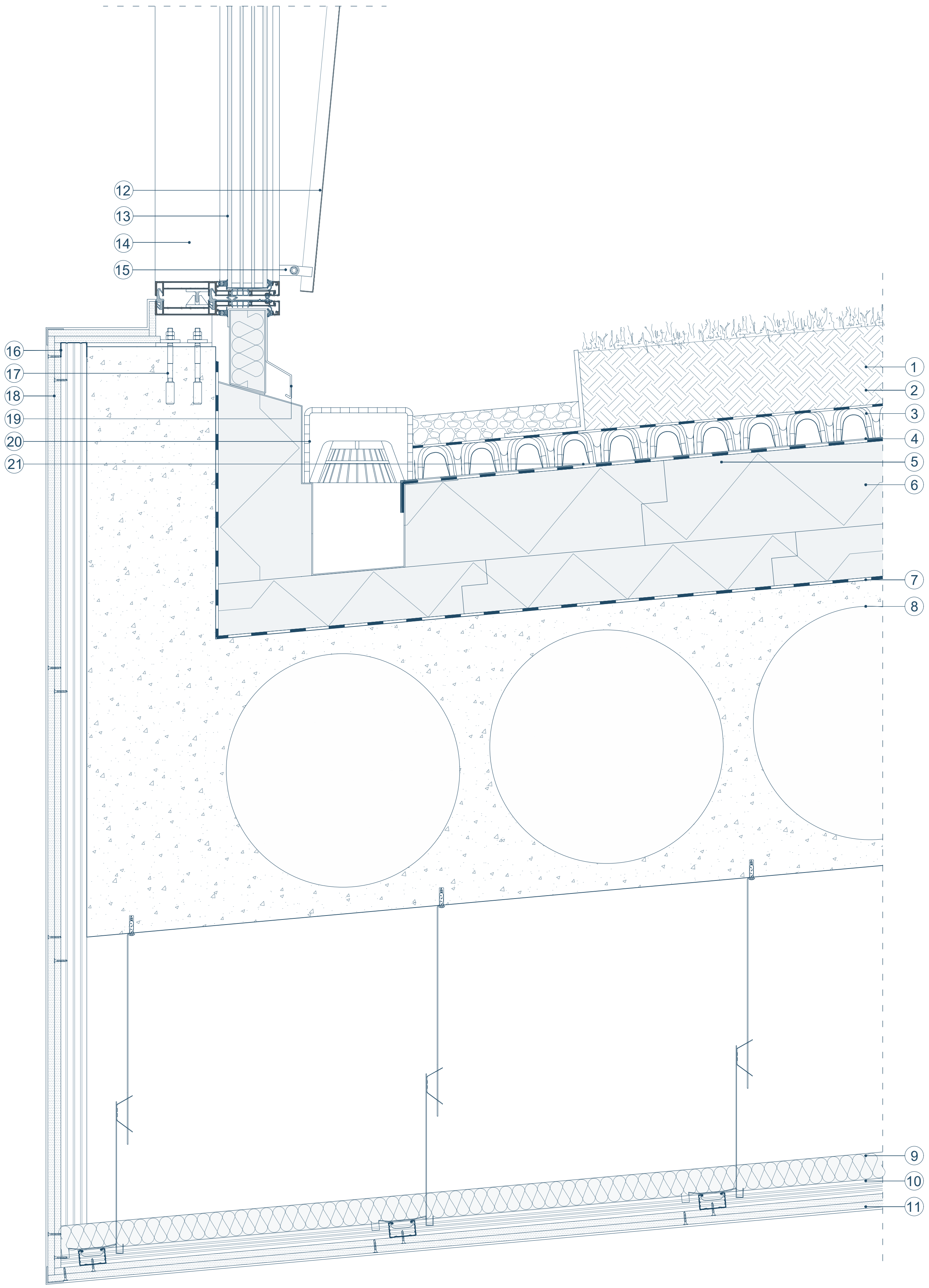




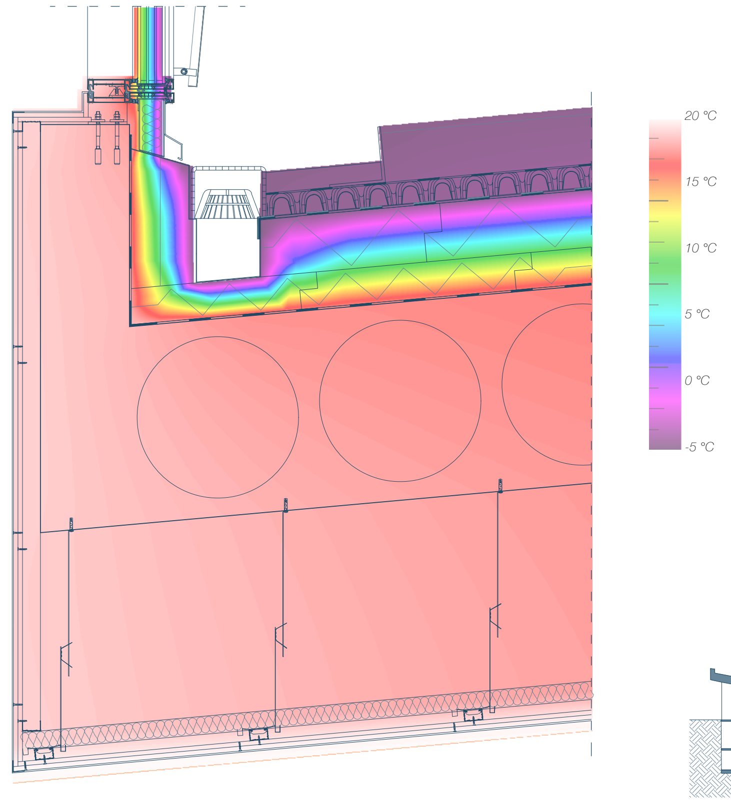
1. Finishing layer: simil wood porcelain stoneware, dim. 60x120 cm, th. 2 cm
2. Load distribution layer: slightly reinforced concrete, th. 4 cm
3. Sound insulation layer with impact noise: polymer-bitumen elastoplastic membrane coupled with a layer of polyester fiber, dimensions: 1x1 m, th. 1.3 cm, λ = 0.032 W / mK
4. Load bearing layer: prefabricated BubbleDeck slab, height 55 cm, spheres diameter 45 cm
5. Sound insulation layer: rock wool panels, sp. 5 cm, λ = 0.035 W / mK, ρ = 40 kg / m3
6. C-shaped load-bearing profiles crossed with appropriate orthogonal union hooks and fixed to the bearing layer by means of adjustable spring hooks and hangers, dimensions 50x27 mm, thickness 0.6 mm
7. Finishing layer: double plasterboard sheet, th. 2x1.25 cm, width 120 cm, with a leveling and finishing layer
8. Equipped cavity, th. 25 cm
9. Support layer: vertical frame of C-shaped profiles, width 10 cm, th. 0.6 mm
10. Sound-insulation layer: rock wool panels, th. 6 cm, λ = 0.035 W / mK, ρ = 40 kg / m3
11. Finishing layer: double plasterboard sheet, th. 2x1.25 cm, width 120 cm, with a leveling and finishing layer
12. Steel square hollow core shaped profile
13. Steel rectangular hollow core shaped profile
14. Bearing steel plate connecting the unitized system to beams through slotted holes and bolts
15. Unitized-system glass with air fill th. 8, doubled with an opaque component filled with rock wool panels, th. 16 cm, λ = 0.035 W / mK, ρ = 40 kg / m3
16. Pre-painted aluminum carter
17. Anodized aluminum panel with punctual fixing, th. 2 mm
18. Triple layered high resistance tempered glass with PVB laye, th 1+1+1 cm, depth 30 cm
19. Triple layered glass with air fill, th. 8/16/6/16/8 mm

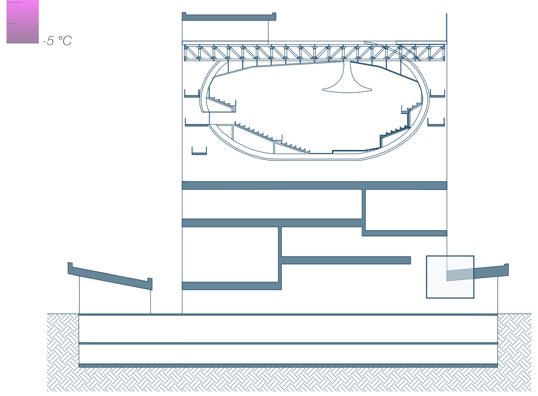


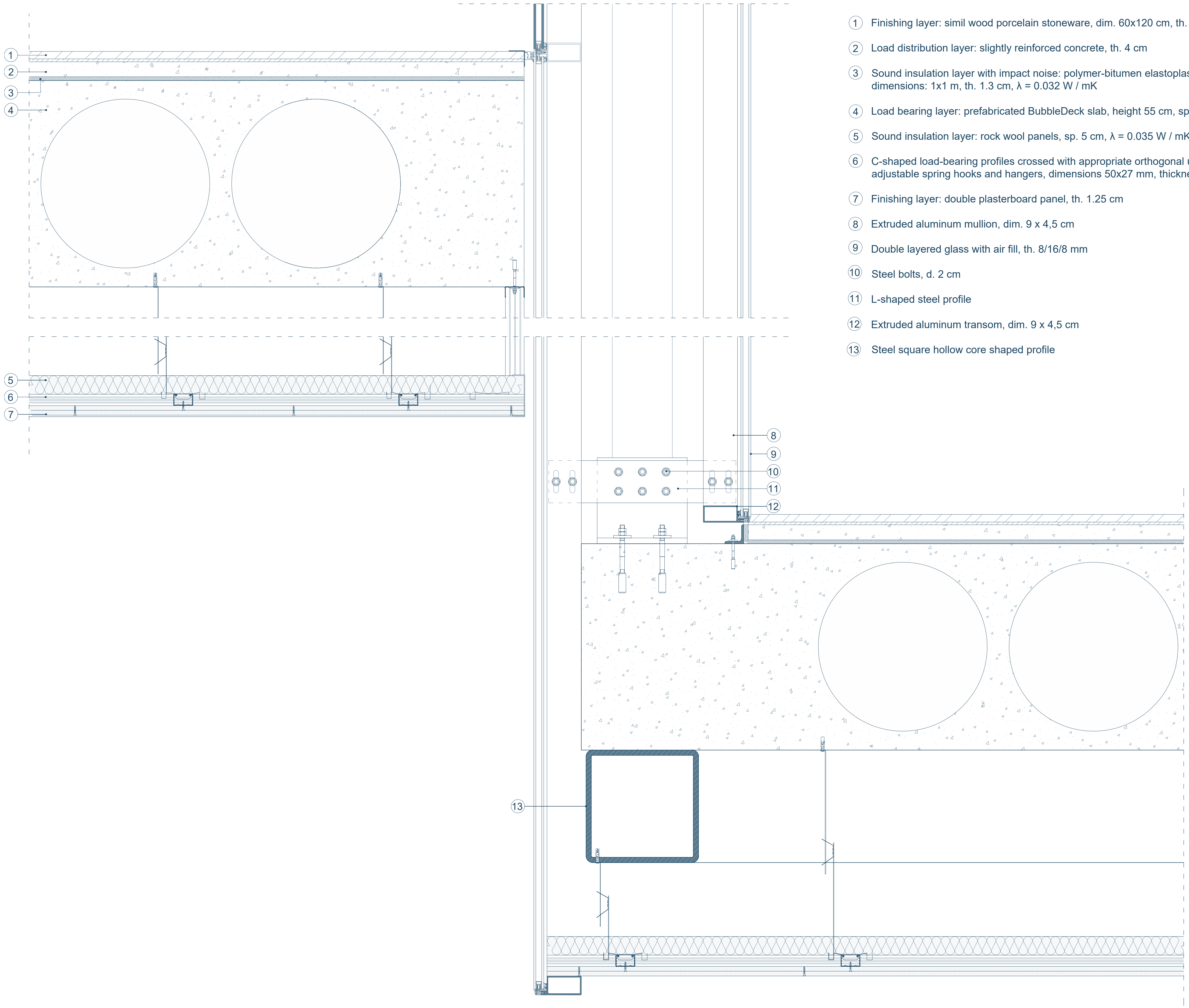


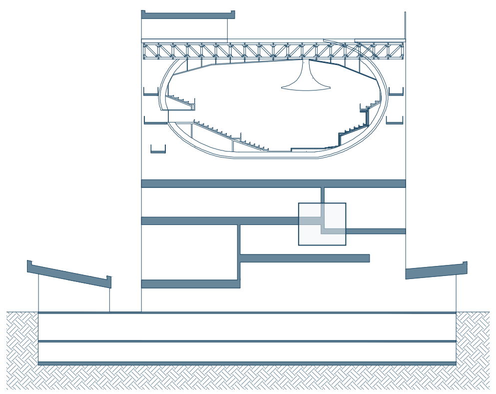


1. Soil layer for extensive cultivation th. 15 cm
2. Anti-root filtering layer, non-woven polyester fabric, th. 0.4 cm
3. Water collection layer: compression-resistant polyethylene storage elements, th. 6 cm
4. Protection layer: geotextile membrane with polypropylene fibers, th. 0.13 cm
5. Watertight layer: waterproof and desolidarizing sheet in PVC reinforced with glass fibers, th. 6 mm
6. Thermal insulation layer: XPS panel, th. 16+10 cm, λ = 0.033 W / mK, ρ = 33 kg / m3
7. Vapour barrier, aluminum foil with glass felt, th. 0.04 cm
8. Load bearing layer: prefabricated BubbleDeck slab, height 55 cm, spheres diameter 45 cm
9. Sound insulation layer: rock wool panels, sp. 5 cm, λ = 0.035 W / mK, ρ = 40 kg / m3
10. C-shaped load-bearing profiles crossed with appropriate orthogonal union hooks and fixed to the bearing layer by means of adjustable spring hooks and hangers, dimensions 50x27 mm, thickness 0.6 mm
11. Finishing layer: double plasterboard panel, th. 1.25 cm
12. Anodized aluminum panel with punctual fixing, th. 2 mm
13. Unitized-system quadrupled layered glass with air fill, th. 8/16/6/12/6/16/8 mm
14. Unitized system extruded aluminum frame profile, dim. 24x6.5 cm
15. Steel punctual fixing
16. Cold-formed steel C-shaped and U-shaped profiles, th. 0,8 mm
17. Concrete screw fixed with epoxy resin
18. Finishing layer: double plasterboard panel, th. 1.25 cm
19. Galvanized pre-painted aluminum flashing, th. 0,4 mm
20. Steel gutter
21. L-shaped profile retaining the soil layer

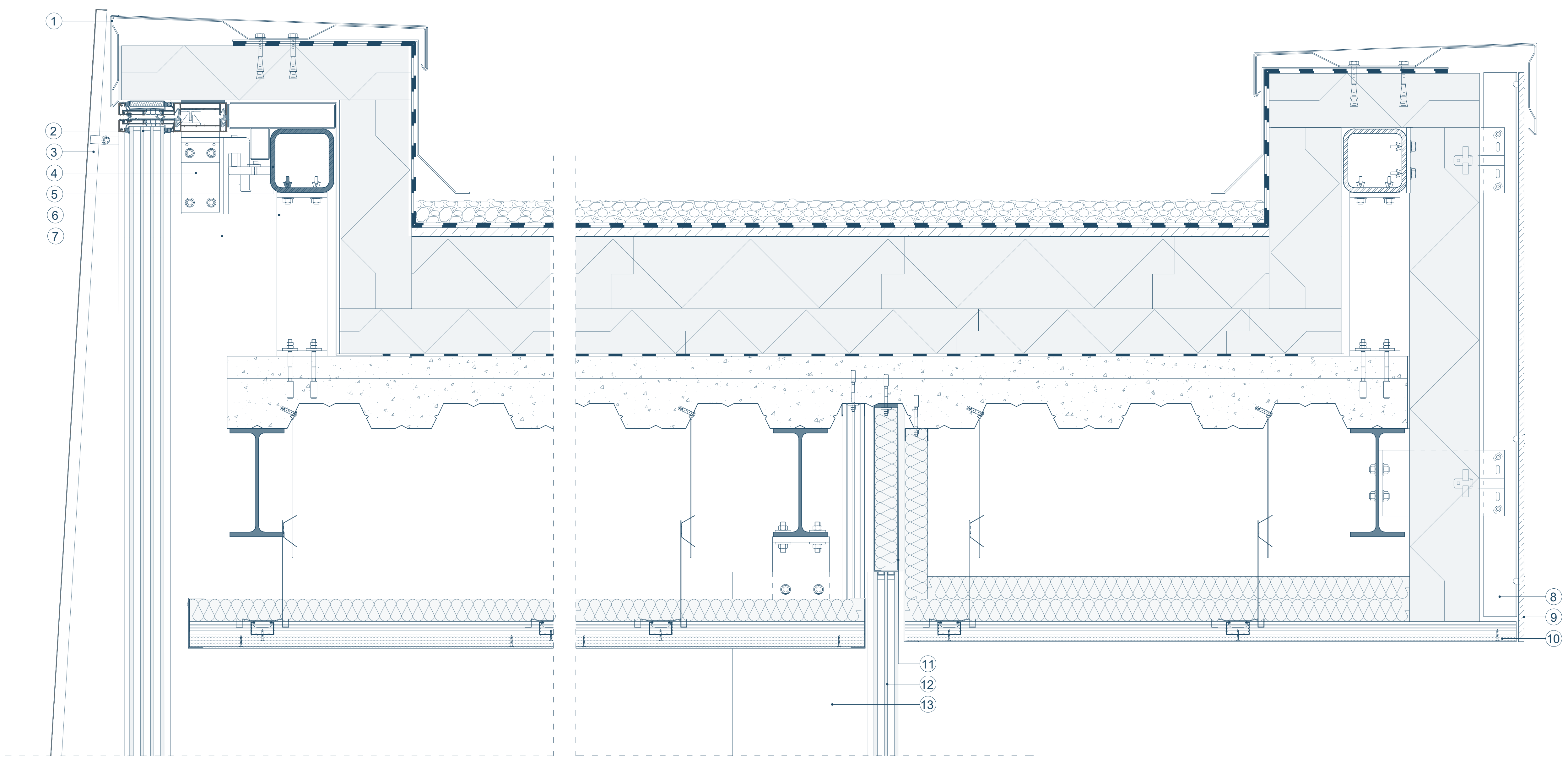




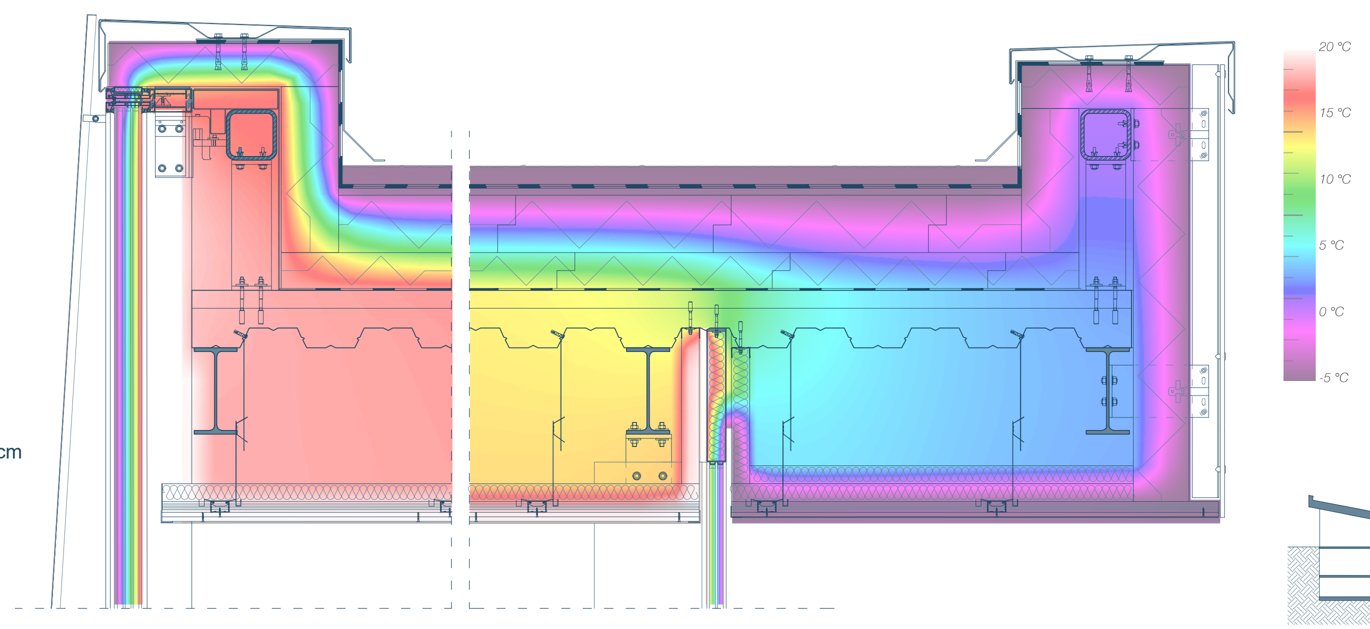


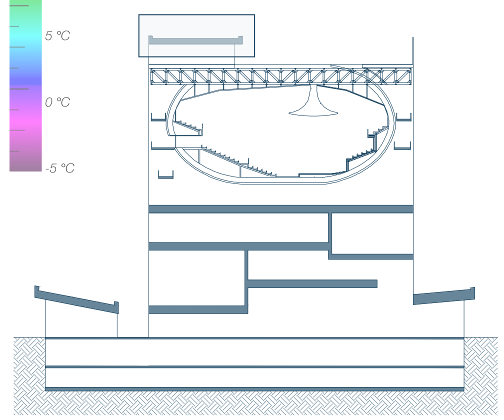


1. Finishing layer: simil wood porcelain stoneware, dim. 60x120 cm, th. 2 cm
2. Load distribution layer: slightly reinforced concrete, th. 4 cm
3. Sound insulation layer with impact noise: polymer-bitumen elastoplastic membrane coupled with a layer of polyester fiber, dimensions: 1x1 m, th. 1.3 cm, λ = 0.032 W / mK
4. Load bearing layer: prefabricated BubbleDeck slab, height 55 cm, spheres diameter 45 cm
5. Sound insulation layer: rock wool panels, sp. 5 cm, λ = 0.035 W / mK, ρ = 40 kg / m3
6. C-shaped load-bearing profiles crossed with appropriate orthogonal union hooks and fixed to the bearing layer by means of adjustable spring hooks and hangers, dimensions 50x27 mm, thickness 0.6 mm
7. Finishing layer: double plasterboard panel, th. 1.25 cm
8. Extruded aluminum mullion, dim. 9 x 4,5 cm
9. Double layered glass with air fill, th. 8/16/8 mm
10. Steel bolts, d. 2 cm
11. L-shaped steel profile
12. Extruded aluminum transom, dim. 9 x 4,5 cm
13. Steel square hollow core shaped profile



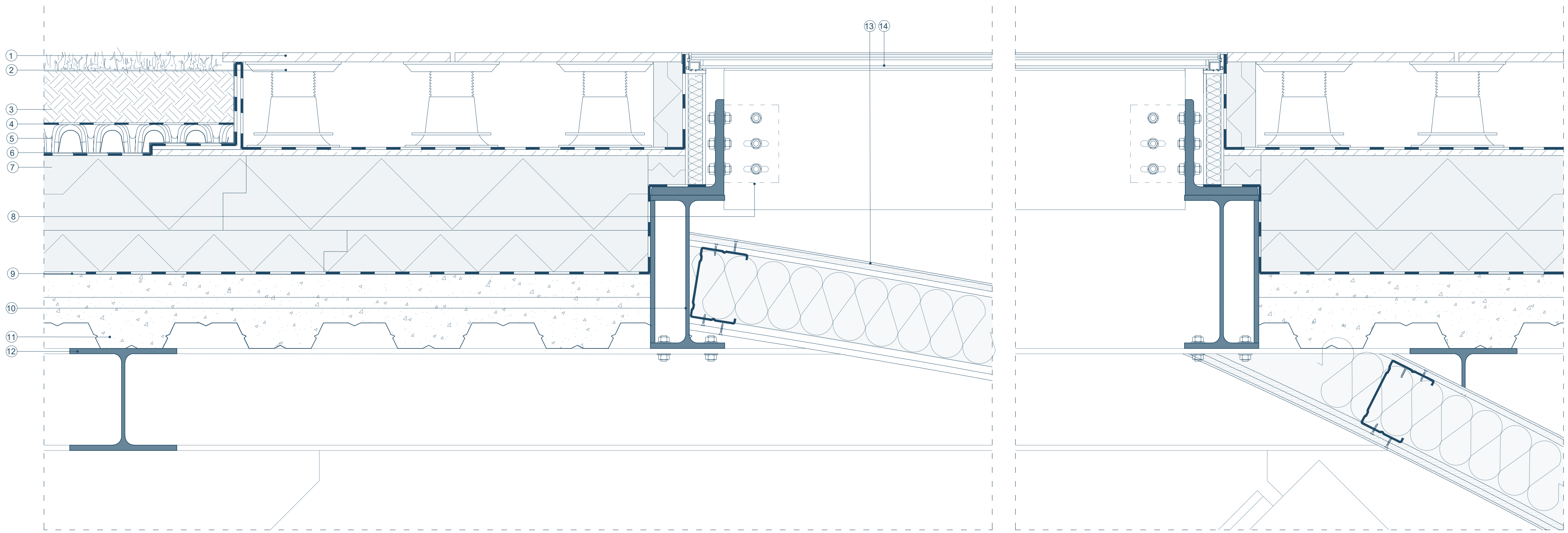
1. Galvanized pre-painted aluminum flashing, th. 0,4 mm
2. Unitized-system quadrupled layered glass with air fill, th. 8/16/6/12/6/16/8 mm
3. Anodized aluminum panel with punctual fixing, th. 2 mm
4. Bearing steel plate connecting the unitized system to beams through slotted holes and bolts
5. Steel square hollow core shaped profile
6. C- shaped steel plate, th. 15 mm , fixed with concrete screw fixed with epoxy resin
7. Finishing layer: double plasterboard sheet, th. 2x1.25 cm, width 120 cm, with a leveling and finishing layer
8. Anodized aluminum panel with punctual fixing, th. 2 mm
9. Steel mullion supporting the aluminum panels and connected to the concrete slabs
10. Panel composed of aggregates and Portland concrete, reinforced with fiberglass mesh on the surfaces, th. 1,25 cm
11. Prefabricated aluminum panel filled with rock wool panel th. 5 cm, λ = 0.035 W / mK, ρ = 40 kg / m3
12. Triple layered glass with air fill, th. 8/16/6/16/8 mm
13. Triple layered high resistance tempered glass with PVB laye, th 1+1+1 cm, depth 30 cm



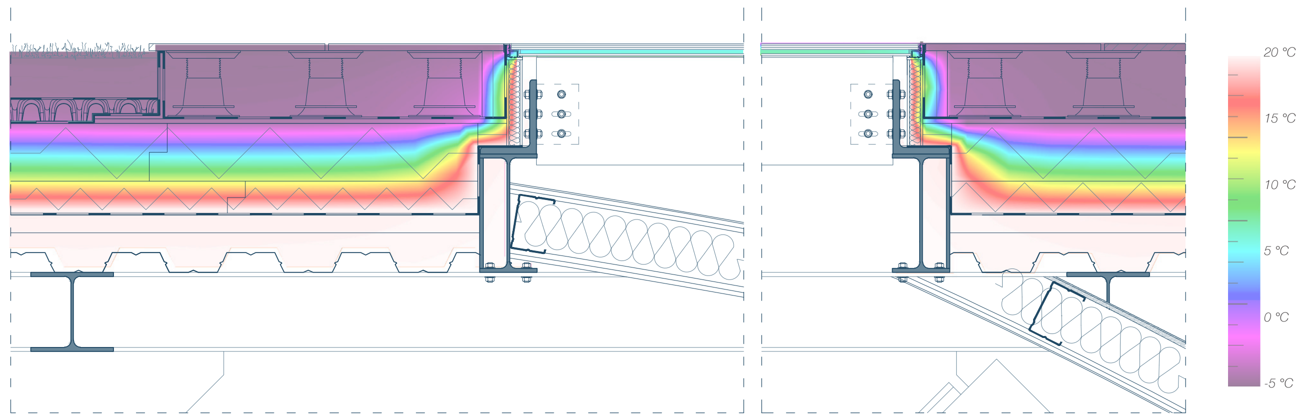


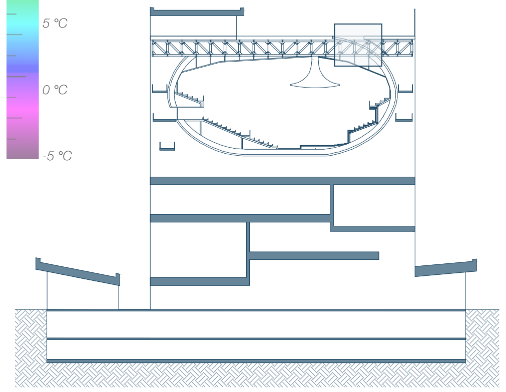
T17

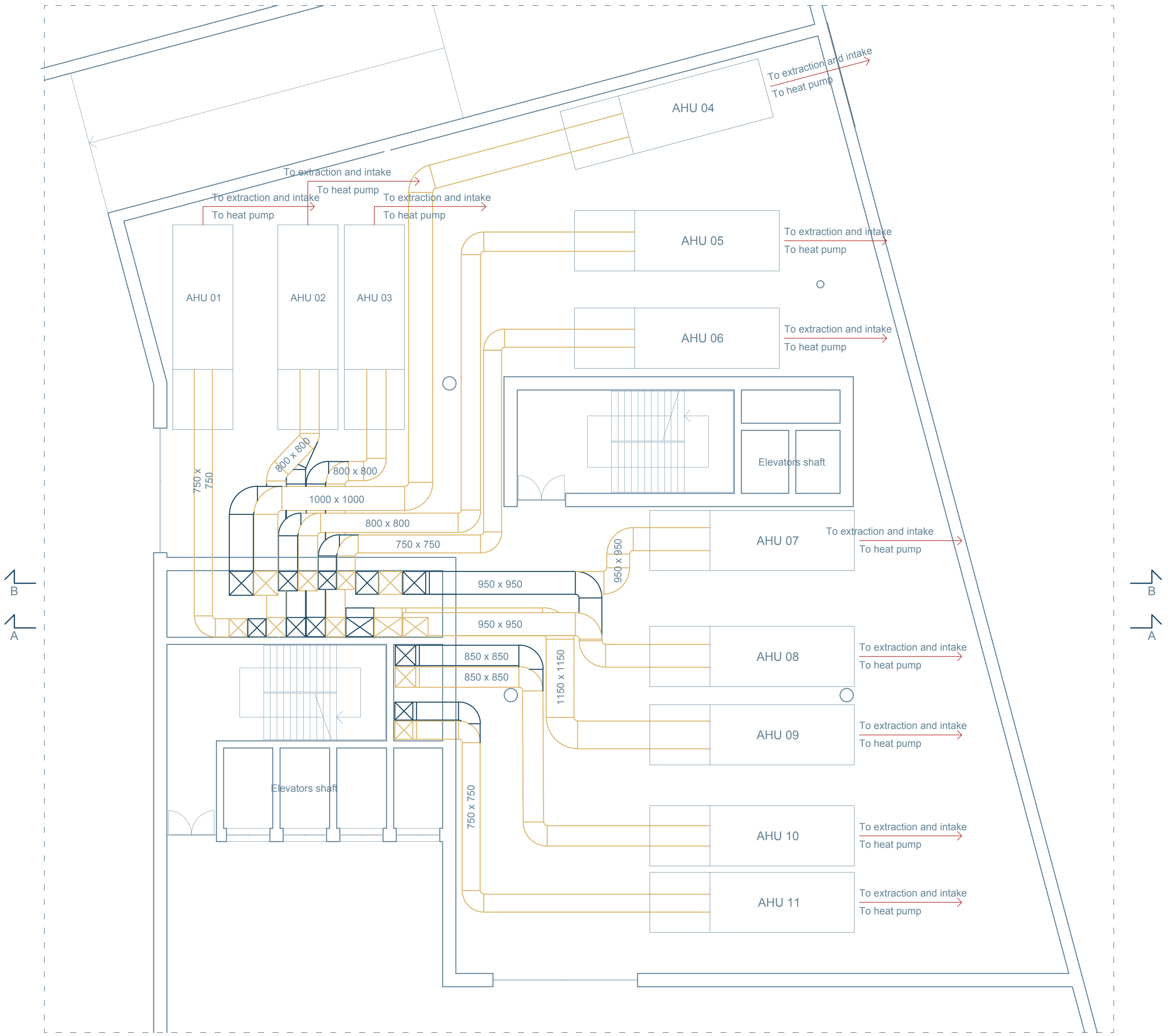
Detailing | Technological detailing | 1:10



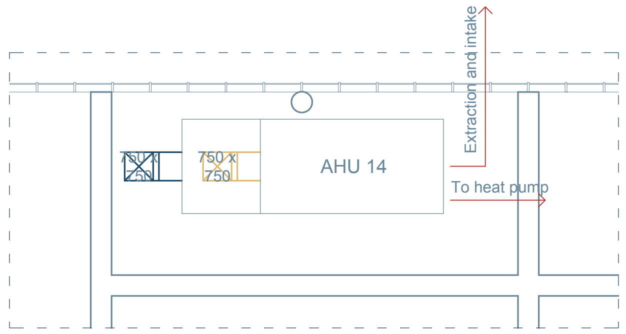
1. Finishing layer: simil wood porcelain stoneware, dim. 60x120 cm, th. 2 cm
2. Bearing elements for outdoor flooring, height 21.5 cm
3. Soil layer for extensive cultivation th. 15 cm
4. Anti-root filtering layer, non-woven polyester fabric, th. 0.4 cm
5. Water collection layer: compression-resistant polyethylene storage elements, th. 6 cm
6. Watertight layer: waterproof and desolidarizing sheet in PVC reinforced with glass fibers, th. 6 mm
7. Thermal insulation layer: XPS panel, th. 16+10 cm, λ = 0.033 W / mK, ρ = 33 kg / m3
8. Steel plate welded to the beam
9. Vapour barrier, aluminum foil with glass felt, th. 0.04 cm
10. Steel profile I-Shaped, IPE 550
11. Load bearing layer: metal deck with reinforced concrete, th. 5,5+5,5 cm, with 5 cm of low density concrete for loads distribution
12. Steel profile I-Shaped, IPE 240
13. Finishing layer: cherry wood panels
14. Laminated glass floor: 4 mm sacrificial layer tempered glass; 6+6 mm tempered glass with PVB layer; 12 air filled cavity, 6 mm tempered glass



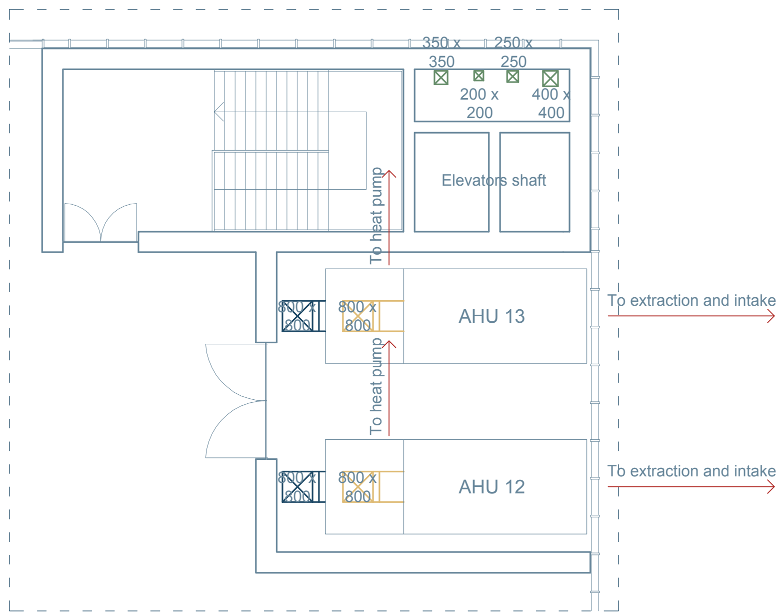




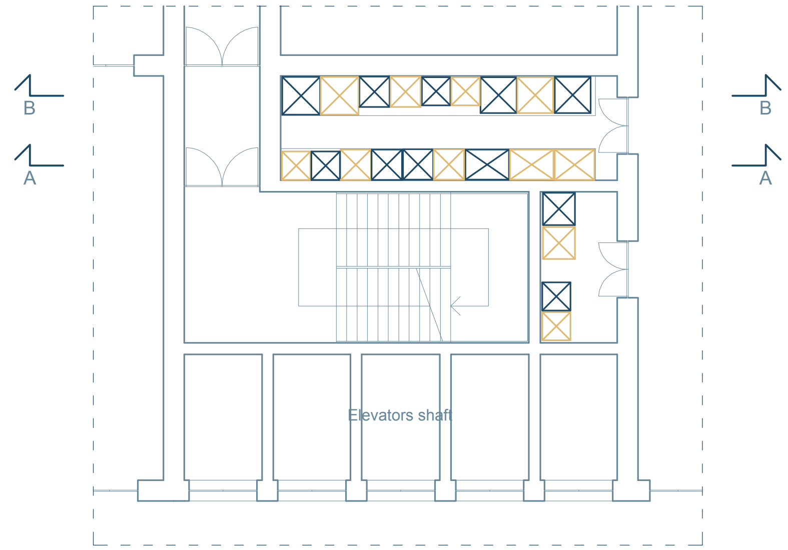
Level -1: Handling Units Layout



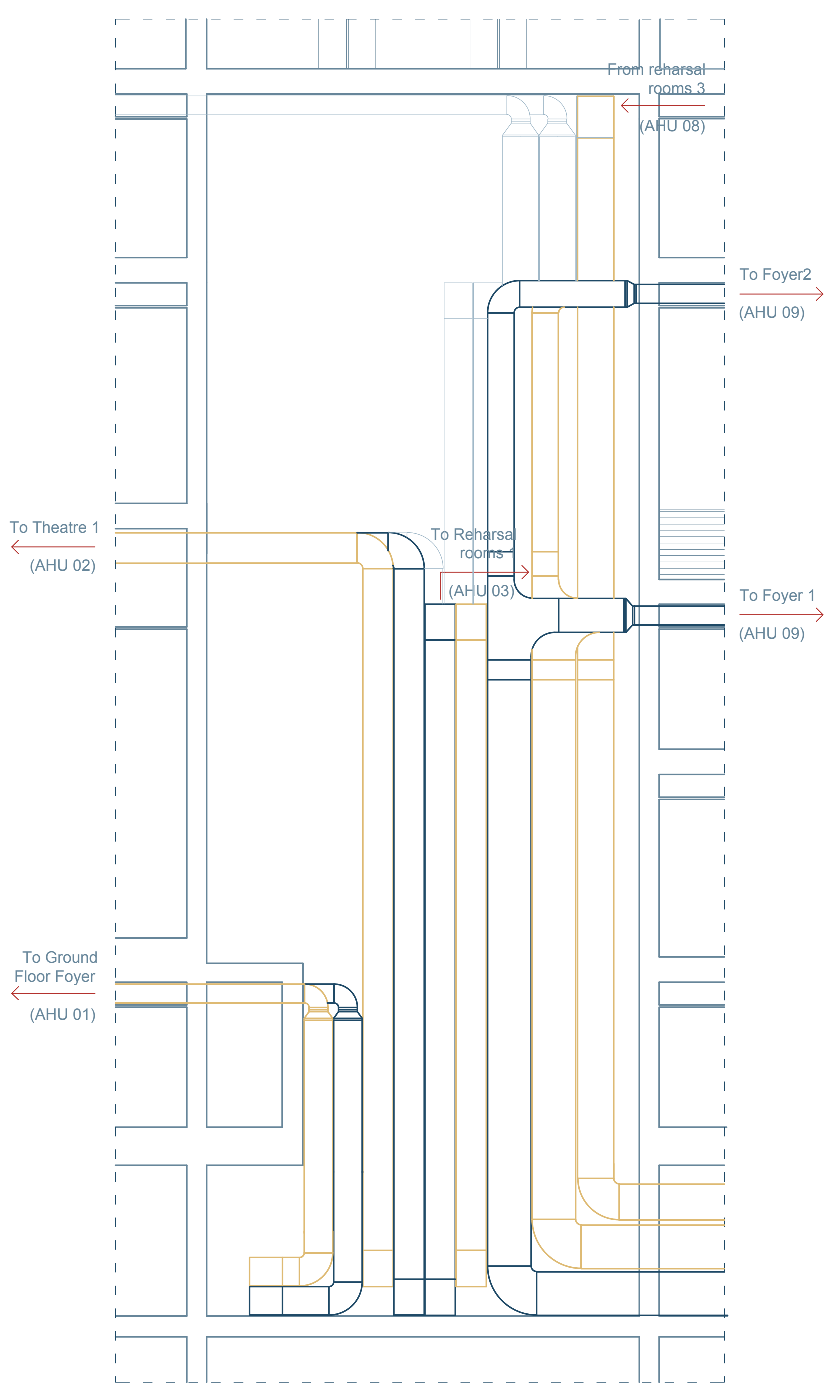
Level 09: Restaurant Air Handling Unit



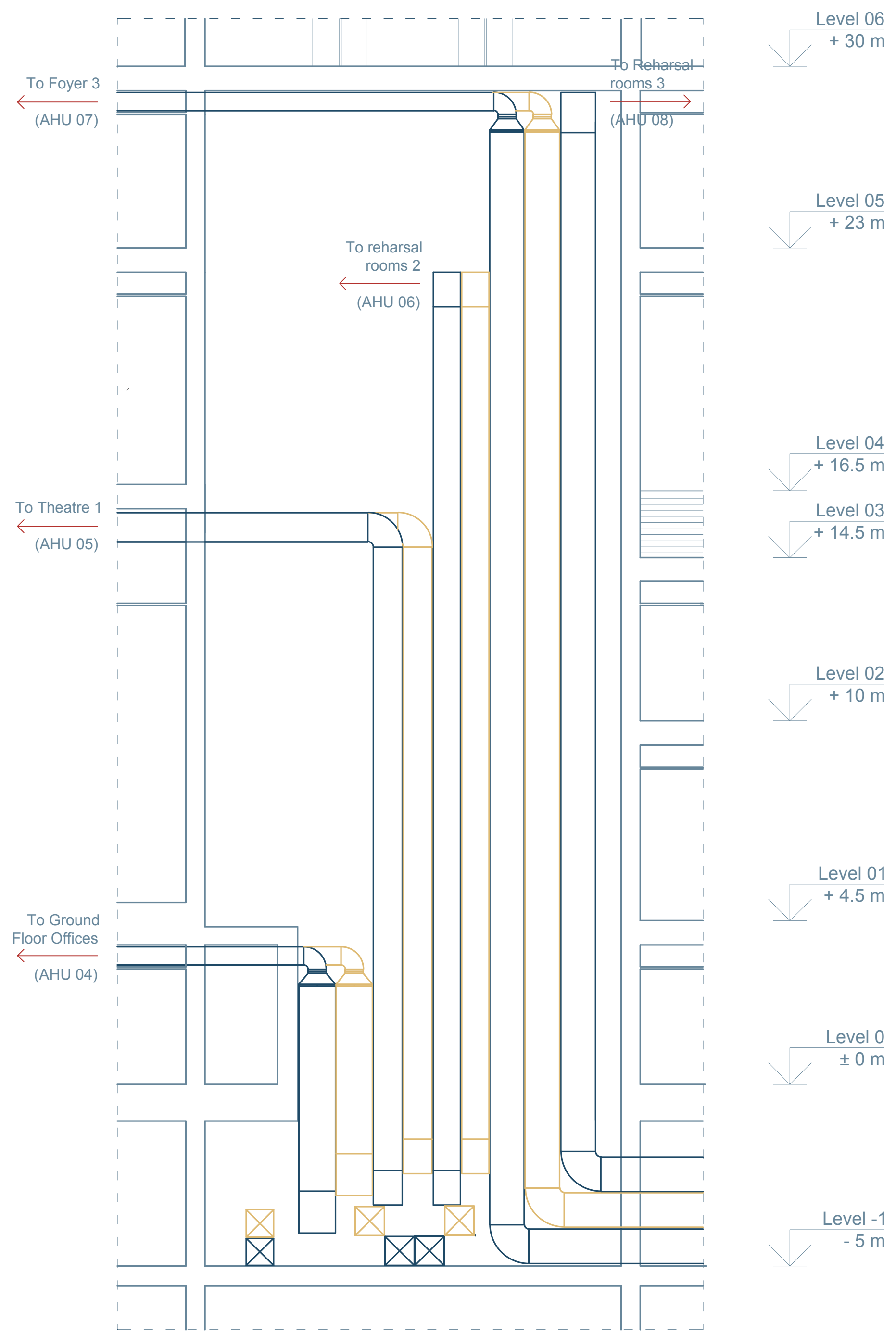
Level 7: Main Hall AHU layout and exhaust shaft layout



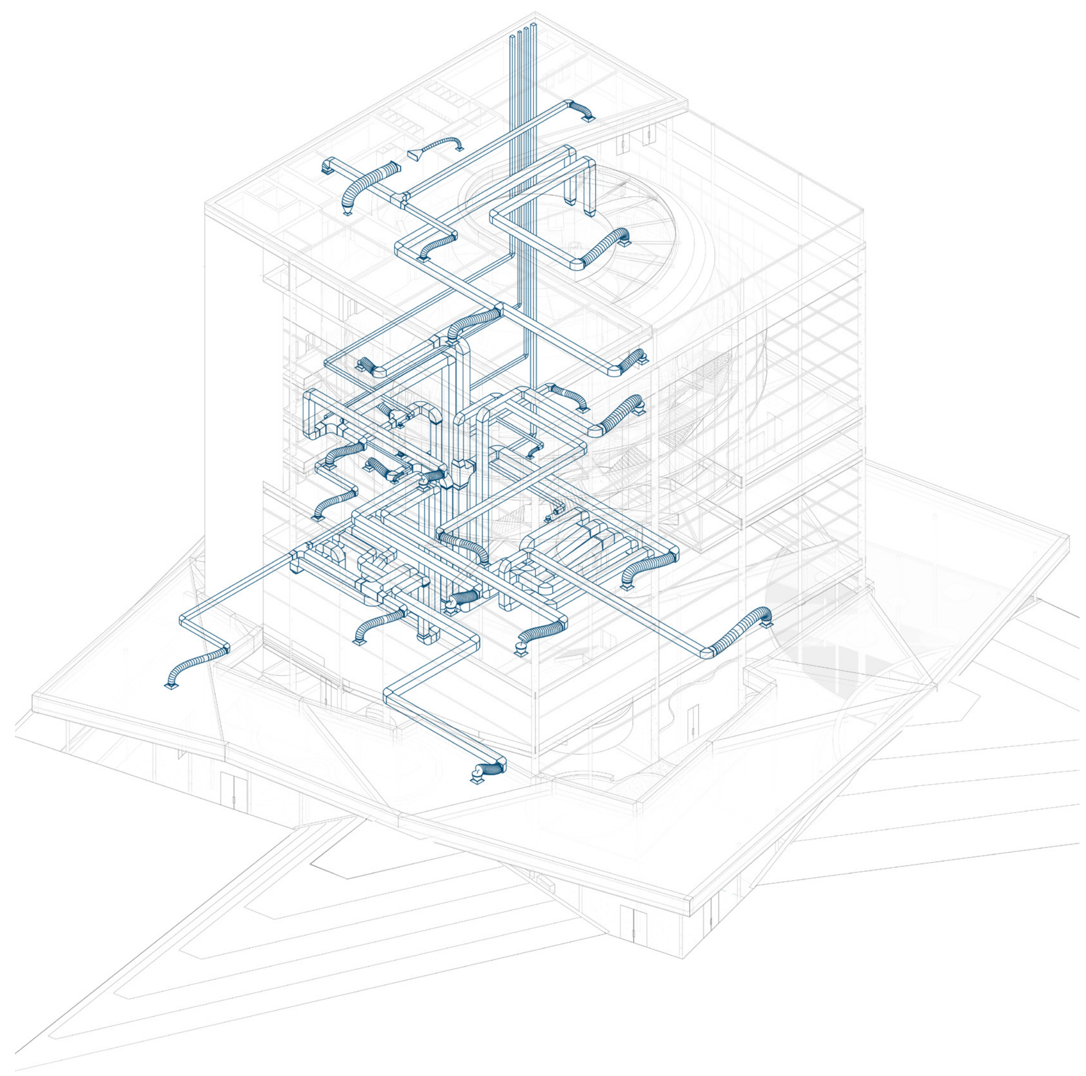
Level 0: Horizontal section of the main systems shaft



Section AA: Main shaft layout



Section BB: Main shaft layout



Axonometric representation of supply air main ducts

Energy strategies to reduce energy consumption

It is important to highlight that the elements discussed in this part have been developed in conjunction with the architectural and structural design, in order to optimize the process and improve the final result.

Heating and cooling loads

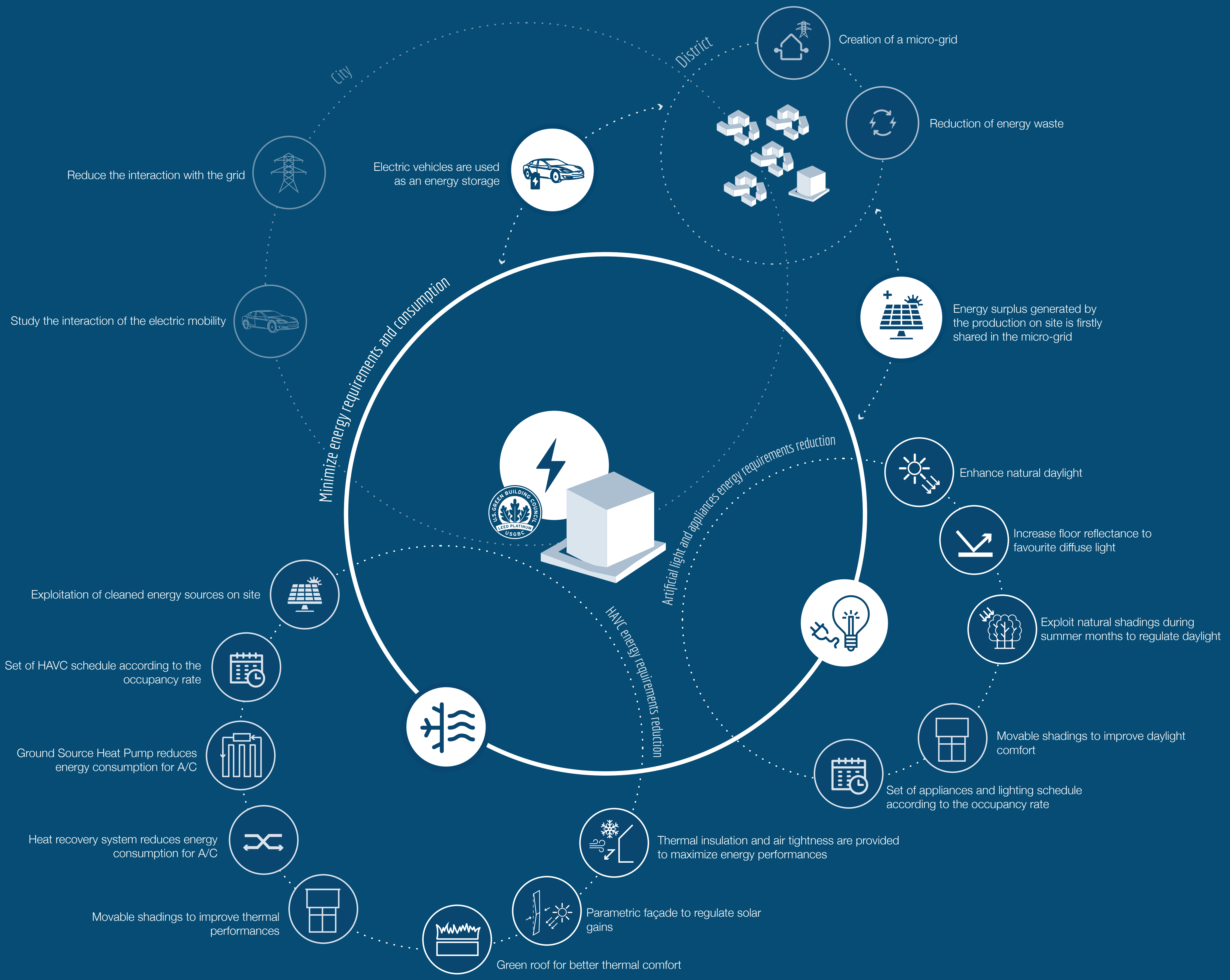
The realization of a building able to reduce at minimum the heating and cooling loads is not only a requirement given by national legislations or certifications, but also necessary of the aim of the research. Indeed, strategies concerning the reduction of heat exchange through opaque and transparent elements are implemented. Besides the design of high performance stratigraphies for the building envelope, as triple glass glazings, highly insulated opaque elements or green roofs, another strategy appeared to be effective for the purpose. While the majority of the units that are composing the unitised façade are transparent in order to allow the view from inside to outside and viceversa, the units corresponding to the theatres don't have this requirements and can be installed opaque. Being the thermal transmittance of the opaque units less than one third of the transparent ones, this choice greatly reduces the total consumption. In these terms, trasparency is still preserved, but well integrated with the energy performance needs.

Daylight comfort

The daylight improvement is crucial for two main reasons: the increase of visual comfort and the reduction of the impact of artificial lighting load on the total consumption. The strategies applied on the building mainly concern the reduction of glare and dark areas, which have been spotted through daylight simulations. Accurate openings in the opaque roofs have been created, in order to prevent the creation of areas without enough natural light. In critical areas floors are implemented with highly-reflective materials in order to diffuse the natural light entering from the windows. The strategies developed in order to prevent glare due to excessive sunlight are mainly relative to external shadings, such as seasonal green, movable shadings and a parametric façade.

HVAC system

The use of highly efficient systems to provide the required thermal and humidity comfort is very important for energy savings. A heat pump with high efficiency, together with a heat recovery system, reduces waste of energy and consequently energy consumption for air conditioning. The reduction of periodic costs for HVAC is mainly committed through the use of renewable energy. The use of geothermal energy helps energy consumption reduction, mitigating the input temperature of the water entering the heat pump. Moreover the use of electric vehicles as a storage for the energy produced on site is greatly reducing the energy consumptions and the general interaction with the grid.

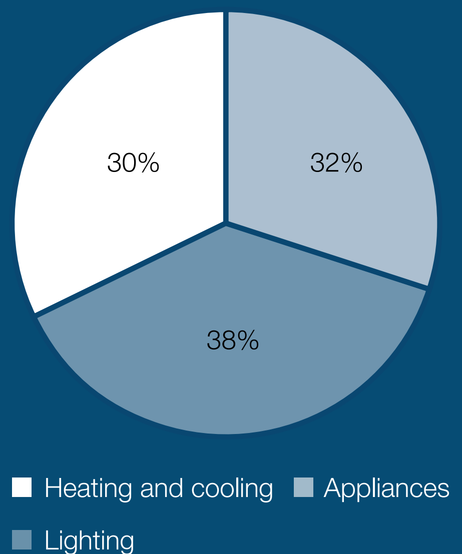


Energy balances of different possible scenarios - SynEnergy Hall

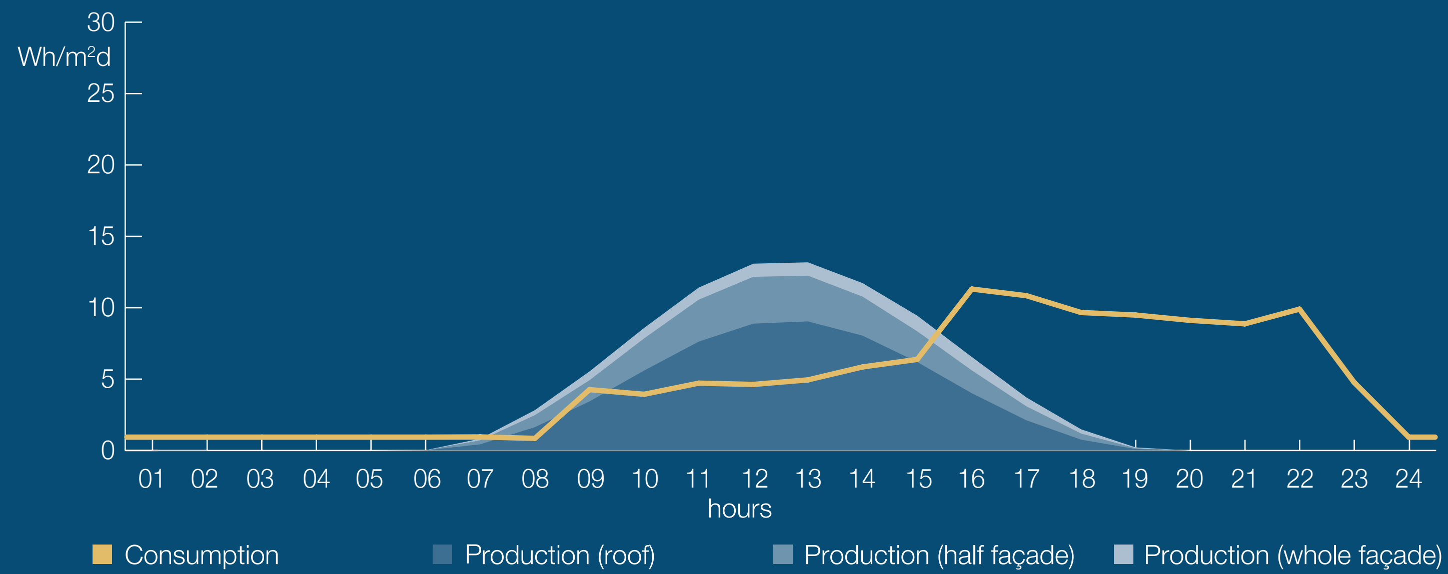
To reach the set requirements (LEED certification) the building is compared with a baseline, which has fixed parameters regarding stratigraphies, HVAC systems and lighting consumption. Once the schedules and parameters are set, the simulations relative to the baseline model and the proposed building are run and the results compared. The improvement of the proposed building is higher than 50% (68%), which means that the energy performance requirements have been fulfilled.

The spaces in the analysed building have very different types of usage, which determine a variation in the schedule for every function especially for theatres, where performances can be played at any time of the day. The different schedules were set considering an usage also during night hours, in order to create an area active all day.

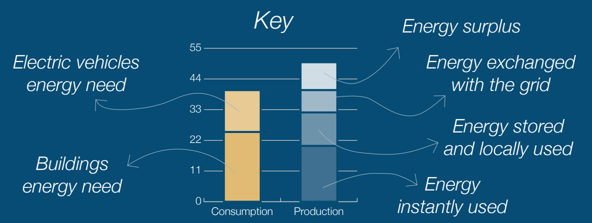
It is visible as the production is not enough to cover the energy need, but this problem is not related to the high consumption of the building, because the value per m² is low for a non residential building, but for the reduced number of PV panels. The building has an important number of storeys above-ground, with only half of the roof available for positioning of PV panels. The three different positioning were formulated trying to increase the energy production, adding photovoltaic panels also on the façade of the building. The use of EV as storage increases the grid independence, showing that even with passive buildings the impact of the strategy is improving the energy performances.



Consumptions in the high performance district



Energy analysis on the equinox of the high performance district



SCENARIO 0: ITALY 2019

45% PEOPLE GOING TO WORK BY CAR IN MILANO

SCENARIO 1: ITALY 2030

1 MILLION ELECTRIC VEHICLES OVER 49 MILLION CARS

2%

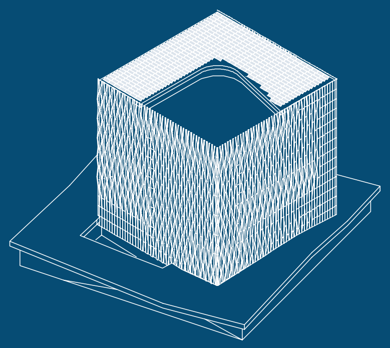
SCENARIO 2: EU 2030

23% ELECTRIC VEHICLES AND PLUG-IN HYBRID VEHICLES

SCENARIO 3: ITALY 2030 WITH SHARED MOBILITY

66% SHARED PRIVATE MOBILITY

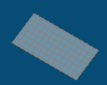
2%



PERFORMING ARTS CENTER

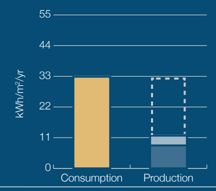
SURFACE: 12758 m²

OPTION 1:

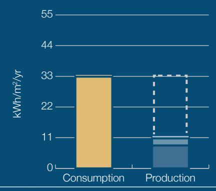


PV PANELS ON THE ROOF

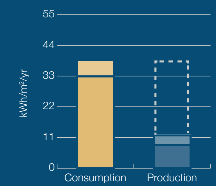
GI: 0.25 PS: -0.64



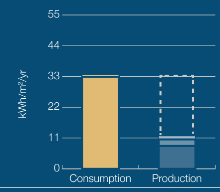
GI: 0.32 PS: -0.65



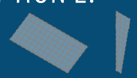
GI: 0.42 PS: -0.70



GI: 0.32 PS: -0.65

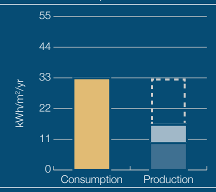


OPTION 2:

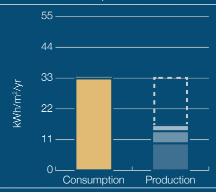


PV PANELS ON THE ROOF AND HALF OF THE FACADE

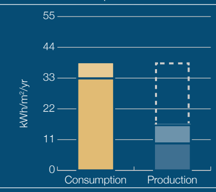
GI: 0.29 PS: -0.51



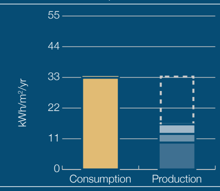
GI: 0.42 PS: -0.52



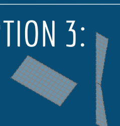
GI: 0.51 PS: -0.58



GI: 0.38 PS: -0.51

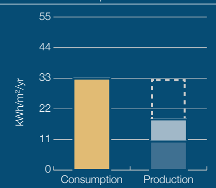


OPTION 3:

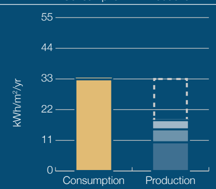


PV PANELS ON THE ROOF AND ALL OF THE FACADE

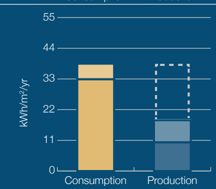
GI: 0.31 PS: -0.45



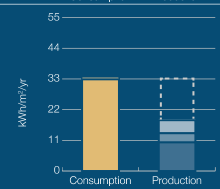
GI: 0.45 PS: -0.45

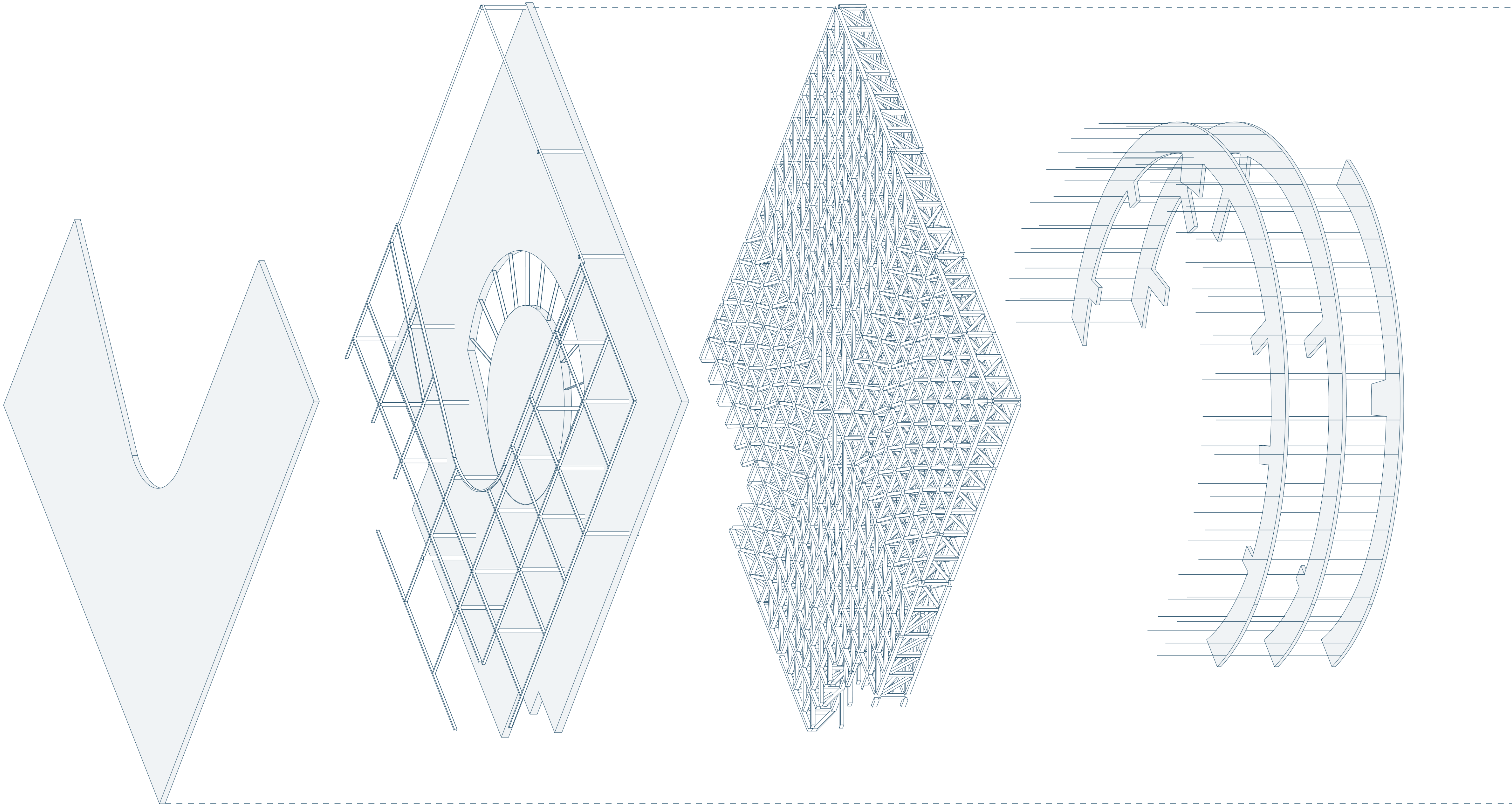


GI: 0.54 PS: -0.53



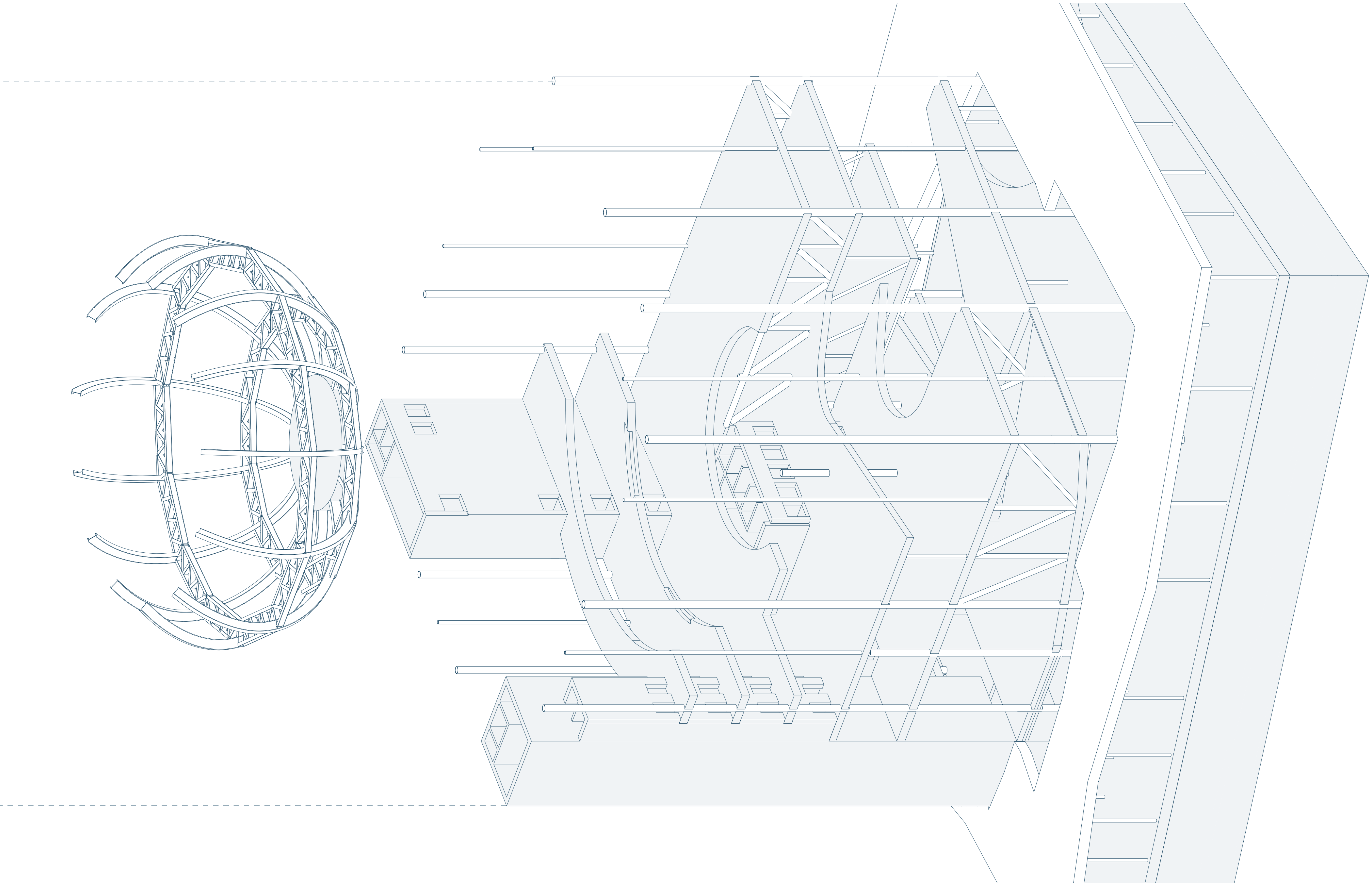
GI: 0.41 PS: -0.45



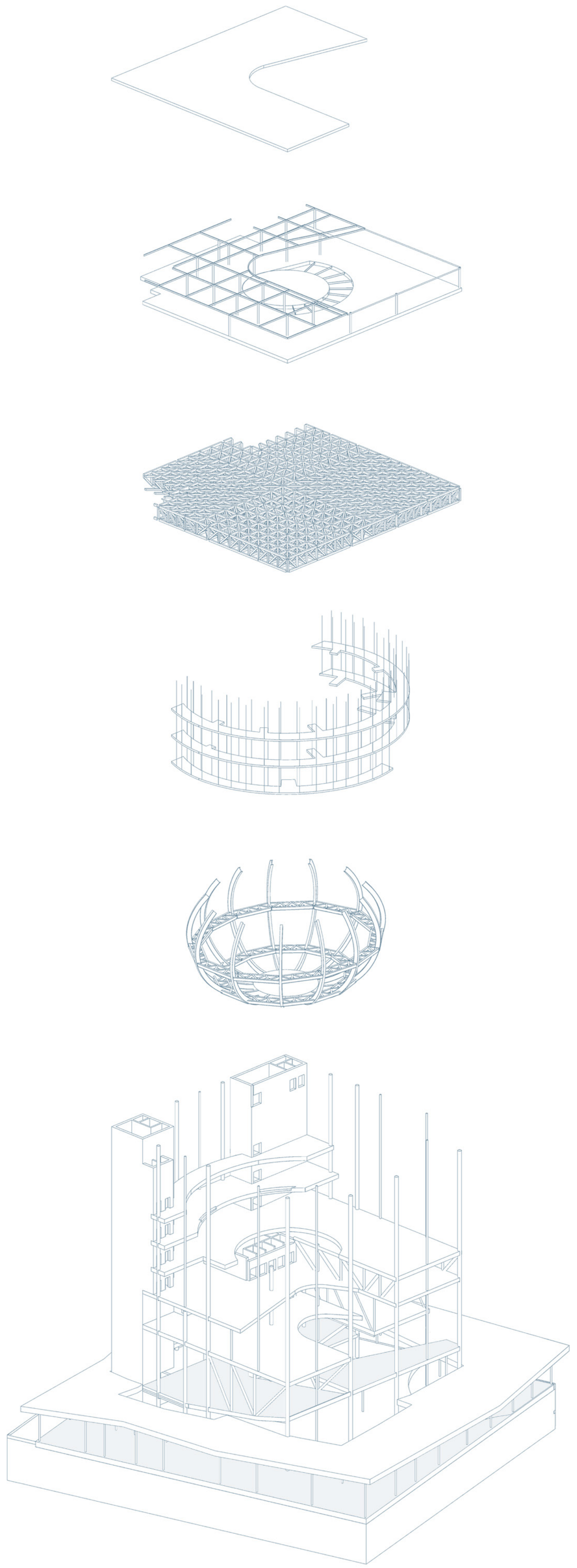


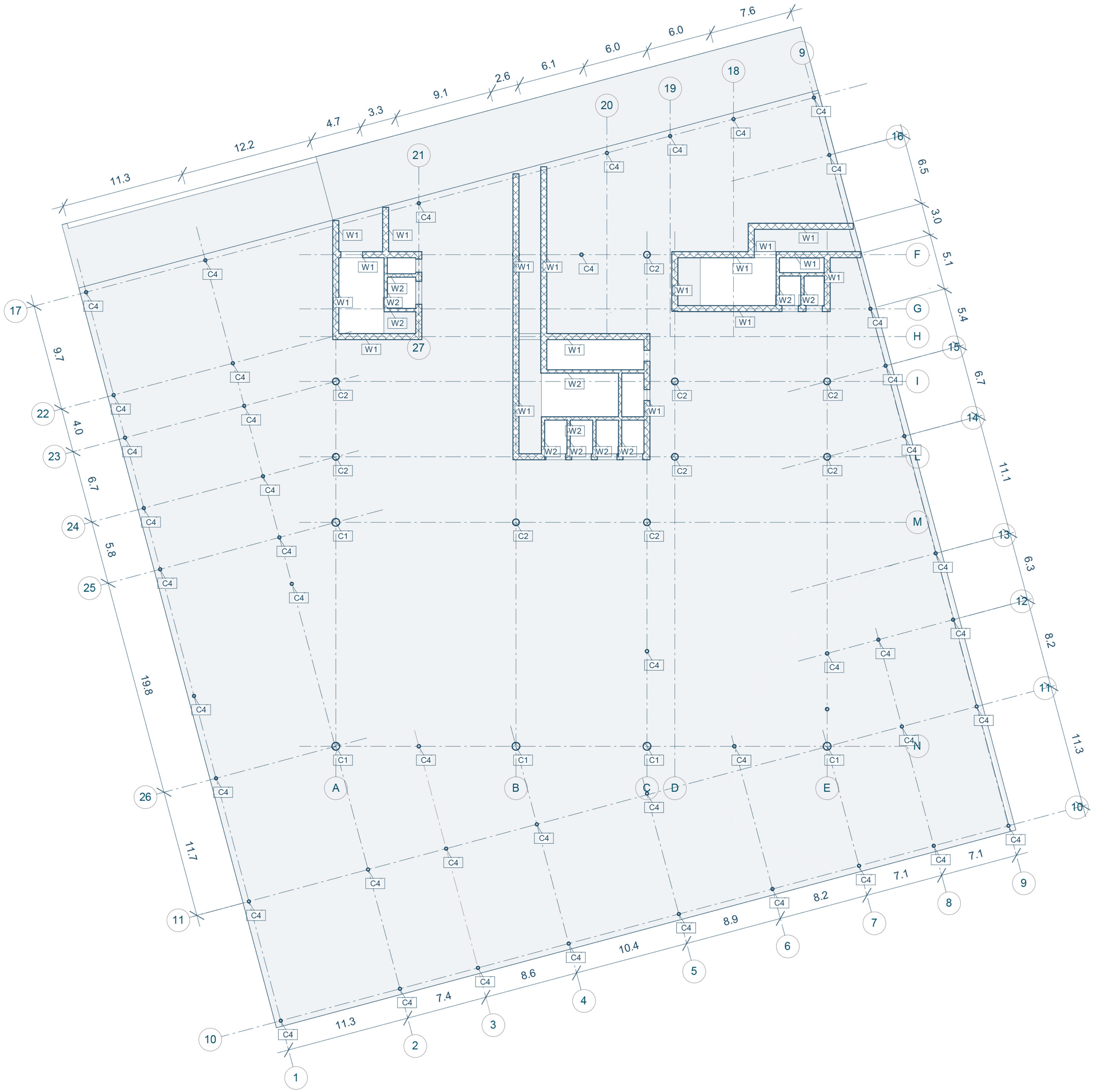
S01

Structural | Axonometric view | 1:300



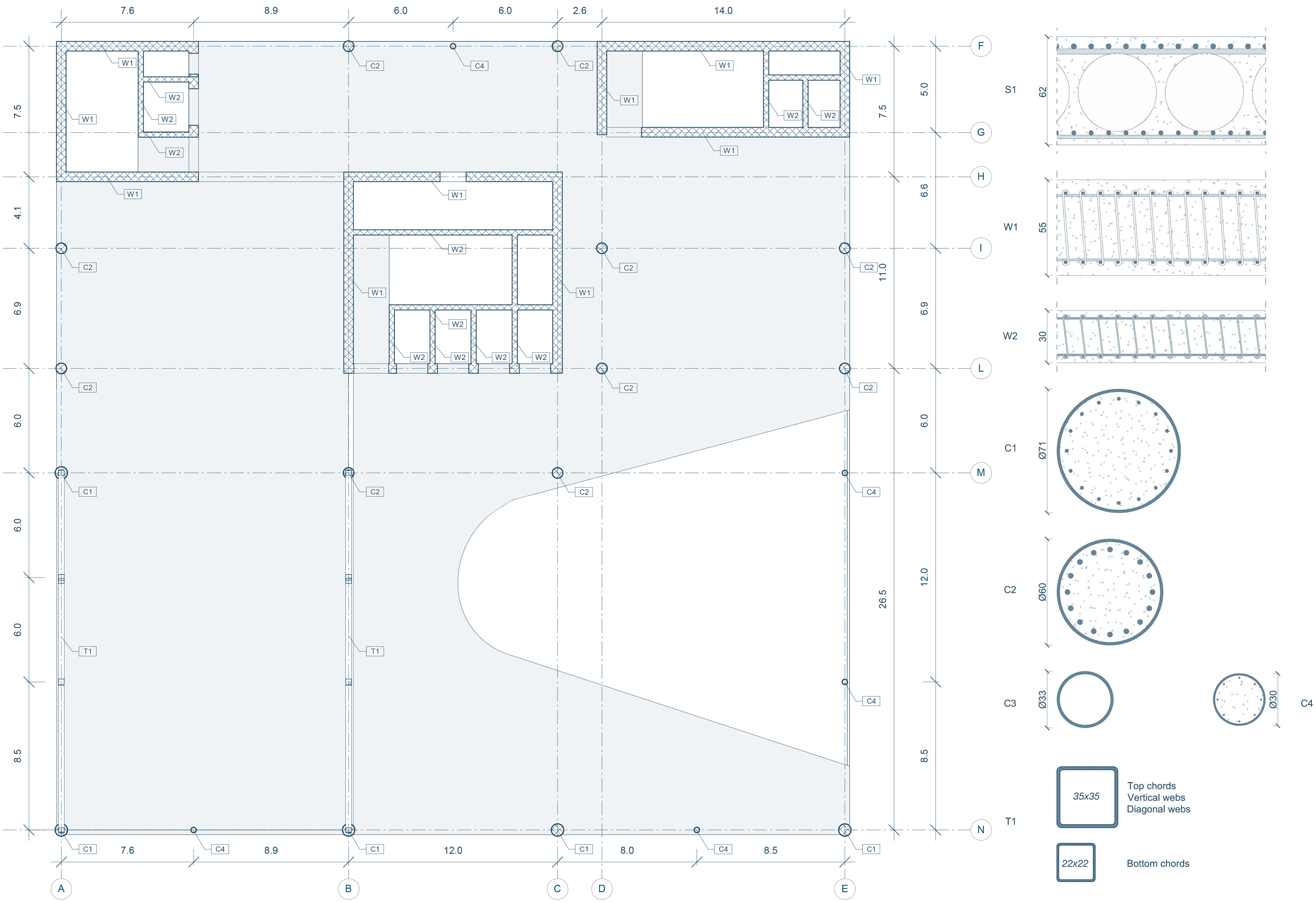
Structural | Axonometric view | 1:300





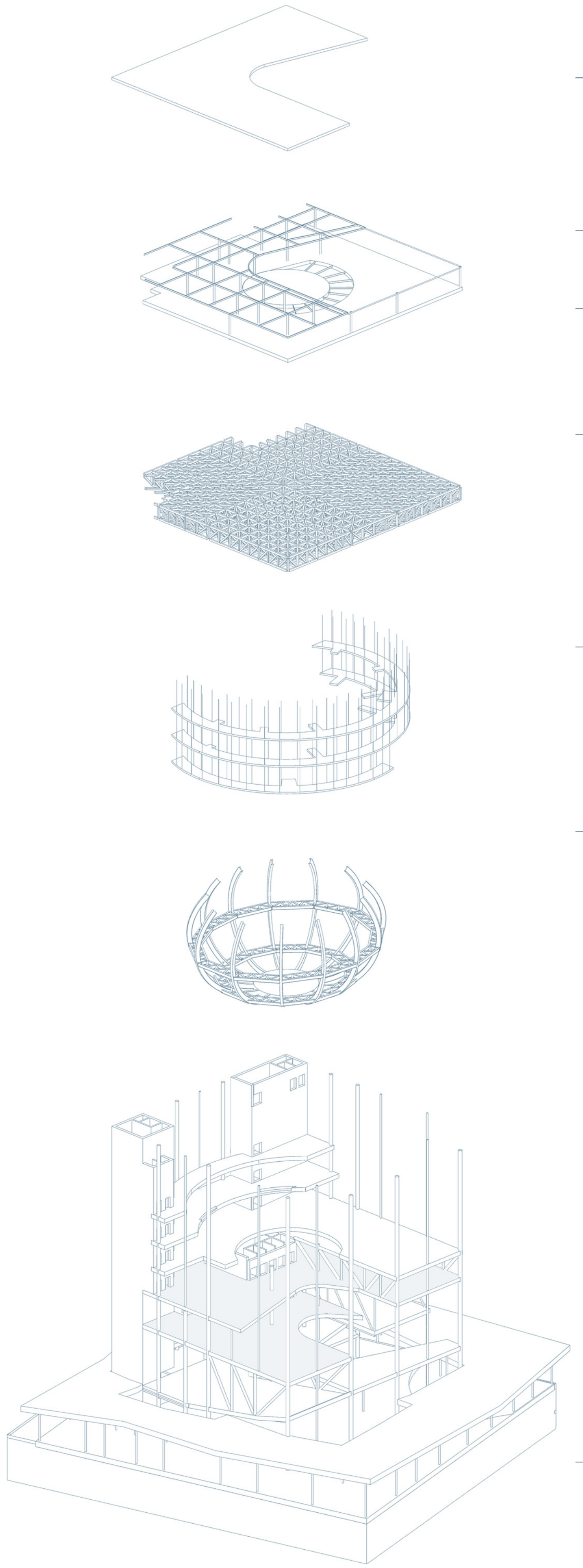
S03

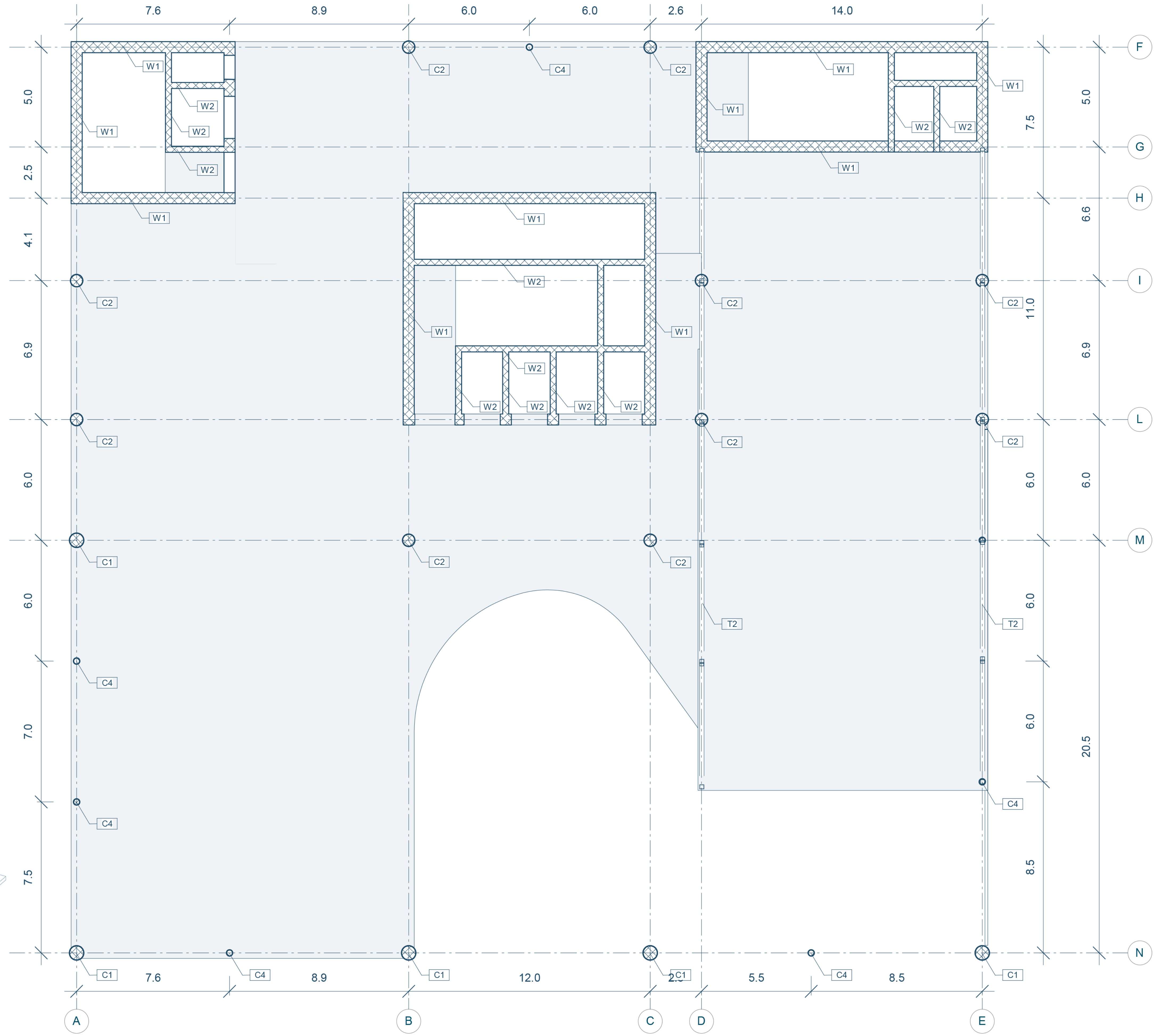
Structural | Level 0 | Ground floor | 1:350



Structural | Level 2 | Shoebox theatre | 1:200

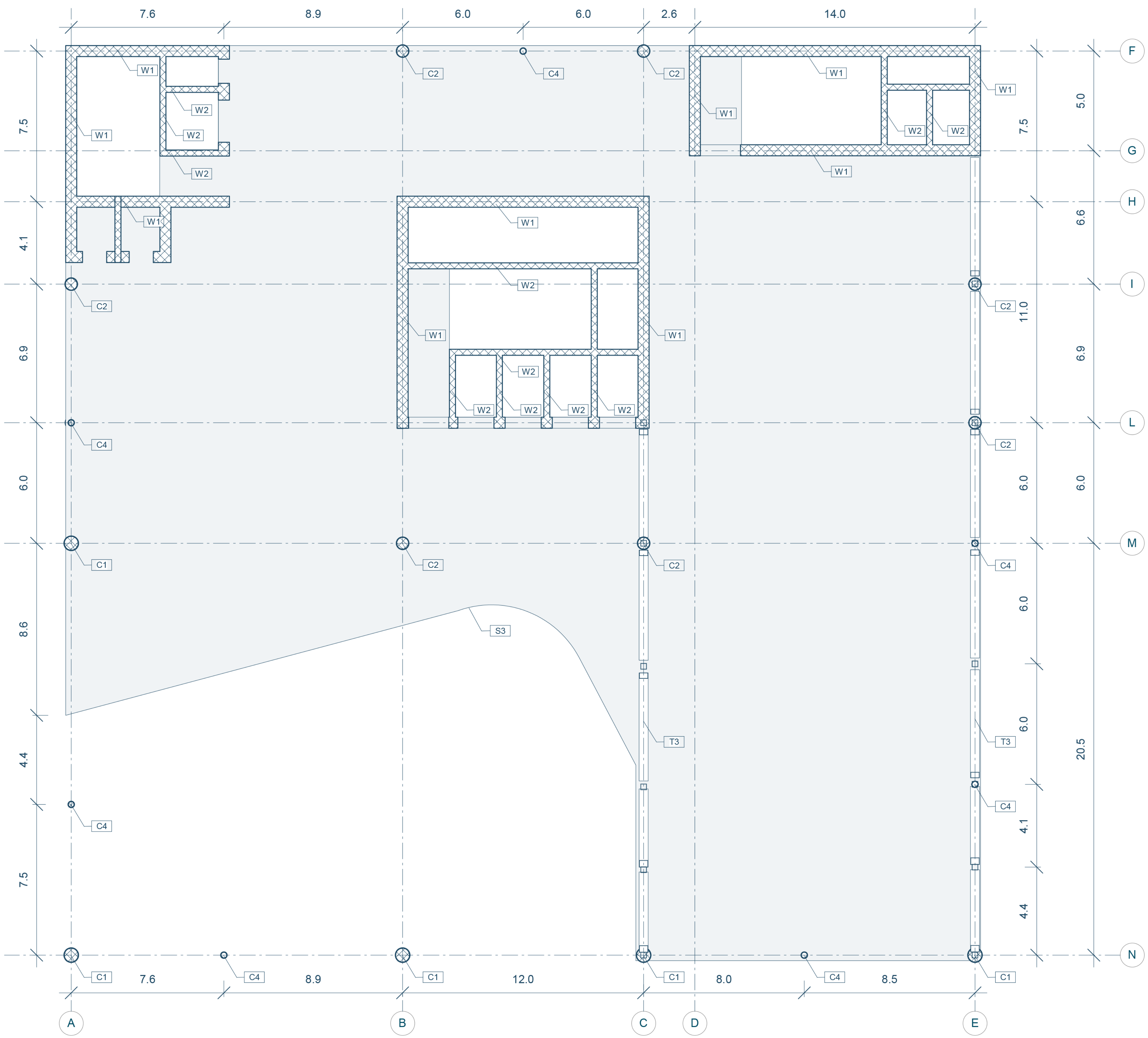
S04

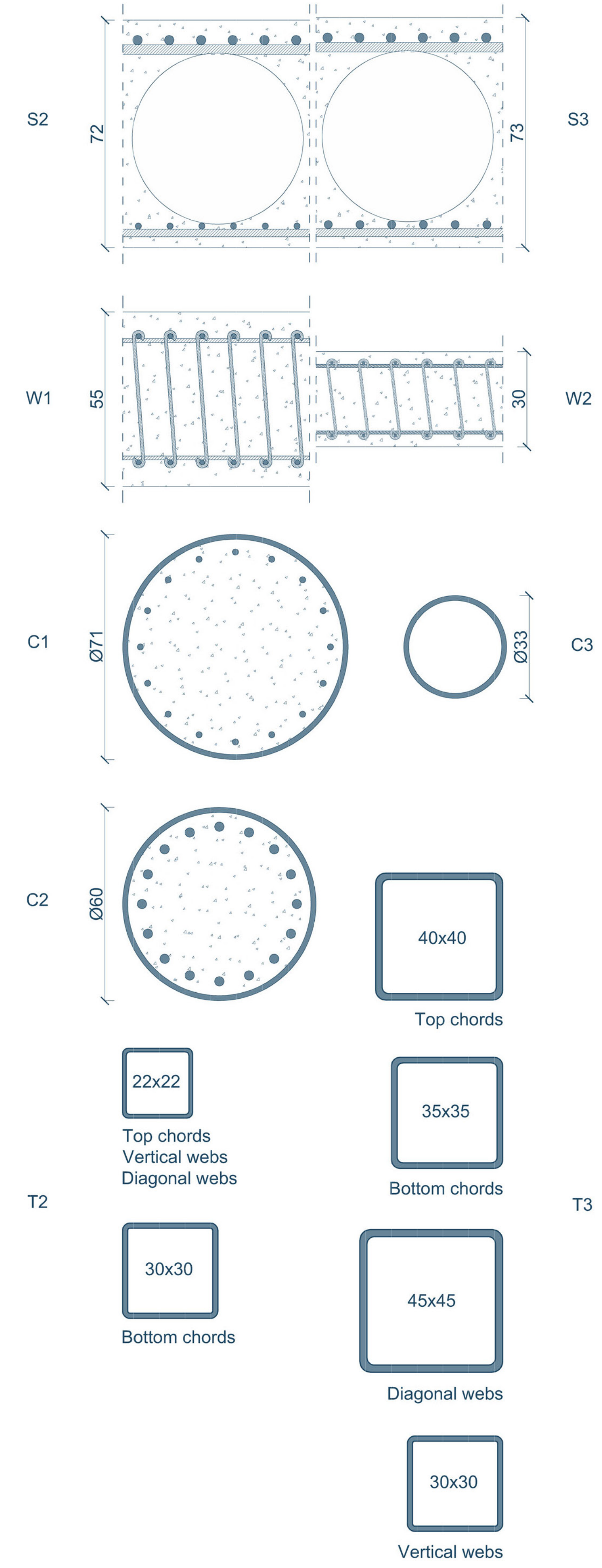




S05

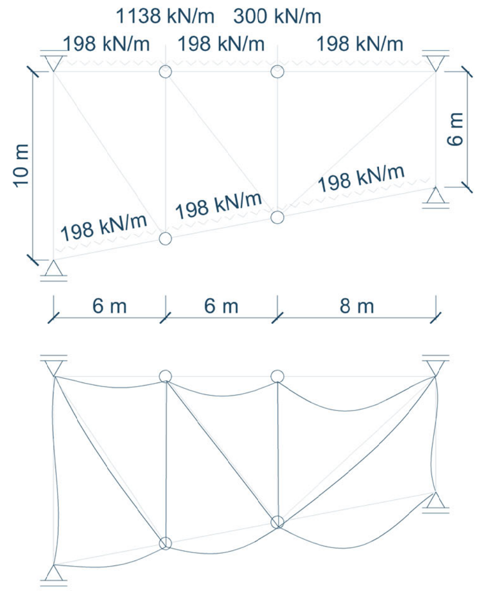
Structural | Level 4 | Experimental theatre | 1:200



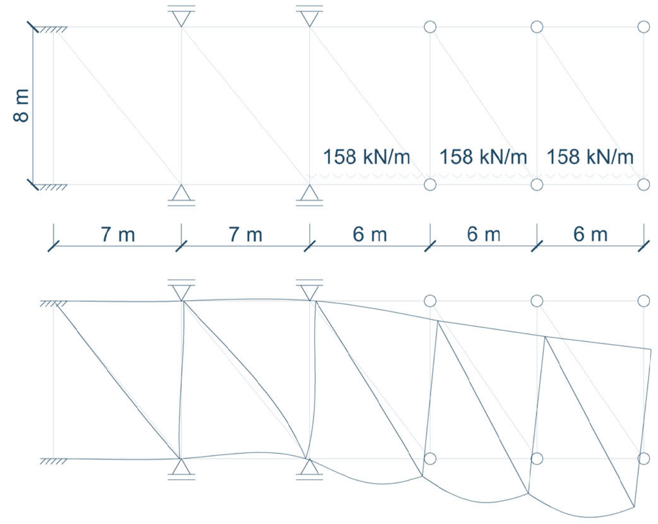


Structural | Level 5 | Foyer 3 | 1:200

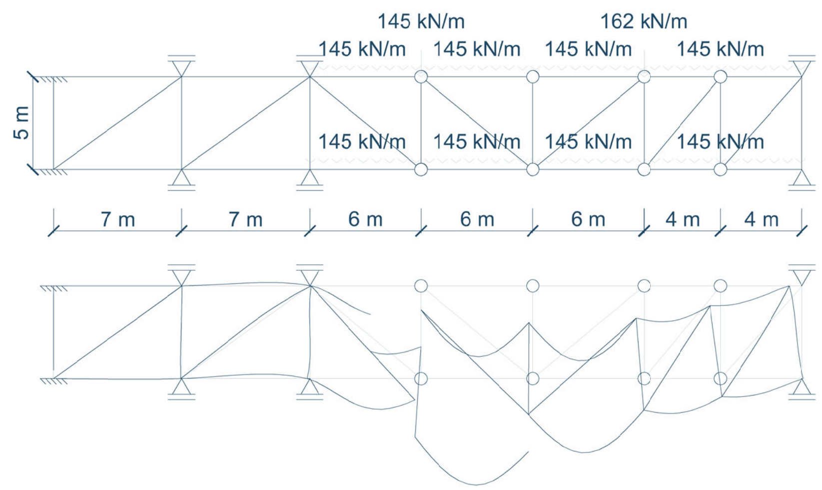
S06



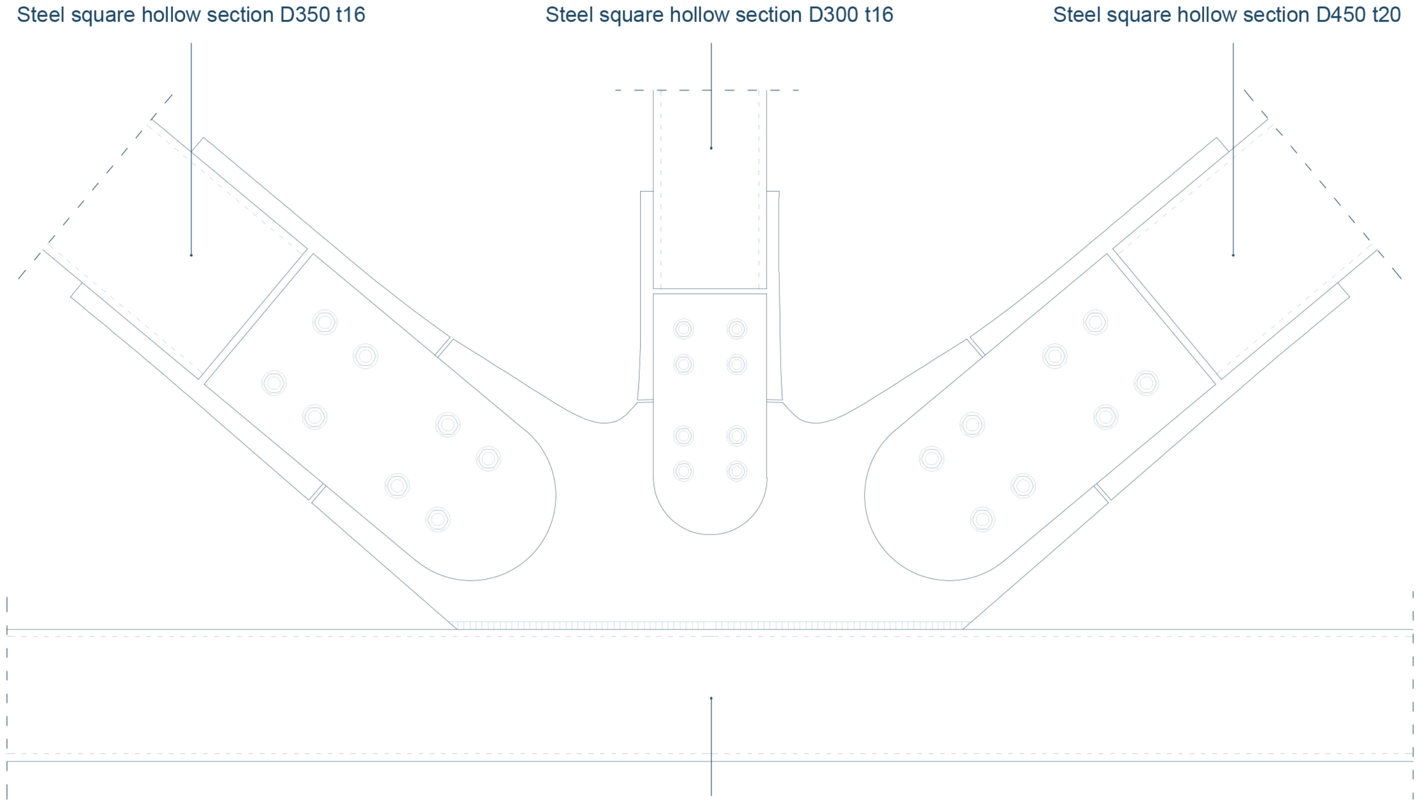
T1



T2



T3



Detail 1

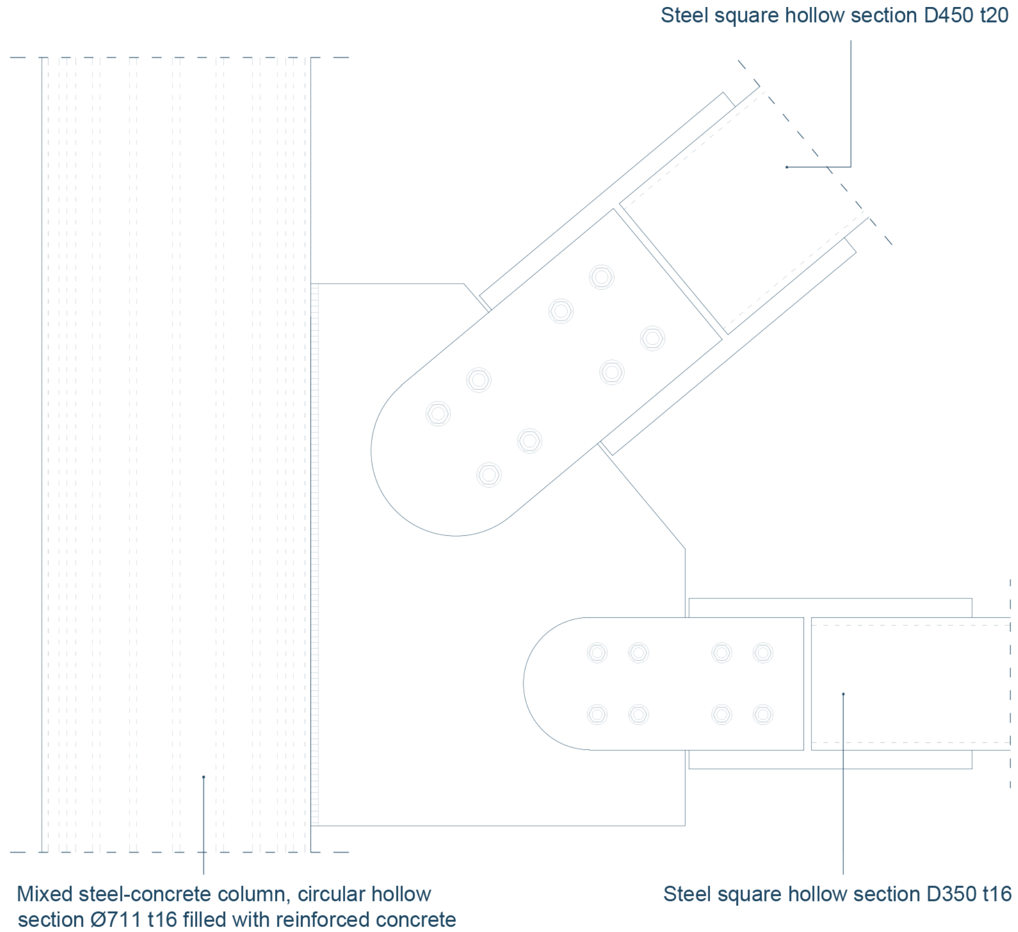
T1 - Bottom chords
T2 - Top chords
T2 - Vertical webs
T2 - Diagonal webs

T2 - Bottom chords
T3 - Vertical webs

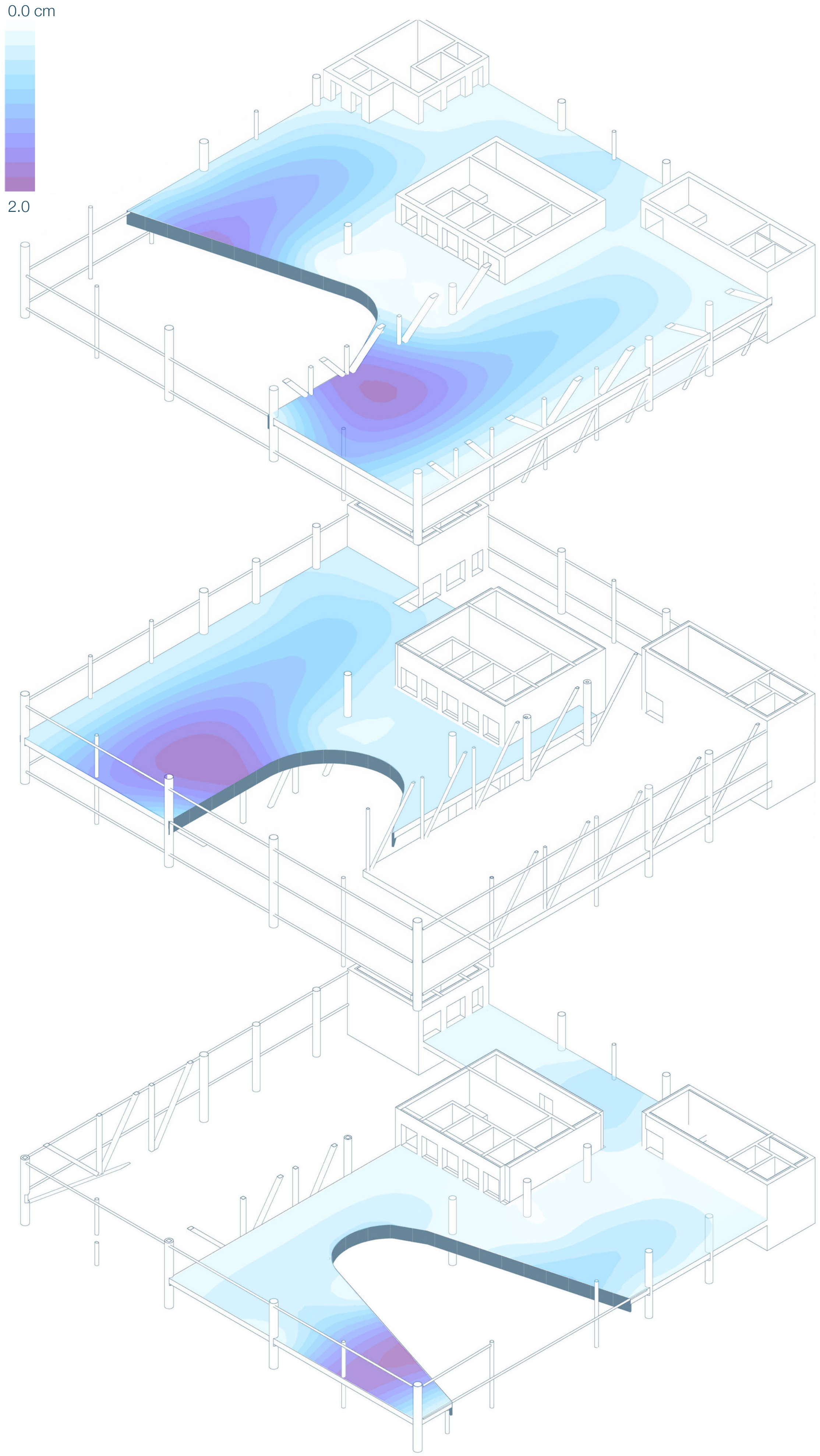
T1 - Top chords
T1 - Vertical webs
T1 - Diagonal webs
T3 - Bottom chords

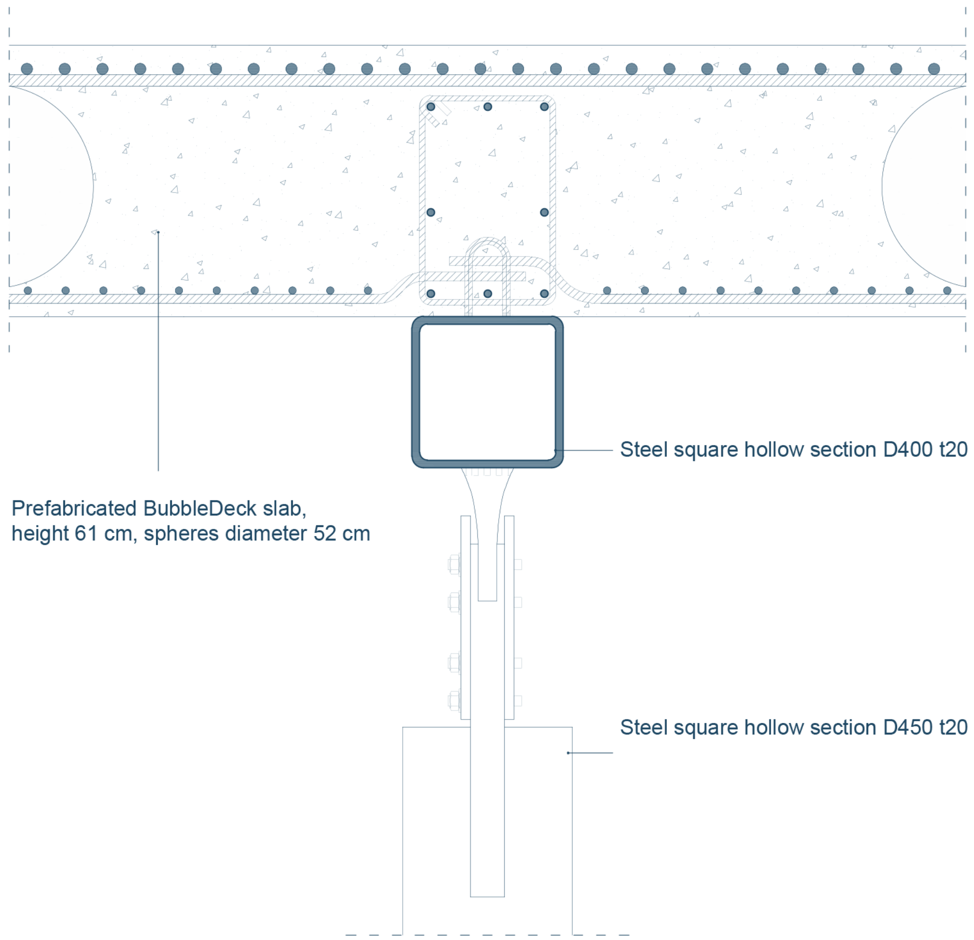
T3 - Top chords

T3 - Diagonal webs



Detail 2





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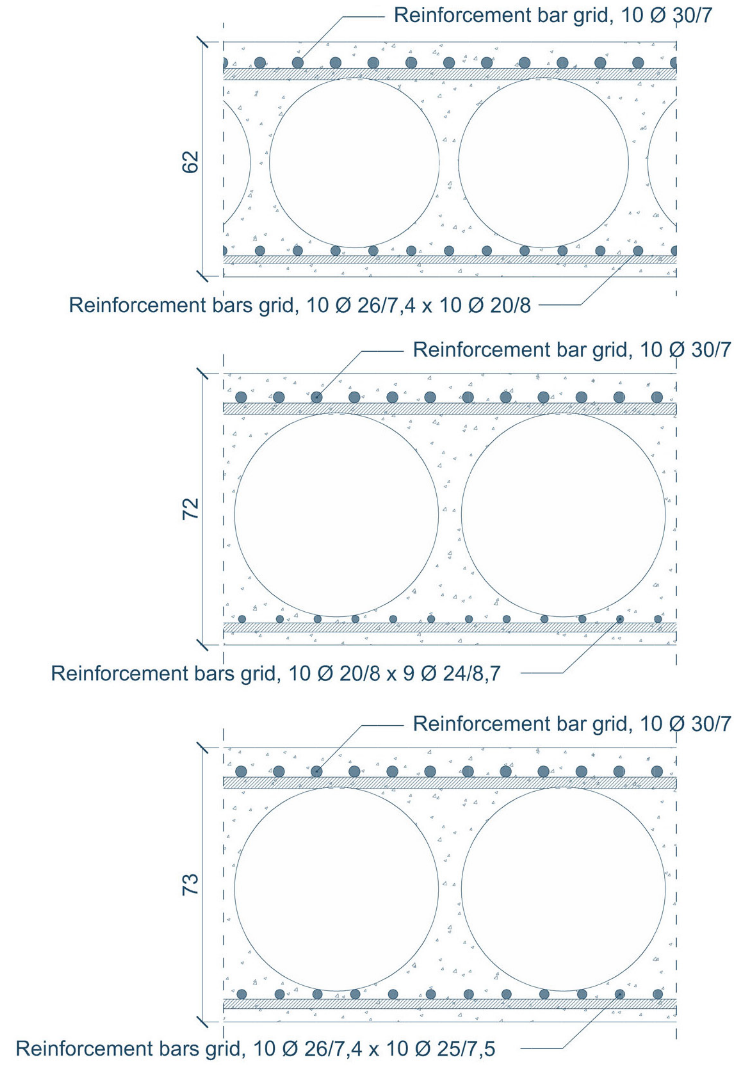

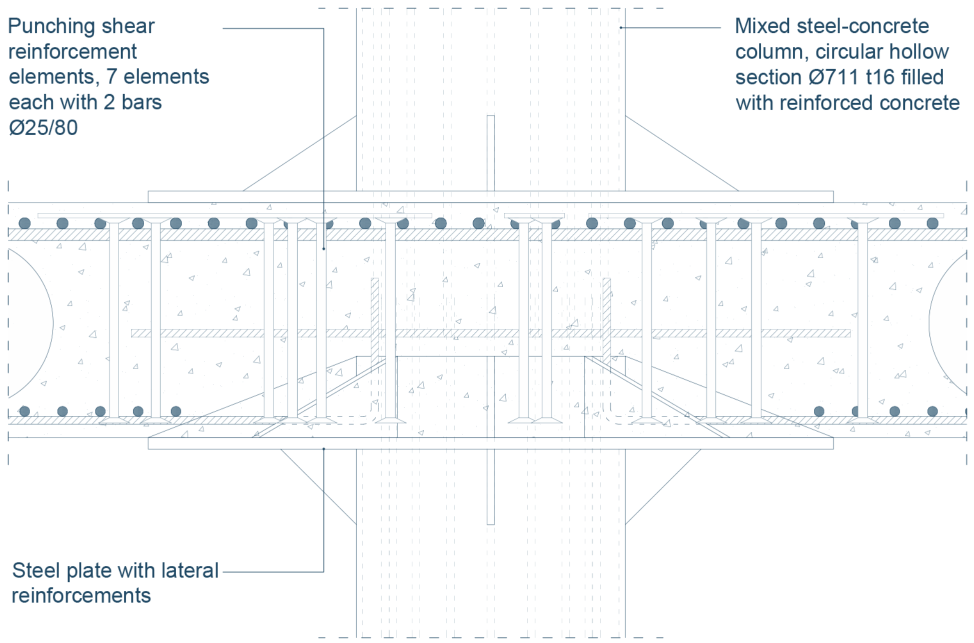

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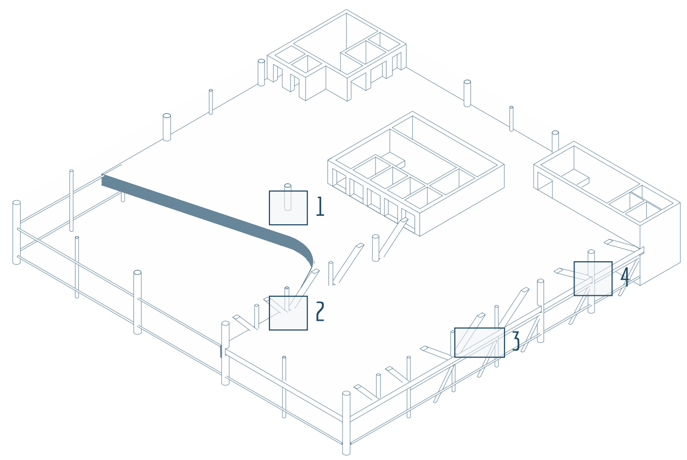
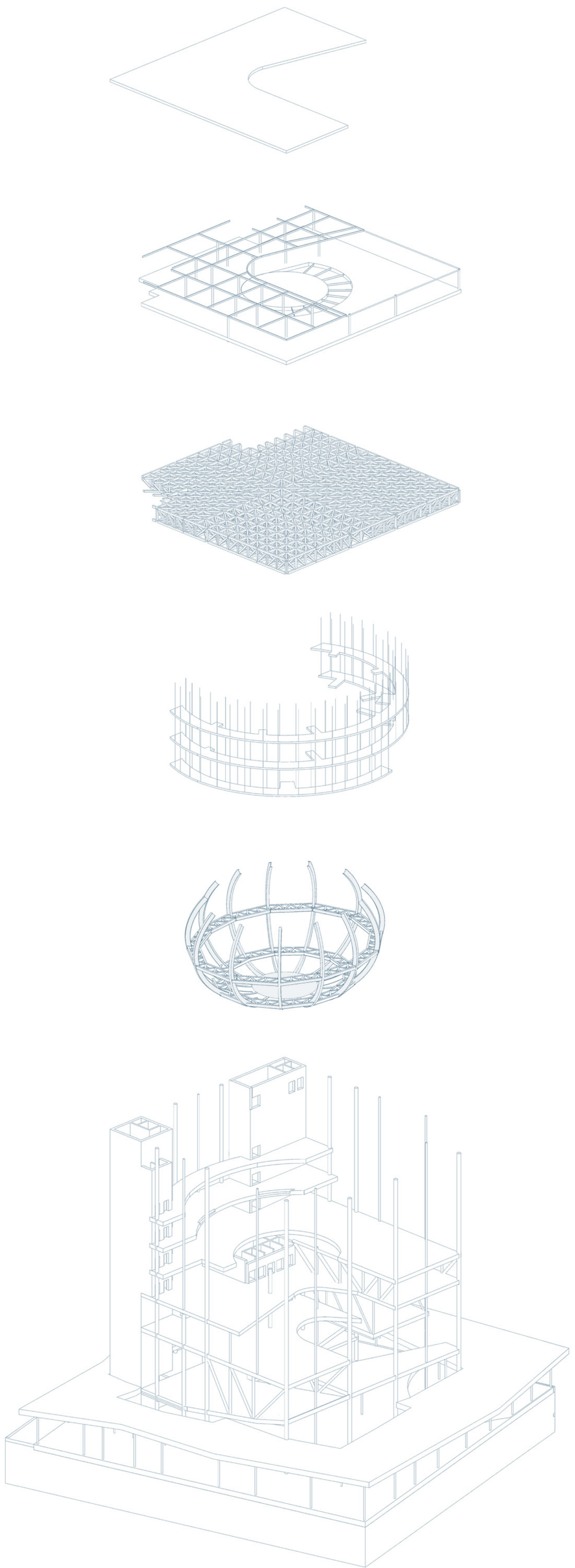
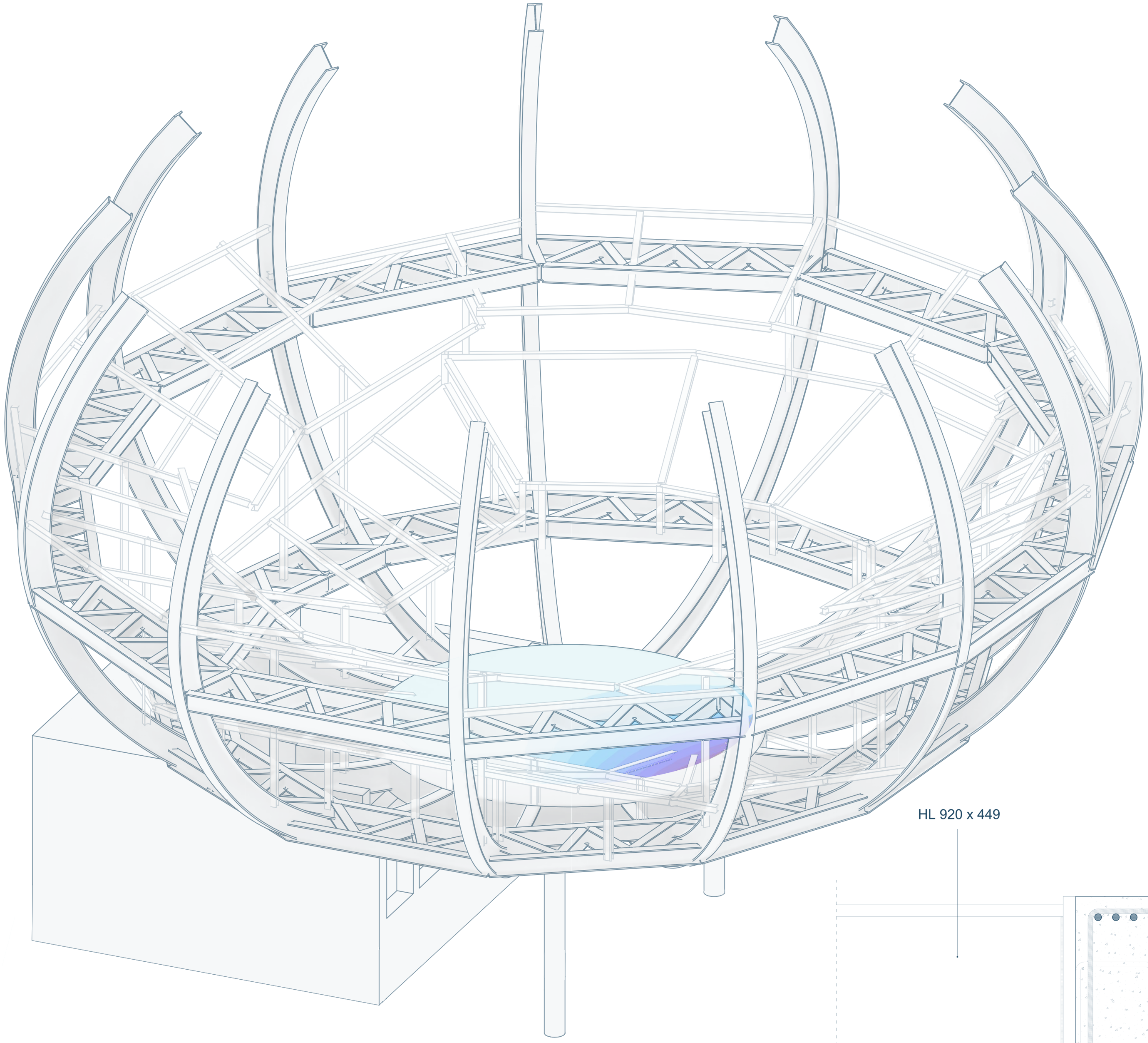
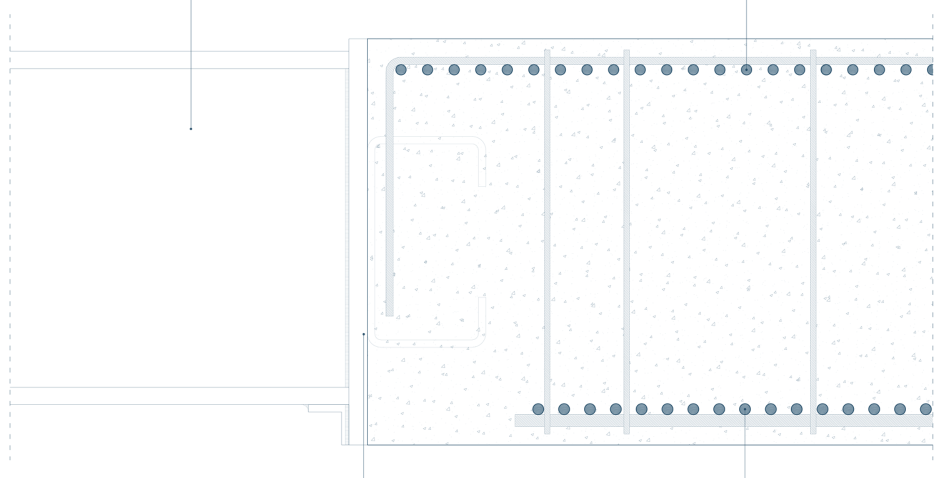


Structural | Plates | 1:10

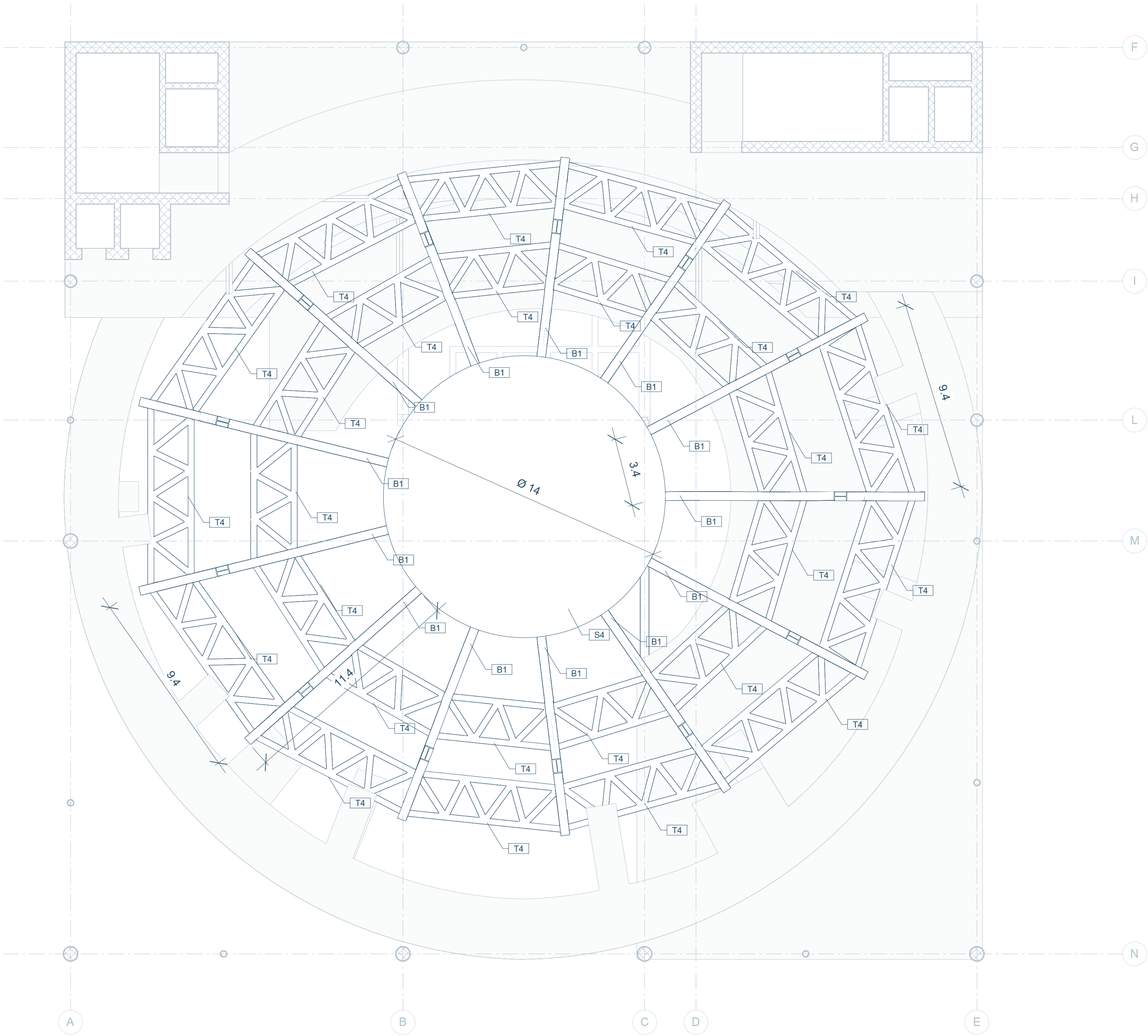
S08

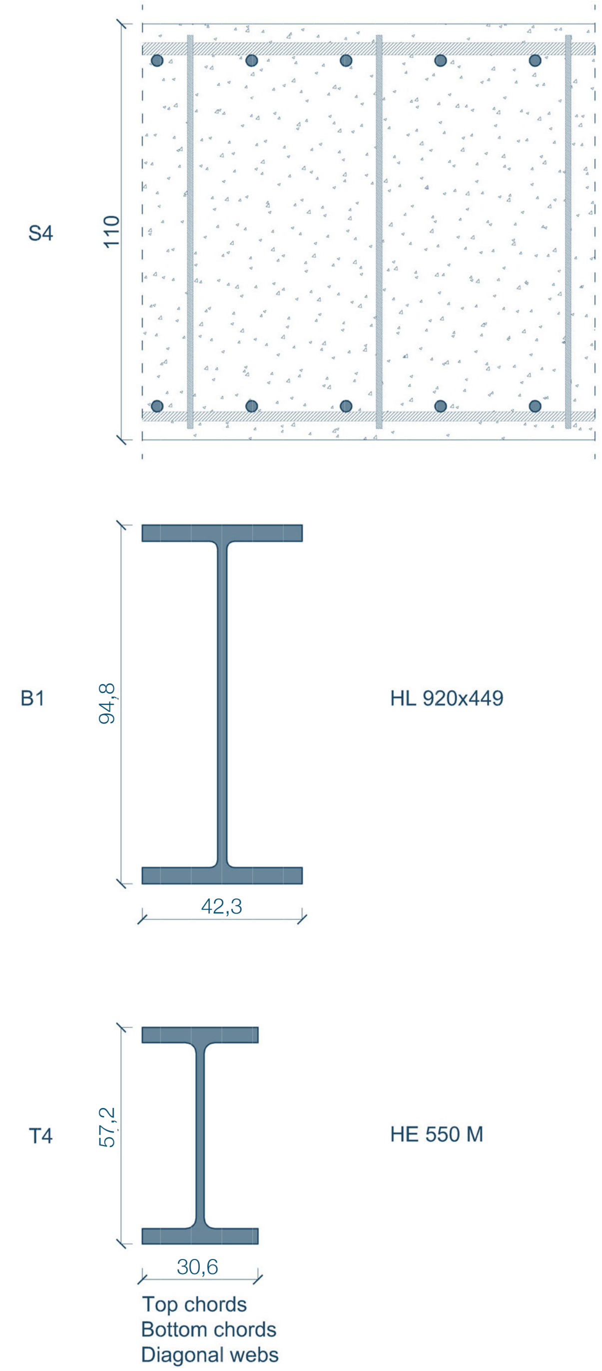




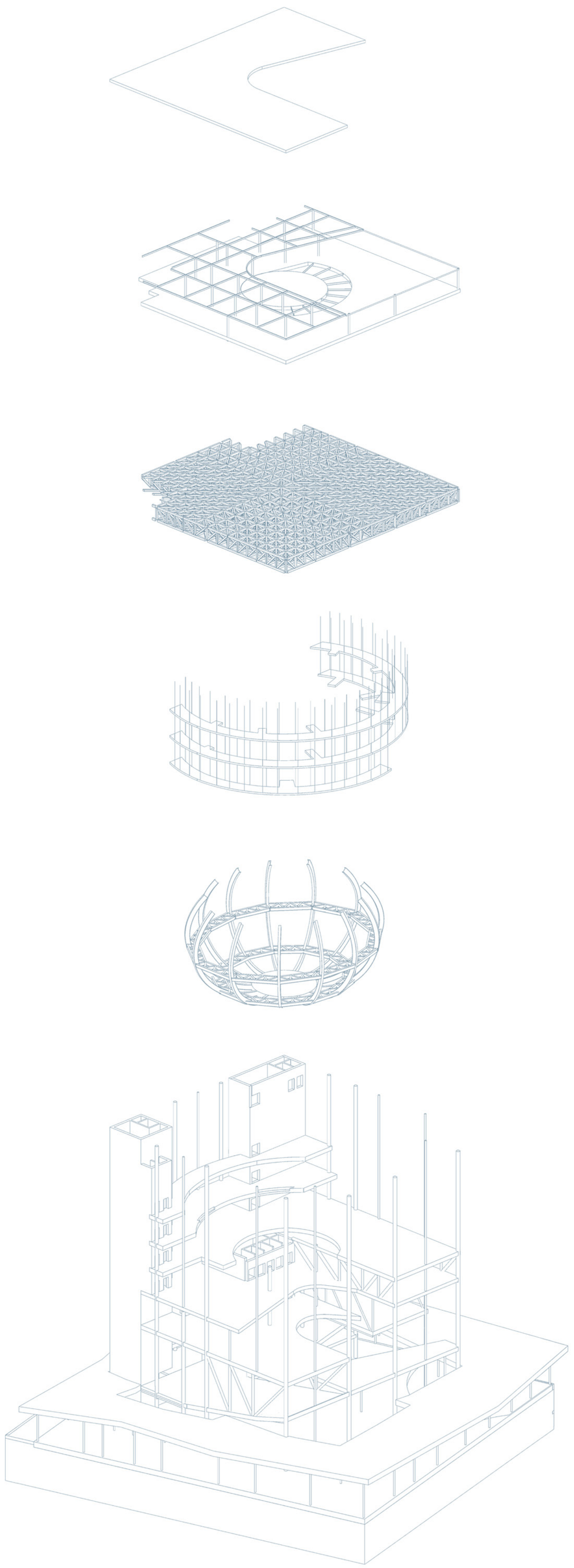


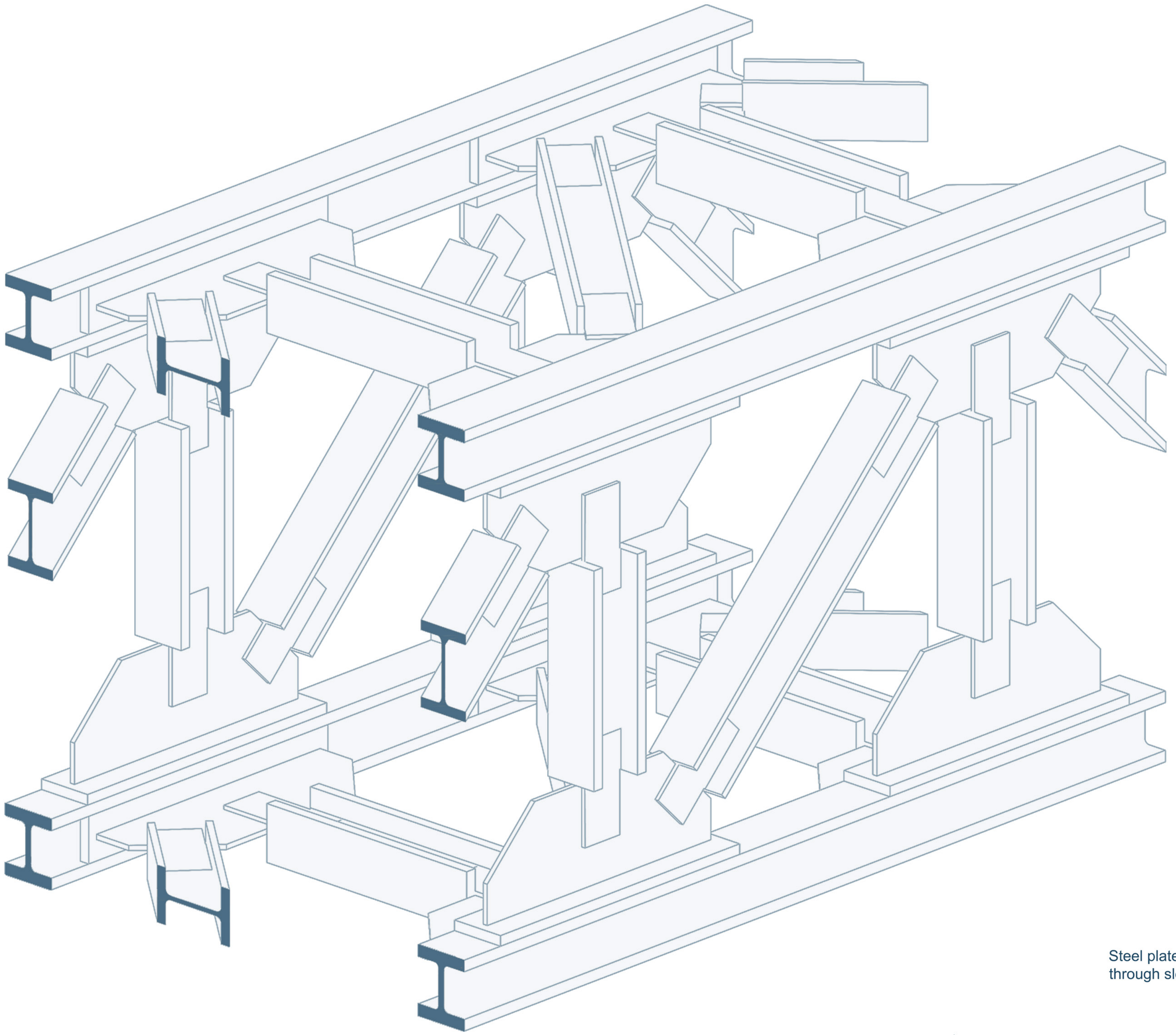
Structural | Main Hall | 1:20

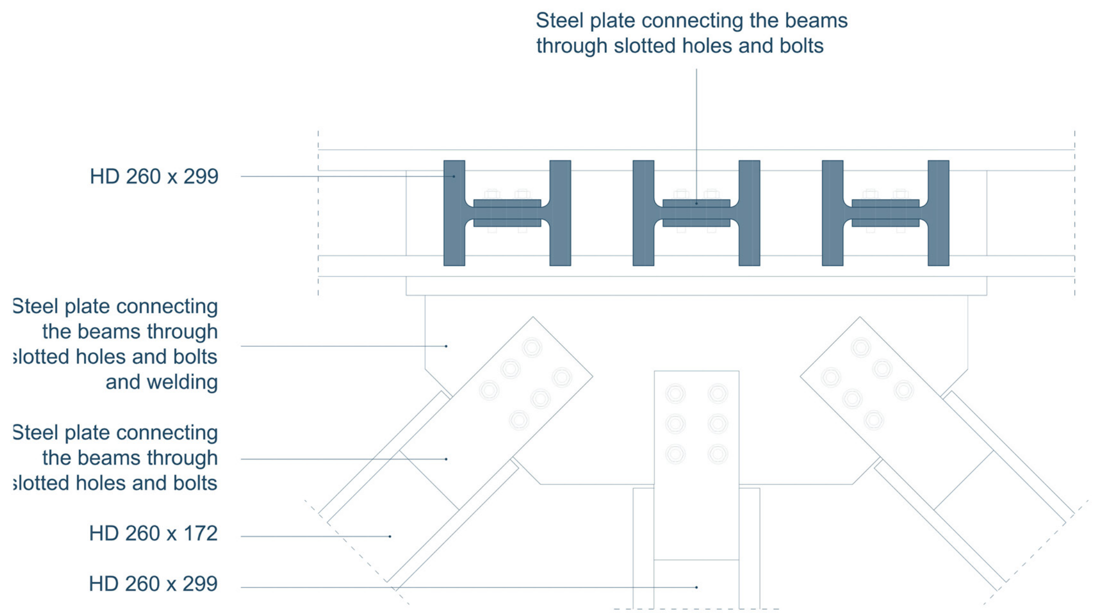




Structural | Level 6 | Main Hall | 1:200

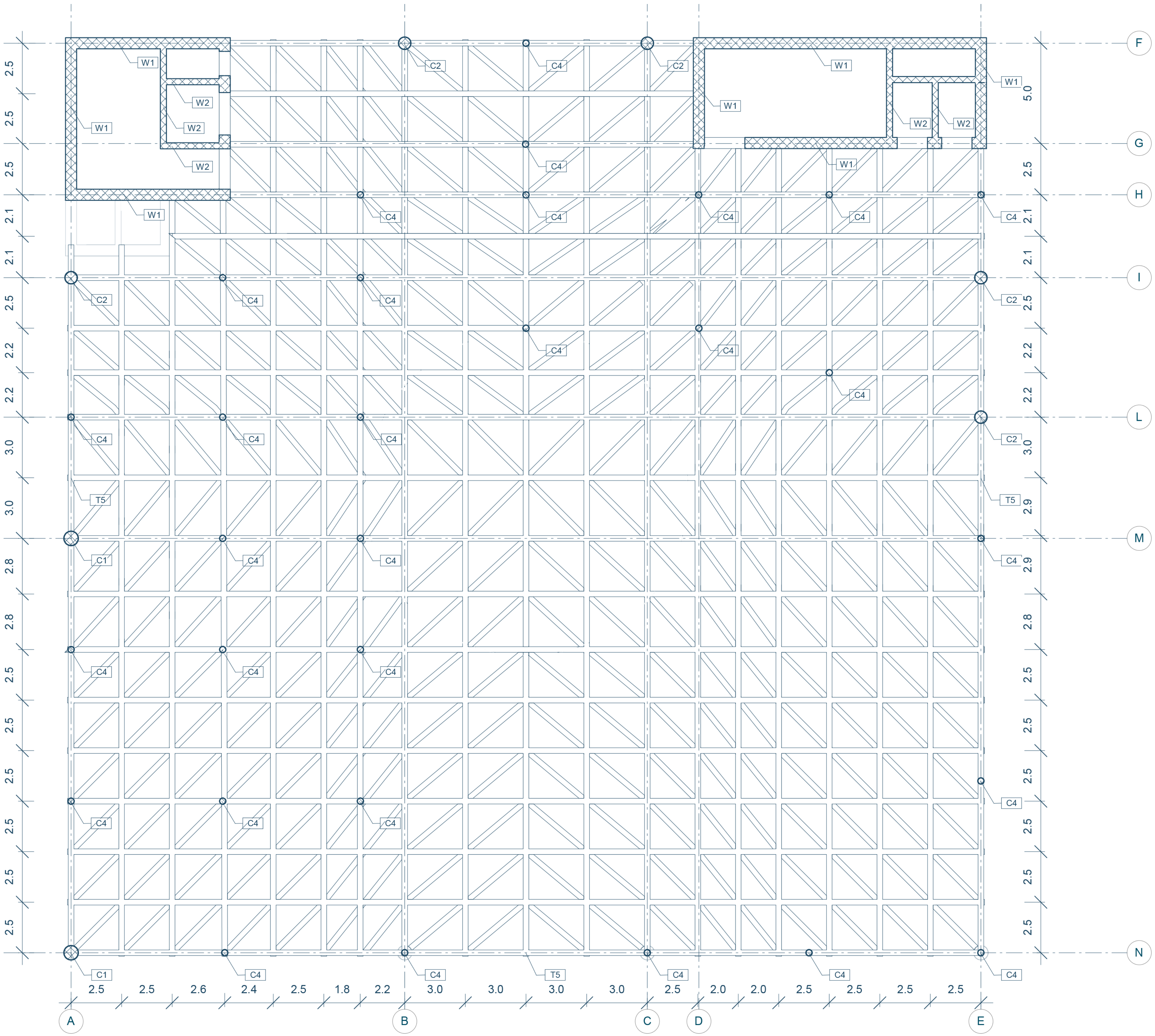


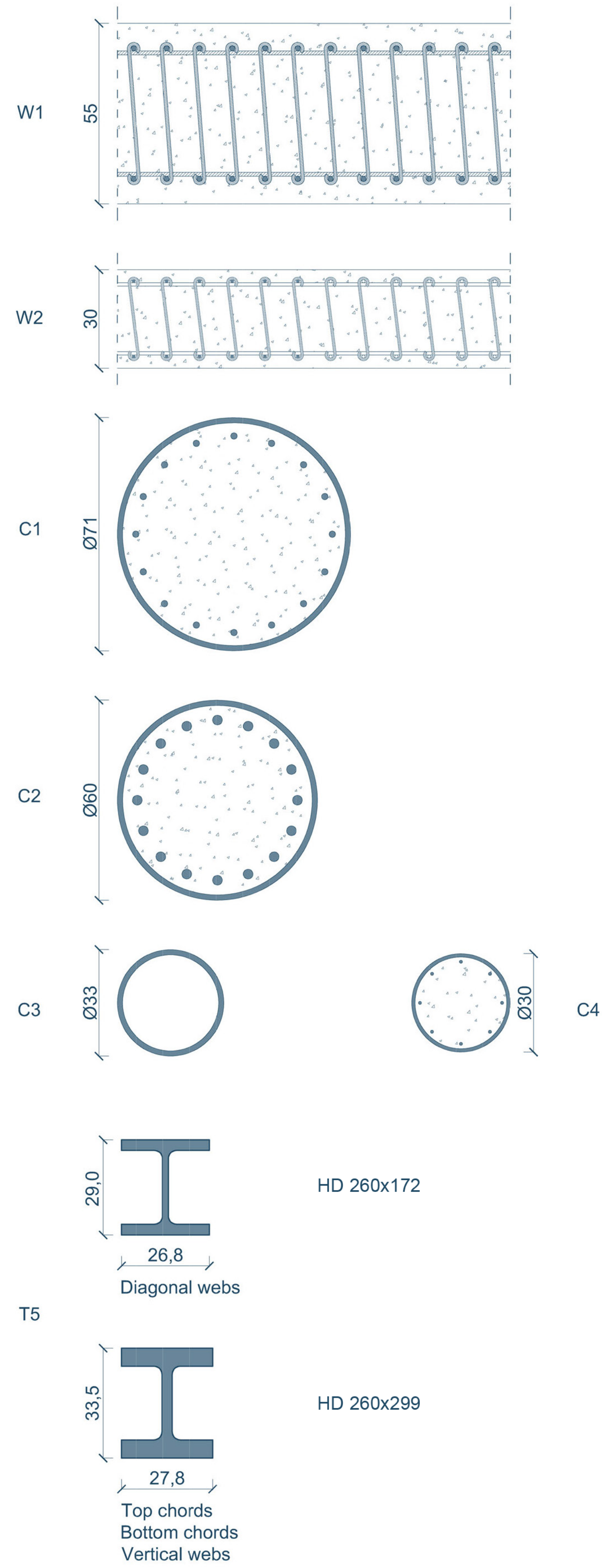




S11

Structural | Spatial truss | 1:20





Structural | Level 9 | Restaurant | 1:200

Conclusions

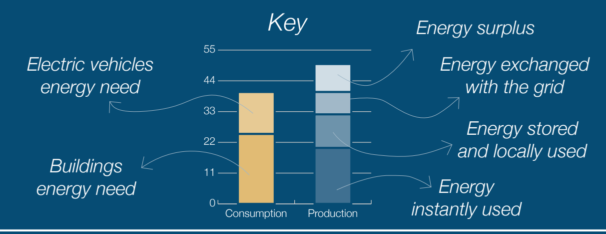
It is important to understand how the collected data could be efficiently used in a real case scenario of the new construction of a high efficient urban district. In fact the last analysis carried out, mixing active and passive buildings, could represent a realistic case. The passive building could be a public building, such as in this case, or also a refurbished building, that reaches good energy performances and through the installation of PV panels can partially produce the energy consumed, without however reaching the active standards. Another realistic comparison could be a near future in which the renewable energy sources, due to their unpredictability in their production profiles, will become less convenient for the energy providers, reaching a point in which the energy will have to be "given" for free, without any reward like it starts happening nowadays. In these scenarios the designers and the urban developers will have to face choices on how much PV systems to install, or if to invest money in the creation of a micro-grid within the district, or if investing in house energy storage. The future diffusion of electric vehicles, starting from the most populated cities, will represent a new term into this equation. On one side it will require more electric energy, on the other side it will represent an opportunity to use the energy produced on-site, without wasting or giving it for free to other users. In case of the presence of the necessary technology, the possibility will also be to use the EVs batteries as temporary energy storage.

Even if in this the total energy requirement will be higher, the amount of energy used on-site will be much higher. An hypothetical developer could start from the first line of the table on the right page (installing PV panels only on the roof) and after the introduction of a consistent amount of electric vehicles in the district move downwards into the table, producing more energy per square meter and at the same time augmenting the energy efficiency of the entire district.
Even if nowadays it is very optimistic, it can be than in the future we will face scenarios of this kind, where the buildings and the cars will not be seen as just energy "consumers" but also producers and energy managers.

The results obtained from energy simulations showed how the worldwide penetration of electric vehicles in cities could improve the energy performance of buildings. They could not only be considered as energy consuming subjects, but as a way to improve the effectiveness of the use of renewable energy. To achieve these results it is necessary to create a collaboration between the buildings and the vehicles trough the creation of a proper infrastructure, evenly distributed on the territory. The most important advantages which emerged in the discussion were summarised below, clustered following the different scales of their impact. It is clear how the energy strategy which has been developed could increase the grid independence, with a greater impact on bigger areas. This could allow the reduction of the stress on the grid, beside a cost reduction for energy consumption. The benefits would also regard people comfort, a reduction of noise and air pollution, as well as an increase of green public areas.

Effects of EV on different urban scales

Energy balances of different possible scenarios - District



SCENARIO 0: ITALY 2019

45% PEOPLE GOING TO WORK BY CAR IN MILANO

SCENARIO 1: ITALY 2030

1 MILLION ELECTRIC VEHICLES OVER 49 MILLION CARS

2%

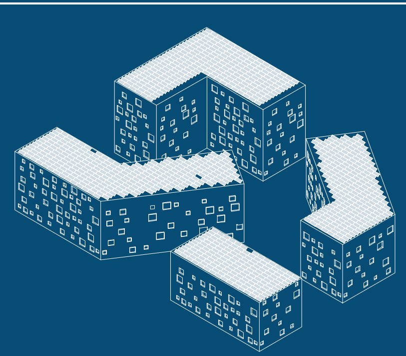
SCENARIO 2: EU 2030

23% ELECTRIC VEHICLES AND PLUG-IN HYBRID VEHICLES

SCENARIO 3: ITALY 2030 WITH SHARED MOBILITY

66% SHARED PRIVATE MOBILITY

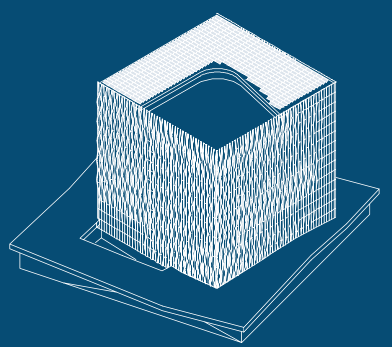
2%



MIXED-USE URBAN BLOCK

SURFACE: 19358 m²

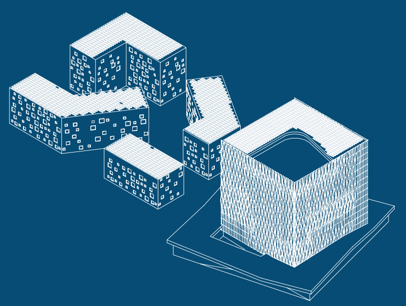
	Scenario 0	Scenario 1	Scenario 2	Scenario 3
OPTION 1: PV PANELS ON THE ROOF	GI: 0.41 PS: 0.36	GI: 0.62 PS: 0.34	GI: 0.78 PS: 0.15	GI: 0.71 PS: 0.34
OPTION 2: PV PANELS ON THE ROOF AND SOUTH FACADES	GI: 0.42 PS: 0.44	GI: 0.64 PS: 0.43	GI: 0.82 PS: 0.26	GI: 0.74 PS: 0.43
OPTION 3: PV PANELS ON THE ROOF AND SOUTH, EAST AND WEST FACADES	GI: 0.44 PS: 0.54	GI: 0.66 PS: 0.53	GI: 0.85 PS: 0.39	GI: 0.78 PS: 0.53



PERFORMING ARTS CENTER

SURFACE: 12758 m²

	Scenario 0	Scenario 1	Scenario 2	Scenario 3
OPTION 1: PV PANELS ON THE ROOF	GI: 0.25 PS: -0.64	GI: 0.32 PS: -0.65	GI: 0.42 PS: -0.70	GI: 0.32 PS: -0.65
OPTION 2: PV PANELS ON THE ROOF AND HALF OF THE FACADE	GI: 0.29 PS: -0.51	GI: 0.42 PS: -0.52	GI: 0.51 PS: -0.58	GI: 0.38 PS: -0.51
OPTION 3: PV PANELS ON THE ROOF AND ALL OF THE FACADE	GI: 0.31 PS: -0.45	GI: 0.45 PS: -0.45	GI: 0.54 PS: -0.53	GI: 0.41 PS: -0.45



ZERO ENERGY DISTRICT

ANNUAL ELECTRIC PRODUCTION = ANNUAL ELECTRIC CONSUMPTION

	Urban blocks surface	Scenario 0	Scenario 1	Scenario 2	Scenario 3
OPTION 1: PV PANELS ON THE ROOF	18570 m²	GI: 0.33 PS: 0	GI: 0.48 PS: -0.02	GI: 0.62 PS: -0.25	GI: 0.53 PS: -0.02
OPTION 2: PV PANELS ON THE ROOF AND SOUTH FACADES	10390 m²	GI: 0.34 PS: 0	GI: 0.50 PS: -0.02	GI: 0.64 PS: -0.19	GI: 0.54 PS: -0.02
OPTION 3: PV PANELS ON THE ROOF AND SOUTH, EAST AND WEST FACADES	6210 m²	GI: 0.35 PS: 0	GI: 0.51 PS: -0.02	GI: 0.63 PS: -0.18	GI: 0.51 PS: -0.02