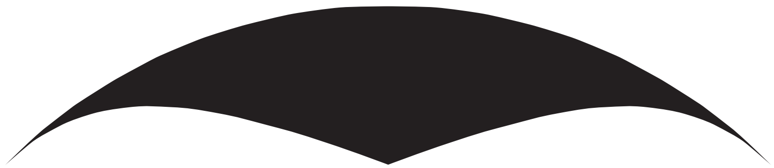
Ørestad Arena

A multi-purpose stadium in Copenhagen



MA4-ARK14 2011
ARCHITECTURE, DESIGN AND MEDIA TECHNOLOGY

Synopsis

The project describes the development of an indoor multi-purpose arena in Ørestaden, Copenhagen. It is a final thesis project that aims to introduce transparency elements into an otherwise closed typology while also addressing the urban design Ørestaden.

Title

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Title: Multiarena Ørestad

Project period: Spring 2011

Pages: 151
Issues: 5

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Motivation

This short text is written with the purpose of showing you, the reader, why we chose to design a stadium as our final thesis project – in short: What is our motivation?
When we had to choose our subject, we found that we could boil the decision down to two mindsets:
We could do a dwelling or something else similar to previous semesters, or we could choose to challenge ourselves one last time and take a chance on something exciting but difficult.
Obviously, we chose the latter.
We quite quickly came to the conclusion that we wanted to do a stadium for a number of reasons:
A stadium is huge in every way, and thereby offers a chance to work on a scale previously untouched.
The floorplans alone can be a challenge, but the large dimensions also means that it offers a chance to work on tectonic elements, as there are large spans to be covered. The stadium typology also offers a possibility to work with transparency elements, as stadiums by nature have the bulk of their functions turned inward which results in closed facades. There is also the more loose challenge of the experience of the stadium as framework for events – this is linked to acoustics seating arrangements. Finally there is a lot of planning involved with designing a stadium – both logistics as a whole – but also urban qualities of the area surrounding the stadium.
In combining all these elements we have a large, but also extremely exciting task ahead of us – and a final chance to learn something new at the Department of Architecture.

Method

Problem based learning
At Aalborg University some of the key factors in the teaching is problem based learning combined with group work. This entices a multi-angle approach and gives great possibilities to develop qualified solutions. When working in groups, more competences are brought into play and resemble the project team just as in the professional world.

Integrated Design Process
Where problem based learning describes the overall philosophy of the project work, IDP describes the methodical base of the project work. With IDP as a main structure, planning and workflows are derived. IDP is mainly about combining technical aspects with aesthetic and functional aspects. This is done in order to achieve a unity where aesthetic, functional and technical aspects go hand in hand, supplementing and complement each other. The integrated design process contains different phases which form an iterative process, where conscience and knowledge are increased through each repeated design loop.

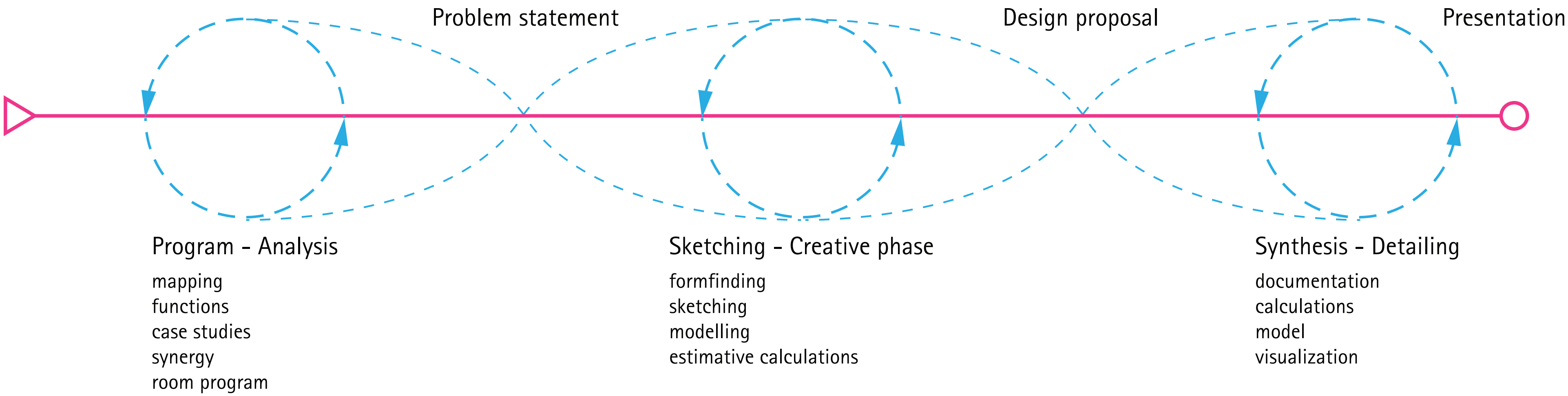
Problem
At the beginning of the project an initial problem must be defined in order to establish a theoretical base upon which the project can take its beginning in the right direction. Later on when the final problem statement is described the project goal is to come up with a solution to this problem through an explorative iterative process.

Analysis
This part of the process focuses on knowledge gathering in order to shed light on the problem statement and contribute to the reach a solution. Typical topics to be covered could be; context, weather conditions, topography, infrastructure, law, municipality plans and demands from the builder.
The output of the analysis phase is a list of demands, concepts and ideas which should be explored and "reached?" during the later phases.

Sketching
During the sketching phases, the demands from the analysis are to take shape and end up with a sketched proposal. Through sketches come ideas for solutions on different problems, some more detailed than others and dealing with different aspects. In the process they are concretized and getting more complex and are to be gathered in a final proposal which fulfill the demands derived from the analysis phase.

Synthesis
From the sketching phase a proposal which meet the required aesthetic, functional and technical demands as listed in the analysis is chosen. This proposal will be concretized and further developed. Within this phase constructions, indoor climate and expression will be verified. Through verification and development the level of detail will increase to detailing of joints.

Presentation
During this phase the final proposal from the synthesis phase will be presented. The spatial qualities are presented through plans, sections, facades and perspective drawings. It's emphasized that the presentations should fulfill the demands from the analysis [Knudstrup, 2005]



Iterative process
This method is widely connected to the integrated design process where the process is looping. Through iterations processes are repeated several times, each with larger knowledge and more complexity.

The illustration shows the combination of phases of the integrated design process and iterative process. Through loops, knowledge is continuously added to the project, not only within each phase, but also back and forth between phases.

Introduction

The sports arena - evolution and history

In the minds of many, the sports arena may be seen as a modern building type, but as a typology it is one of the oldest. The earliest sports events go as far back as cave paintings; in those times the activities were often a means to worship the gods of their time. The first arenas followed some time later, in the utilization of natural landscapes, such as valleys. These were subject to modifications with dirt to achieve extra capacity and improve comfort.
In the antique period the ancient Greek sought to follow the ideals of the healthy body and enlightened mind, perhaps because of this, they were the first to build man-made arenas in the form of amphitheatres which were host to a range of activities. Later they constructed stadia and adjacent covered facilities for indoor sports and academic activities.
Following the Greek, the Roman Empire made large scale facilities with sufficient capacity to contain all the citizens of the city it was situated in, most famous of these is the Coliseum. During the reign of the Roman Empire, utilization of stadia experienced a shift from that of the healthy body, towards being used more as a tool to showcase the military prowess of the emperor. As Christianity started to grow in popularity, the ideal of the healthy body declined, and later followed the abolishment of gladiators which marked beginning of the middle ages – a period almost without sports facilities.
In the middle ages, physical recreation as a whole saw the opposition of the church. However, jousting in tournaments gained popularity as it became an integral part of a courtly upbringing. The tournaments evolved into grand and colourful festivals usually held on fields on the outskirts of cities.
Coming out of the middle ages, the enlightenment period followed and facilities for sports, indoors as well as outdoors, flourished, and bloody activities such as jousting was replaced with other less dangerous activities such as regattas.
Around the 18th century, stadia construction begins to gain momentum as modern sports are invented in England, and the Champ de Mars in Paris is remodelled into a roman-style circus.
Less than one hundred years later, the first modern Olympics are held. For this event an arena is created, a u-shaped stadium based on an ancient design, which proved to have some drawbacks in regards to crowd-control in a modern environment.
From here on the stadia has kept steadily growing in size and popularity throughout the 19th and 20th century, with such buildings as Kenzo Tange's Olympic sports halls in Tokyo and Pier Luigi Nervi's Stadio Flaminio. The paradigm of the industrial revolution is higher, faster, better. As a parallel discourse, sports and personal exercise grow equally in popularity which leads to the first fitness centres and multi-purpose halls spring up across Europe. As time pass, new

types of sports activities emerge to compete with the traditional activities (football etc), which in turn challenges architects to design buildings that can meet the needs of an increasingly diverse user base – or design individual facilities tailored to each activity. [Marg, 2006]

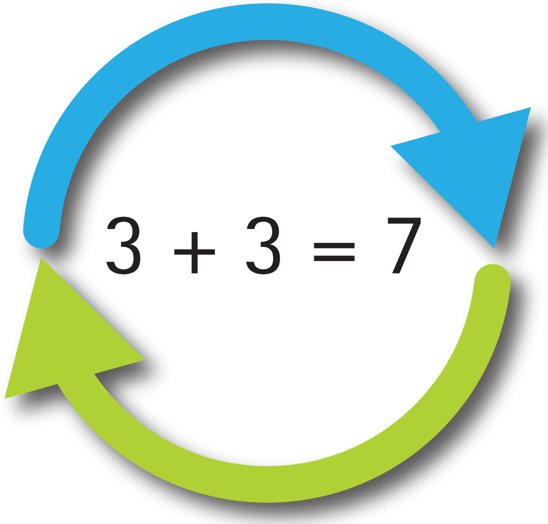
Contextual and social responsibilities

As the history of stadia indicates, the evolution of this building type points towards bigger and better. The fact that each new stadium is bigger than the one it precedes, means that each time a new one is constructed; it is even more likely to have an impact on its neighbours than stadia before it. This increased impact on the surroundings means that the designers of the building have a responsibility to make the building harmonize in the context that it is situated.

Some designers see contextual considerations as restraints that prevent them from achieving the design expression that they desire. However, this obligation to contextualize, to tailor a building to its surroundings is not necessesarily a bad thing for the designer. Inherent in making a contextual design, are a number of potential rewards that can be reaped, if executed correctly. In the business world, these rewards are called 'synergy effects'. Explained briefly; synergy effects is when an object is stronger when placed nearby other objects from which it has a mutual beneficial relationship. That way, the sum of the objects is greater than the sum of each individual object combined. For a building that can be implicated in a number of ways, for example via the room programme.

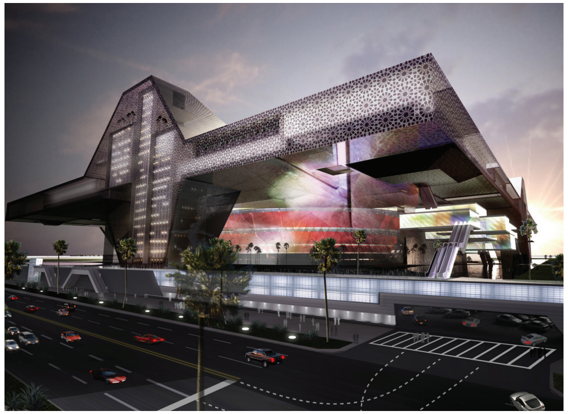
Programming your building to have a number of functions that are otherwise missing or immediately compatible with those of the surrounding neighbours – like a small sports facility in a residential neighbourhood. That way the context, ie. the surrounding buildings, becomes more attractive because of the opportunity for recreational facilities and the sports facility also improves as this will give life to the building. This means that the components are better as a whole, than as individual pieces, and is as such is a way to achieve synergy effects. On the opposite end of the spectrum, is a building that disrupts existing synergies and makes a context less attractive – that could be an industrial complex nearby a holiday area. The concept of synergy effects primarily finds use in the commercial aspects programming, but it can, as mentioned, be used as a tool to improve building design.

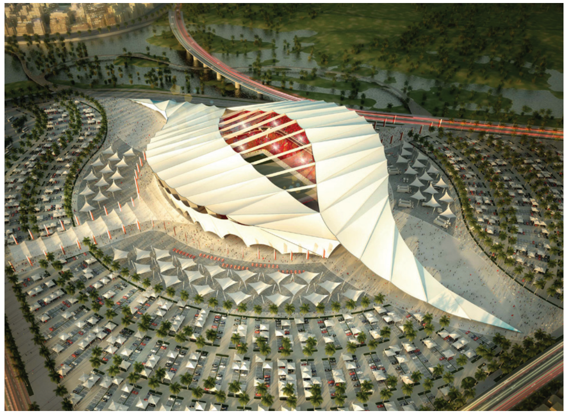
The lesson to extract from the theories of synergy effects is that when designing a building – modelling it to complement the context may give extra value to the whole in addition to that already inherent the design. Therefore, there is no reason to see the building context as an obstacle that holds back the design – correctly analysed it can be utilized as a tool to improve the design. [COWI, 2007]



Views on the future of sports arenas in Denmark

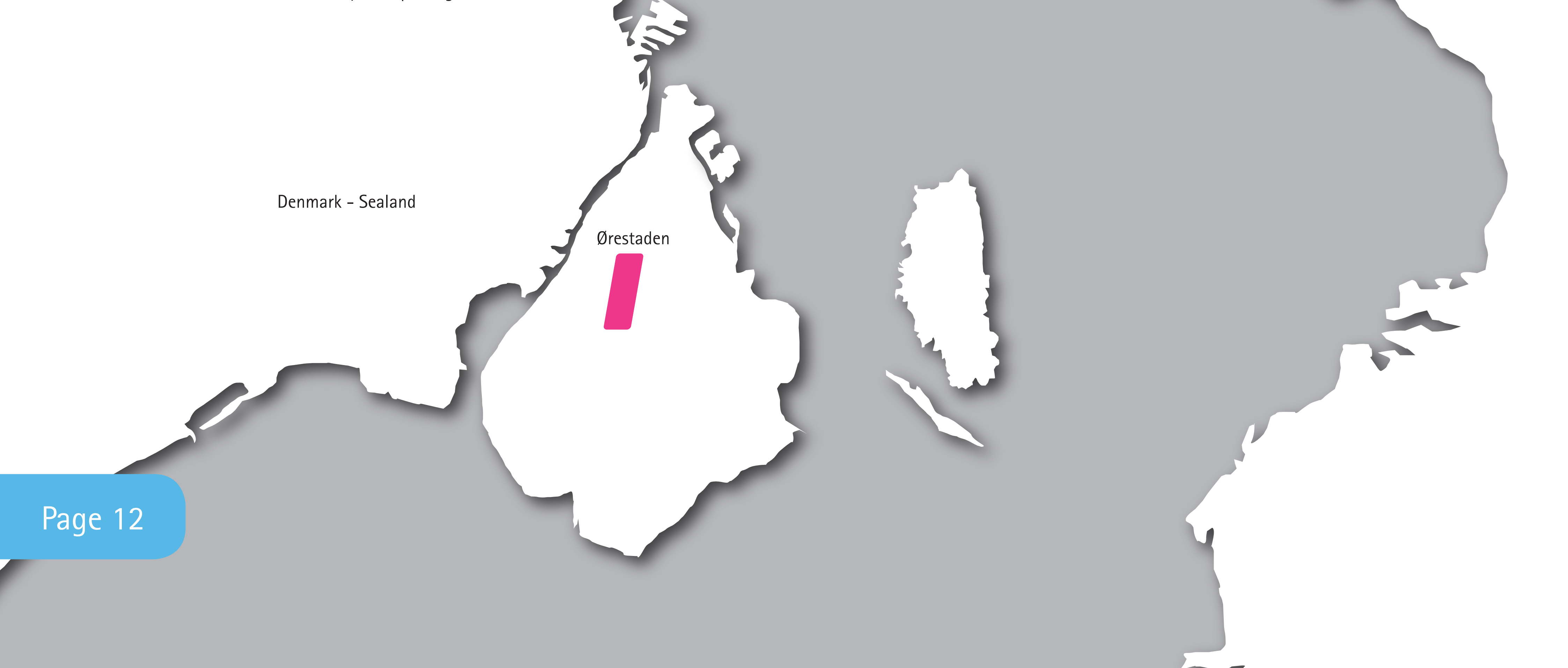
Searching to uncover the future of a building, we are not only working to uncover new groundbreaking shapes or materials, but we are trying to foresee which functions will be relevant in the future.
The functions as a whole comprise the building programme which has and will always be an integral piece in any building design. Therefore we can assume the following: As the building programme affects the form and synergy effects, it also affects the future of the building as it defines its relevance for the users. This means that by investigating which functions are relevant in future, we simultaneously search for elements which make a building better for a longer period of time.
Since the number of available sports activities is not a constant, there will be at any given time more or fewer activities – this means that some sports grow and others shrink, based on their popularity. Studies have shown that a tendency for the past decade is a move away from some of the traditional branches and towards new sports with a more individual flavour, leading towards two different paths [Kural, 2000]:
A: Facilities which offer a wider range of sports, and thereby chooses to lessen the specialist capabilities, that for examples makes football stadiums such a emotional arena.
B: Facilities with focus on the major sports, which have a stronger following. This is the direct opposite of A, and as such chooses to narrow its range of available applications, in turn for better performance at one or few event types.
The question is, how will this trend influence the development of future facilities?





Region

Looking at our site, it is placed in the most eastern parts of the country, but still close to the capital, Copenhagen and close to Malmö – the third largest city in Sweden. It is here between these cities, on the island known as Amager that you will find Ørestaden, the newest addition to the city of Copenhagen.



City

As a new part of Copenhagen, it is relevant to review how this new addition relates to the rest of the city. Ørestaden is situated on the north western part of Amager, just south of Islands Brygge. Therefore it is not in the centre of but a few miles to the south-east of the centre of Copenhagen. The airport is a few kilometers further to the southeast. As such the area is not central, but is still closely connected to the city and within walking distances of nature scenery of Amager commons.

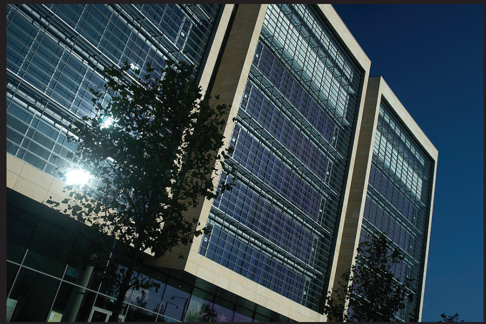
History

Ørestaden itself does not have much of a history; it was once hunting fields, later a dump site and until a few decades ago, agricultural fields. The history of Ørestaden only got off to a start in the late 80ies and early 90ies, when it was planned that the stretch later to be known as Ørestaden should be the newest addition to the city, and that it was to be the catalyst that would save the economy of the city. From the late 90ies and into the new millennia, construction boomed in the area. After the financial crisis, things have cooled down, but new developments are still underway in the vacant plots on the southend of Ørestaden.

Ørestad 2011

Architecture

The collage shows the big variety in the architectureal expression on the many new buildings in the Ørestad region.




Bjerget

Surroundings

The site is in some ways unusual and self-contraditory because it is close to the urban fabric of the city, while having the wide natural expanses close by as well. On a map, Ørestaden is a long thin stretch of land, running from north to south. This means that different parts of the area, completely different genus loci can be experienced. On the north edge the area connects to Copenhagen, it has a feeling of history and urban sprawl. To the east the area meets old Amager, primarily consisting of residential housing which gives a more calm, and during the day, vacant feel. The south and west borders connect to the open flat expanses of Amager common, the quiet and cool winds gives the impression of being on the outskirts of civilization. In contrast, close by you find the centre of Ørestaden, which has a feel similar to a larger modern European city.


NORTH


EAST


SOUTH

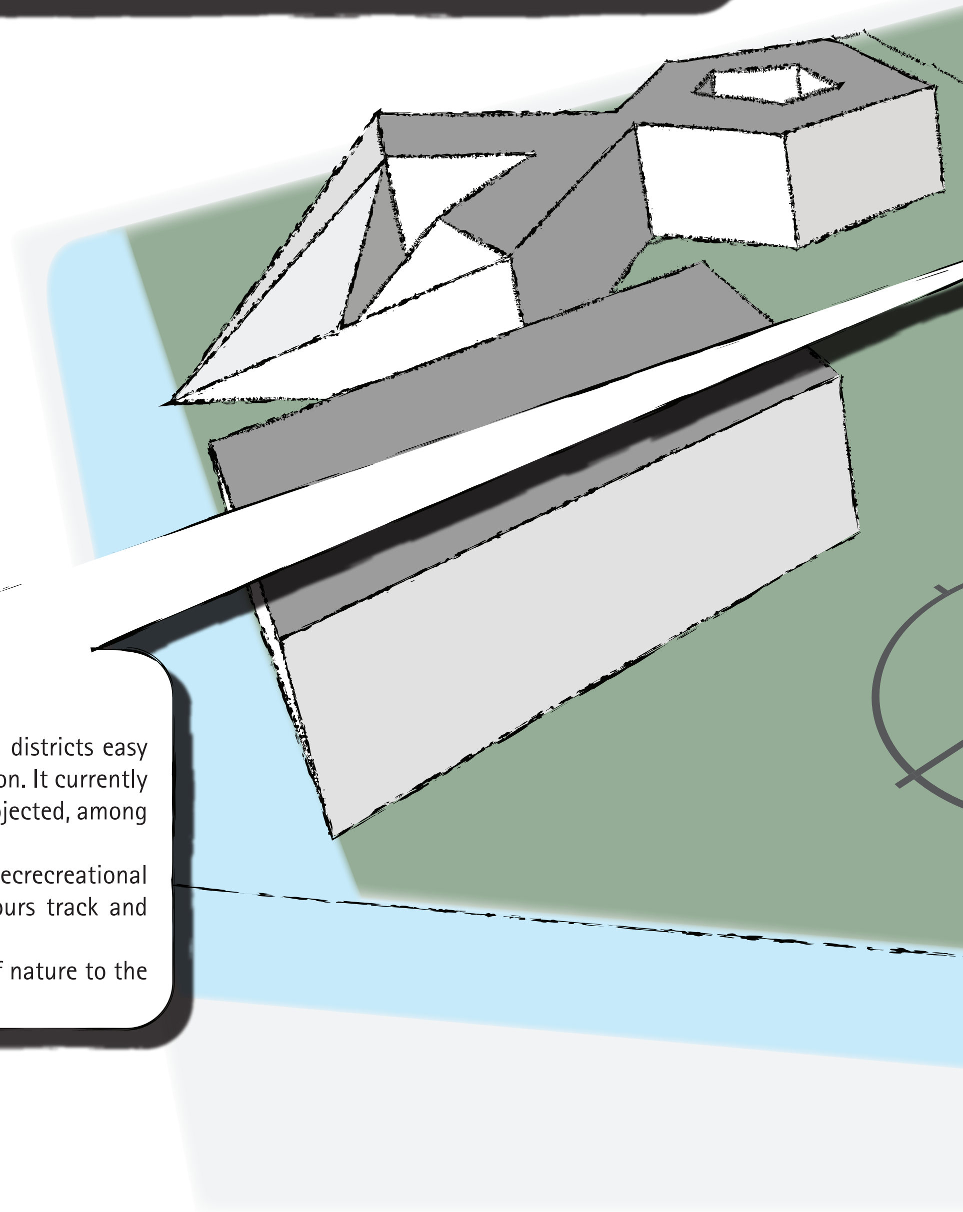

WEST

Mapping

Mapping v2 is all about analyzing the landscape from a fresh point of view. Based on a combination of maps and a phenomological analysis of the area, we have constructed diagrammatic overview of the site and its relations to the surroundings.
It is an explanation attempt; it tries to visualize the gap between the current state of the area, and the planned future state. The diagram displays how this new part of the city is an elongated strip of land reaching up to the centre of the city, culminating in the bubbly transport hub and from there transitioning like a typological gradient from business via mixed-use to dwelling.
Running along its full length and intersecting from south and west is the veins of the city, ensuring that getting to and from our site could not be easier.

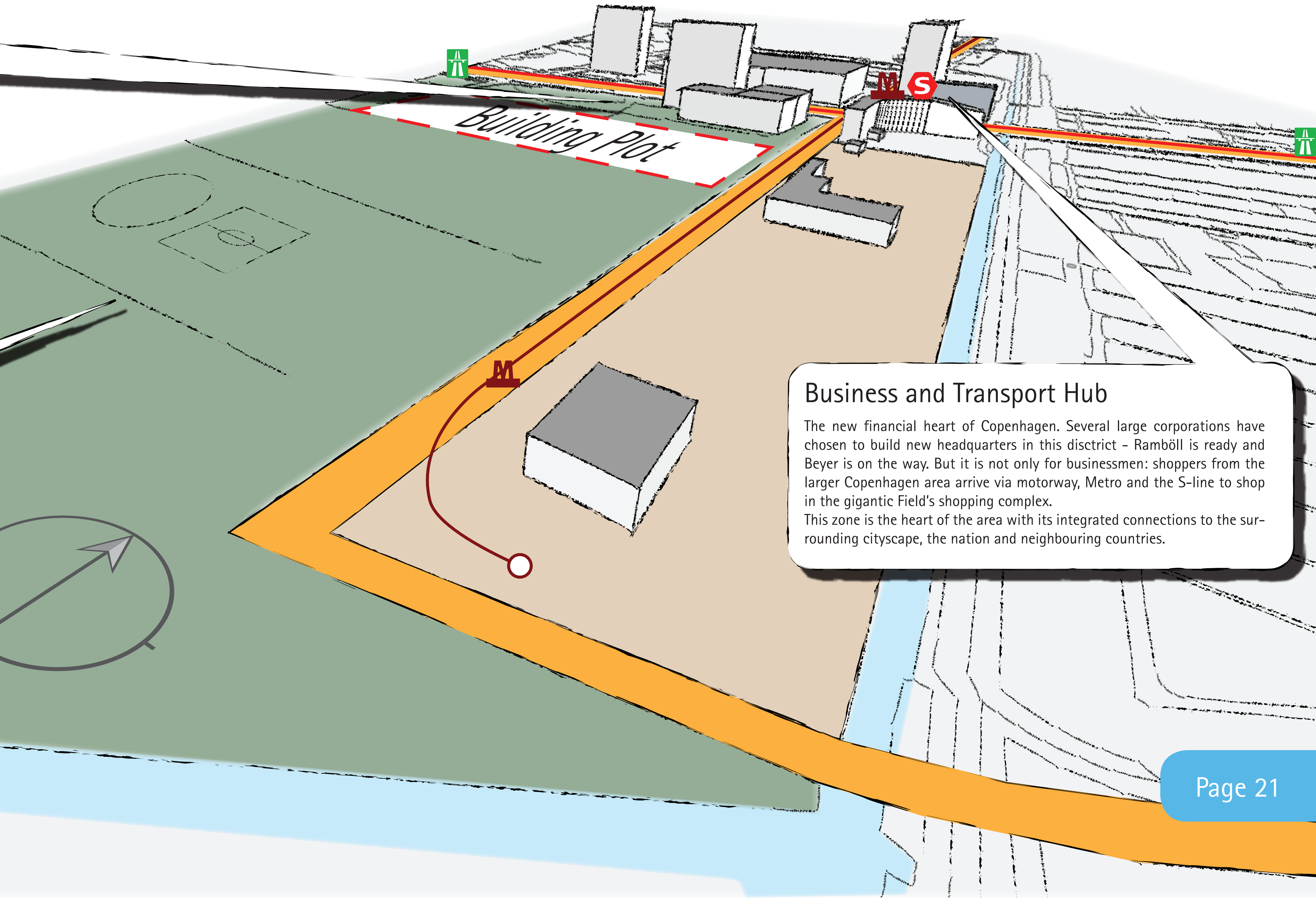
Mixed-Use Zone

This zone is a transition from the hard surfaces of the business district to the north. Here you will find an office hotel with conference facilities and the projected Copenhagen Business Park - a facility the contents of which are unknown. Also there is planned a large dwelling complex, Hannemanns parken which will stretch along the building site. This area is posed to have a different rythm than the business district.



Dwelling and Recreation

This is the breathing hole of Ørestaden, where the pressure of the urban districts easy up, as this dwelling area fades out into the open nature of Amager common. It currently features to iconic dwellings, the figure 8 and 'Stævnen. Many more are projected, among those a collegium for students.
Also this area is host to the popular Plug-in Park, a area with a suite of recrecreational facilities not found elsewhere in the city: Rollerskate speedtrack, Parcours track and artificial grass football to name a few.
Here, Ørestaden slows down, before it dissolves into the wide expanses of nature to the south.

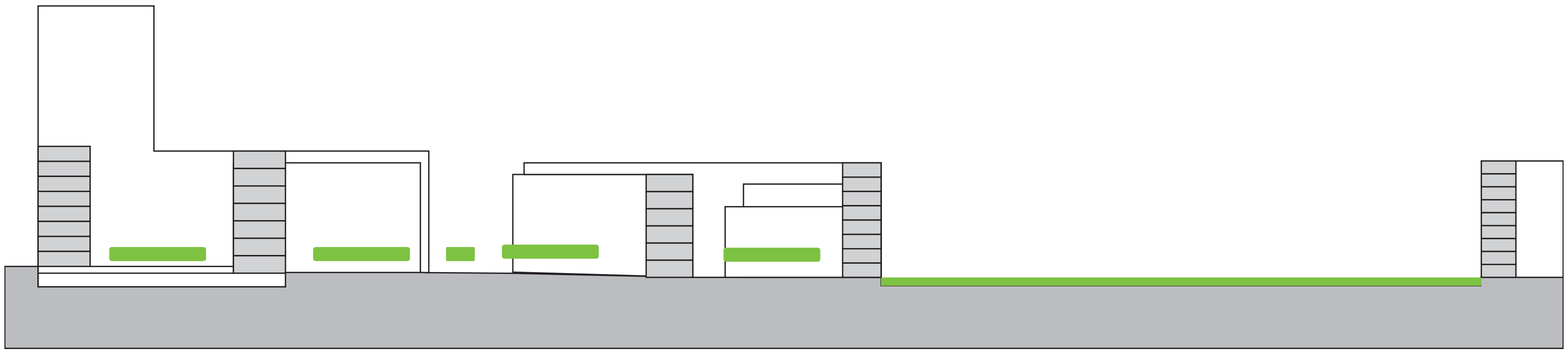


Business and Transport Hub

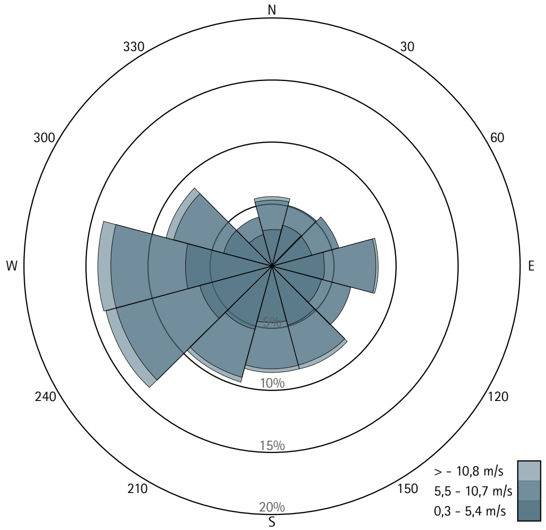
The new financial heart of Copenhagen. Several large corporations have chosen to build new headquarters in this disctrict - Ramböll is ready and Beyer is on the way. But it is not only for businessmen: shoppers from the larger Copenhagen area arrive via motorway, Metro and the S-line to shop in the gigantic Field's shopping complex.
This zone is the heart of the area with its integrated connections to the surrounding cityscape, the nation and neighbouring countries.

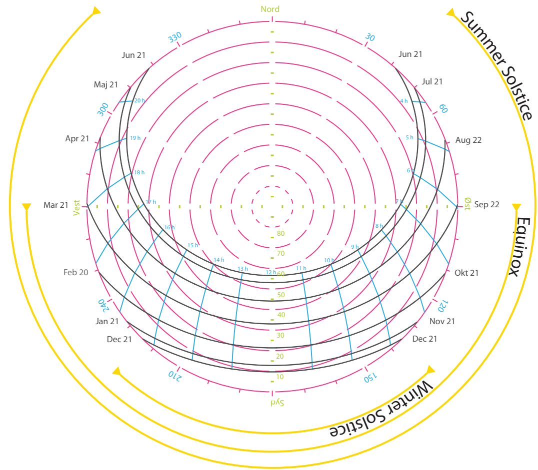
Site conditions

Apart from mapping the landscape, we have also cut a section from the motorway to the southside of our plot. I shows that the area is almost completely flat, only rising slightly towards the motorway, which is likely to due to landscaping. Also it is worth noting that our section (and the rest of the analysis) work on the assumption that all future buildings in the surroundings will be made the maximum allowed height. This creates a urban wall on both sides of the plot which we will need to relate to – both in architectural design but also in the masterplan.



Weather conditions





Throughout the world, there exists architectural works which have the similar basic functions but have different shapes. The reason for the variations in design is multi-facetted, but a primary reason is the weather conditions. The following text works towards uncovering the weather conditions of our site.
Scandinavia is famous for its cold climate, but as this is the at the southern end of Scandinavia the climate can best be describe as tempered with a varied weather throughout the year. The summers are cool with mean temperatures around 16c and the winters are cold with mean temperatures just above zero.
Weather statistics from the national weather service – DMI which show that during the last century and a half there is a clear tendency towards rising temperatures and rising downfall.
The wind diagram shows that area is relatively windy and that the wind predominantly comes from a west to south-western direction.

Also we have a sun dial which shows the sun path in the course of a year. This sun dial is for Copenhagen, but it does not differ much from the sun dials from other areas of Denmark. The diagram shows that we have long bright nights during summer and short dark days during winter – also it shows that during winter the angle of the sun is quite low. This is relevant for later observations of shadow conditions for the site.
All in all with the weather data available, we are able to paint at picture of Danish weather: Warm summers that rarely are very hot, and cold winters that often are quite wet. In all a pleasant environment when the weather is nice, but often an environment that invites indoor activities.
[UBK2][DSD]

Infrastructure

Viewing our site from an infrastructural perspective; Ørestaden as a whole is extremely well connected. Close to our site is a Metro station and underneath it runs a train station. Parallel to the train tracks is the motorway and the nearest off/on-ramp is no more than a few hundred meters away.
This means that on all scales of transportation this place is interconnected with the world: The metro system connects to the inner city and the airport, the railroad also connects to the airport, but also the rest of the nation and neighbor countries such as Sweden and Germany. The motorway connects all this and everything in between. Travelling to and from our site could not be easier.

Motorway

Metro line

Train


te
Malmö
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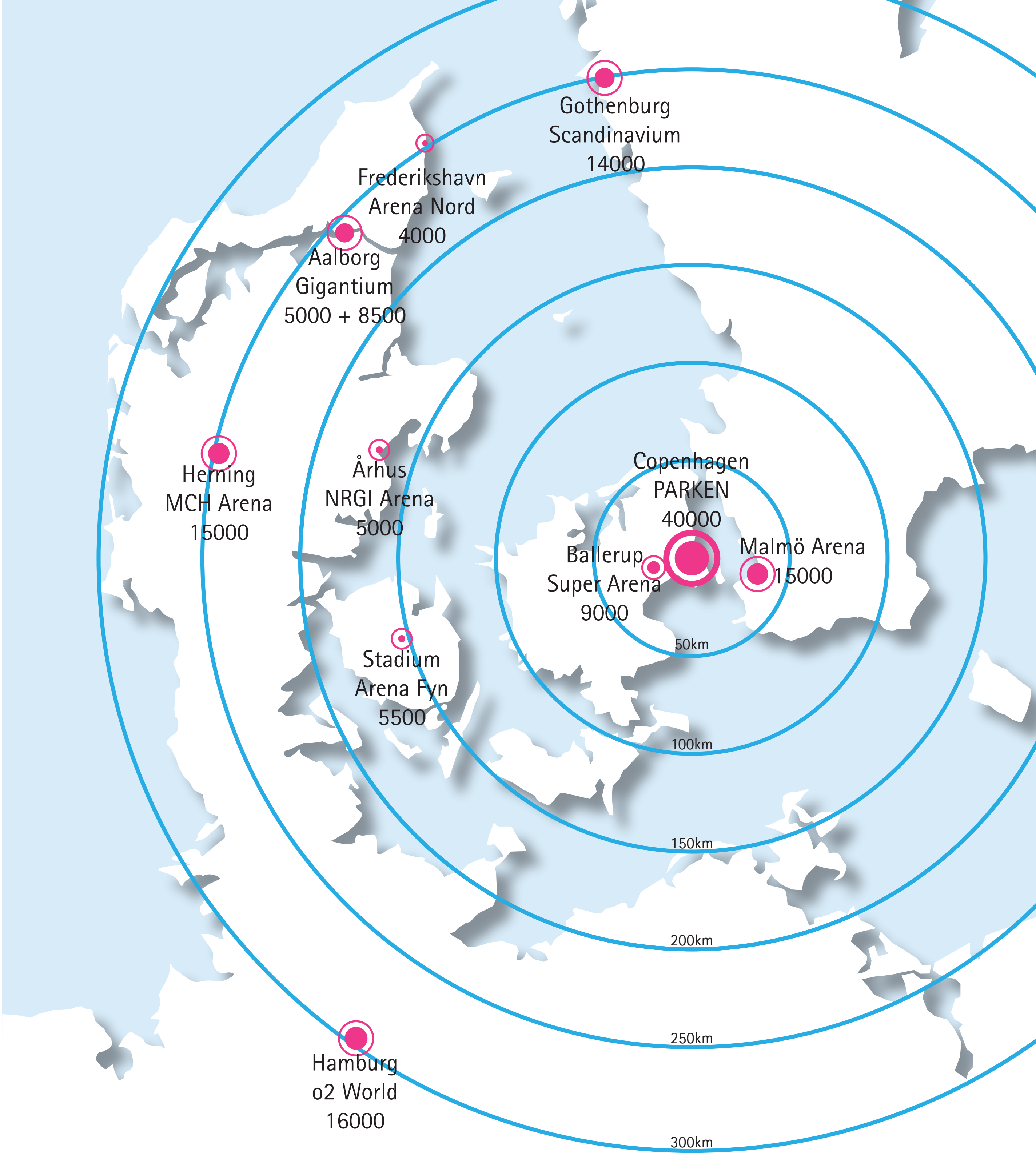
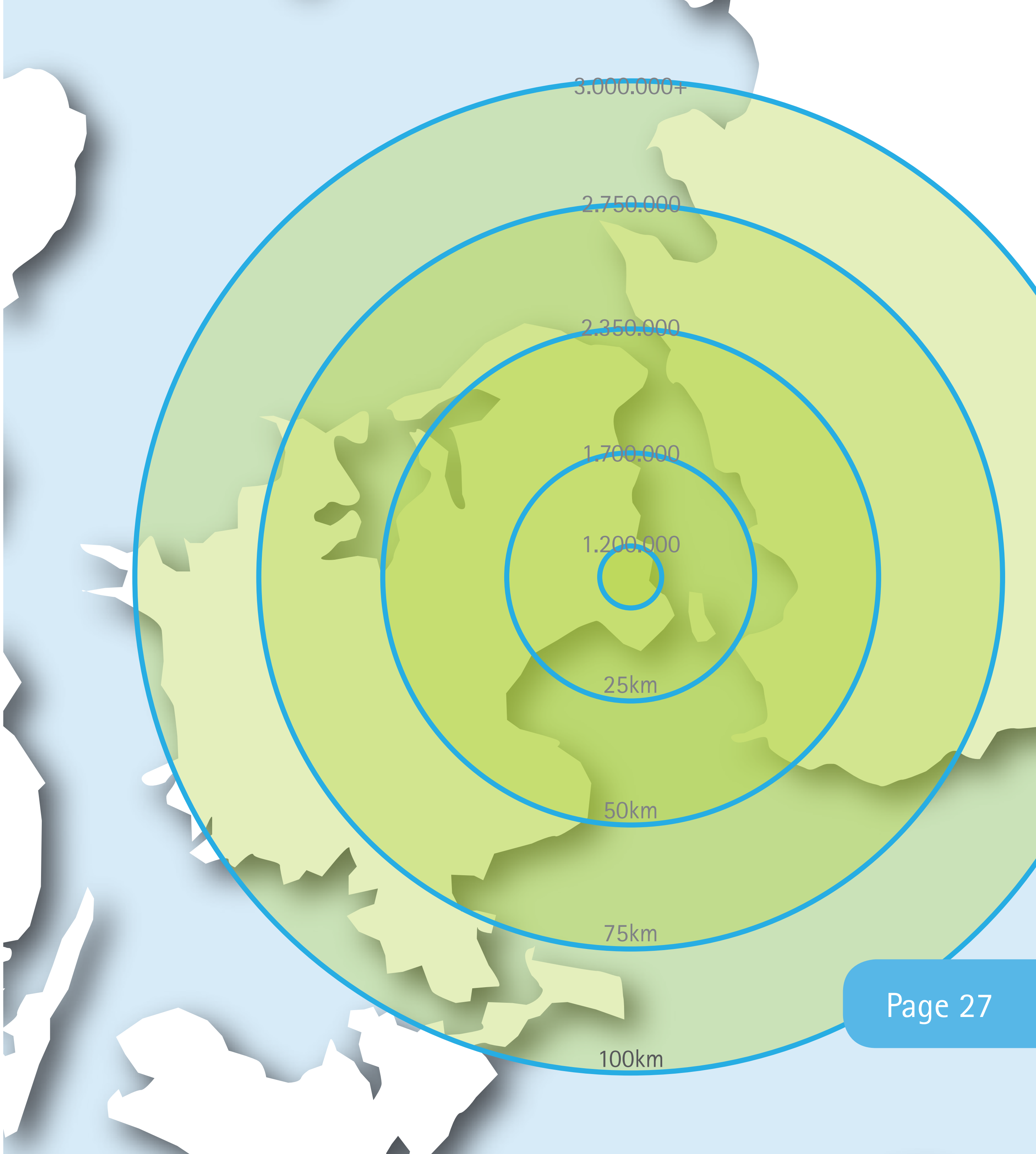
Distance

When analyzing the context for a sports stadium, different aspects and factors are in play compared to when analyzing a context for a dwelling project. In regards to a sports facility, we chose to zoom out in order to see what other stadia exist in the surrounding cities – from here we look at large indoor facilities as far away as 300km. This is done as a large scale context analysis aiming to map out competitors.
Spectator capacity is for maximum capacity scenarios – i.e. concerts with standing crowds. Aalborg Gigantium is a multi-hall complex, and capacity is therefore divided. [Cap]



Density

When planning a new stadium, an important element to factor in is the user base. This is based on the density of the population in a given radius from the proposed building-site. In a European context the norm is to achieve between 3,5 and 10 million inhabitants within a 100km radius, but in the context of Denmark this criteria cannot be applied due to socio-economic factors and populace density. COWI did similar investigations for a similarly sized stadium in Århus – they concluded that approx. 10% of the normal European criteria would be sufficient. [COWI, 2007]
Looking at Copenhagen, the city itself has a population of approximately 1,2 million inhabitants, the Copenhagen Metropolitan area is 1,7 million and the entire island of Sealand combined is 2,1. In close vicinity is Malmö with an additional 650000 inhabitants which brings the total up to 2,75 million within a radius of less than 100km. If you include the surrounding area of Skåne the total exceeds 3000000. [Wiki3]

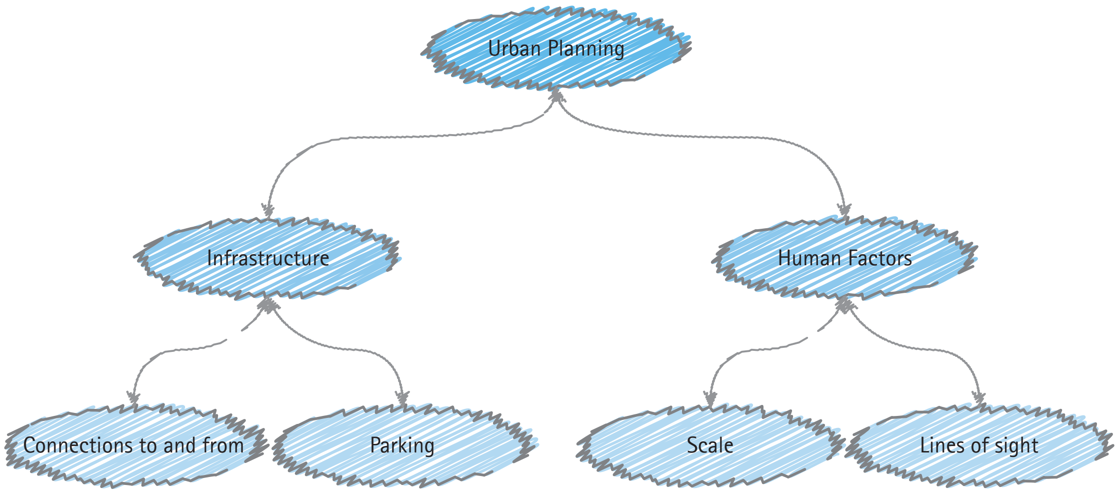


Urban planning

Stadia, when viewed as architecture or arenas for events – it shines through that functionality weighs in heavier with this typology compared to others. This is also true when looking at the urban planning aspects connected with designing a stadium for thousands of spectators. In many cases priority is highly focused on functional aspects of the design, such as convenient parking and transport. As much that it is true that skillfully designed infrastructural facilities are in place, there are other design elements within urban planning which have a big influence on the stadium experience.

The stadium experience does not begin the same second as the planned event itself begins – it begins much earlier; it begins with the journey towards the stadium. It begins when you meet with friends that you travel with. It continues with the casual conversation with the stranger who is going the same way. It builds up as you see the glowing stadium rise in the distance. The excitement builds as the crowd gets more and more dense, and the noise levels rise. This journey that precedes the event inside the stadium is an integral part of the whole experience. The factors that influence this experience are interlinked with factors which are closely linked to softer, more human values. These might be use of human scales, lines of sight or something as simple as not placing the parking elements right next to the venue – creating a last journey on foot.

It is realizing the interrelations between the human factors and infrastructural factors and the ability to combine them that enables the architects to design a truly great experience.



San Nicolai -Bari Stadium by Renzo Piano

The Stadio San Nicola is a multi-use all-seater stadium designed by Renzo Piano in Bari, Italy. It is currently used mostly for football matches and is the home stadium of Associazione Sportiva Bari.

The stadium holds roughly 60,000 people, but has never been filled to capacity, as the football club have been moving back and forth between the Italian serie A & B. The stadium was built in 1990 for the 1990 World Cup, during which it hosted five matches

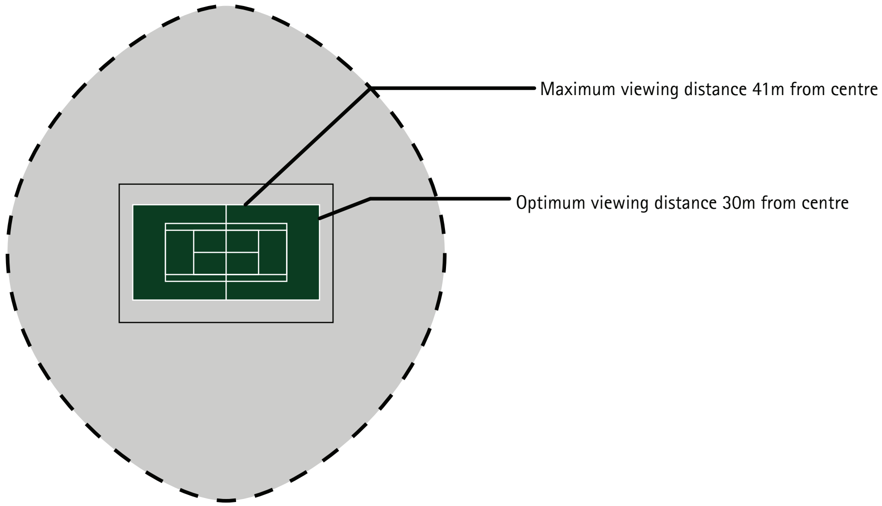
The stadium itself resembles a 'flower'. To create this particular design, the stadium consists of 26 'petals' and upper tiers of the higher ring which are separated by 8-metre empty spaces, sufficient to guarantee satisfactory security conditions.

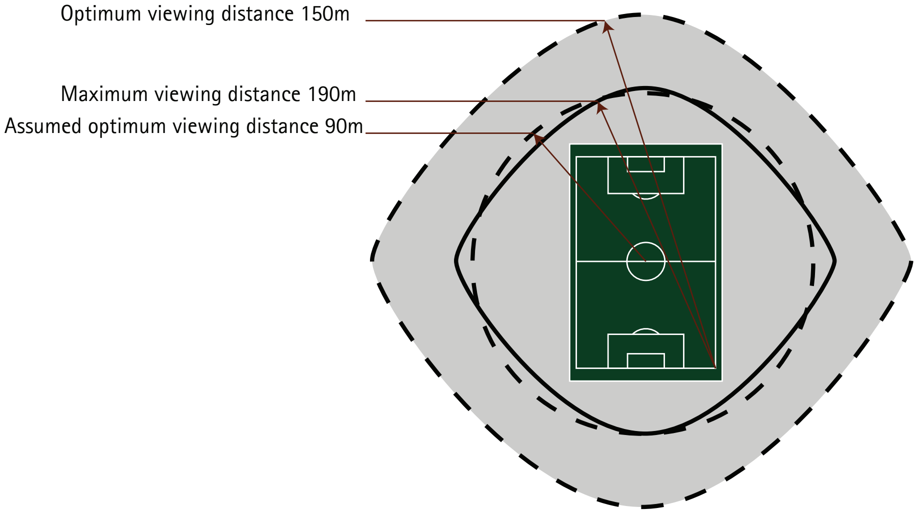
The stadium premises show a beautiful and very clear urban planning which originates from the design and layout of the stadium. The division of spectator tiers into 26 'petal' and voids between them are used for pathways which radiates straight outwards from the center of the stadium. These pathways leads through a circular green area around the stadium connecting to the also circular parking area in the out perimeter of the stadium premises. When coming to the stadium in car, you are forced to park a bit away from the stadium and then join one of 26 processions leading into the stadium. [Wiki 2][RPBW]

Multiuse

Earlier we were examining the history and future of sports arenas and their role as a typology. As we proceed through further investigations we begin to close in on what type of arena we want on our building plot. One thing that we have discovered is that there are two diverging trends within sports – one concerning the consolidation of the strongest of sports and one which concerns development of new sports which in turn push out some of the smaller, older sports. These two trends each have one other general inherent characteristic: the first trend towards consolidation often has focus on team sports, the second one has towards new sports has focus on individual efforts.
Now in designing a sports centre there is no need to prove that it requires users for it to be a successful arena. By extending this logic, we assume that it would be desirable to have as many users in the arena at any given time.
To achieve this it is necessary for the design to place itself 'between two chairs'. Here by meaning that the design must not only embrace larger traditional sports events, but also smaller more diversified events. This will enable the stadium to fill up for 'prime-time' events such as handball world cup matches, but also to have it populated for smaller events such as table tennis tournaments or other non-sports events – for example a concert or a business conference. From a

financial perspective, this model is more desirable as opposed to exclusively following either of the two aforementioned trends, as it has potential to have more visitors during a given timeframe and thus potential to generate higher revenue.
It is obvious that once we have decided to make an arena which supports multi-use, this will have a big impact on the design, and needs to be thought in already in the creative process.
Tailoring the design to multiuse requires that we identify which sports and activities we intend to house within the arena, so that we can create optimum conditions for all users. This is due to that each activity has different characteristics – for example the optimum viewing distances for snooker and football

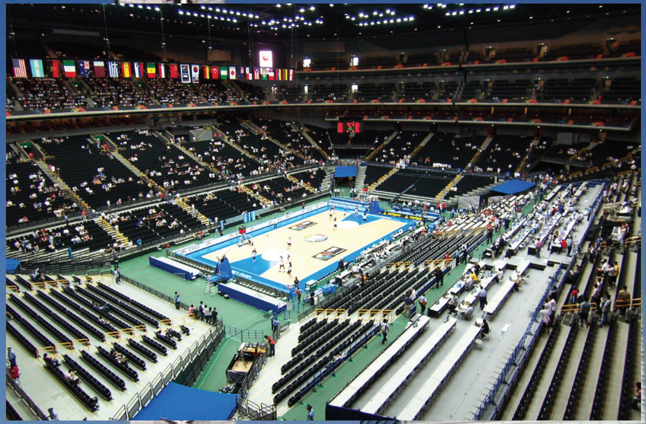




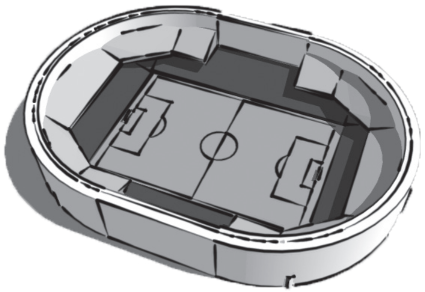
are very different which in turn means that they need different seating facilities. The diagrams shown display how spectators a differently setup for two major sports: football and tennis. Were these two events to be held within the same building, there would be a need for flexible spectator stands. This we examine further on the following pages.

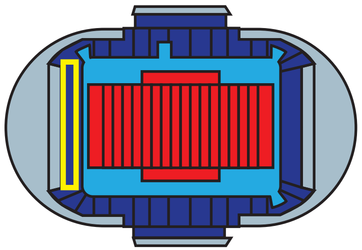
Saitama Super Arena

In Japan is an indoor venue that takes multi-functional to an extreme that is rarely seen. The arena is named after the town in which it is situated. The Saitama Super Arena features a large mechanized stand that can be configured to suit almost any scenario. From the smallest possible configuration to the largest, the amount of possible spectators rise more than six-fold from 6000 to 37000. It hosts everything from American football to mixed martial arts (MMA).
On the following page we will go over the possible setups and their uses.



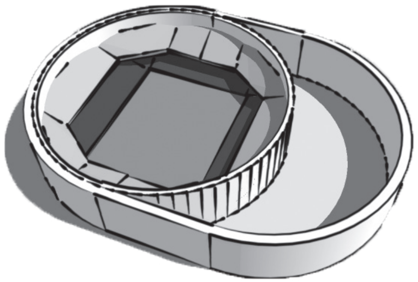
Stadium mode

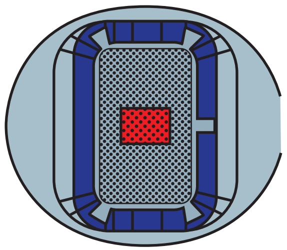




With the moving block fully retracted, the pitzh size is big enough to accomodate american/eurpeoan football match. with a capacity of around 27,000 people.
If used for concerts capacity can reach up to 37,000. If used for exhibitions or fairs, theres a total floor area of 14,600m^2 available.

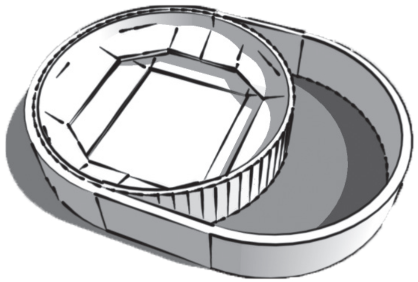
arena mode

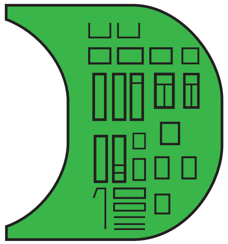




The main arena is used for a variety of inddor sports such as basketball, tennis, gymnastics and different music event. With the moving block contracted it creates a more intimate atmoshpere and strong unity between audience and performers on the stage. Depending on event type and seating layout capacity ranges between 12,500 to 22,500 people.

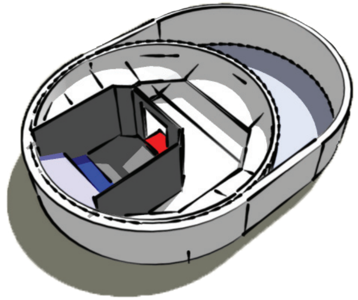
community area

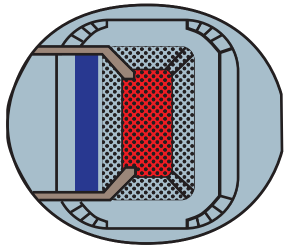




When the venue is put in arena mode it creates an 'unused' space outside. This area is greatly lit up by daylight and with a floor area of more than 7,000m^2 it can be used for exhibitions, fairs etc. It has a seating capacity of 3,000 and can host minor sporting events, concerts or in conjunction with the main area as warm-up area during tournaments.

concert mode



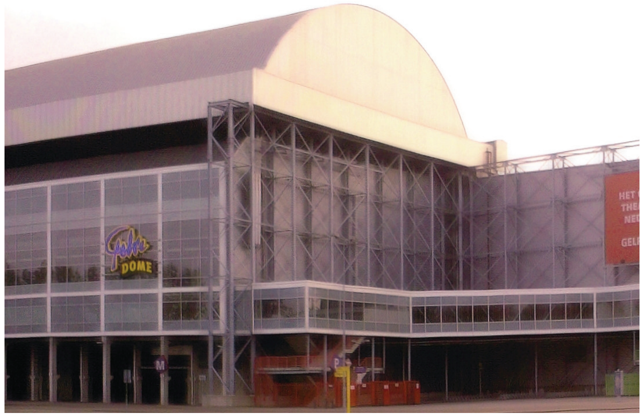


If special acoustics or ekstra intimacy are required for concerts, the main arena can be transformed optimized by lowerable curtains and wall-elements. Capacity will be around 6,000 i this mode.

Feature - sliding grass pitch

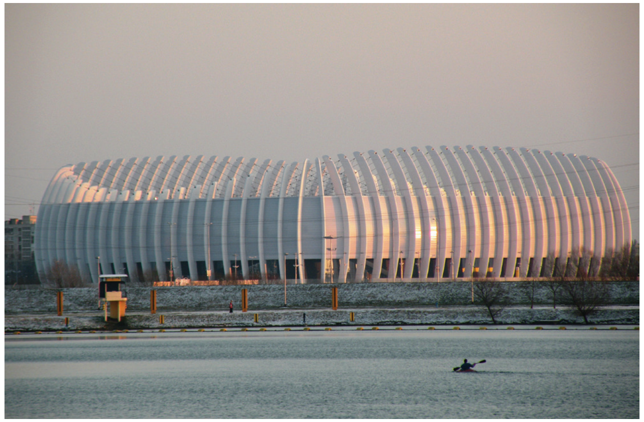
GelreDome, Vitesse Arnhem stadium

The Gelredome represents a fresh approach to making a multi-use arena. On the surface it looks like any modern football stadium, but it has functions that enable it to do much more.
As a football stadium it is one of the most modern in the Netherlands and was a venue of the Euro 2000 tournament. With a relatively modest capacity of 22,000 spectators it is not large enough to be a UEFA World Cup which requires a minimum of 44,000 seats. However, the Gelredome has two tricks that makes up for its size and enables it to be host of a variety of other functions. Firstly it has a retractable roof and climate control which enables it to be used as a large indoor venue. This does however present some problems with the grass, which is solved by the second feature of the Gelredome. The grass pitch is planted in a box which in turn is mounted on rails. This system enables the grass pitch to be rolled out into the parking lot of the facility. Now the Gelredome is transformed from a modern open-air football arena to a grand indoor arena suitable for large concerts and festivals. A positive by-product is that the grass pitch gets time to breathe and recover when placed outside.



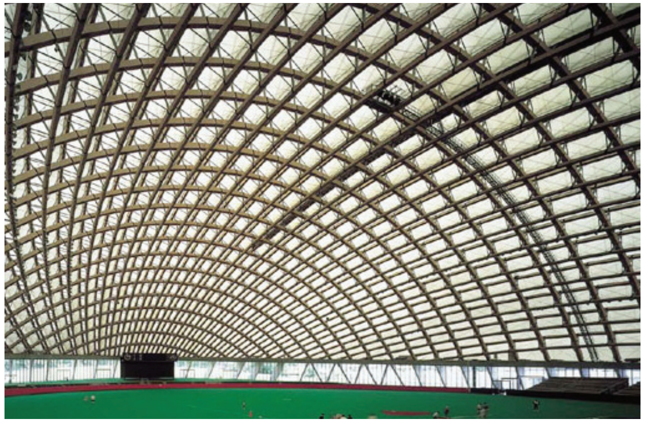
The arena as a piece of architecture

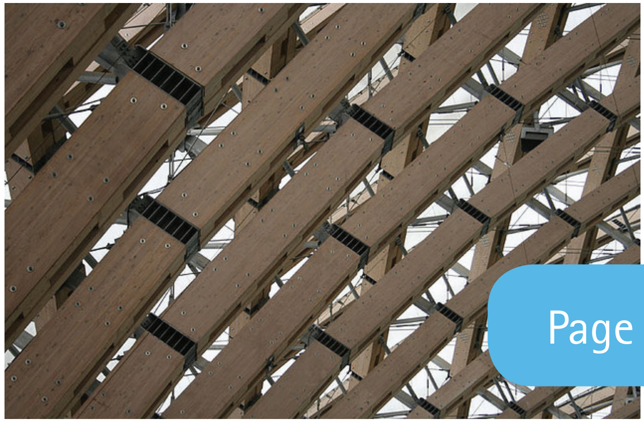
In the introduction it is mentioned how the stadium is a building typology with ancient roots. These roots are connected to the fact that the bowl shape of the stadium is the natural formation formed by a crowd around a spectacle, the next natural evolution was to utilize natural formations, and finally to build a bowl from scratch.
A classic example of stadium architecture is the iconic Coliseum in Rome, an ancient building which even today holds relevance as a prototype for stadia as even today, not just because it still is impressive, but also because it encompasses many of the traits of modern day stadia.
The Coliseum has a capacity of 50000 spectators; an elliptical arena in the centre surrounded by steeply rising spectator rows and is as such a classic bowl. The Coliseum has aesthetic qualities expressed via symmetric a design and a repetition of elements with a slight variance as the building rises. This simplicity makes it easy to appreciate because it is easy to understand as a machine for entertainment, but also as a tectonic composition that clearly demonstrates its systems. This legibility is something that sets the good designs apart from the bad even today. Also as a contemporary parallel, the iconic expression and constructive transparency of the Coliseum cannot outweigh the inward focus of the design which means the life of the building is invisible to the surroundings – another common trait among modern stadia.
The Coliseum demonstrates that it is s challenging task for any architect to design a sports facility of scale. It is primarily a machine for entertainment, which need to be well functioning in its basic fields. This requires simplicity. At the same time, there are a number of design elements that are desirable from an aesthetic as well as sensory point of view, these needs to be incorporated with the functions as an enhancement. Integrated design elements and simplicity are key points, as recognized by famed philosopher Johann Goethe:
"Such an amphitheatre is actually made in order to impress the folk with itself... The general need to satisfy is the task of the architect here. He prepares such a crater through art, as simple as possible, so that its embellishment becomes the folk itself."
Goethe – Italian diary
In summary, a stadium is in essence a machine for entertainment and its beauty will come from great functionality, integrated construction and intelligent use of materials.

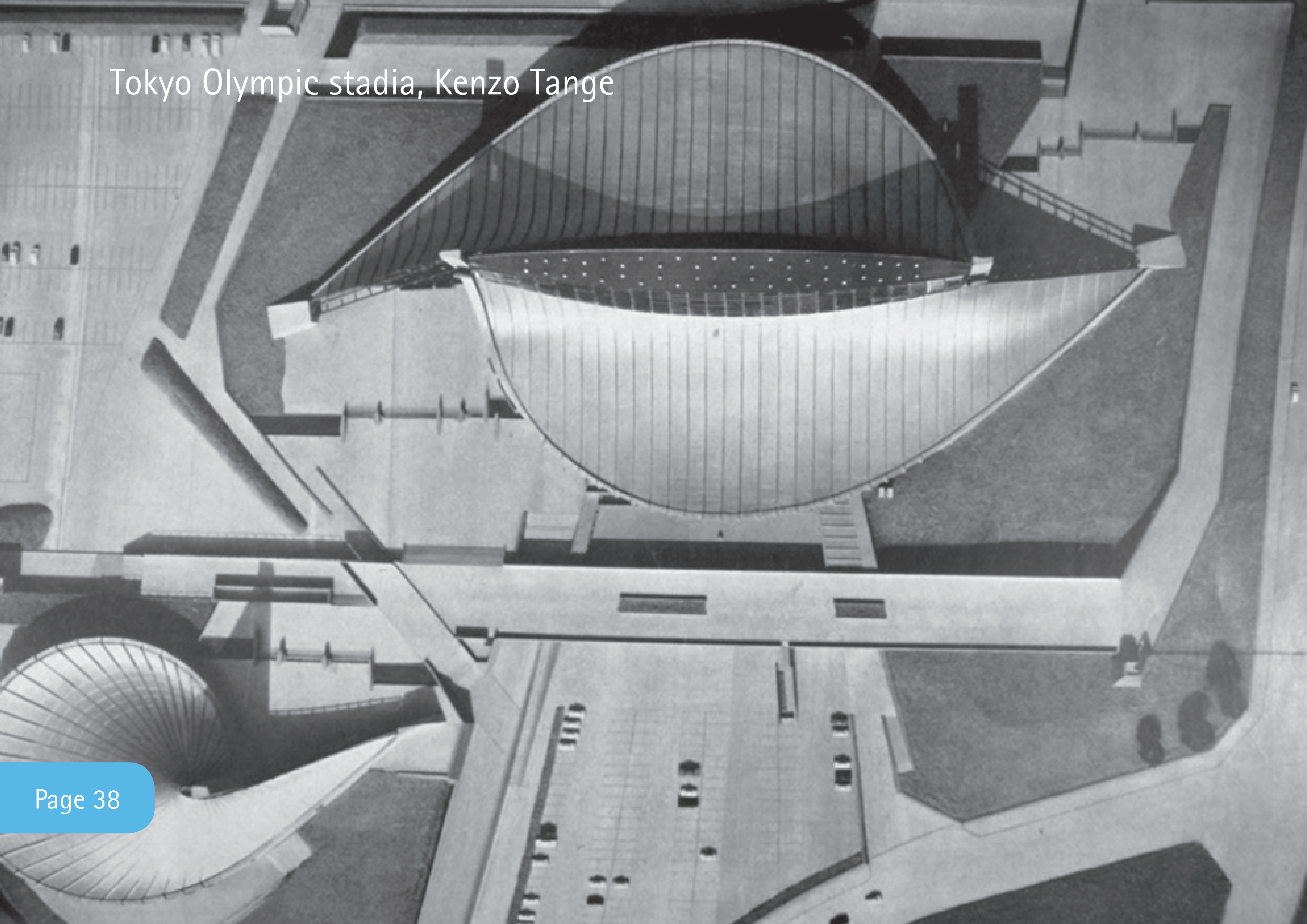


Odate Jukai Dome, by Toyo Ito

In 1997 the city of Odate in the northern part of Akita, Japan, erected a marvelous indoor arena designed by Toyo Ito. The city is situated in a mountainous area with heavy snowfall almost half of the year. The dome was built for local so they could play primarily baseball and football during the winter period.
The dome should be able to withstand severe weather conditions with heavy snowfall and harsh winds. For the structural system local cedar timber was used to build a phenomenal laminated timber structure, which can endure 1,5 meters of snow and high wind loads. The trusses span impressive 180 meters; the largest ever build in wood.
The ovoid shape of the dome was determined by the projected arch of a baseball in flight and to reduce impact of the persistent strong wind loads experienced in the area.
The wooden truss assembly is connected to a concrete tension ring in the bottom and is resting on big concrete pillars to elevate the dome roof of the ground to provide unhindered view of the indoor environment from the outside.
The curvature of the roofing is made to prevent whirlwinds during snowstorms, and is covered with double layered Teflon film which lets in natural daylight during the day. After dusk the building glows when lit inside. [Ito]







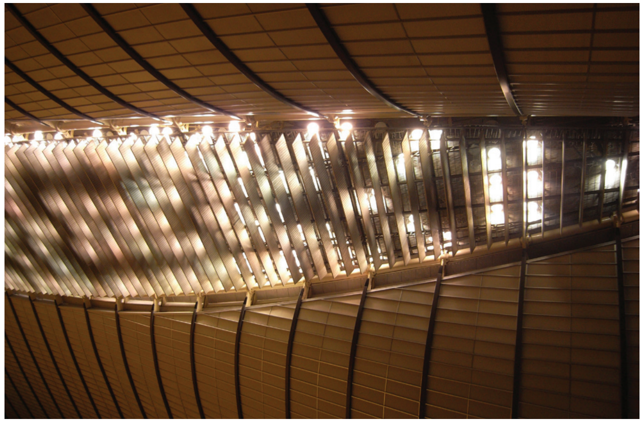
Tokyo Olympic stadia, Kenzo Tange

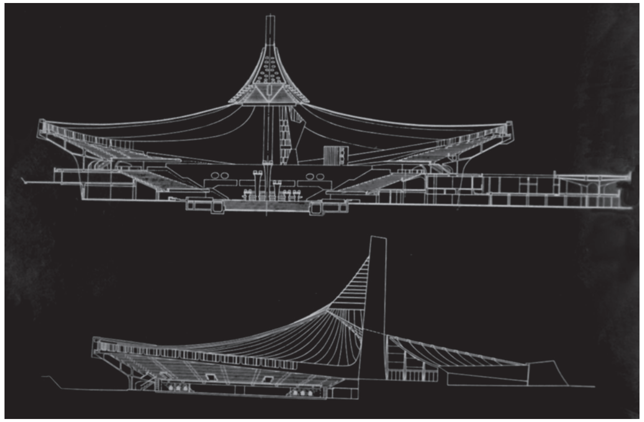
In the first half of the 60'ies Kenzo Tange designed a sports arena, a design that was later to be considered amongst his finest work.

This piece of architecture has been described as a structural expressionist design, which in some part is due to it being built of steel and concrete. Today the building is still every bit as enticing and dynamic to behold as it was upon its construction half a century ago. The unique roofline is a consequence of a design that attempts aid the building to cope with the high winds that are common for the region.

The Yoyogi National stadium was built for the summer Olympics in 1964 and for that reason it was desirable for it to be able to house more than one sports discipline at once – this is solved by designing the stadium as a duoplex with one main hall for swimming and diving and a smaller hall for boxing and volleyball. It has a total capacity of 13,000 spectators – a decent size considering it is already a half decade old.

The characteristic design was inspiration to Frei Otto's design for the 1972 Olympic complex in Munich.



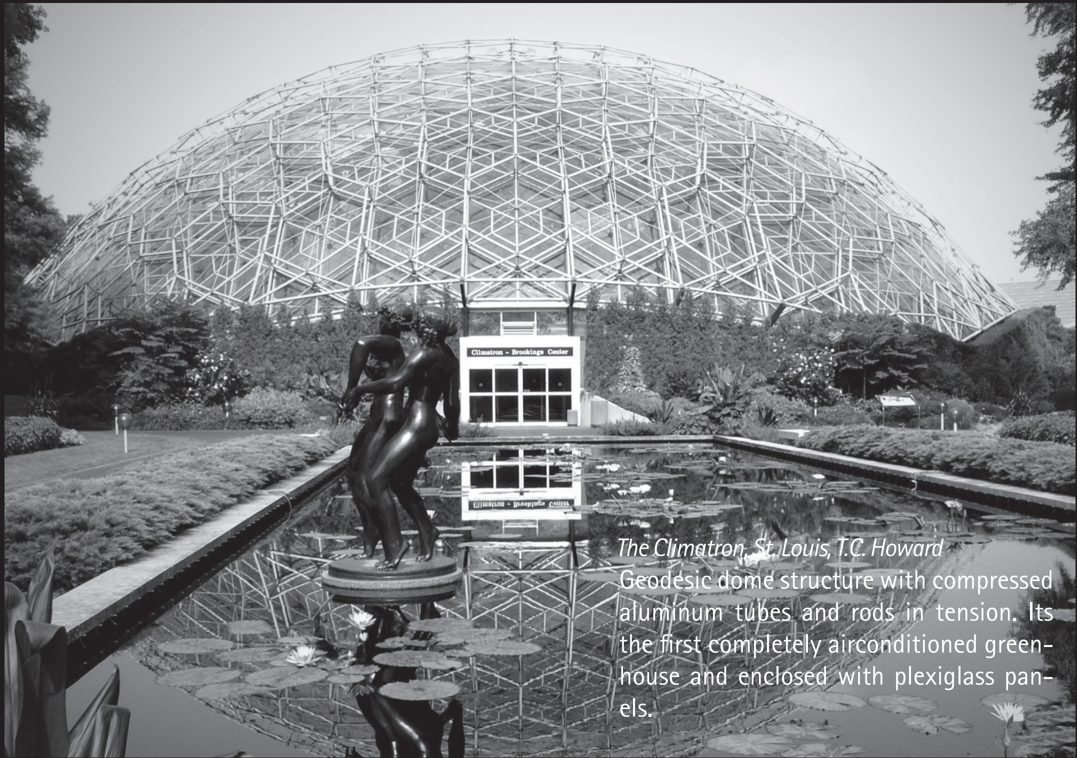


Form & structure

In certain time periods and in certain architectural styles, construction has been a means to achieve a goal instead of an integrated part of the design.
On the following pages we present a small collection of works that integrate constructive elements and techniques to create high quality architecture . These will serve as inspirational elements in the sketching phase.

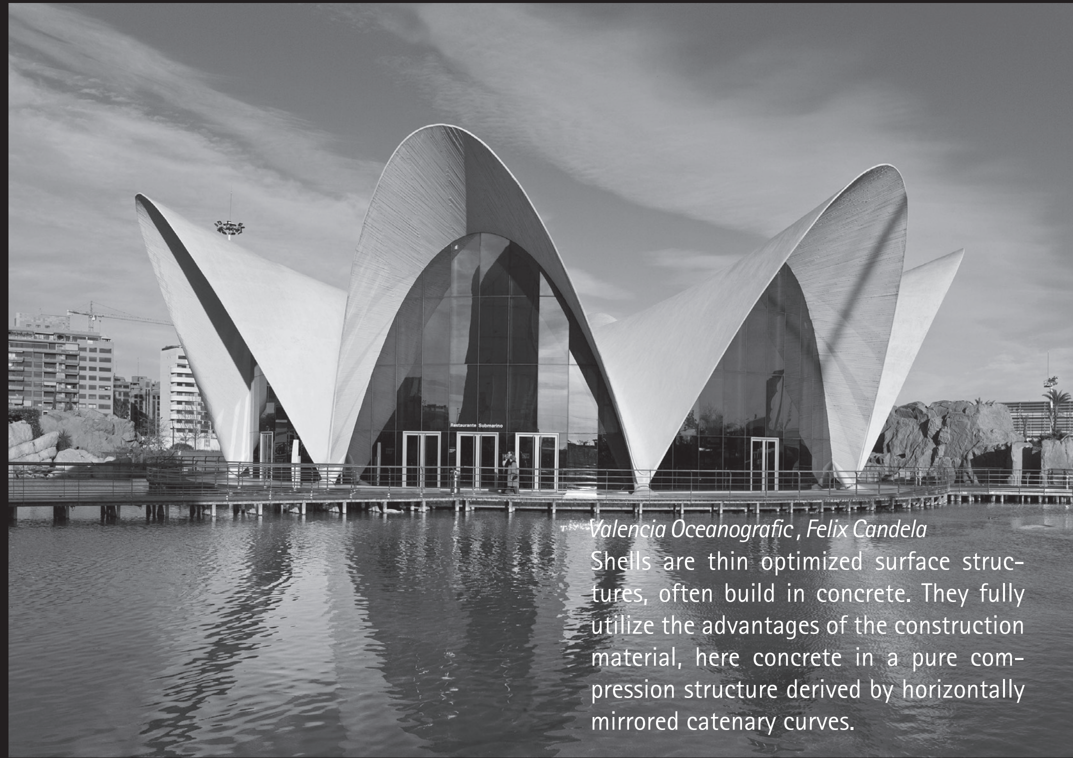
Millenium Dome, London, Richard Rogers.

The Millenium Dome in London is hybrid construction being part cable net and part membrane structure with a surface in pure tension. Membrane parts find its optimal shape purely from the elasticity of the fabric, while cable net part is regulated by a number of nodes to define form & structure of the building.



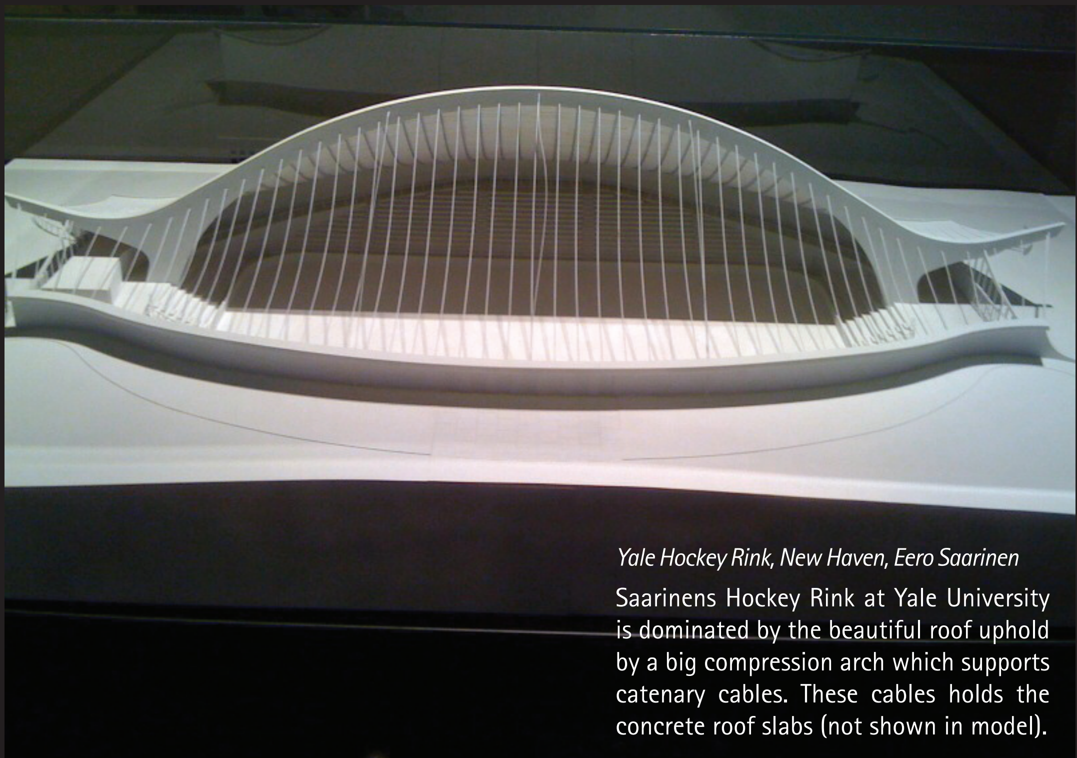
The Climatron, St. Louis, T.C. Howard

Geodesic dome structure with compressed aluminum tubes and rods in tension. Its the first completely airconditioned greenhouse and enclosed with plexiglass panels.



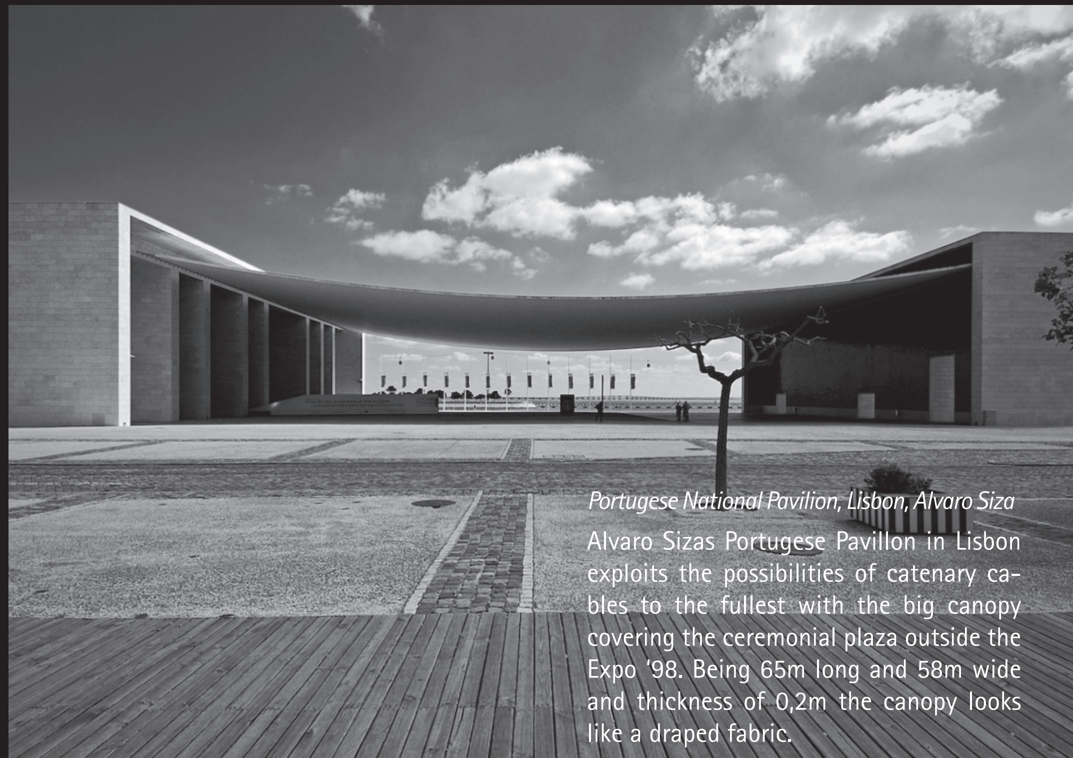
Valencia Oceanografic , Felix Candela

Shells are thin optimized surface structures, often build in concrete. They fully utilize the advantages of the construction material, here concrete in a pure compression structure derived by horizontally mirrored catenary curves.



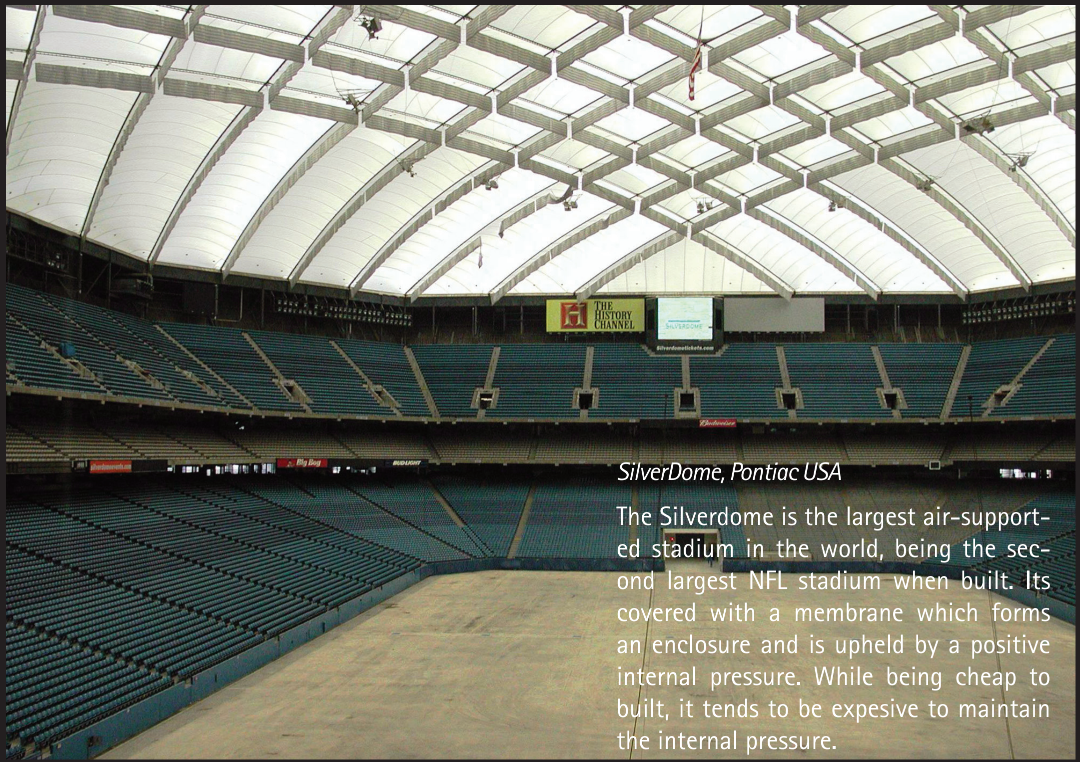
Yale Hockey Rink, New Haven, Eero Saarinen

Saarinens Hockey Rink at Yale University is dominated by the beautiful roof uphold by a big compression arch which supports catenary cables. These cables holds the concrete roof slabs (not shown in model).



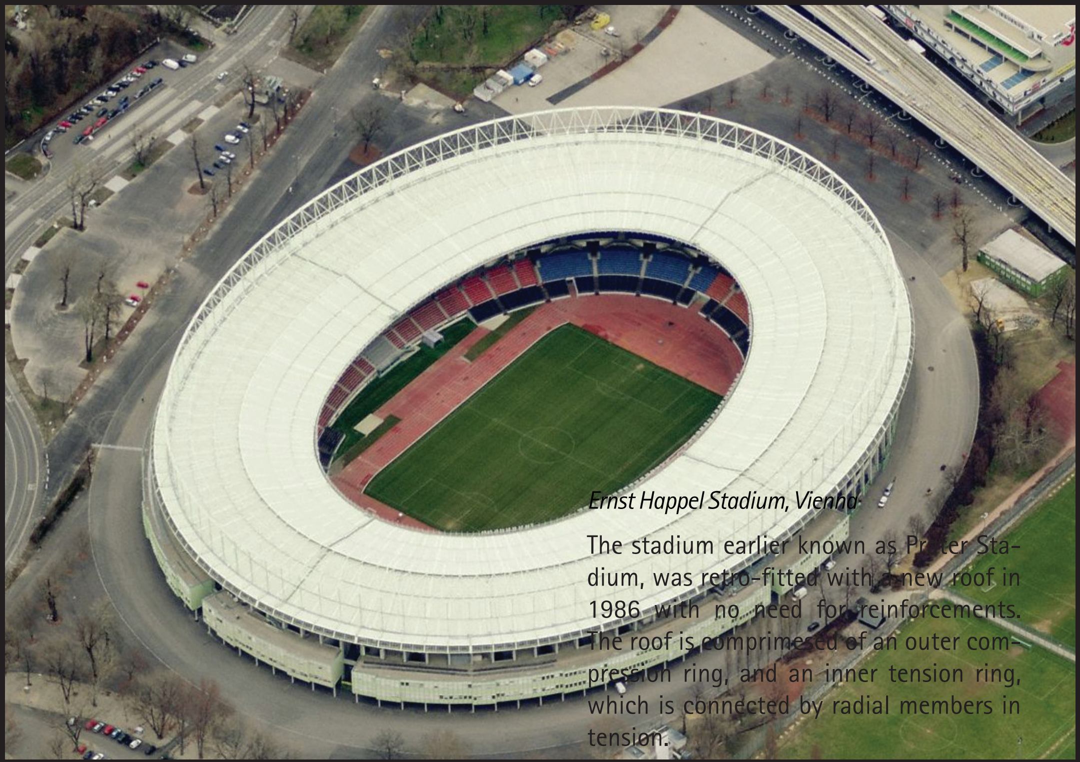
Portugese National Pavilion, Lisbon, Alvaro Siza

Alvaro Sizas Portugese Pavillon in Lisbon exploits the possibilities of catenary cables to the fullest with the big canopy covering the ceremonial plaza outside the Expo '98. Being 65m long and 58m wide and thickness of 0,2m the canopy looks like a draped fabric.



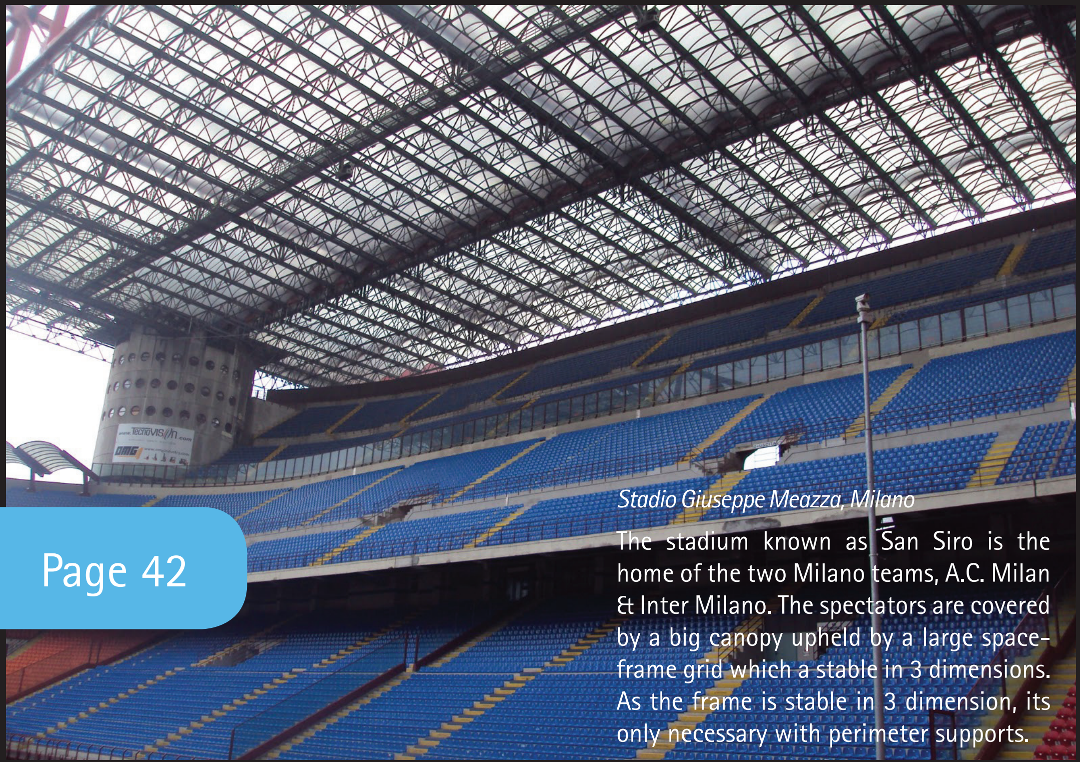
SilverDome, Pontiac USA

The Silverdome is the largest air-supported stadium in the world, being the second largest NFL stadium when built. Its covered with a membrane which forms an enclosure and is upheld by a positive internal pressure. While being cheap to built, it tends to be expesive to maintain the internal pressure.



Ernst Happel Stadium, Vienna

The stadium earlier known as Prater Stadium, was retro-fitted with a new roof in 1986 with no need for reinforcements. The roof is comprimesed of an outer compression ring, and an inner tension ring, which is connected by radial members in tension.



Stadio Giuseppe Meazza, Milano

The stadium known as San Siro is the home of the two Milano teams, A.C. Milan & Inter Milano. The spectators are covered by a big canopy upheld by a large spaceframe grid which a stable in 3 dimensions. As the frame is stable in 3 dimension, its only necessary with perimeter supports.

Olympic Staium, Munich, G. Behnisch & Frei Otto

The Olympic stadium from 1972, features an extrodinary roof which is carried by a net of steel cables. These cables supports the transparent acrylic panels. The design with rigid steel net, required the cables to be highly pre-tensioned and thus extra strong masts and anchoring was needed.

Planetario, Valencia, Santiago Calatrava

The planetarium was built in 1998 and is another example of Calatravas unique blend of structure and architure. It consists of steel arcs spanning approx. 90 meters. The glass sides can be moved up with hydraulics to cool the building on hot days.

Allianz Arena, Munich by Herzog & de Meuron

In July 2000 Germany was chosen to host the 2006 World Cup in football. As a part of that, the city of Munich was to host a number of matches during the World Cup. However, no stadia in Munich could live up to FIFA standards, which meant that either the old Olympic stadium had to be rebuilt, or a new stadium had to be constructed. In the decade leading up to Germany winning the hosting of the World Cup, the major football teams in Munich did well, and as a result of this, the fans wanted larger, better stadia. In the following public debate, the city of Munich denied the wishes of the fans, until Bayern Munich & TSV 1860 formed an alliance to better promote the idea. In late 2001 the alliance was successful in reaching an agreement to construct a new stadium. [AA1]

The following architectural competition was won in early 2002 by Swiss Architects Herzog & De Meuron. Their proposal features a large shared stadium for Bayern Munich & TSV 1860 with a capacity of 70000 and one of the most modern designs in Europe. [AA1]

The design is host to a number of innovative features, but one of these features has become the trademark of the design – the unique skin of the building. The skin consists of large rhomboidal inflatable EFTET foil panels covering the facades and roof. The panels on facades can be illuminated in three different colours: red, blue and white. The colours are used to signal which team is currently playing and is easily identifiable from large distances. [AA3]

In case of snow build-up, pressure monitoring sensors ensure that the foil elements have the correct pressure in a given situation. This system allows the panels to carry as much as 1.6 metres of snow. The EFTE foil is non-flammable, heat resistant and self-cleans when it rains. [AA2] [JSV]

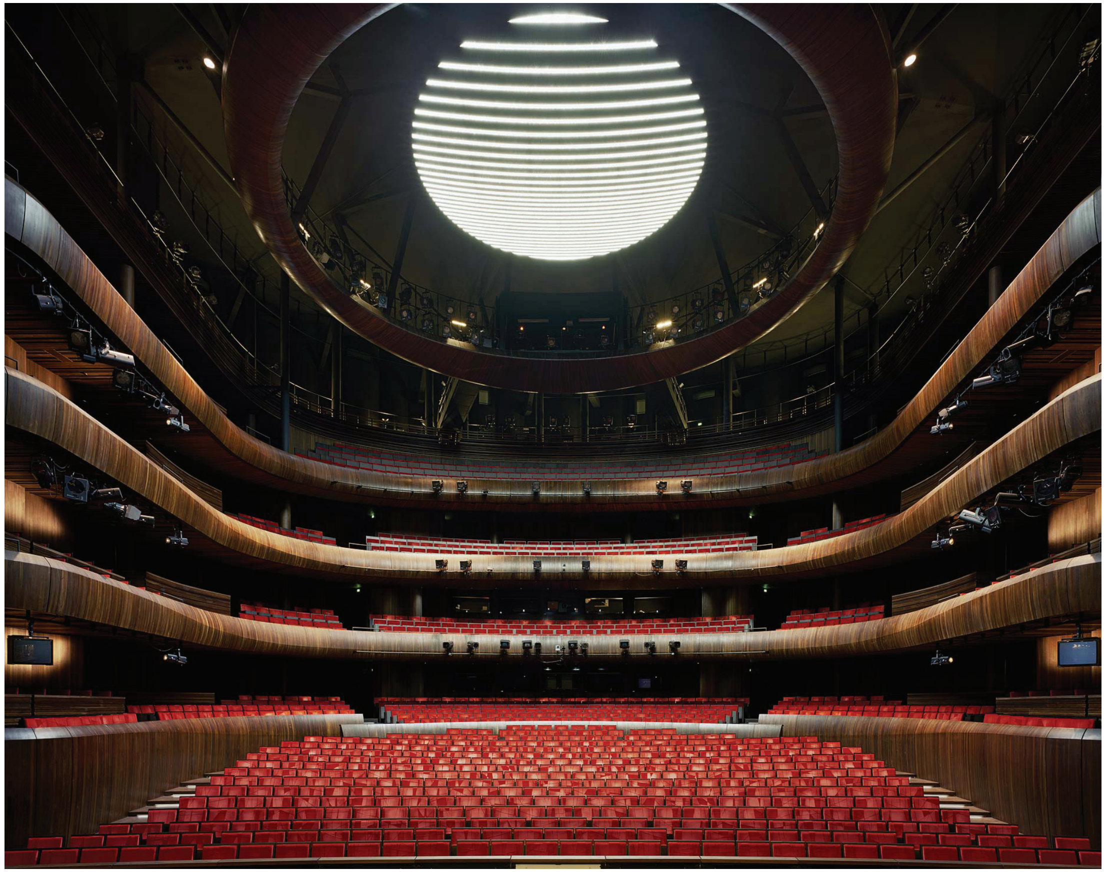
Acoustics, tectonics and light

In many designs, only one or two of the mentioned parameters are thoroughly used – the latter often ends up as an afterthought of sorts, something that is added to the design rather than integrated.
In this section we use case studies to investigate how other buildings have combined acoustics with daylight control and tectonic elements.
The selected buildings are an example of Buckminster Fuller's geodesic domes, Jørn Utzon's famous church in Bagsværd and the Oslo Operahouse. Each of them represent examples of compromises made in order to optimize the buildings characteristics to its intended use. The result of these compromises we can use as a guideline to make a decision as to which type of structure best suits the uses of our design.

Oslo Opera House

An opera hall is an architectural machine that is tuned for high quality acoustic performances. But as with purpose-built designs, it also contains a series of compromises necessary to achieve the desired level of performance.
As mentioned, being a concert hall, all the elements are in place in order to provide high quality acoustic performance for music and speech. The shape of the room is tailored for sound and the same applies to the furnishings.
As the room is designed for great acoustical performances, it is also designed as a theatrhe which means that all natural light is eliminated in order to have complete control of the lighting of the room through electrical light.
Tectonically the opera house does not have much to offer apart from the pureness of its function, and how that is clearly expressed in the design of the rooms.

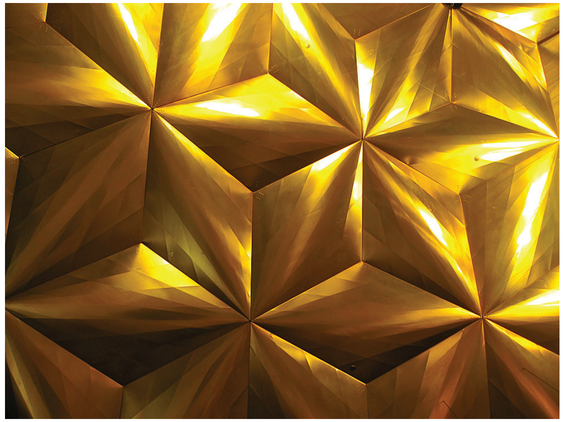
	Best				Worst
Acoustic	■				
Tectonic				■	
Light					■



Citizens State Bank, Oklahoma City

Many stadia are of the dome type, but few banks are built as domes. Exception to the rule is Citizens State Bank, Oklahoma by Buckminster Fuller – or just the Gold Dome as it is known as today.
Domes are notorious for their poor acoustic capabilities which can be attributed to their parabolic cross-section. The concave shape means that the sound will be focused in one or more spots – known as 'hot spots'. Buckminster Fuller's design however is not a smooth dome, but a geodesic dome – a dome divided into areas which makes the form less uniform – and thus has better inherent capabilities. Furthermore each area in the dome of Fullers geodesic dome is convex which should further improve acoustic performance.
In terms of daylight performance the dome is an interesting design as it is very two-sided. In this specific case where the building is situated in very warm climate, Buckminster Fuller chose a opaque material which prevents solar gain, but also prevents daylight through the roof structure. On the other hand, there are examples of domes who use translucent materials which allow soft diffuse light into the room below.
Tectonically the dome roof itself is an impressive tectonic entity, using geometry to enable wide spans with a minimum of material usage. Along with other pioneers, Buckminster fuller perfected a shape which have enabled larger buildings and longer spans than ever before.

	Best				Worst
Acoustic				■	
Tectonic	■				
Light			■		



Bagsværd Church

Although not as famous as the Opera house, the church in Bagsværd just north of Copenhagen is among the most famous of his works. The uniqueness of this building has its origins in the architect's thorough knowledge of acoustics and light. The centerpiece of the design is the roof of the main room. The roof is cast in concrete and undulates in the full length of the room and by doing so creates a series of convex surfaces which help disperse and reflect sound throughout the room. In this way, the entire roof is an acoustic element.
Utzon, known as a master of light shows his strength in this room, allowing light to enter through the top of the roofs curvature bouncing off the white concrete – the users of the church hereby experience a only second and third bounce light – giving the room a light and airy feel – allowing the users to sense Utzons vision of streaming clouds across the sky just overhead.

Tectonically the roof is impressive with its curves, but requires straight walls to transfer its weight to the ground.

	Best				Worst
Acoustic		■			
Tectonic				■	
Light		■			

Summing up

In any design, the designers often sit with the problem of having to incorporate a series of features into a design where these features pull the design in different directions. The art of design and engineering is to make educated compromises to ensure the best possible result. A multi-purpose hall must encompass a host of different functions, and therefore more compromises must be made. The quality of these compromises has a profound influence of the quality of the design.
Summing up this small case study, we make a series of part-conclusions on each of the cases – reflecting on the pros and cons, and evaluating which lessons there are to be learnt from each case.
The Opera house is the most extreme of our candidates which is reflected in the purity of its functions. It can hardly be said to be tectonic and daylight is consciously deselected. It is all about the inside, all about focusing on the show, all about the experience. It is from the interior of the opera hall we can find inspiration to further investigate. The inside of the room is beautifully crafted to give a strong ambience and optimum viewing conditions for all.
The Gold dome is an unusual case in that most domes have poor acoustic properties, but the design of Buckminster Fuller with an internal convex covering should improve acoustic performance. Also domes as sports arenas are popular in power of their unusual acoustics – the loudness gives intensity to the atmosphere.
Tectonically it is extraordinary and in regards to light it also has some interesting properties. From this case we can gather that this variant of the dome encompasses many of the features that we wish to incorporate. It is great tectonically, has interesting light properties and the acoustic properties are not all bad. We need to further investigate the acoustical properties of the Buckminster Fuller's roof design, and if introducing translucent materials to the roof will cause glare.
The famous Bagsværd Church has many merits, but is interesting as churches often are multi-purpose facilities – for example the acoustics must tuned to both speech, music and the long reverberation required by the church organ. The church roof is both an acoustic element and a tectonic centerpiece that also plays a part in filtering the light. From the church we learn a number of important lessons; it shows ways of letting in light without glare and how a series of convex shapes can benefit sound quality.
So, to sum up: From the Opera hall we can learn from the shape of interior and seatings, the church shows how convex shapes can help define light and acoustics while the dome shows how geometry can bridge a large span while letting in light.

Ventilation

Natural ventilation
An integrated system utilizing the concept of natural & controlled ventilation providing a healthy alternative to air conditioning systems in modern buildings. The design of natural ventilated building emphasizes the advantage of renewable resources through wind power, thermal buoyancy through passive solar gains. The benefits is a reduction in carbon emissions and a reduction in running costs allow designers the opportunity to develop more environmentally friendly buildings

Mechanical ventilation
Often natural ventilation would proof insufficient or

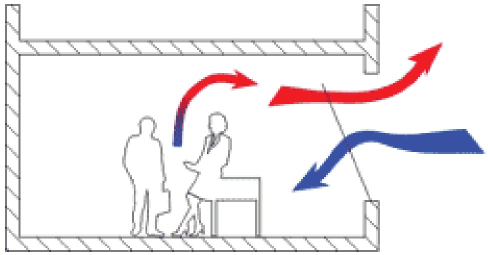
With the dilution ventilation, also known as mixed ventilation, where air is blown into the room with a temperature higher or lower than the current temperature of the room in order to heat or cool the room. The velocity with which the air is pushed into the room is high in order to mix the air in the room. Inlets are often placed close to the ceiling so the cold air will be mixed with the hot air to avoid exposing people with draught in the room. This type of ventilation is best used for smaller rooms or rooms with a low ceiling height.

Another room air distribution strategy is displacement ventilation where (mostly cold) air is supplied at floor level or as close as possible to cover the floor area. When cold air meets heat sources, people etc., it will rise from the floor because of now lower air density and move heat and contaminated air upwards. This is great for large high spaces, such as indoor arenas, moving the heat and contamination away from the occupants towards the roof.

Hybrid ventilation

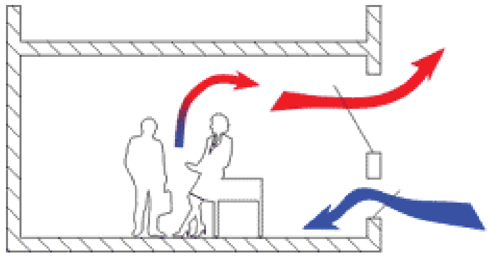
Natural ventilation

Single sided ventilation is for rooms with windows on one side only. Cold air will stream in, and warm air will

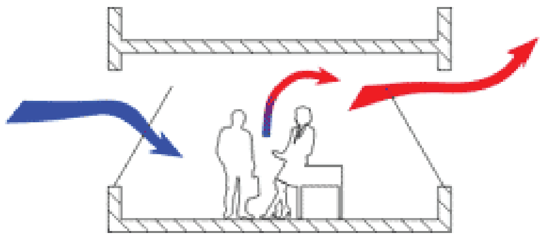


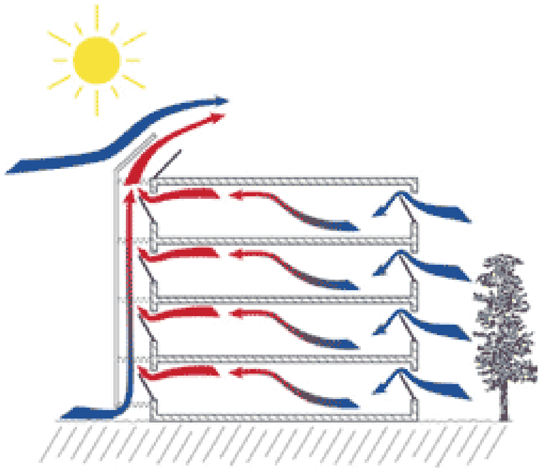
stream out again through the same window. This kind of ventilation is normal and generally practiced, but it is only useful up to a certain room depth.

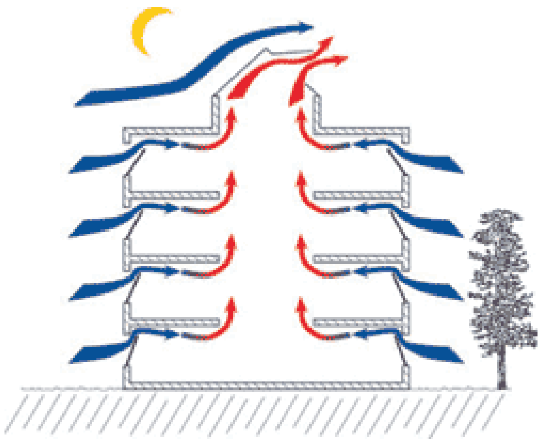
Single sided double openings, an advancement of the single sided principle provides a double opening, which is considerably more efficient.



In the case of cross-ventilation, (windows open on both sides of the room/building) the pressure difference is between the side of the building facing the wind and the away from the wind. The positive pressure on the windward and/or a vacuum effect on the lee side of the building cause air movement through the building from the windward to the lee side.
In order to obtain the optimal airflow with mini-







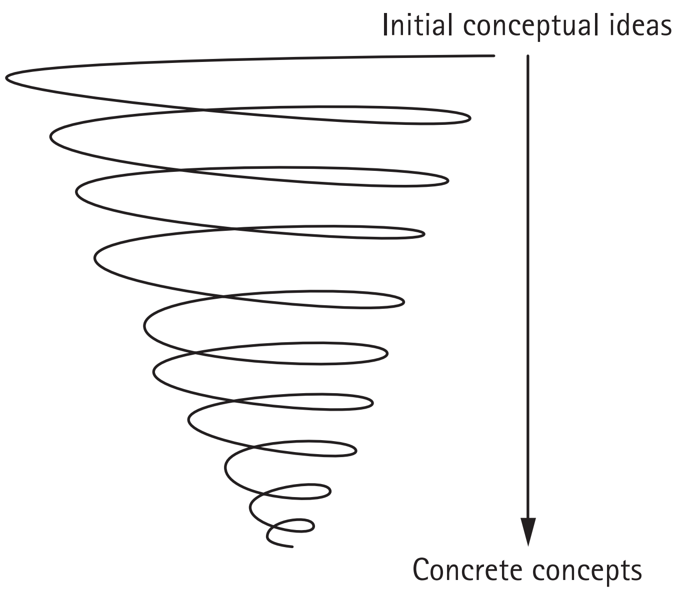
mal draught, the windows on the windward side are opened less than on the lee side.

Stack ventilation, in a similar way to smoke ventilation, the natural buoyancy of hot air is used to allow venting through high level vents. Replacement fresh air enters from the lower vents. An advancement of this system is via a double façade. This works on the principle as above (utilizing both cross and stack ventilation) but also offers an ideal solution when the building is adjacent to roads and areas of high acoustic emissions.

A variation to the stacked ventilation is the solar chimney where air is heated inside the chimney by direct solar gain, and thus thermal buoyancy is created to create an upwards airflow inside the chimney and suck air in from below to cool the building.

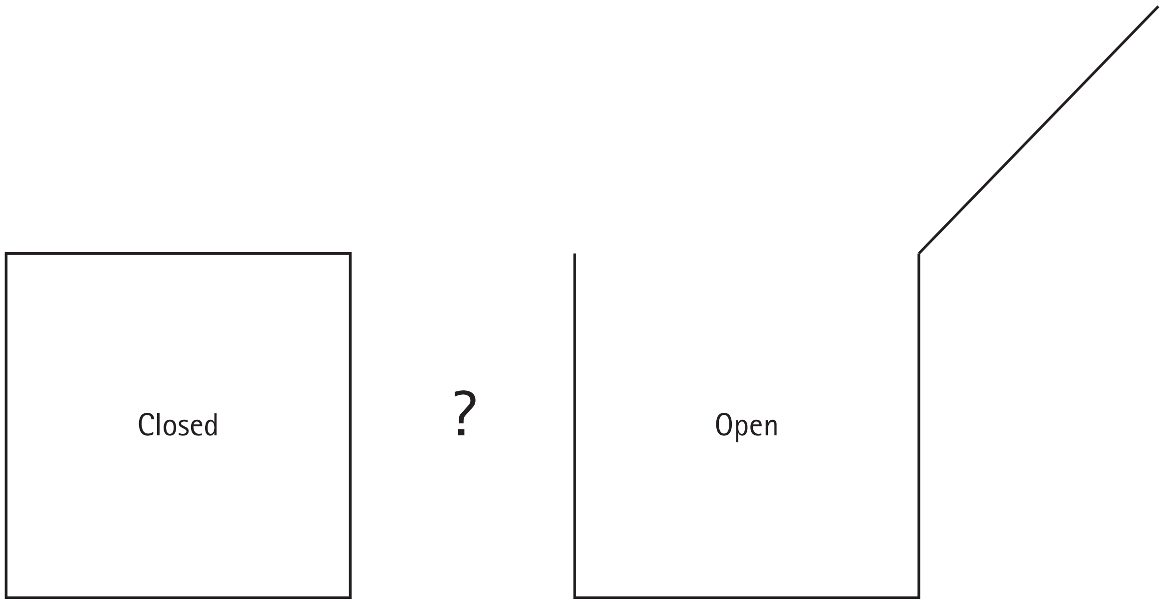
Sum up - distilling information

The main object of the analysis is to collect and process information that can help guide the project. In the beginning of the analysis, we are starting out with an open mind and a very general conception of how a multi-purpose hall could be designed. Moving forward we use the information of the analysis to focus our ideas for the following creative process.
Eventually the analysis process ends with a problem formulation that in short terms describes the task we wish to solve – but we also need to have some general outlines for the project so that we can create a room program. For that we need to decide crucial elements such as approximate size of the building, open or covered structure to name a few. These decisions are based on data collected and processed earlier in this chapter. These decisions can be seen as the final sum up of this chapter.



Sum up 2 - Open or closed type?

A big step in distilling information from the analysis, is to generate a framework that will guide us in the design process. In this chapter we will sum up on how environmental and business factors influence the typology and design of the sports arena.
Big or small - open or closed?
As mentioned in a previous segment about climate conditions of the site and Denmark in general, we saw that the weather conditions does not favor outdoor activities – it is not cold enough for winter sports, but not warm enough to enjoy all-year outdoor sports. For the same reason, some of the sports disciplines in which Denmark is a top competitor, are indoor predominantly indoor sports such as handball and badminton.
The dominance of indoor sports and the cold and windy characteristics of our site are indicators that our arena should be of the closed type.

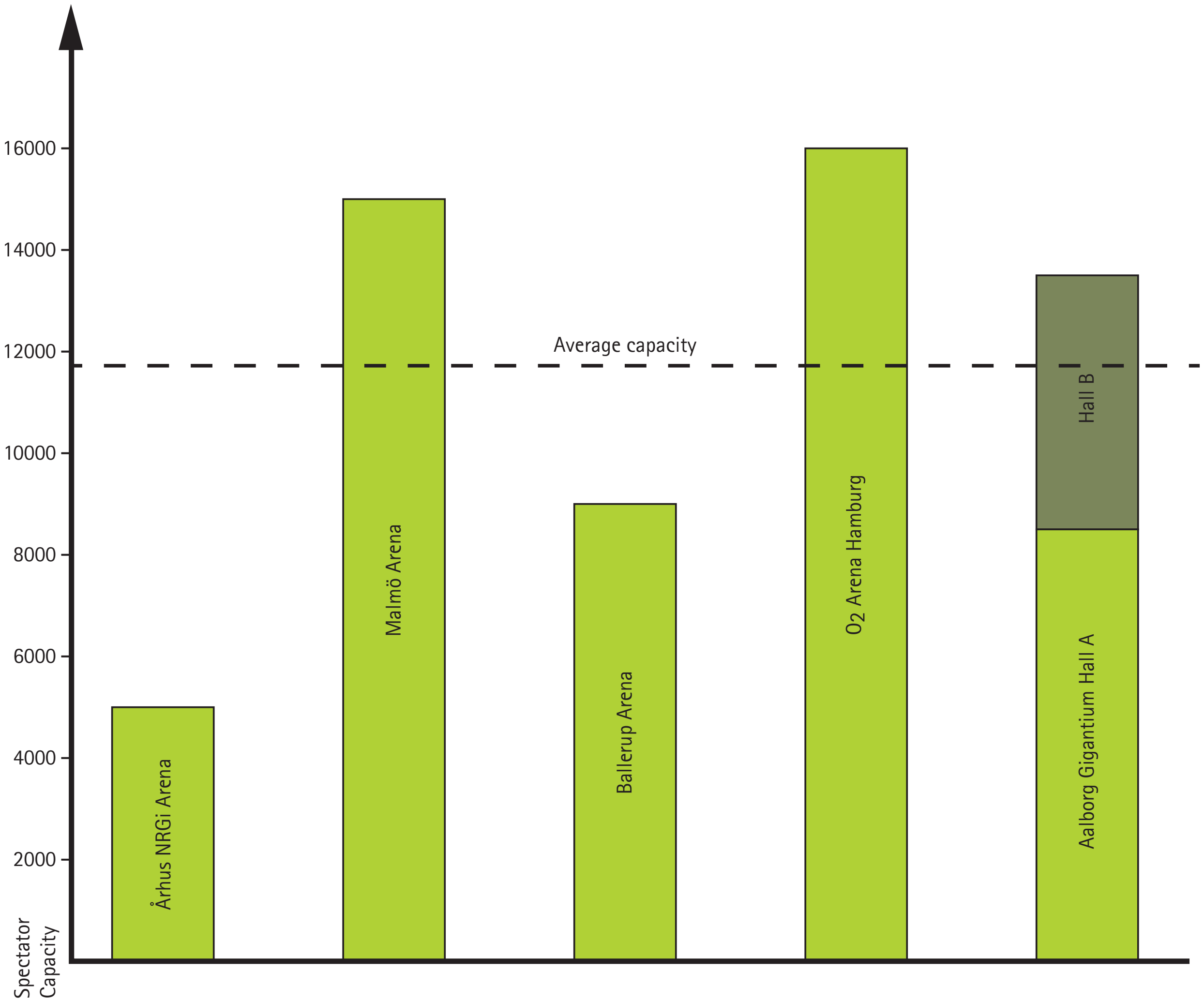


Sum up 3 - Sizes

The second important element in distilling information from the analysis is to decide a rough guideline of the size of the building. This inherently also means that we are making some general decisions about which activities can be performed inside, as size restrictions will rule some out.

Earlier in the analysis we indentified which multi-arenas existed within a radius of 300km. It also showed the maximum capacities of these arenas (in a concert configuration with standing spectators). In this graphic Parken is included mostly for comparison sake as it is almost exclusively a football stadium. If you look away from this stadia, the average capacity is around 11000 thousand.

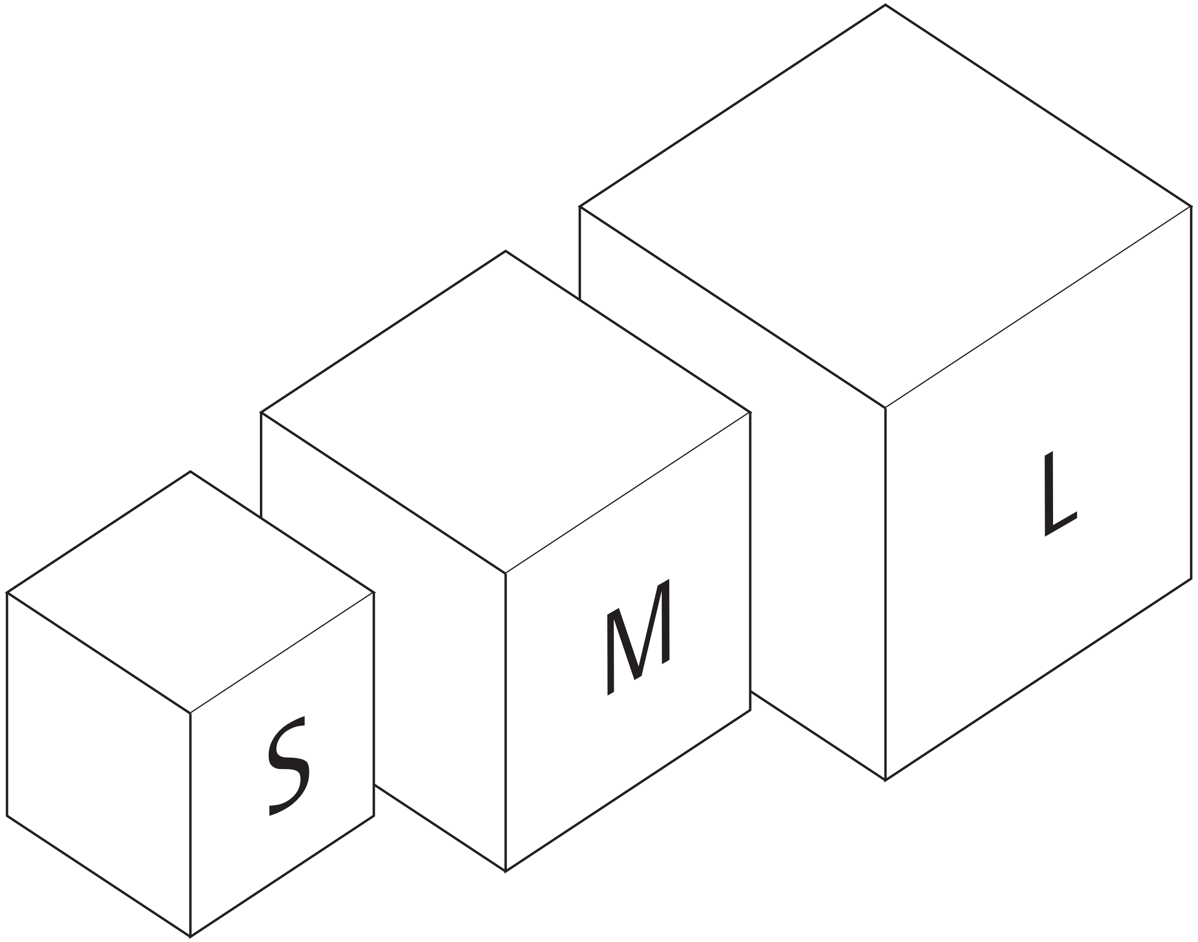
To ensure the relevance of the design, it is important that the facilities we design are also in demand. To ensure this we have researched which types of sports are searching for bigger, better facilities in the Copenhagen area. The prime candidate is the sports club AG København (AG Copenhagen) who has risen to the top of the mens handball league in record time. The owner



of the club, known in the public as "Kasi-Jesper", has officially spoken of his wishes to obtain better and bigger facilities. Currently they are playing at Ballerup arena which has a maximum capacity of 9000. Kasi Jesper has also mentioned that Malmö Arena (15000 spectators) is a good stadium within reasonable driving distance, but it is probably not relevant for major events such as national men's handball finals, as it is situated on foreign soil. On this basis it seems very realistic that an arena that can function as a handball stadium with around 15000 spectators would be attractive to clubs like AG København.
Also in the news, different sports federations have publicly stated that they would apply for hosting their respective world championship or other major tournaments if there existed facilities for them – preferably in the Copenhagen area. These sports are volleyball, tennis, icehockey, swimming and handball.

Finally this multi-purpose arena is not a novel idea for the city of Copenhagen. Actually both private and public groups have attempted to get a multi-purpose arena constructed in the Copenhagen area. Most recent the international event company AEG were in negotiations with the municipality for a indoor multi-purpose arena with a capacity of 15000 spectators. After the deal with AEG fell through, the municipality has attempted to attract investors for a new project. The capacity of this proposal is currently unknown.
The conclusion is that the stadium should be able to:

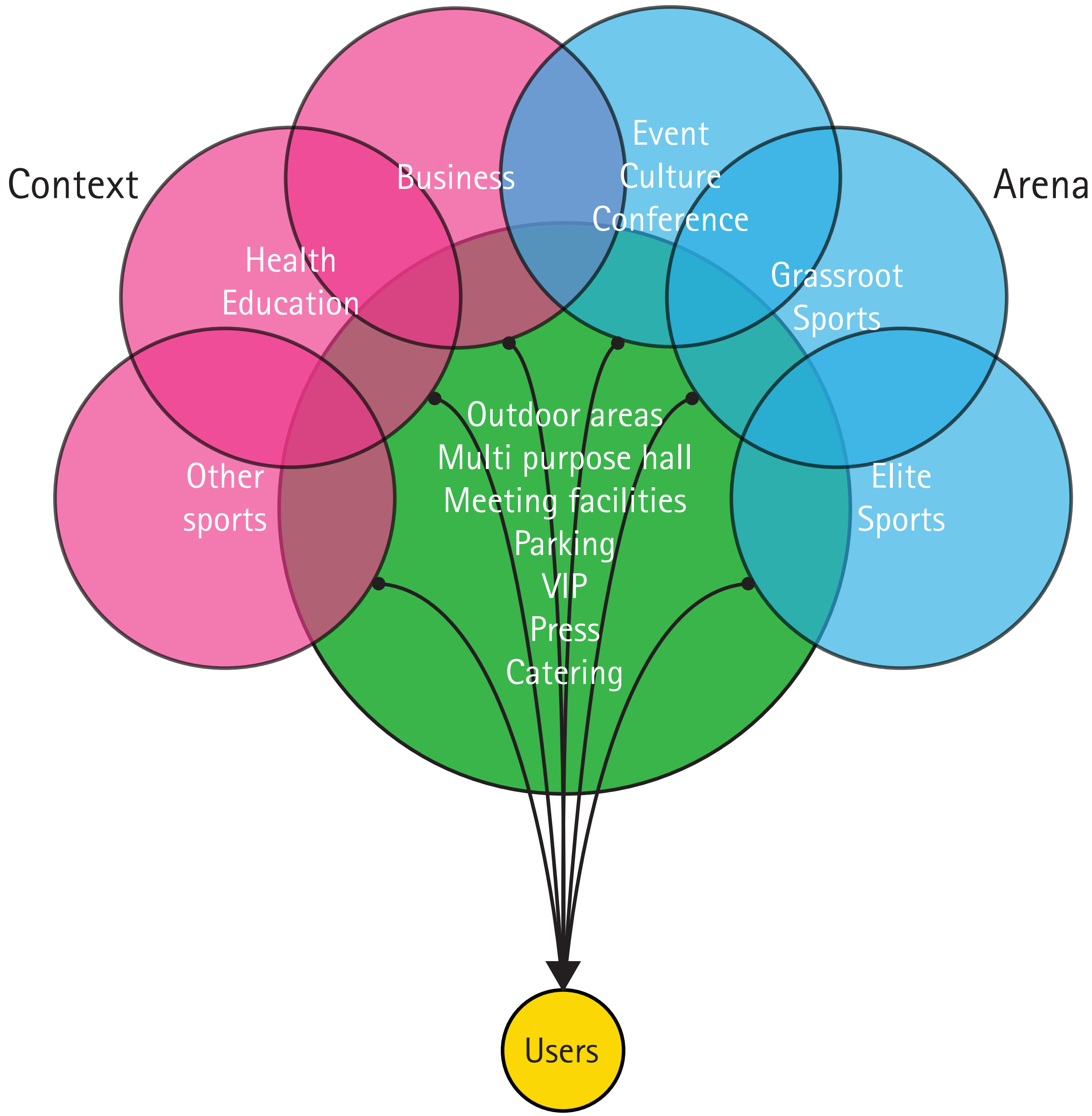
Have a capacity in the 15000 spectator range.
Be flexible to house a range of indoor sports such as handball, volleyball, basketball and also house a temporary ice skating rink or swimming pool.



Functions and users

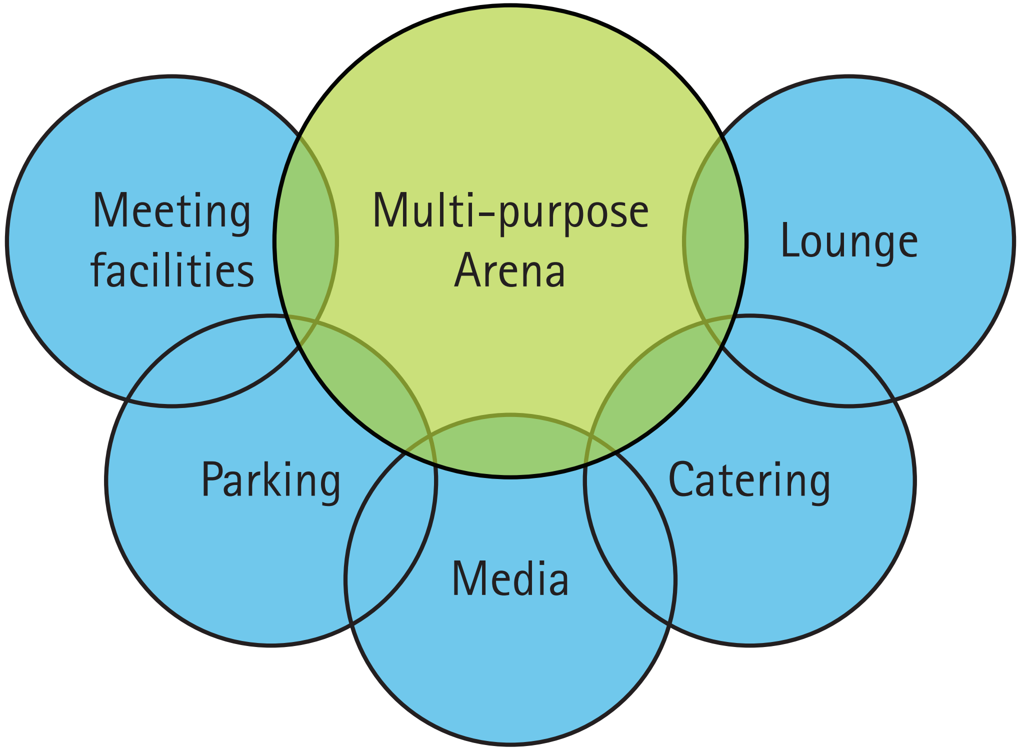
As we come closer to the end of this analytical chapter, we are beginning to see that the choice of building functions is a mix of different factors, some context related – others are design decisions.
It is a part of our vision for the area that we want a building that gives something to Ørestaden instead of taking something away – embodied by Field's shopping center whose internalized functions have proven to be an urban black hole. We want to activate not only the building, but also the surroundings as a means to breathe life back into Ørestaden.

Activating the area is not an exact science, but we aim to achieve this by offering activities that we believe are attractive for the surrounding area. Combining this by making this activies not only internalized by also externalized – either through transperancy or by physically having activies outside the building. Some of professional nature, but also some for and by the locals



Programming for dual-use

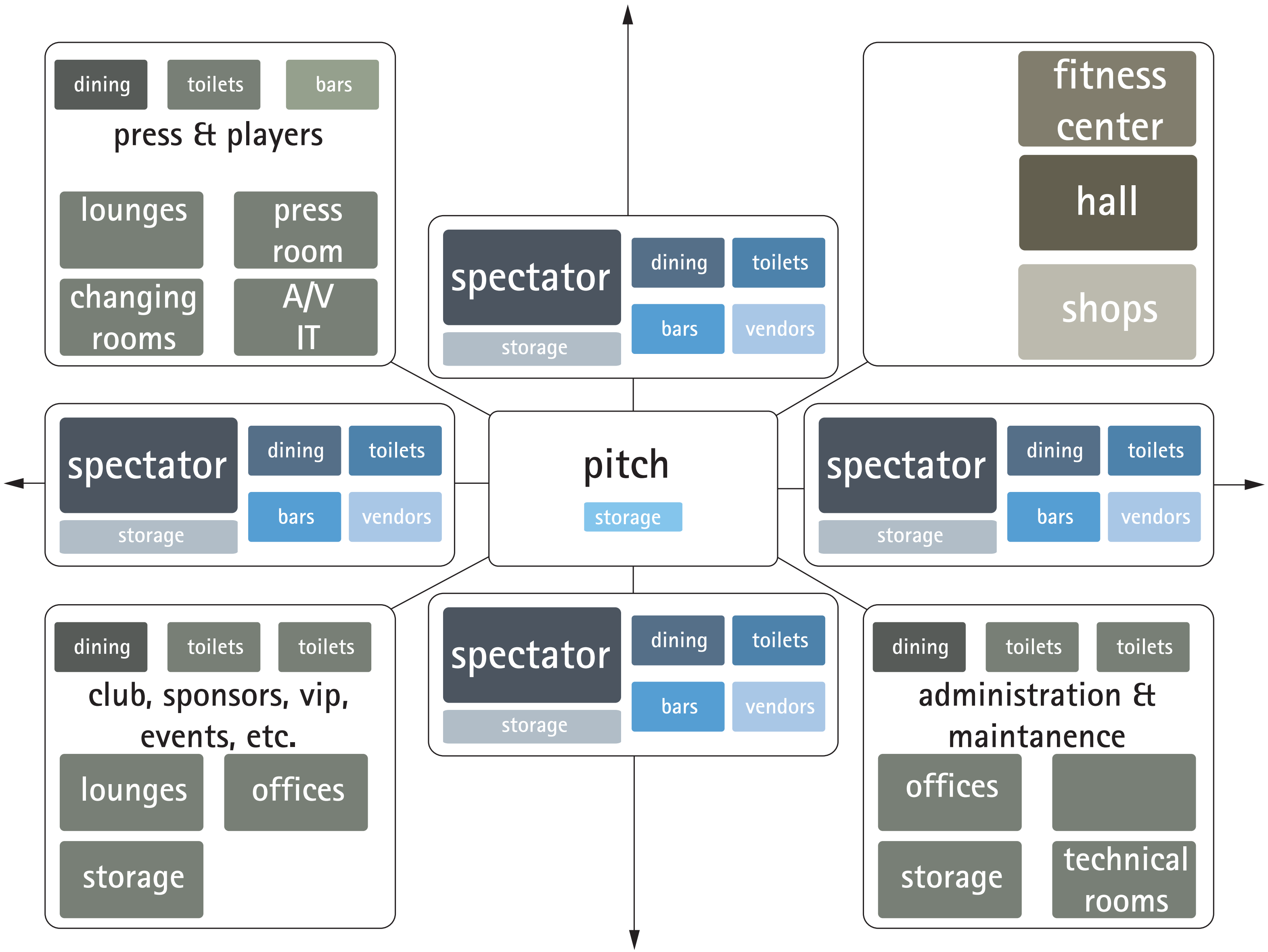
Centrally for the design is of course that it is a sports arena – and as such the primary focus is on creating a setting for great sporting experiences. With that said it is a multi-purpose hall which means that is should also encompass other functions – for the sake of the surroundings but also for economic viability. As a result we have a listed how different functions can be double programmed.



Rooms:	Primary use:	Secondary use:
Arena floor	Sports events	Concert, exhibition, conference
Restaurant and club	Dining	Dances, Weddings
Concourse and hall	Circulation	Exhibition
Bars	Refreshment	Private parties
Private boxes	Spectator	Meetings

Functions diagrammatized

After deciding what type of users we intend to service and how we can program facilities for them, we now show how we intend to connect these functions. That way we can ensure a good flow in the building and optimal working conditions for each zone.
The pitch is the focalpoint of the arena, and it has a natural connection with the spectators who are in turn surrounded with functions supporting their needs such as refreshments and toilets.
Also connected to the pitch but slightly more detached from the spectator clusters which require a bit more privacy – among these are press, players and vip's. Also there are functions which are intended to work outside of the hours when the pitch is in use. This includes administrative personnel but also merchandize shops and fitness centre.
Each cluster has facilities to function on its own, but each should also be flexible enough to support each other when needed. Together these clusters emcompass the arena.



Room programme

With a building as large as a sportsarena for 15000 spectators, it quickly becomes apparent that in order to accomodate all essential functions the building must span over thoundsands of squaremeters.
For this purpose we have made a roomprogram which can act as a guide in the coming designphase.

Desired number of spectators: 15000

Room/function	Number	Size (each)	Size total	% of total floor area	Light type	Lux
Pitch	1	2275	2275	11%	Artificial	1000
Foyer	1	750	750	4%	Mostly natural light	300
Hall	1	750	750	4%	Mostly natural light	300
Spectator tiers			7184	36%	Artificial	100
VIP lounges	30	30	900	5%	Artificial	200
Sponsor Lounge	1	200	200	1%	Artificial	200
Press lounge	1	200	200	1%	Artificial	500
Commentary Boxes	4	10	40	0%	Artificial	500
TV/press/redigeringsrum	1	100	100	1%	Artificial	300
Office - Director	1	20	20	0%	Mixed	500
Office - Board room	1	30	30	0%	Mixed	300
Offices	10	12	120	1%	Mixed	500
Toilets	370	2	740	4%	Artificial	100
Restaurents	2	250	500	3%	Artificial	200
Bars	2	250	1000	5%	Artificial	300
Vendors	16	15	240	1%	Artificial	300
Changing rooms	6	35	210	1%	Artificial	100
First aid/medical room (players)	1	100	100	1%	Artificial	500
First aid/medical room (spectators)	2	25	50	0%	Artificial	500
(mixed zone)	1	50	50	0%	Artificial	500
stairs	20	30	600	3%	Mixed	50
Hallways, catchment areas			1000	5%	Mixed	50
Storage (diverse)	10	100	1000	5%	Artificial	50
Service lifts	6	10	60	0%	Artificial	100
Fitnesscenter	1	500	500	3%	Mixed	300
Techics	2	100	200	1%	Artificial	100
Training hall	1	1000	1000	5%	Mixed	700
Total interior			19819			
Parking public	2000	12,5	25000			
Parking disabled	30	36	1080			
Parking Service	30	36	1080			
Parking VIP	200	12,5	2500			
Parking press	20	12,5	250			
Parking total			29910			
Total interior + parking			49729			

Problem statement

By densifying our goals into a few senteces, we will have a consise formulation of the task we wish to complete which in turn defines the future design proces:

How can we design a multi-arena for Ørestaden which can support both the needs of the near-context, and those of international events?

Vision

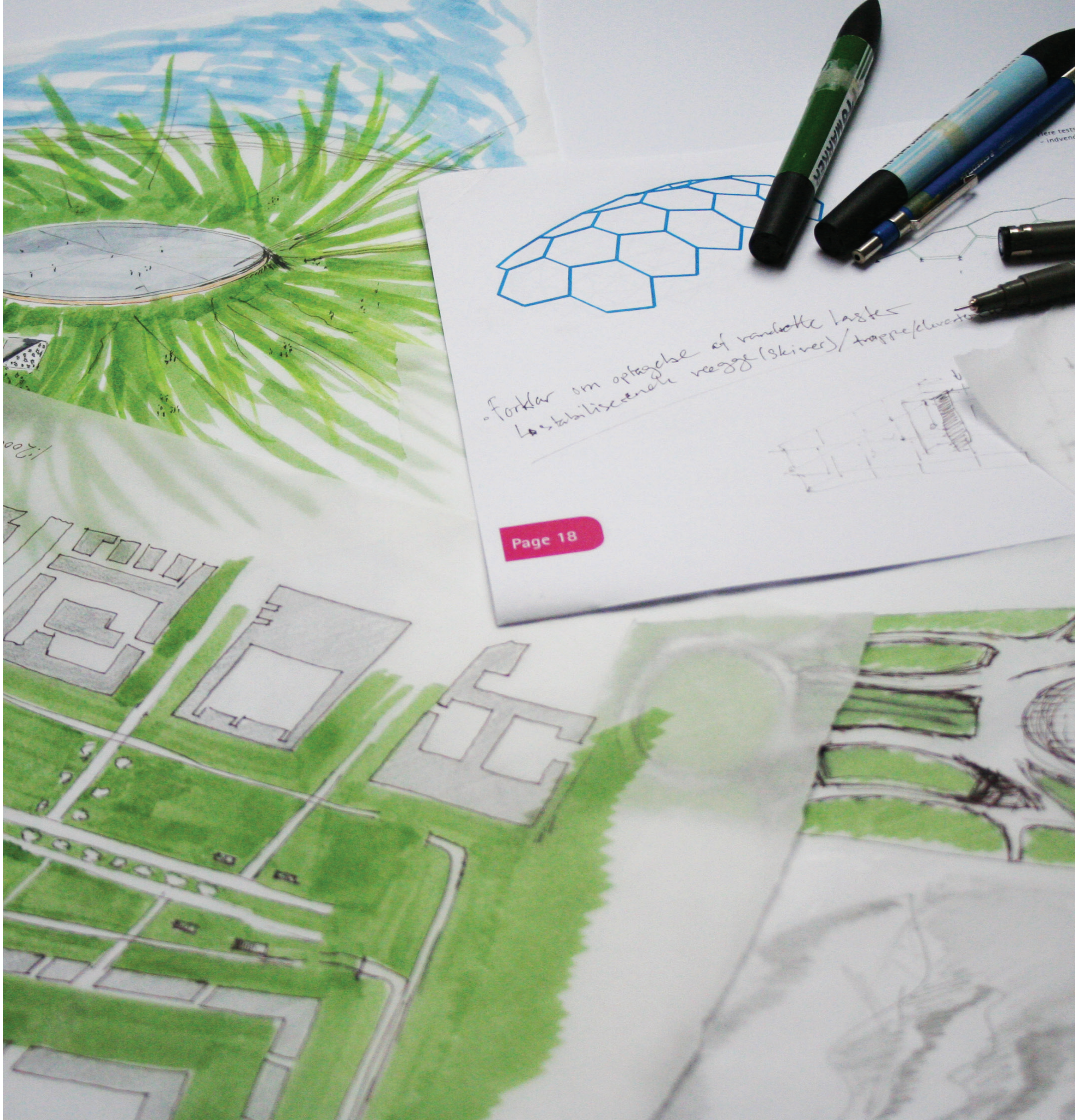
As the final chapter of the analysis, we will describe a vision for the design. The vision will serve as a means to add detail to the problem-formulation and as our success criteria.
In a context with many strong designs, we envision a building that has the qualities to stand out – without engaging in a shouting match with its neighbours. It is not just another box; it will differentiate itself via design-language and by being easily identifiable and readable – both structurally and functionally.
The arena is the setting of a great experience – the stadium should support and amplify the emotional response of the crowd during a game flowing back and forth. This will be enabled by creating a setting that reinforces the sensation of unity through seating and acoustics.
One thing is to create a setting for a great experience during an event, but with stadia, this experience often become very introverted in order to create an atmosphere of intimacy. Utilizing the principles of transparency we wish to create a design that allows the excitement of the intense atmosphere of a Champions League finale to be projected to the outside. That means that when passing by the stadium, you should be able to read from a distance if anything is happening.

With buildings of size there are considerable spans that need to be covered, we envision approaching this challenge in a tectonic manner – not just treating engineering as a means to cover a span – but as a part of the architectural expression which can be used to enhance the experience and atmosphere.
Spectators often arrive hours before the games starts and stay some time after the game – we want to be able to support this by providing spaces to relax – both inside and outside. That way it becomes a place you can enjoy even at times when there are no activities. Thus, we want to keep the building active by making it public so that the sports facilities can be used by smaller teams or amateurs.

We want to extend the concepts of creating great experiences, places to relax and year-round activities to the entire building plot. That means we envision a masterplan that amplifies the sensation of pilgrimage when travelling to a game, by creating an experience that is much more than crossing a dull carpark. The concept of extending stadium to the outside means a masterplan that has outside spaces for recreation – it could be just for drinking a cup of coffee, but it could also be locals playing a game of basketball. There should be room for it all.
This vision gives value to the spectators before, during and after a game, but also gives value to those who live in the context.

Delimitations

In order to ensure that we reach the goals of the project, it is necessary to specify the scope of task. Practically that means that we make choices that limit the project in order to meet our deadlines.
The first place we limit the project is in the technical aspects – we have chosen to investigate acoustics and construction, other technical areas such as energy will not be treated in this report.
Also we choose to limit the degree of design detail in this project. Due to the tight timeframe of this project, it is to be viewed as a conceptual proposal and not a fully planned and detailed project. Focus will be more on the flow and placements of functions in and around the building, and not necessarily on in-depth detail of each office, toilet etc.
Finally we keep in mind that any multi-purpose building is set on a foundation of compromises. In order to ensure the correct focus of the building, we decide which functions receive the highest priority in recognition that no multi-functional arena can be equally suited for all its activities.
A relevant candidate for comparison is Jyske Bank Boxen which prioritizes music first, then events and sports lastly. We choose to reverse that list so that sports are highest priority, then events and music lastly. This is due to that Copenhagen already has several venues for music, but are severely lacking when it comes to indoor-sports.

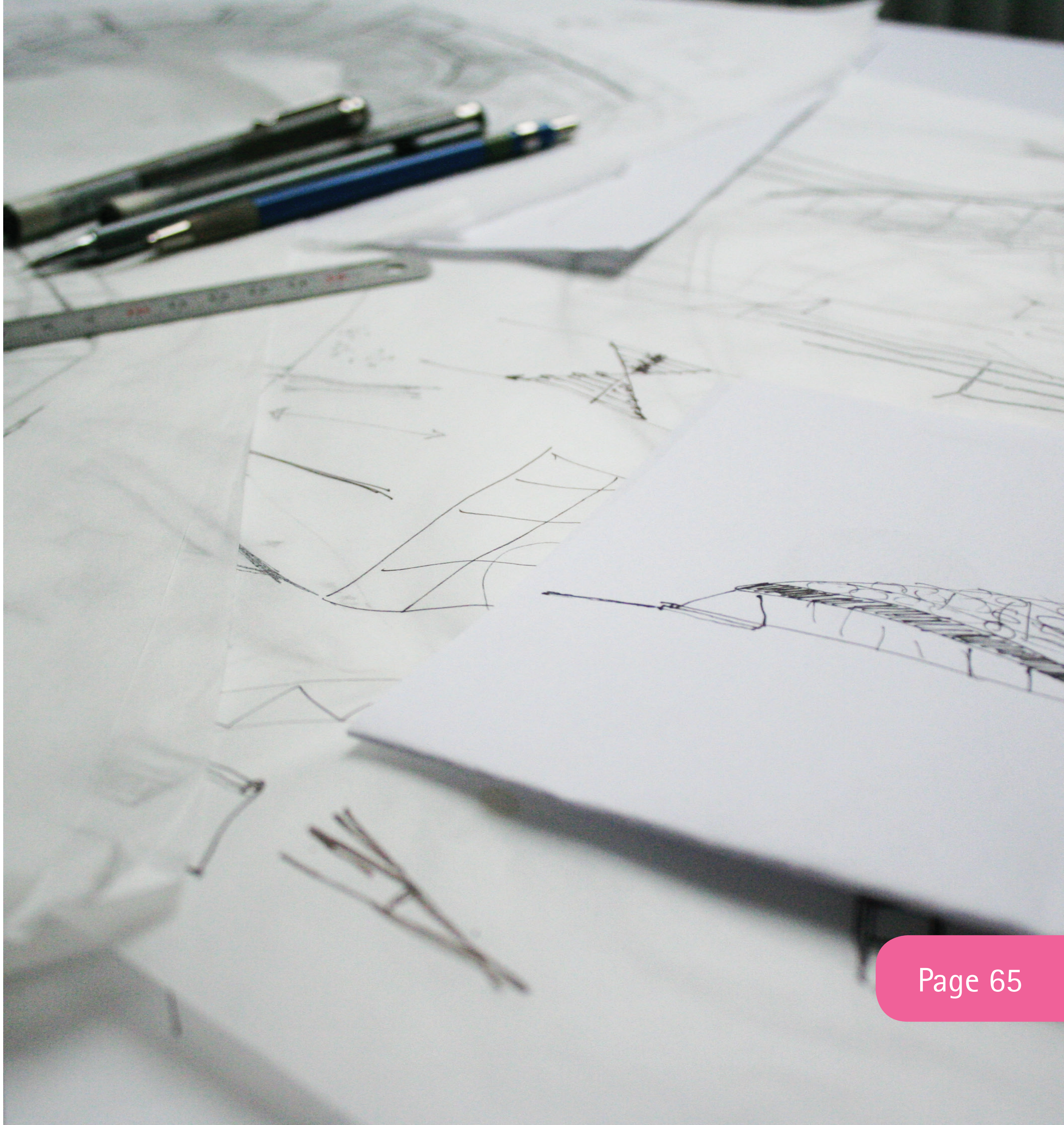


Formfinding

the elusive process of finding the perfect form

Intro

For each project we gain more formfinding experience, but still there is no guaranteed method. A part of the explanation could be that as each project is different, the formfinding proces that creates it must also be different.
For this project the formfinding is a two-step process.
First step is a free formfinding sketching process, followed by a sum up. Distilling on the collected ideas, we use them to guide the second leg of the sketching process. In the second step we sketch with our guidelines as an aide, helping find the final form more effieciently.



First phase - formfinding

Phase one was a completely free sketching session that stretched across several days and generated a plethora of drawings and ideas. We kept on working on this, the goal not necessarily being complete shape, but rather a framework of common elements that would guide future designs for the next phase of design. This would help ensure that our vision for the project could synchronize. Therefore the framework primarily concerned the overall concept, ie. the overall form and planning of the large buildingplot.
To describe the first phase in greater detail, the following pages present a series of selected sketches to illustrate how we examined different typologies in relation to the context and aestethic qualities. There are three general typologies: box, dome and cylinder.

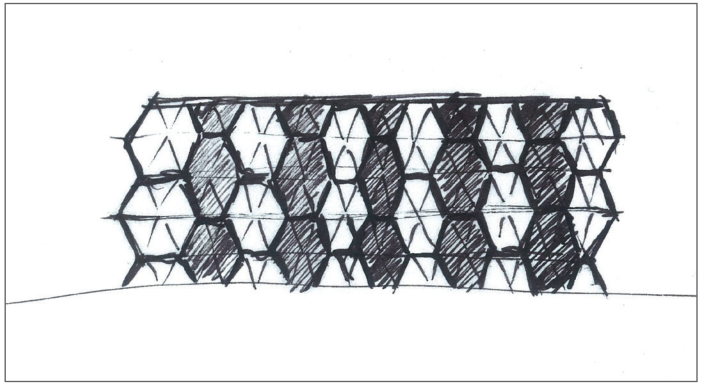
box

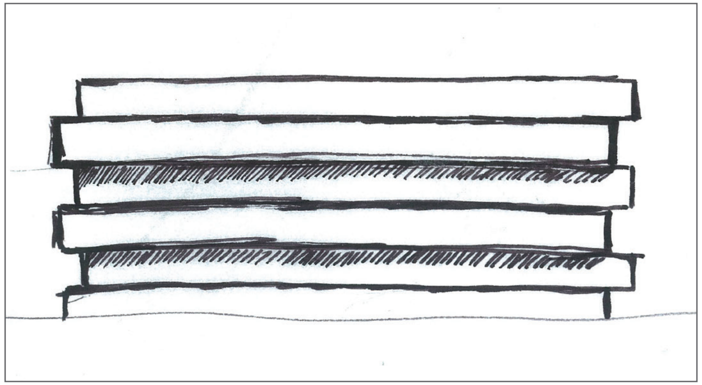
dome

cylinder

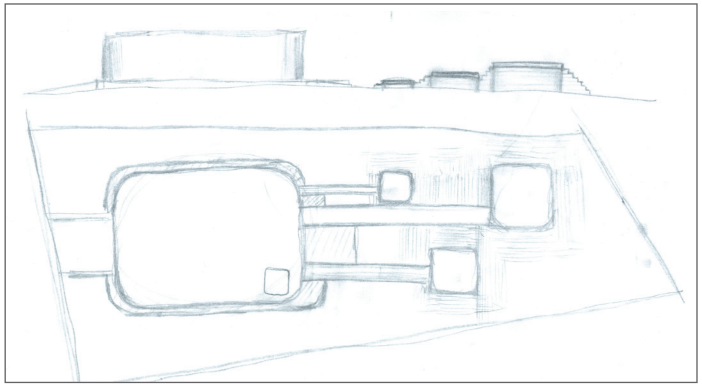
Typology One: Box

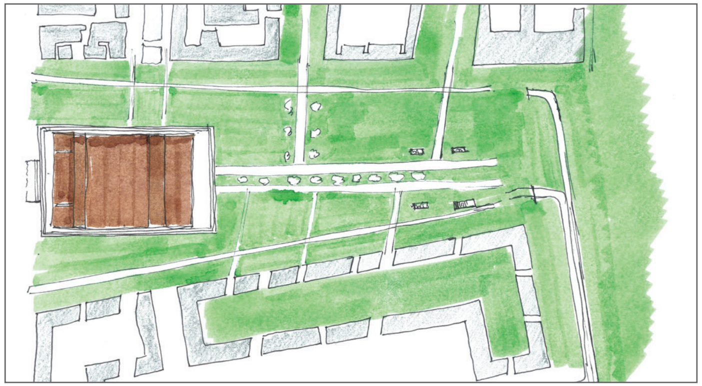
Typology study



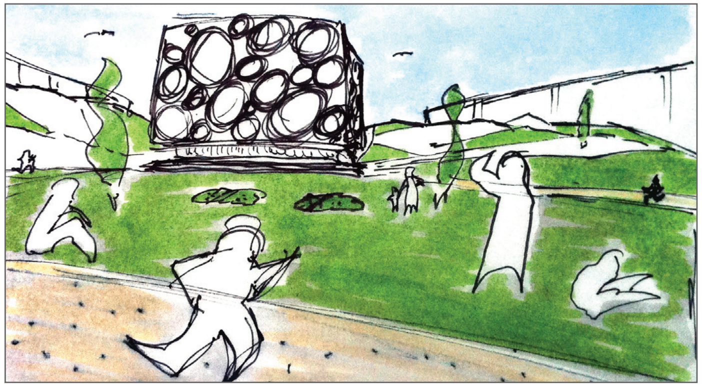


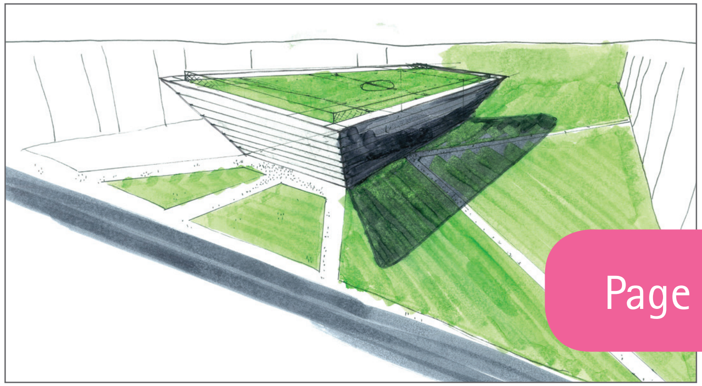
Urban study





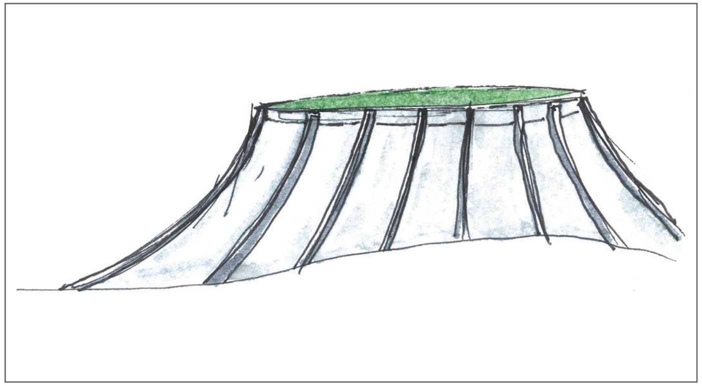
Combined study

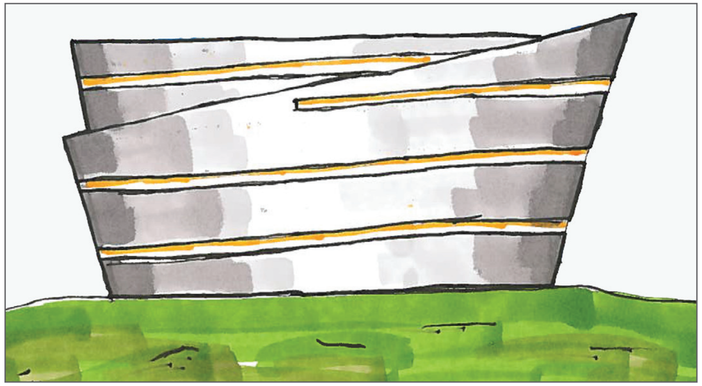




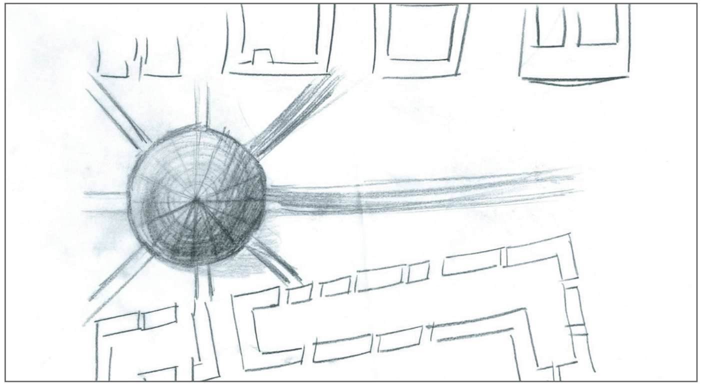
Typology Two: Cylinder

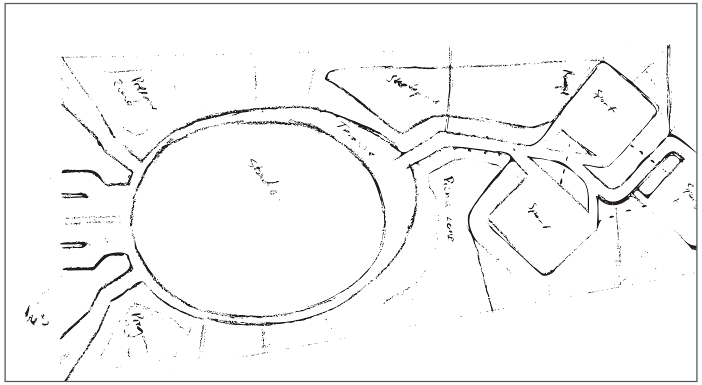
Typology study



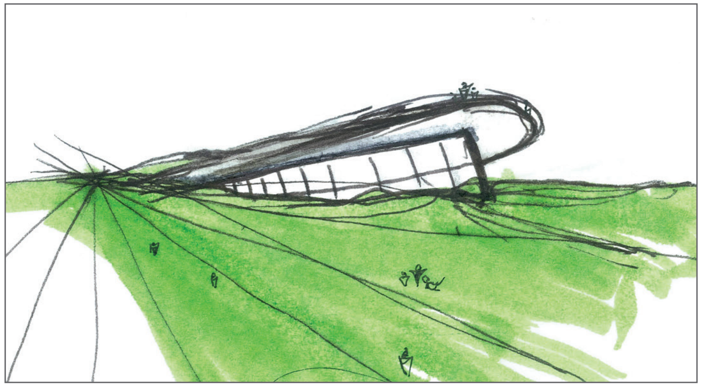


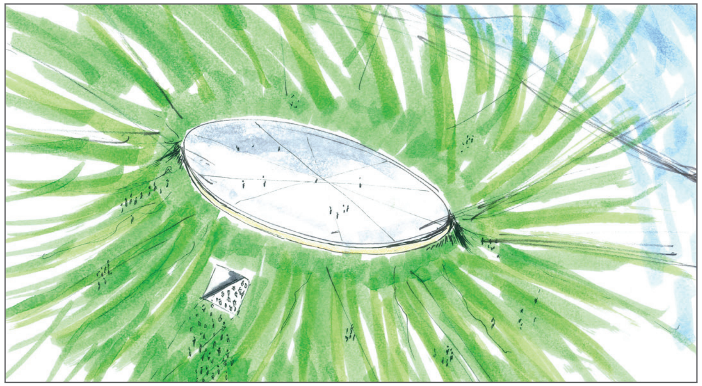
Urban study





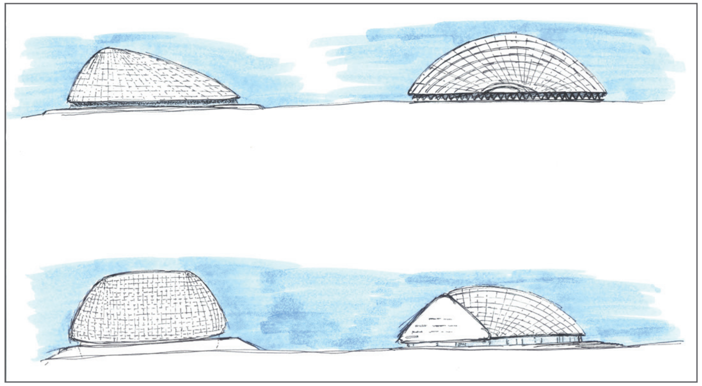
Combined study

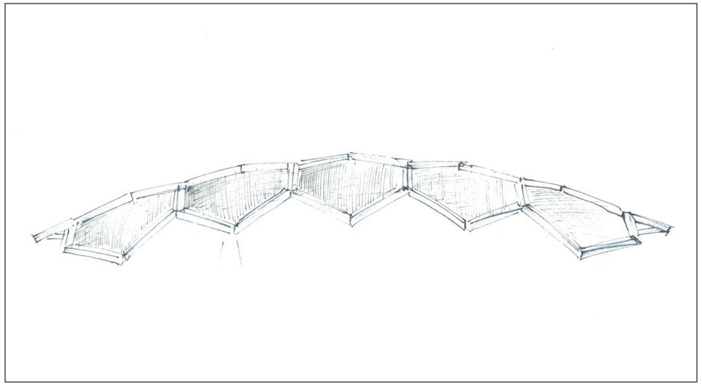




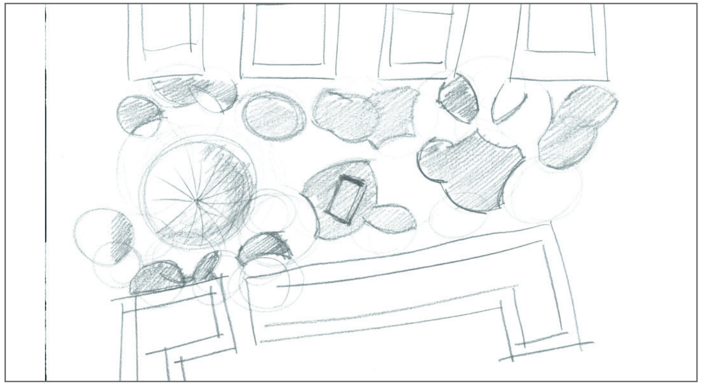
Typology Three: Dome

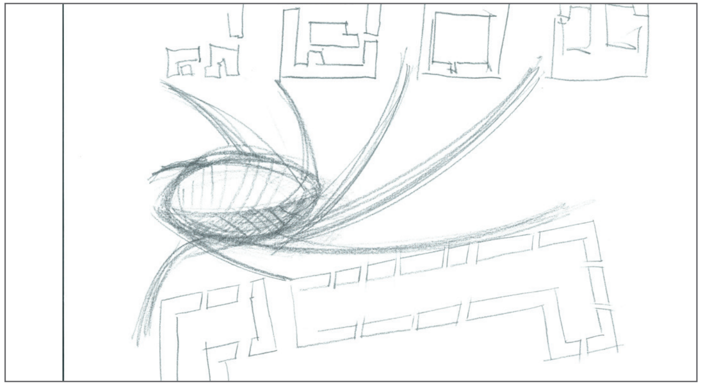
Typology study



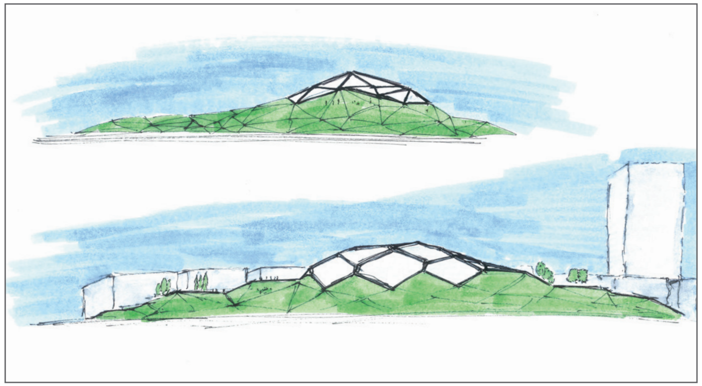


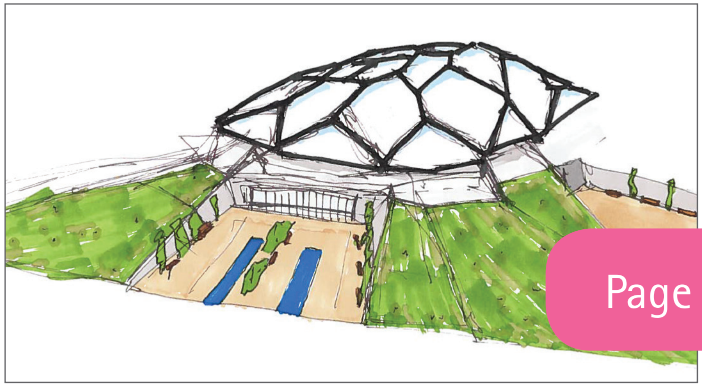
Urban study





Combined study

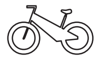
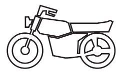
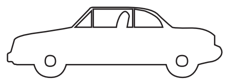
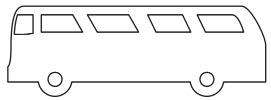
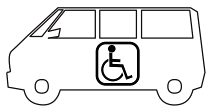


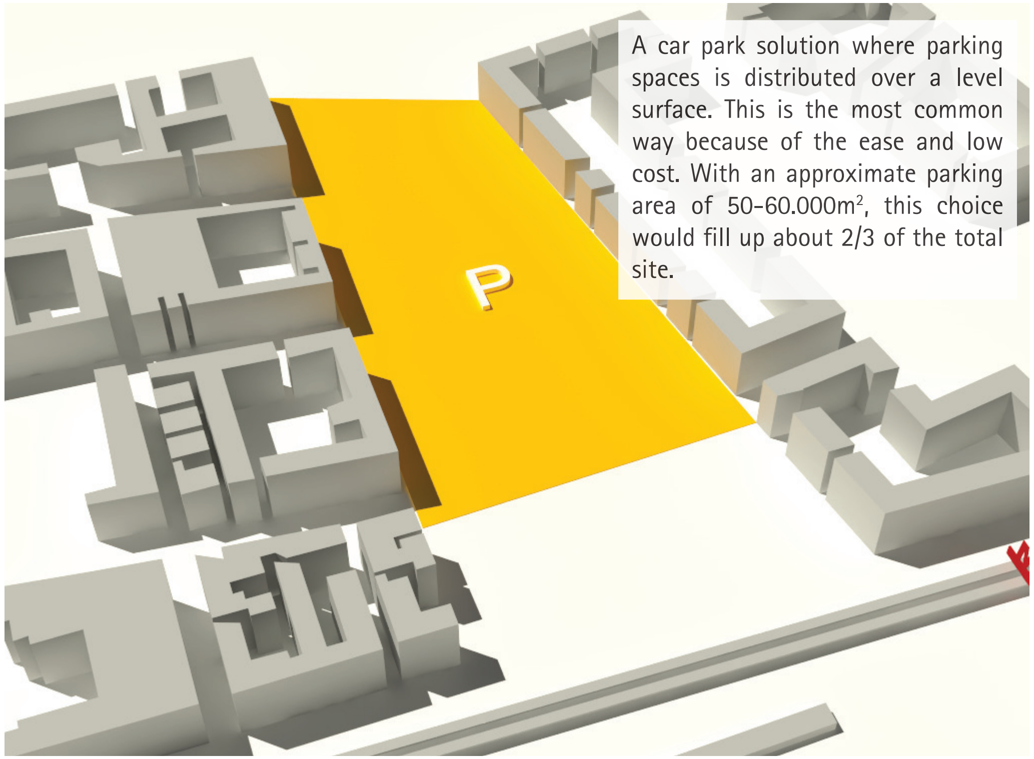


Parking

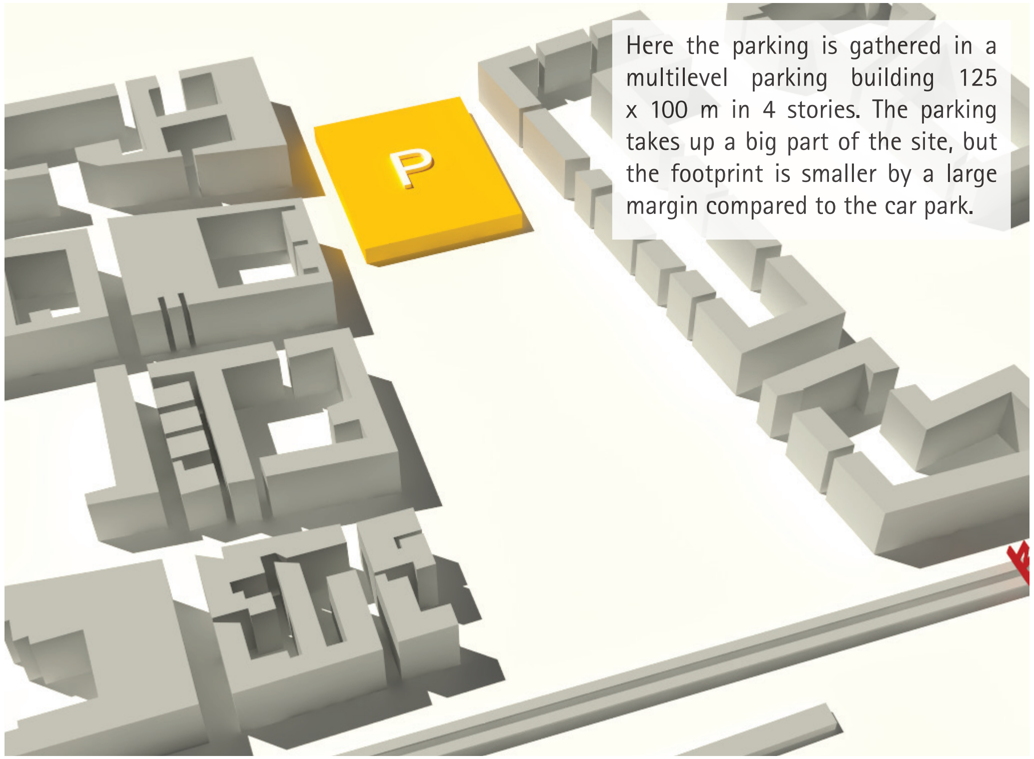
In the analysis we had worked out that we needed roughly 25000m2 of parking plus another 5000m2 to be placed near or below the stadium. With such large amounts of parking needed to be included in our design, it is obvious that we have to examine how it will affect the design.
The 25000m2 is parking space only, therefore we need to add additional space for paths which roughly doubles the space needed. This is depicted in the diagram to the right.
We need parking for spectators which will primarily consist of a mix of cars and buses. For nearby parking the composition is a bit more complicated, it will need to contain team vehicles, press, vip, handicap and staff parking.
On the following pages we study how much of the plot the parking facilities take up, and how distributing it in different ways impact our design options.

Estimated parking needed for spectators

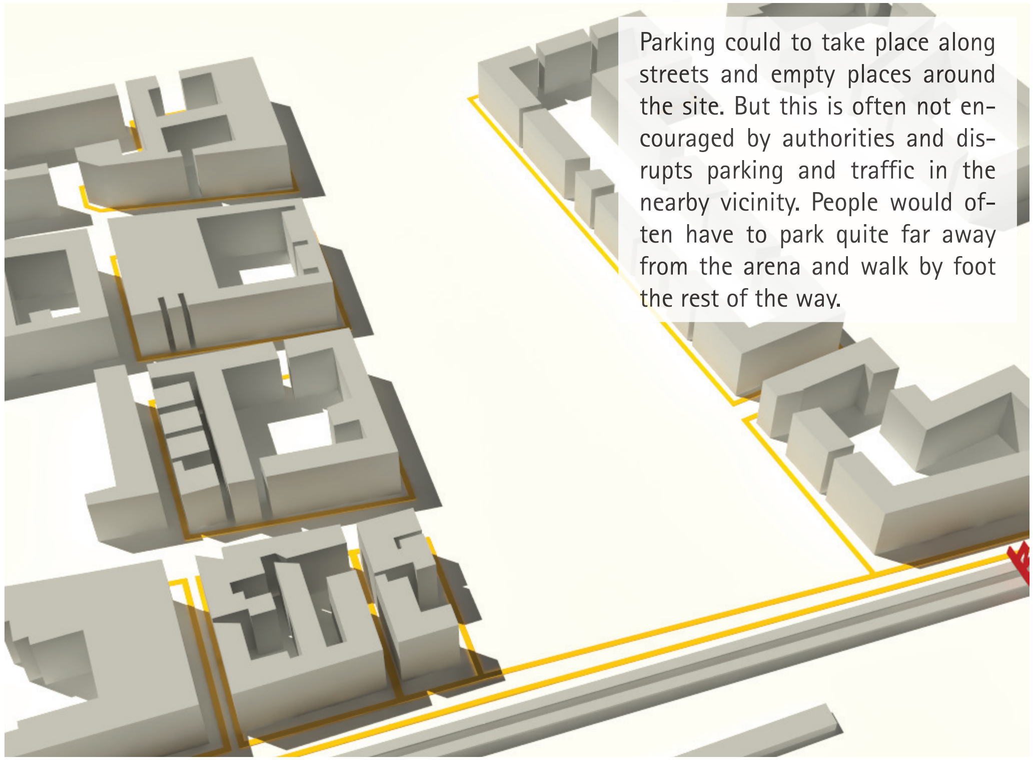
1/?		persons avg.	parking booth dimensions (m)	booth size. (with paths)	no.	total size
		1	0,65 x 1,90	1 m^2 (2 m^2)	500	1000 m^2
		1	1,0 x 2,30	2,3 m^2 (4,0 m^2)	30	120 m^2
1/6 1/10 1/15		2,5	5,0 x 2,3	11,5 m^2 (22 m^2)	2000	44.000m^2
1/120 1/240		50	12,5 x 3,0	37,5 m^2 (55 m^2)	60	3300 m^2
125 in total		1 (5)	5,0 x 3,5 (8,0 x 4,5)	17,5 m^2 (36 m^2)	30/ 5	1080 m^2
						49.500 m^2



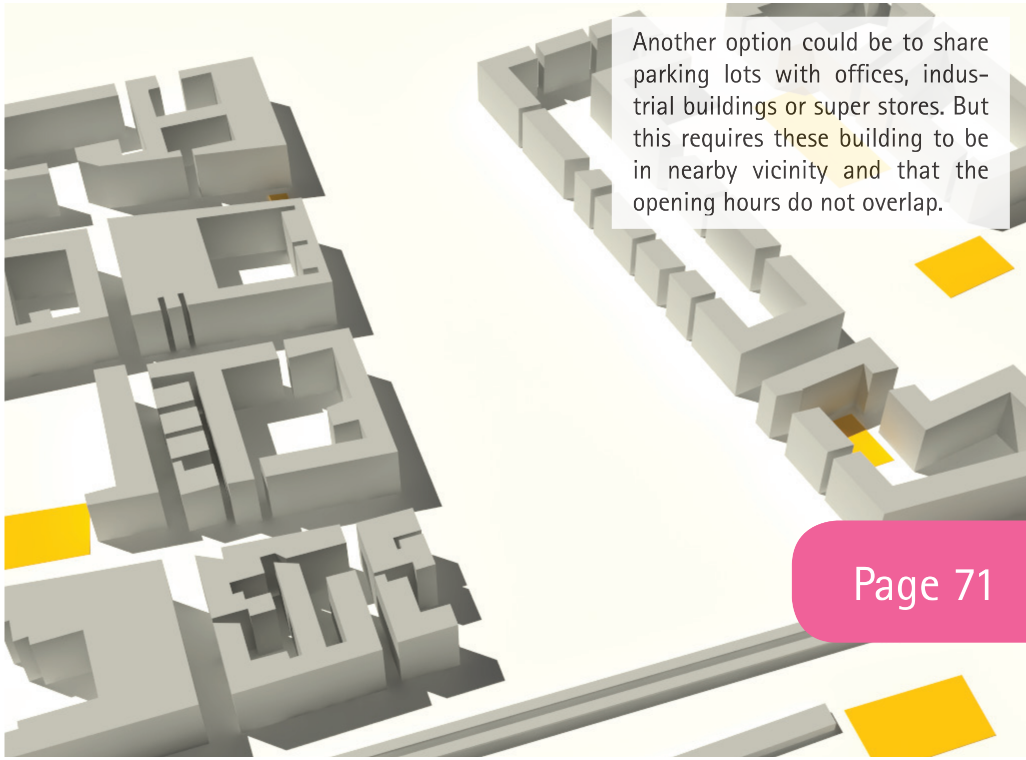
A car park solution where parking spaces is distributed over a level surface. This is the most common way because of the ease and low cost. With an approximate parking area of 50-60.000m², this choice would fill up about 2/3 of the total site.



Here the parking is gathered in a multilevel parking building 125 x 100 m in 4 stories. The parking takes up a big part of the site, but the footprint is smaller by a large margin compared to the car park.

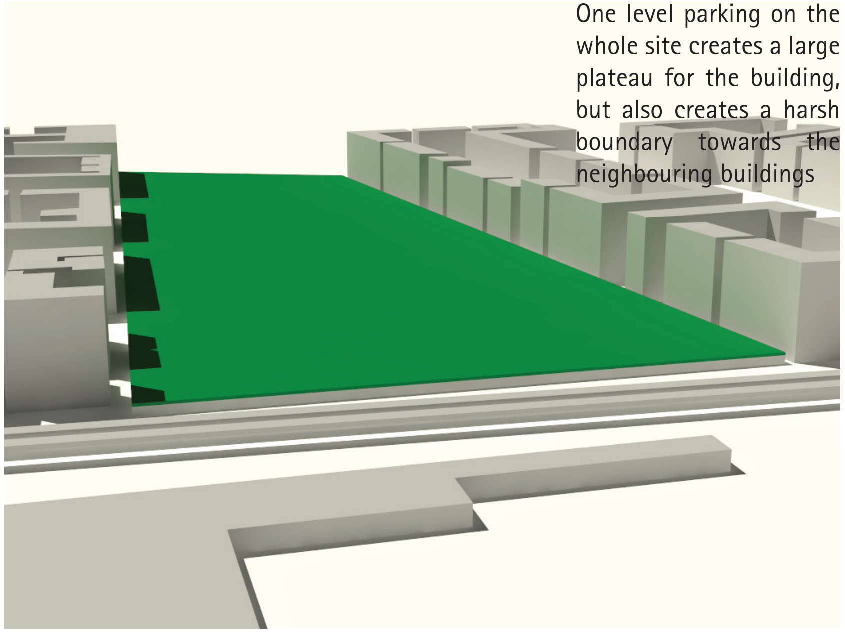


Parking could to take place along streets and empty places around the site. But this is often not encouraged by authorities and disrupts parking and traffic in the nearby vicinity. People would often have to park quite far away from the arena and walk by foot the rest of the way.

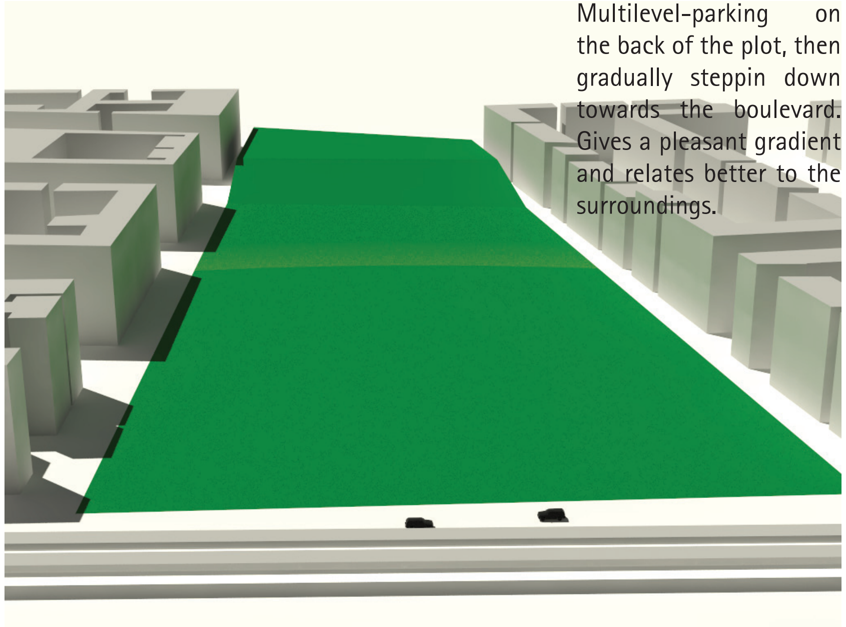


Another option could be to share parking lots with offices, industrial buildings or super stores. But this requires these building to be in nearby vicinity and that the opening hours do not overlap.

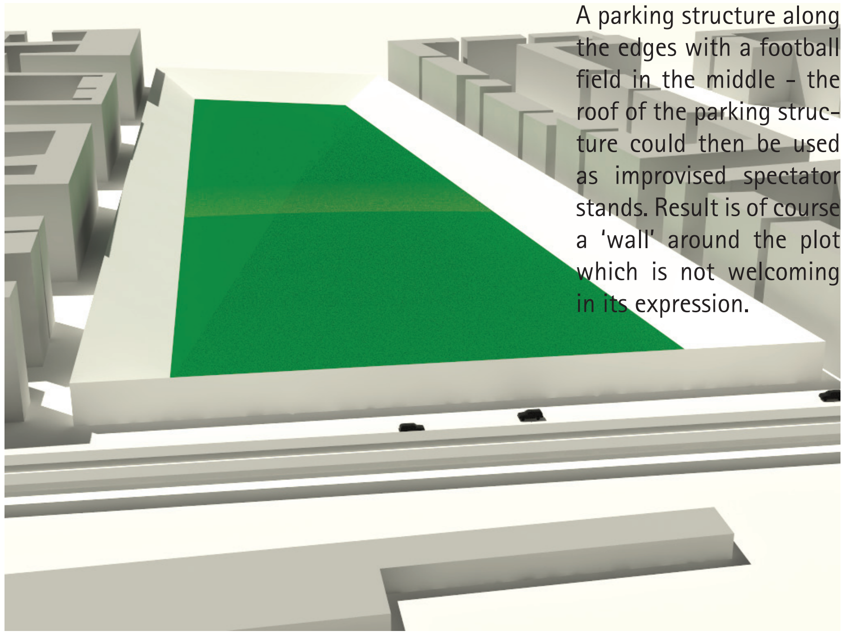
We see from the previous page that having the parking offsite is probably not a plausible option, if we take into consideration the traffic problems it could generate after a sporting event. Therefore we examine further the consequences of placing the parking on the plot.



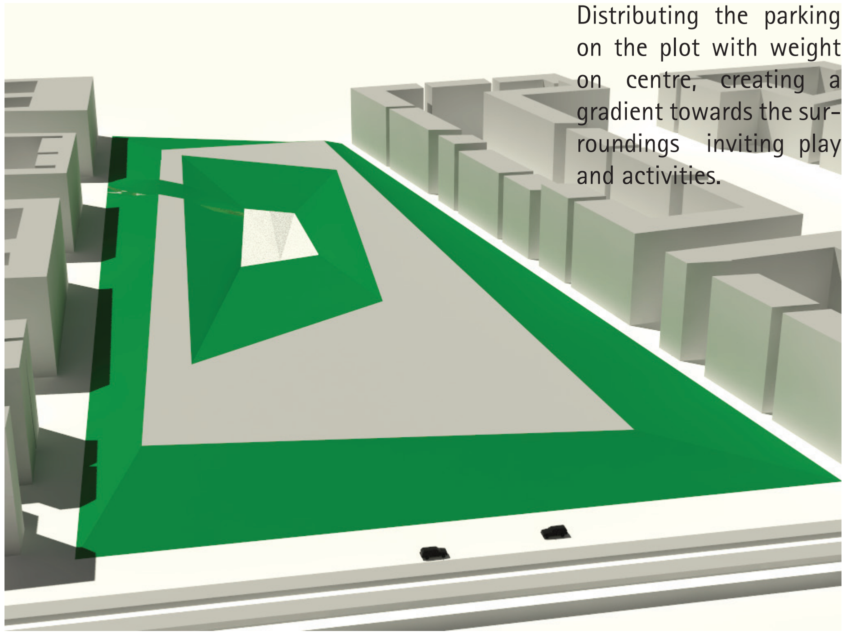
One level parking on the whole site creates a large plateau for the building, but also creates a harsh boundary towards the neighbouring buildings



Multilevel-parking on the back of the plot, then gradually steppin down towards the boulevard. Gives a pleasant gradient and relates better to the surroundings.



A parking structure along the edges with a football field in the middle - the roof of the parking structure could then be used as improvised spectator stands. Result is of course a 'wall' around the plot which is not welcoming in its expression.



Distributing the parking on the plot with weight on centre, creating a gradient towards the surroundings inviting play and activities.

Parking - sum up

The parking study has helped visualize how much space parking for a facility like this requires. It also shows that in relation to our vision of keeping the parking underground, and create a landscape around it, we need to keep it away from the edges, so that we can use them to create a landscape gradient – connecting the plot to its surroundings.

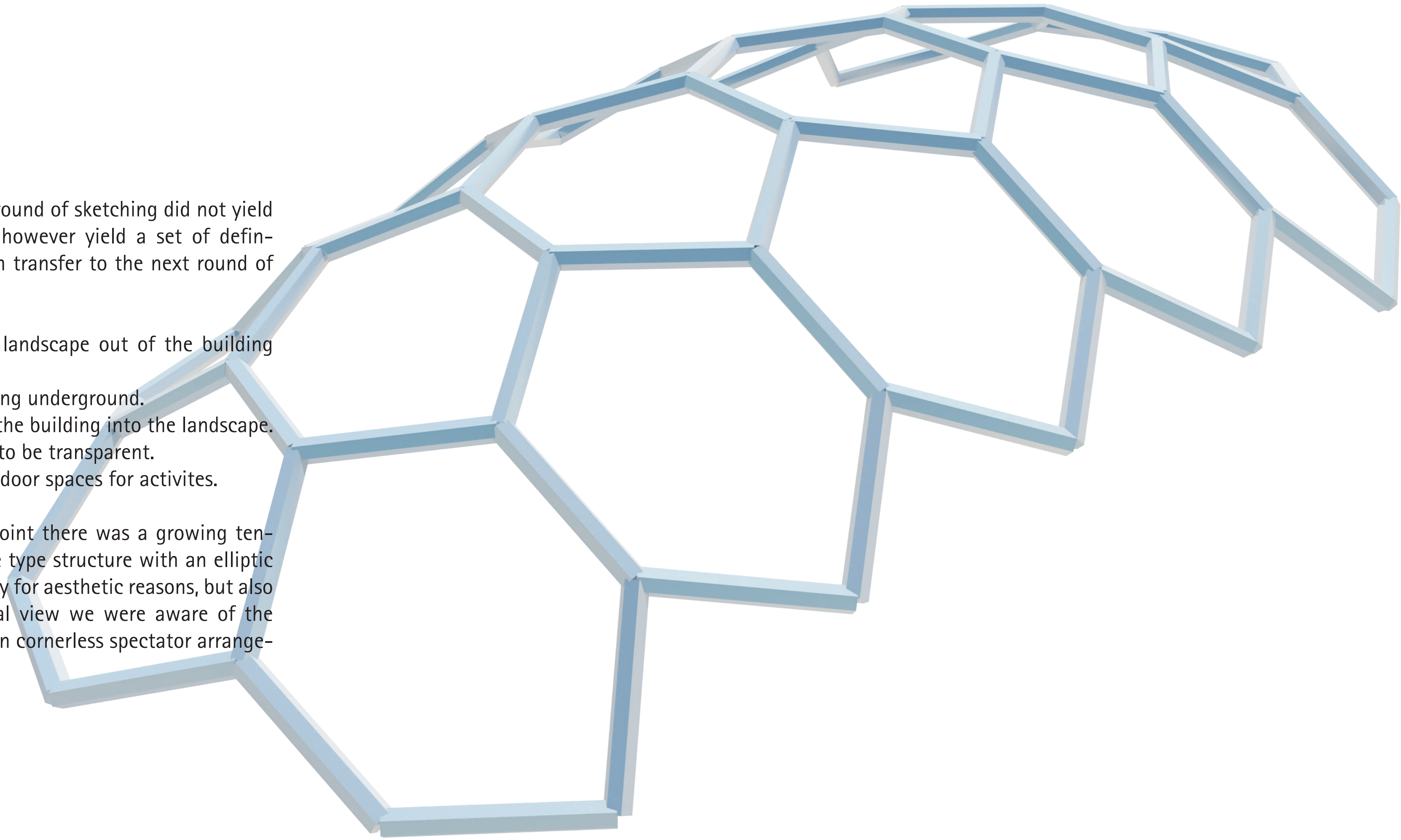
It is situations like these we wish to avoid

First phase - sum up

Even though our first round of sketching did not yield a final design, it did however yield a set of defining parameters we can transfer to the next round of sketching:

We want to create a landscape out of the building plot.
We want to keep parking underground.
We want to integrate the building into the landscape.
We want the building to be transparent.
We want to create outdoor spaces for activites.

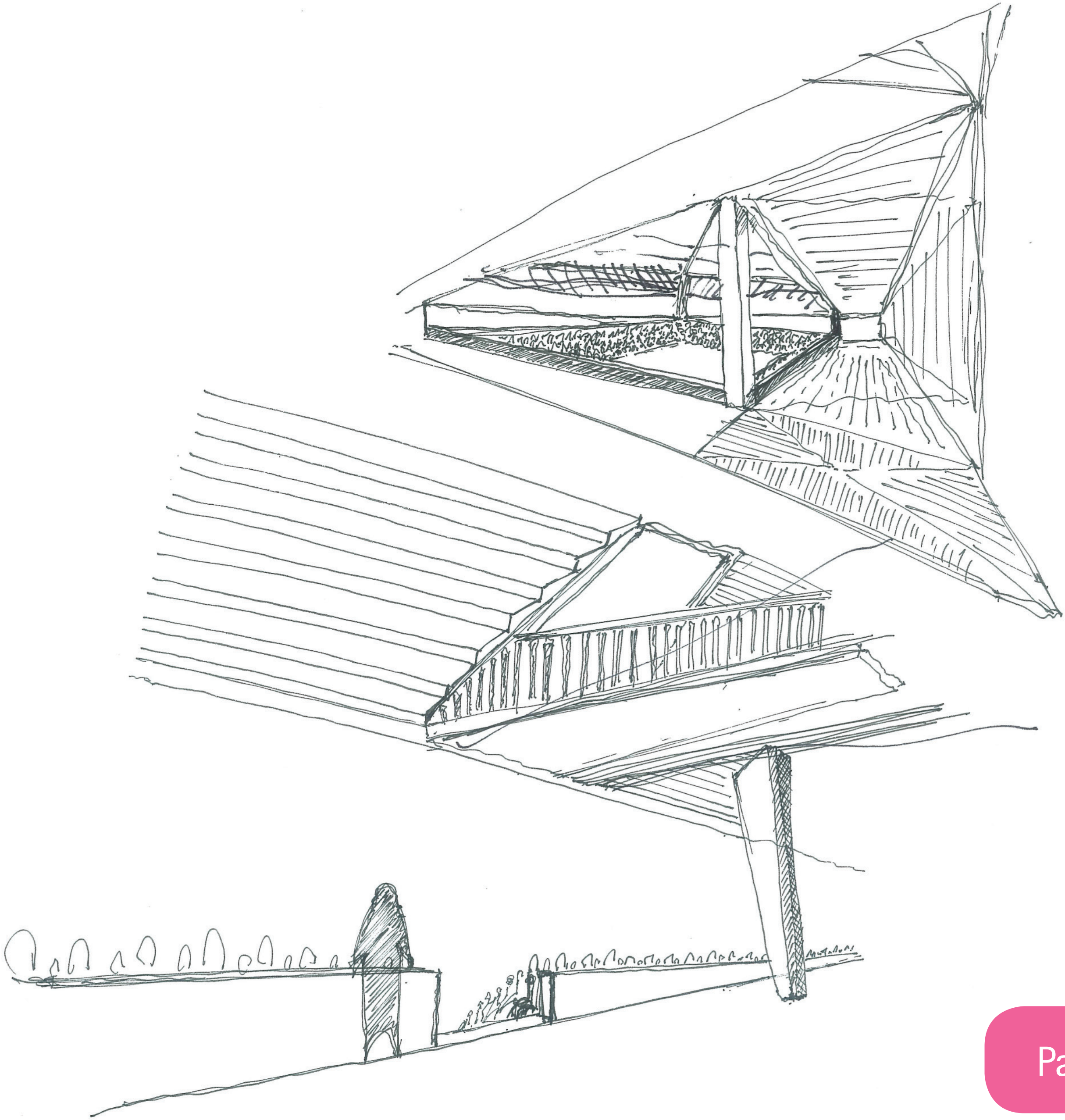
Furthermore, at this point there was a growing tendency towards a dome type structure with an elliptic seating structure. Partly for aesthetic reasons, but also from a phenemological view we were aware of the benefits of an unbroken cornerless spectator arrangement.



A render of one of the very earliest sketches

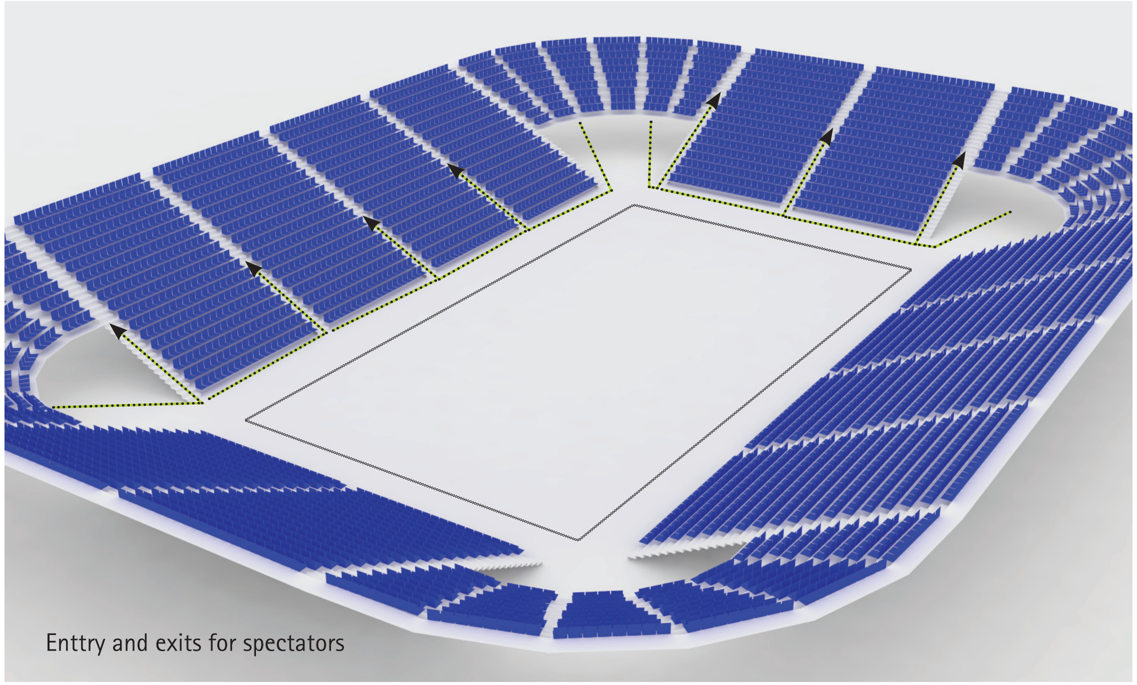
Second phase

Moving on from the first phase where we designed from the outside and in, we now continue on to design from the inside and out. This is done to investigate the correlation between exterior and interior aspects. This second phase is also an investigation in the impact of technical aspects and thereby a part of the IDP process.

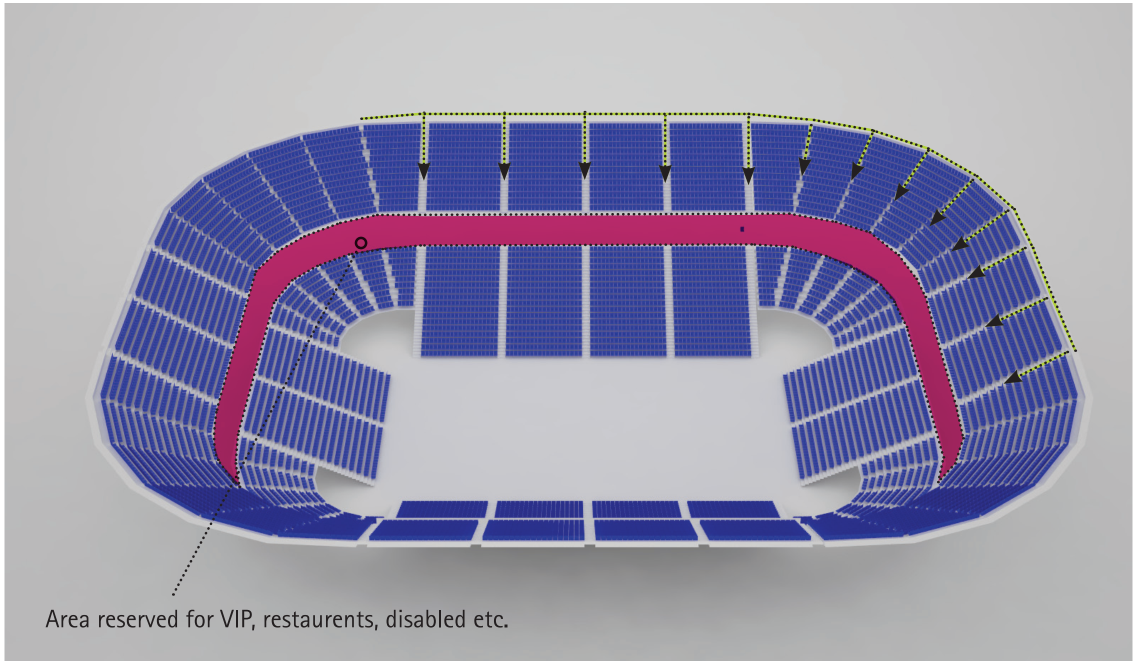


Spectator view/ seating

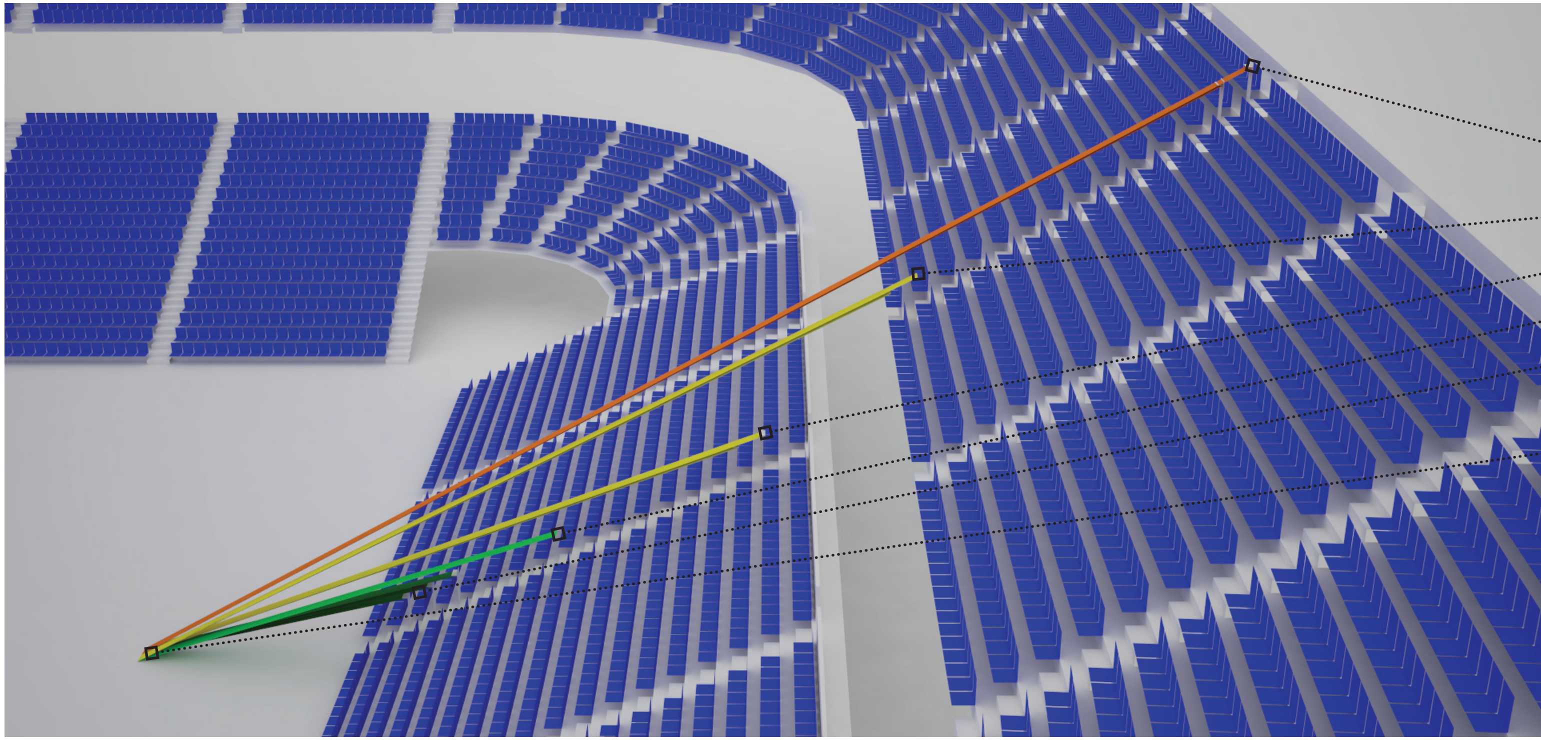
One of the most central aspects the interior of an arena is the seating arrangements. Here we model a seating arrangement based to examine how design changes affects the experience for the spectator.
To add some structure to this investigation, we chose a series of factors to investigate.
A central element in the spectator experience is density. Obviously we want to have as many seats as possible per m2, but this field is regulated by law in most countries. In Scandinavia the norm is no more than 2½ persons per m2.
An important design element that the spectator may not experience directly is the safety and logistics of the stand layout. We investigate how a spectator would get to and from their seat. We also investigate emergency escape routes.
Vomitories are openings cut out into the stands, and the number and placement of these are interlinked with safety and logistics design, as well a factor in regards to density. We investigate the necessary amount and their spacing.
As well as creating standard seating arrangements, we also investigate how we can create space for disabled individuals. An ideal placement would be in a corner of the middle level to avoid vertical travel, and to minimize head movement.



Entty and exits for spectators



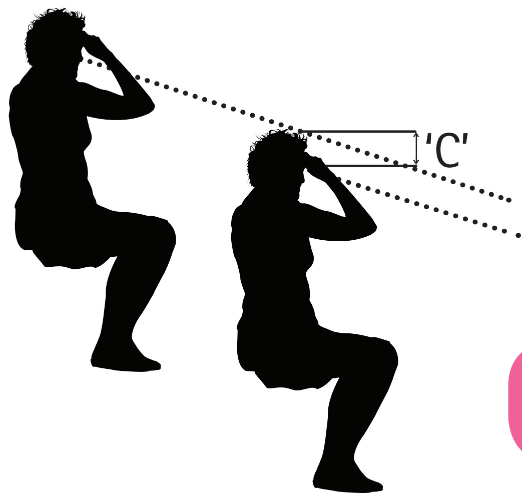
Area reserved for VIP, restaurents, disabled etc.



As a means of measuring the quality of views, we use a term called C-value. It is a measurement of a spectator's ability to see the nearest point of interest over the head of the person in front of them. As the figure depicts; more space equals better view, and is as such an expression of the quality a spectators view. C-values are measured in millimeters and the guide-lines are as follows:
150mm: excellent height.
120mm: recommended height.
90mm: minimum recommend height.
60mm: absolute minimum height, not recommended.

One way to affect the C-value of the stands is to change steepness of the rake. Basically, as we increase the angle, we get the spectators closer to the pitch and improve the c-value. Elevating the angle is the most effective the further back you go. Therefore some stadia are designed with a variable angle that increases the further you go back. As a general rule it is not recommended to go steeper than 34 degrees as this can cause vertigo in some individuals. In some countries it is allowed to go as steep as 41 degrees, but this is only found on the last few rows which are then fitted with handrails.

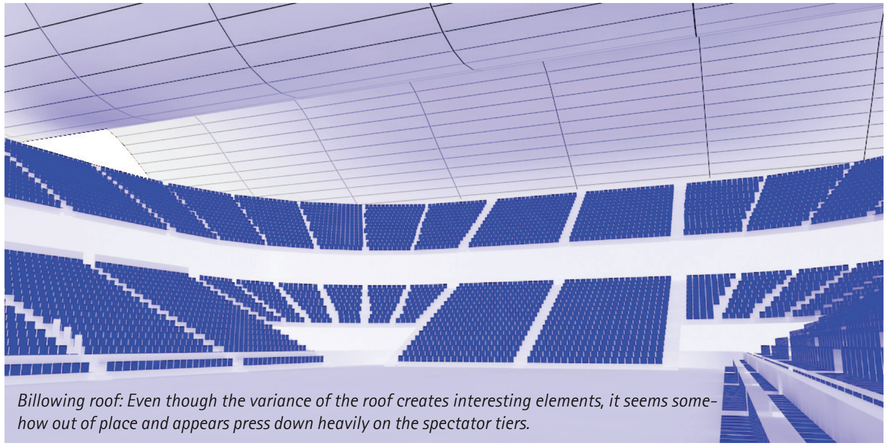
We also experimented with dividing the spectator arrangements into multi-level setups, to see how it would impact the quality of the seats and logistics.



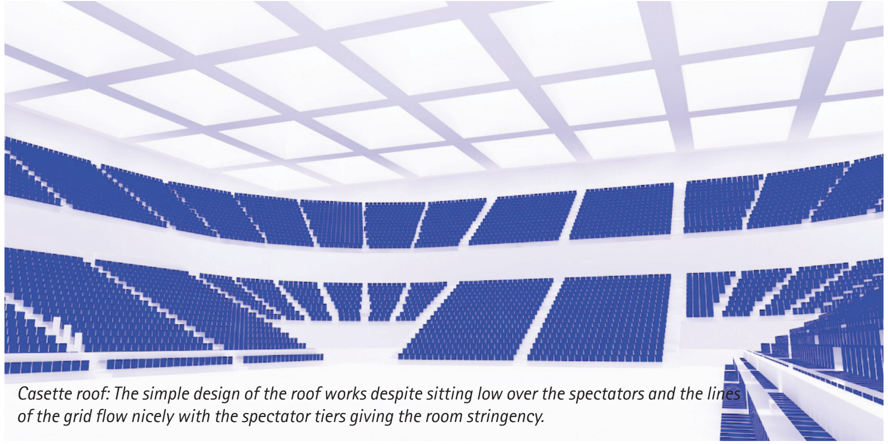
Investigation of roof types

As mentioned in the beginning of this chapter, we try to design from the inside out in this phase. After investigating how manipulating the seating arrangements can affect the spectators view and general experience, we now turn to a brief investigation of how different roof-types can change the way the stadium is experienced.
For this purpose we have created three different roof types: A traditional flat roof, a dome roof with visible structure and an untraditional billowing roof.

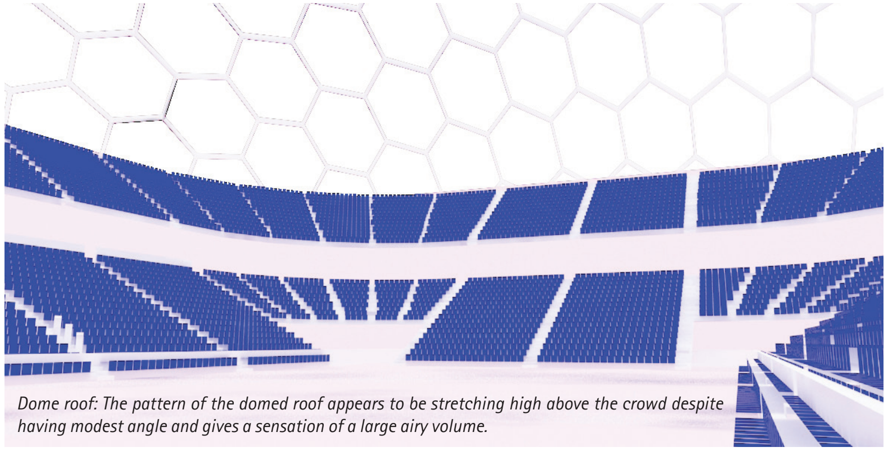
The visual investigation of the roof types proved that of the three types, the dome type had the most promise in relation to creating powerful setting for a sports arena. Therefore we decided to test the structural stability of the dome, by making a series of quick finite element tests each based on different structural systems.



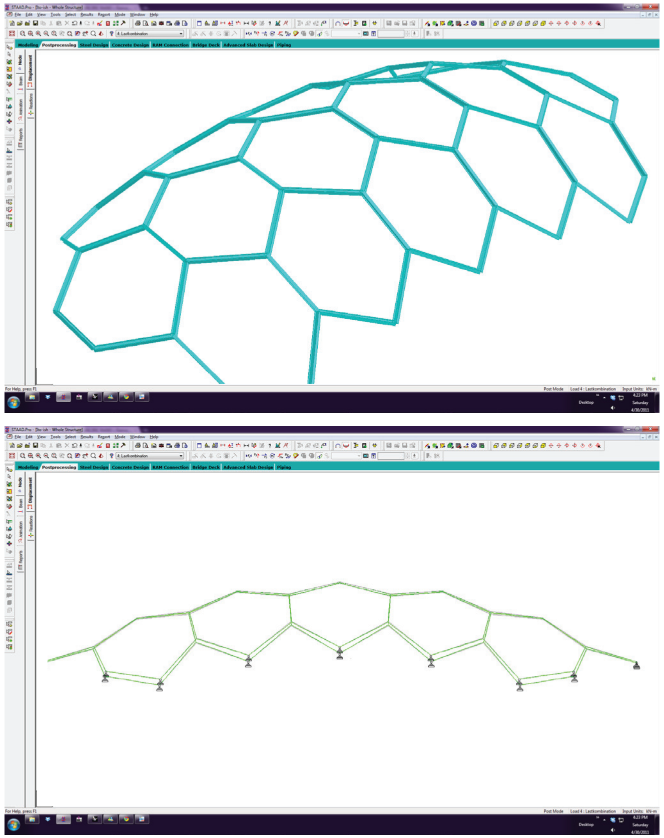
Billowing roof: Even though the variance of the roof creates interesting elements, it seems somehow out of place and appears press down heavily on the spectator tiers.



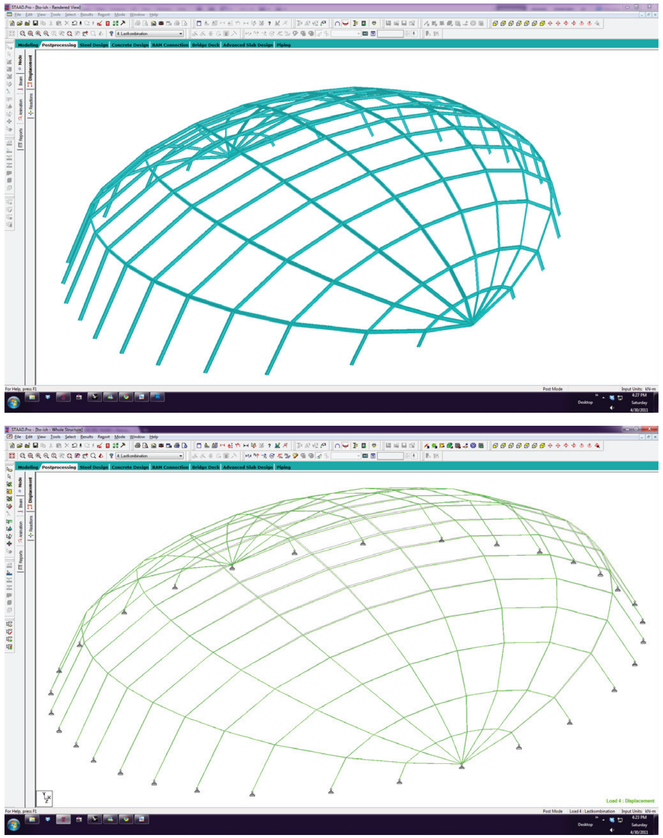
Casette roof: The simple design of the roof works despite sitting low over the spectators and the lines of the grid flow nicely with the spectator tiers giving the room stringency.



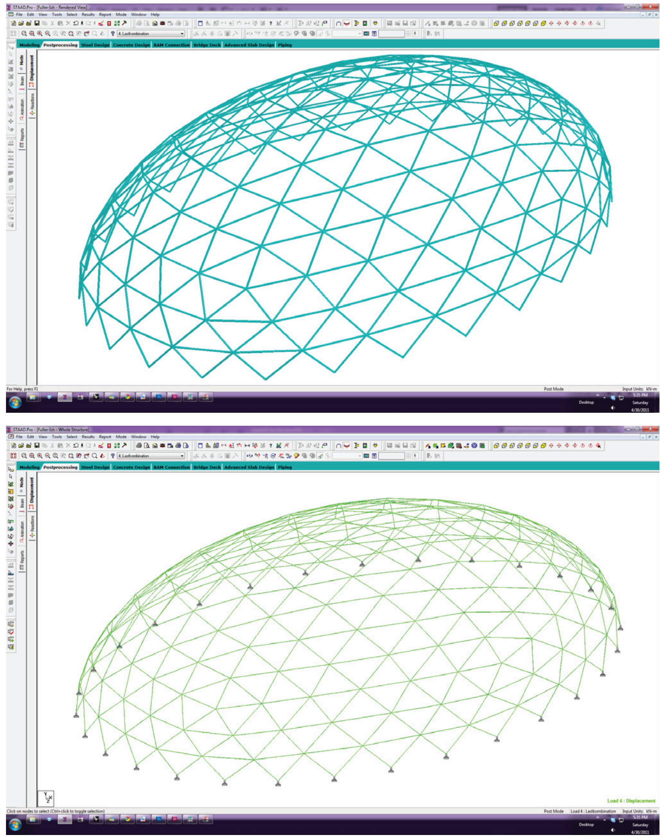
Dome roof: The pattern of the domed roof appears to be stretching high above the crowd despite having modest angle and gives a sensation of a large airy volume.



Type A: Based on an early sketch, this grid consist of a series of hexagons. The construction was able to pass the demands for ultimate limit state and servicability state. Though individual beam members required large sectional profiles.



Type B: Based on a design by Toyo Ito, we decided to test this grid, to see if we could adopt the constructional principle into our project.



Type C: Based upon platonic solids, we tested a type of defined geometric shapes, which we sliced to our demands.

Acoustics

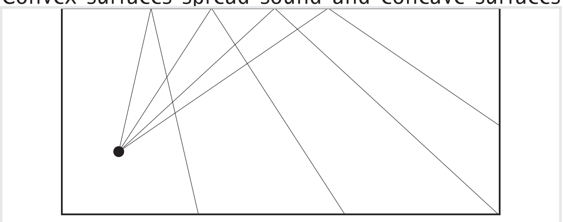
Continuing the investigation of interior design aspects, we reach another parameter that is important for a multi-functional arena: Acoustics.
Different situations have different requirements in relation to acoustic performance. Since this building is multi-functional it is likely that it will see several different acoustic scenarios. Therefore we need to make decisions about the acoustic performance and how it relates to the design of the building.
On the following pages we test the performance of three basic acoustic configurations.

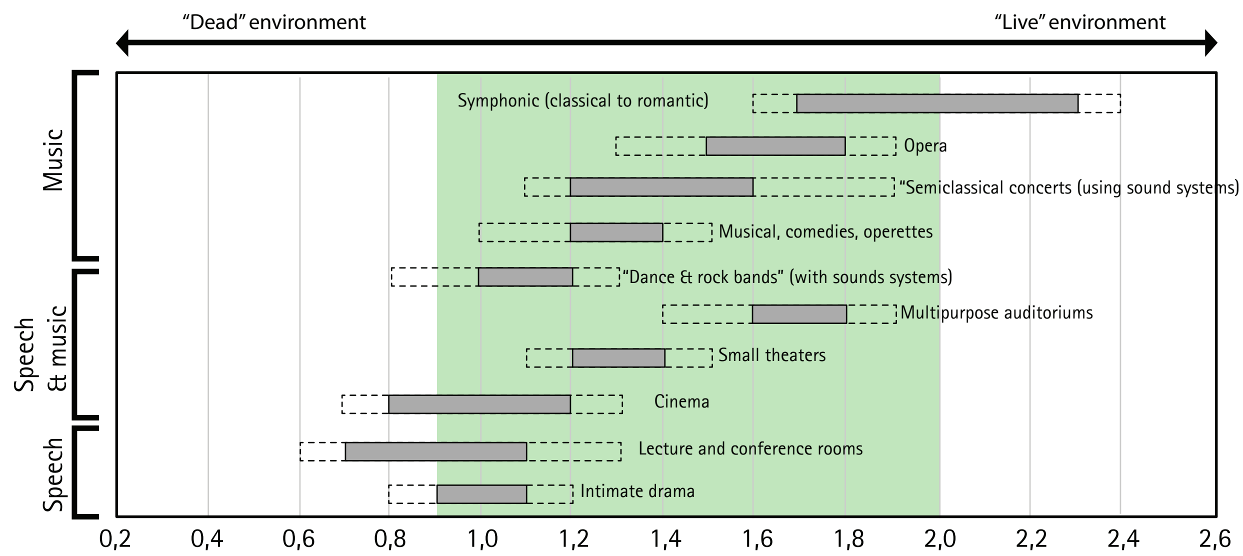
When viewing a football match or similar live-event, the sounds backdrop plays an integral part of the experience. While the visual part of the experience happens in front of you, but the acoustic impressions is a blend of the event and sounds from the crowd which embraces you from every possible angle. Depending on the type of sports, cheering from the crowd is used for heightening the morale of home team players, or to intimidate to opponents players.

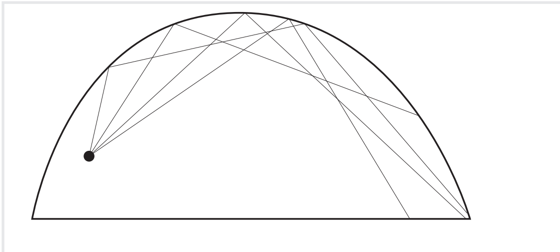
Optimum space
For every type of sports or non sporting events, there's an optimum space and sound quality. On the other hand the multi-purpose hall will inherently be a compromise as it has to suit different types of events.

Reflection/Absorption
When sound is emitted from a source in an enclosed space, it will eventually hit a surface from which it will be reflected, absorbed, transmitted or a combination of two or more.
If sound is reflected back into a confined space, depending on surfaces and geometry, it might start bouncing back and forth between surfaces and cause reflections. A space with a low reverberation time is often referred to as an acoustically 'dead' environment. If reverberation time is long, it's often referred to as a 'live' environment. A 'dead' environment is best for speech, whereas 'live' environment suits music better. Speech and electronic amplified music is best enjoyed within environments with a reverberation time around 1 sec.

Depending on the geometry of a given space, reflected sound can be spread out or focused on a single spot. Convex surfaces spread sound and concave surfaces







focuses sound into a spot. This should be considered early during the design phase as this can greatly impact on the acoustic properties of an interior space. (illustration)

Transmission
In the case that sound is not reflected or being absorbed by a surface, it will instead be transmitted through the surface into adjacent spaces.

Acoustic

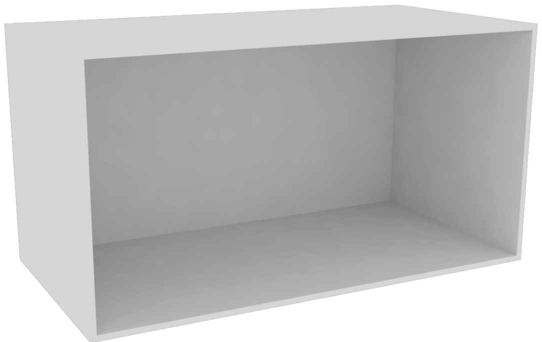
Shoebox

First of the three prototypical acoustical concert rooms; is the "Shoebox". Tall and narrow with parallel walls, the resemblance to a shoebox is clear. It originated from the 18th & 19th century court ballroom which now was being used for classical orchestral concerts.

Most of the audience was formally placed in front of the orchestra. While sometimes additional balconies was placed along the walls for better view of the stage/orchestra. Floor seating was often flat or slightly raked.

Positive acoustical attributes are often associated with the shoebox shaped rooms, as the sound is evenly distributed to all seats, due to the blending of the orchestral sections. The design allows the audience to be immersed in a reverberant energy that fills the room. The top half of the room, called the "hard cap", often functions as a reverberation chamber with a higher reverberation time than the lower half because of parallel walls and often very little absorption. This enables better sectional blending, but can even out spatial versions.

Looking at negative elements regarding the shoebox layout, there is the seating arrangement in which spectators can be quite far away from the orchestra, which leaves little or no sight to the orchestra. Also the room geometry with parallel walls, reflect badly and causes a less powerful early energy arrival compared to other layouts such as the vineyard layout.



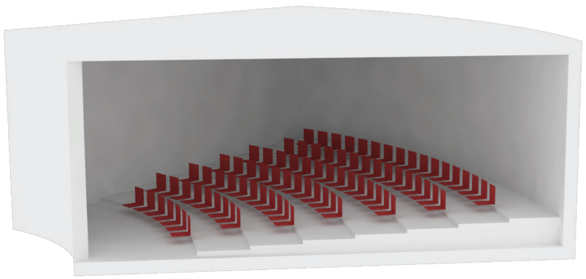
Vienna Musikvereinsall (1869)

Fan shape

A later version of the concert room is the fan-shaped concert hall, which is a mix of the antique theatre and the shoebox. It shares a lot of features with modern lecture rooms. The audience is placed in fan widening away from stage on a steeper rake compared to that seen in the shoebox-version. This gives better sightlines for the audience and increases spectator capacity. This concert room was not widely available until the reinforced concrete beams of the 20th century made it easier to span across the room.

Despite being a commonly found typology, most of the associations in regards to acoustic properties are negative.
The most obvious problem of the fan shaped hall is that the rear wall acts as a big concave curved surface, which will produce a focused echo at the back if not properly absorbed. Another problem of the fan shaped halls is the lack of early reflections due to the fact that the sound will hit side walls at a low angle. Here the problem with the curved back wall is compounded as it should act as a reflector when the walls cannot.

If the rear wall is to be utilized, it should be used as a diffuser to avoid focused echo. The result of the problems is that the seats in centre of the back rows often suffer a severe lack of early reflections. This is especially true concerning the side walls, which will leave the spectators with little spatial impression.
Despite the acoustical problems of the fan shape it still has some advantages over the shoebox. Firstly it offers much better sightlines as the each seat is positioned and directed towards the centre. Acoustically is does have good properties in relation to direct sound.



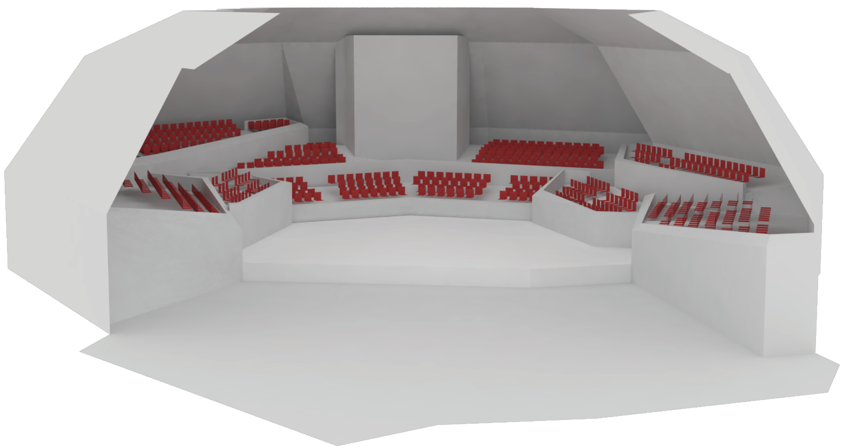
Vienna Musikvereinsall (1869)

Vineyard

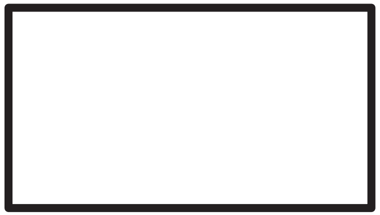
One of the more recent types of concert halls is the terraced concert hall layout called 'vineyard'. In the vineyard layout, the spectators a distributed around the orchestra in terraces in varying sizes and height, creating a non-uniform layout. With the enveloping of the audience, more spectators are brought closer to the performers just like people gathering in a circle around something interesting. Though the spectators are placed all around the orchestra, most terraced vineyard layouts dictate and overall irregular shape with most of the audience in front of the orchestra due to the directional effects by some of the performers.

The benefit of the irregular layout and terracing is the related to the early reflections within 50ms after the direct sound, which has been more emphasized in modern times due to intensive research combined with trial and error. The fragmented balconies around the audience provide early lateral reflections which are essential to give the spectator spatial acoustic impression.

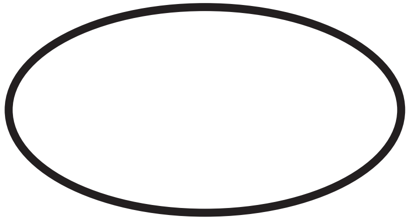
The downside of the vineyard layout is the relatively poor efficiency of space, and the low flexibility of the seating arrangements. Furthermore the directional nature of events also means that some spectators will have poor viewing conditions at certain times.



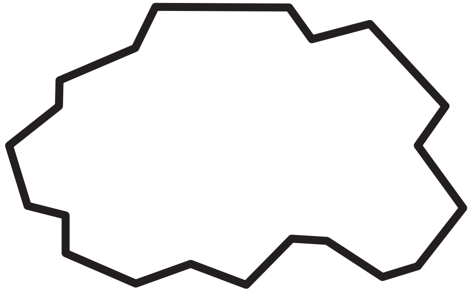
Vienna Musikvereinsall (1869)



From the previous chapter, we have derived that the shoebox layout has some clear advantages regarding the acoustics, due to good lateral early reflections and the spatial impressions caused by these. The spectator layout is clear and regular, but with some limits to cohesion between spectators of the different tribunes. Spectators placed in corner, if used at all, will often be affected by bad vision to the pitch. This affects the cohesion between spectators on the tribunes which is bad during sports performances. When used for music the shoebox layout had proven its worth in the shoebox layout gives some clear advantages regarding the planning of the arena, especially when using moveable spectator blocks



The ellipsoid shape goes way back to some of the earliest arena shapes with the Coliseum as great example of a pure layout. Spectator are situated around the center in a number of ellipsoid shapes with great cohesion between spectators as they are placed on a continuous band with no obvious sectional divisions as often seen in the shoebox layout. The continuous band of spectators has the advantage that the corners are better exploited and gives spectators better view of the action of the pitch. Acoustically the ellipsoid arena has been used only a few times, and special care must be taken, as the overall shapes dictates weak lateral reflections in the front and hotspots could be seen in the rear back of the arena if not handled properly. Due to a bit high reverberation time, the arena are most optimal for sports, where you as player and spectator want an immense spatial impression both visual and acoustically.



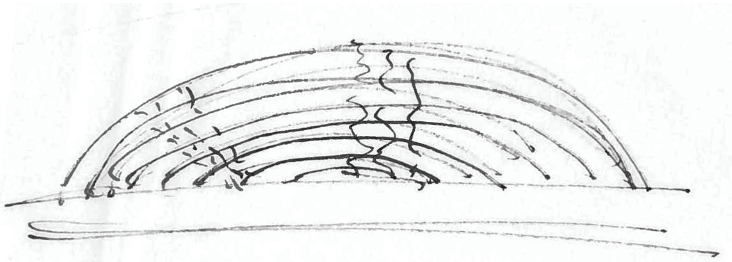
The vineyard offer a great potential regarding the acoustics, as the terraced layout offers good early reflection and envelops the audience with sound giving a full rich acoustic impression. The spectator layout is more complex than most of the other standard layouts and requires a lot more space per spectator. This could be a potential problem regarding the spectator capacity, which is a lot higher than in traditional concert halls with a capacity of merely a few thousand spectators where the arena should be able to host 10-15.000 spectators during concerts. The terraced layout could limit the cohesion between spectators, but be beneficial for private boxes as the degree of privacy would be higher. Most spectators would get good vision over the pitch, as terraces are tilted toward the center at all times. The visual impact of the terraced layout is impressive, but could easily become much disorganized if not planned very thoroughly especially in a large arena, which would require a lot more terraces than seen in the previous examples.

Phase 2 sum up

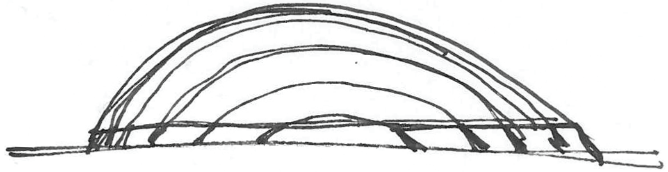
Phase two sum up
In this section we have learned that acoustic performance is a factor to take into consideration early in the design process, but it is not the only significant factor in designing a multi-arena.
This chapter shows that in the field of acoustics, there is no jack-of-all-trades type room that performs equally well in all scenarios. All types have some drawbacks, they can be acoustical but they can also be in relation to placement of spectator stands. Therefore we as designers make a choice based on what we have learned.
Earlier we prioritized the functions of the arena, and they are as follows: Sports, events, music. Because a great sports experience is our foremost goal we choose the ellipsoid shape in spite of its acoustical shortcomings. The vineyard has great acoustical properties in relation to music, but is very impractical and would have to be considerably larger than other types due to poor space efficiency. The shoebox is close to being the jack-of-all-trades, but it offers bad views from the corners and does not invite the same sense of unity as the ellipsoid shape.

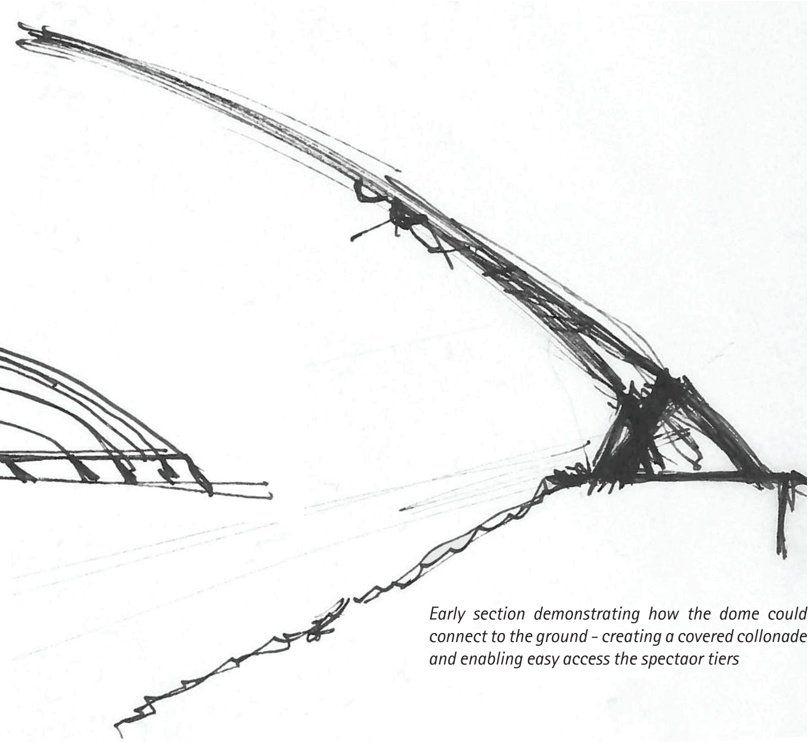
For this particular project the ellipsoid shape is optimal as it has no corners which means we have better chances of avoiding bad seats. Acoustically it may not work very well for music, but at a sports event where the noise of the crowd will come from all directions it able to create the desired atmosphere. Finally the ellipsoid shape lends itself well to the domed roof we would like to cover our arena with.

Third phase - formfinding

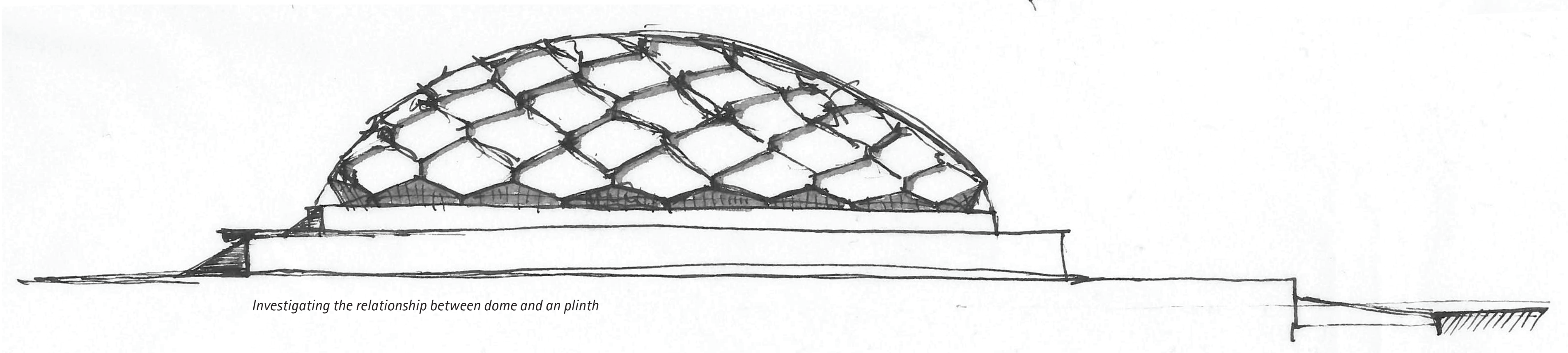


Early second phase sketches on the dome typology



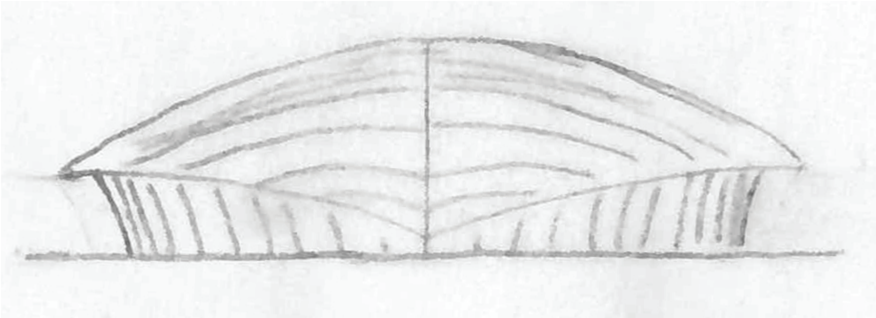


Early section demonstrating how the dome could connect to the ground - creating a covered collonade and enabling easy access the spectaor tiers

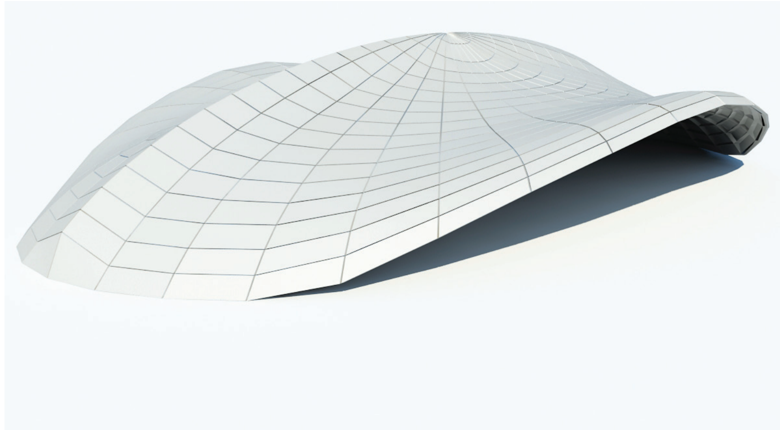


Investigating the relationship between dome and an plinth

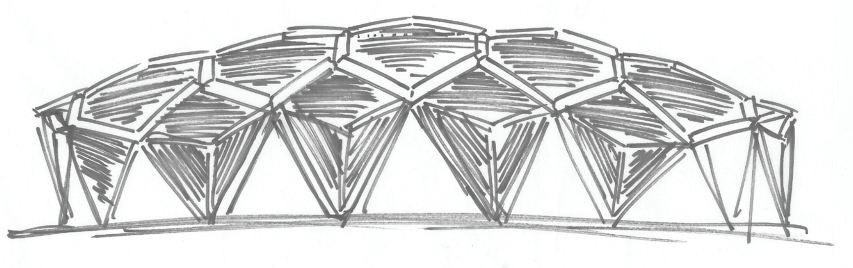
As with the masterplan, our outset were the sketches we used to initialize this second part of the formfinding phase. From there we started to sketch on dome-shapes, sketching both on paper as well as digitally. The closer we got to the expression we searched the more we started leaning towards digital sketching as it was easier to control the complex curved and facetted surfaces.



A sketch on the consequences of removing the supporting struts

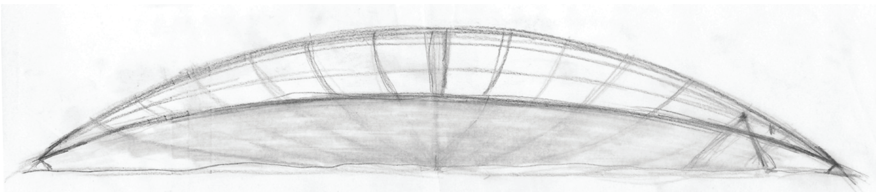


Alternate dome structure with emphasis on the centre axis



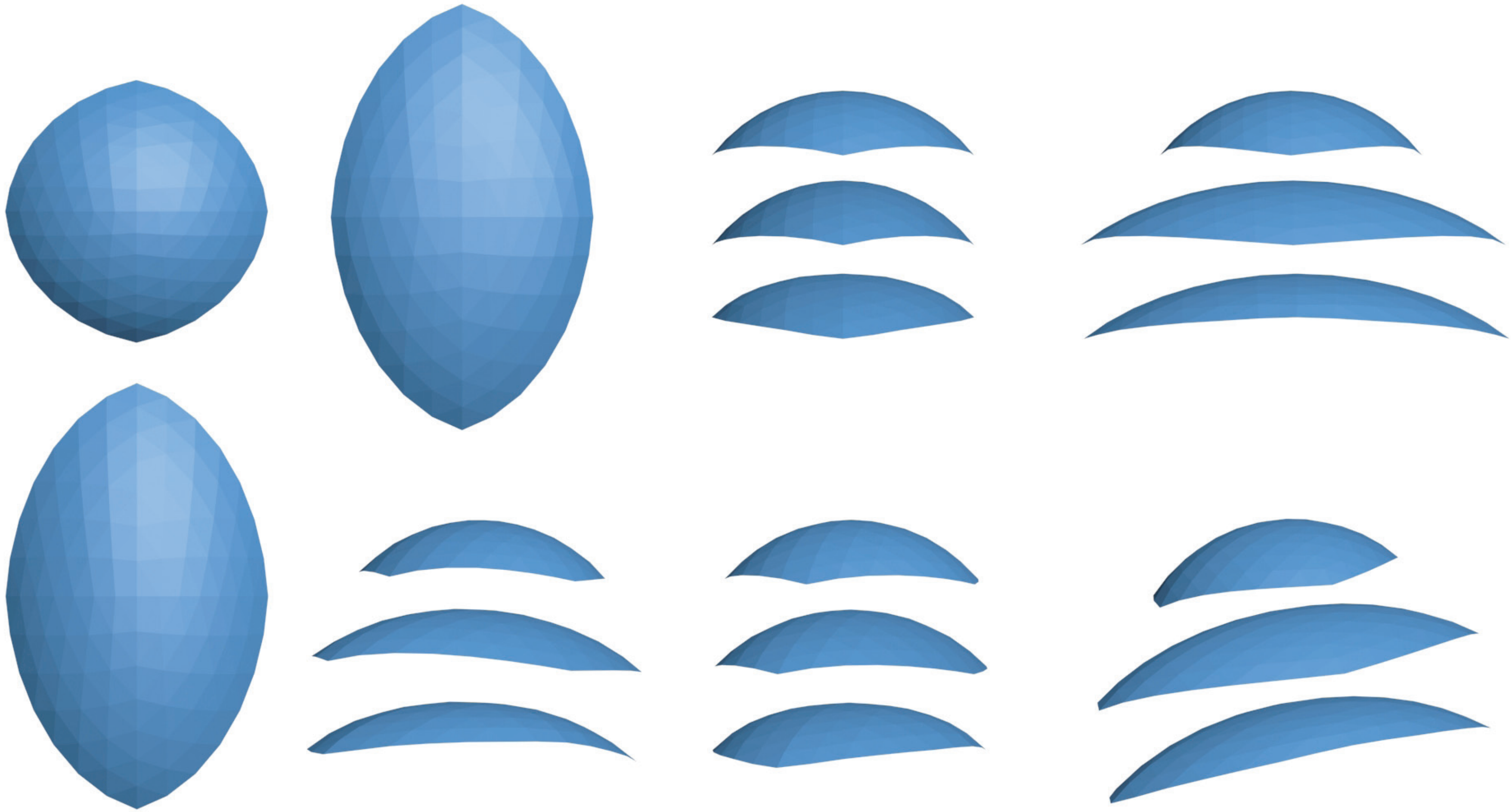
Investigating alternative ways of connecting a dome structure to the ground

Alternate dome structure with open sides as a way to guide visitors



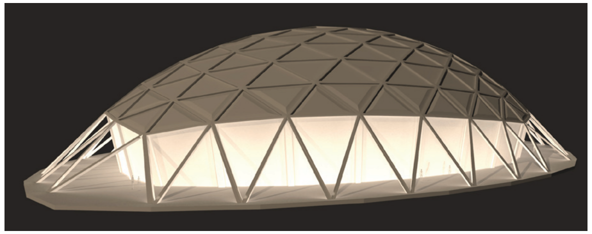
Sketching on raising the sides of the dome to accentuate its axiality

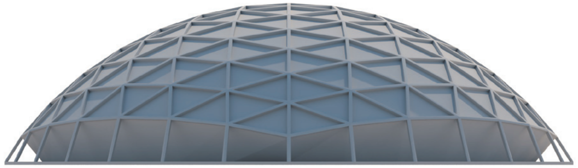
Sketching - going digital

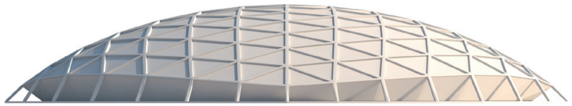


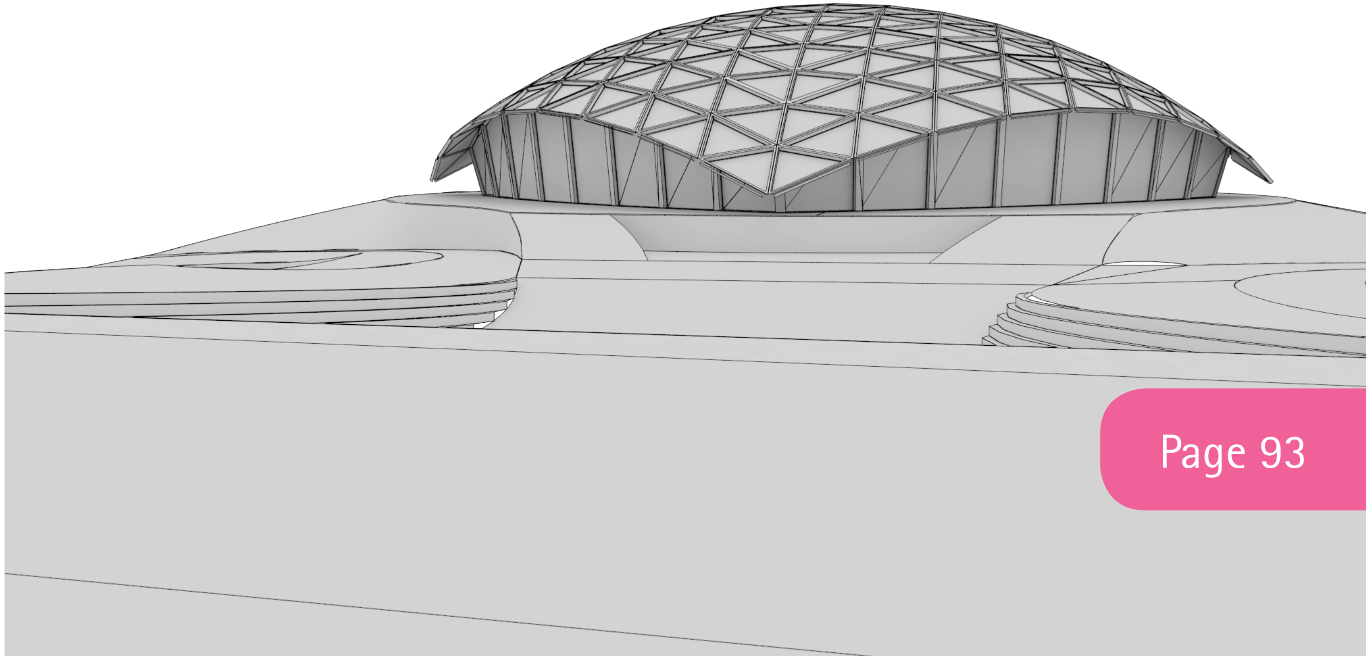
The basic shape of the dome comes from an ellipsiod which is best explained as a three-dimensional ellipse. What makes it special in our case is that the underlying wireframe is that of a geodesic dome (made popular by Buckminster Fuller). It is along this wireframe that we experiment with cutting along and across edges, stretching and compressing surfaces in search for the right form.

We discovered that the wireframe not only functions as a guide from which we can mold a shape, but also doubles as very strong constructive system.
We continued exploring the language of the sphere and the dome, investigating how different heights changed the expression and the relation to the context. Experimenting how a facade could evolve underneath the powerful silhouette while also trying different ways of expressing the construction of the dome through pattens on the roof.





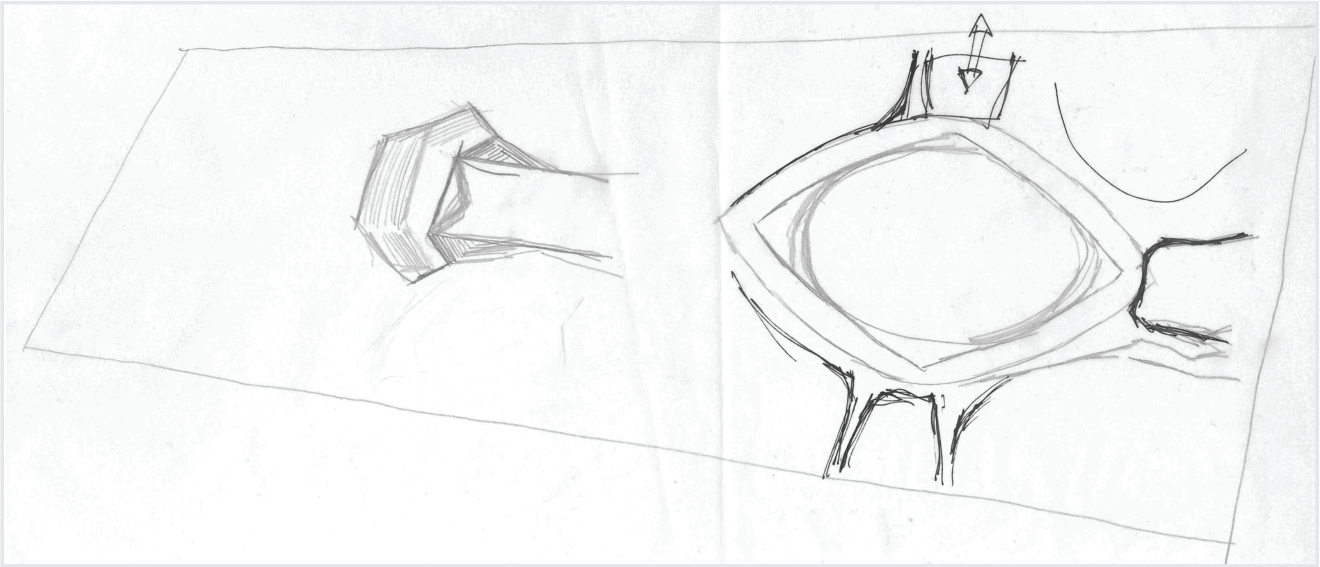


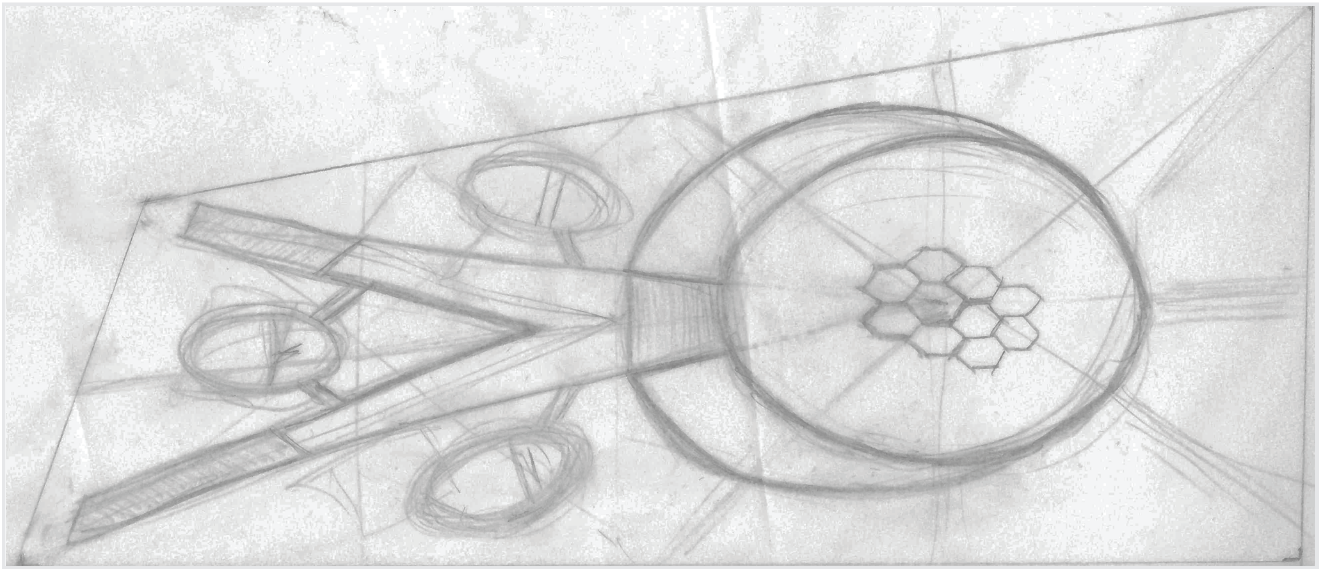


Formfinding

Masterplanning

While sketching on the shape itself we also sketched on how the dome can be integrated into a masterplan for the entire building plot.
At this point we already have an idea of how we wish to position the building on the plot: On the eastern end but still far enough from Ørestad boulevard to allow the experience of pilgrimage for those spectators arriving from that side. Also the building has been pushed slightly to the north in order to creater larger south-facing areas.
T hese first sketches search to examine how one could get to and from the building while testing different ways and degrees of integrating functions in the landscape. Finally we try to create a sense of axiality on this long and narrow plot.

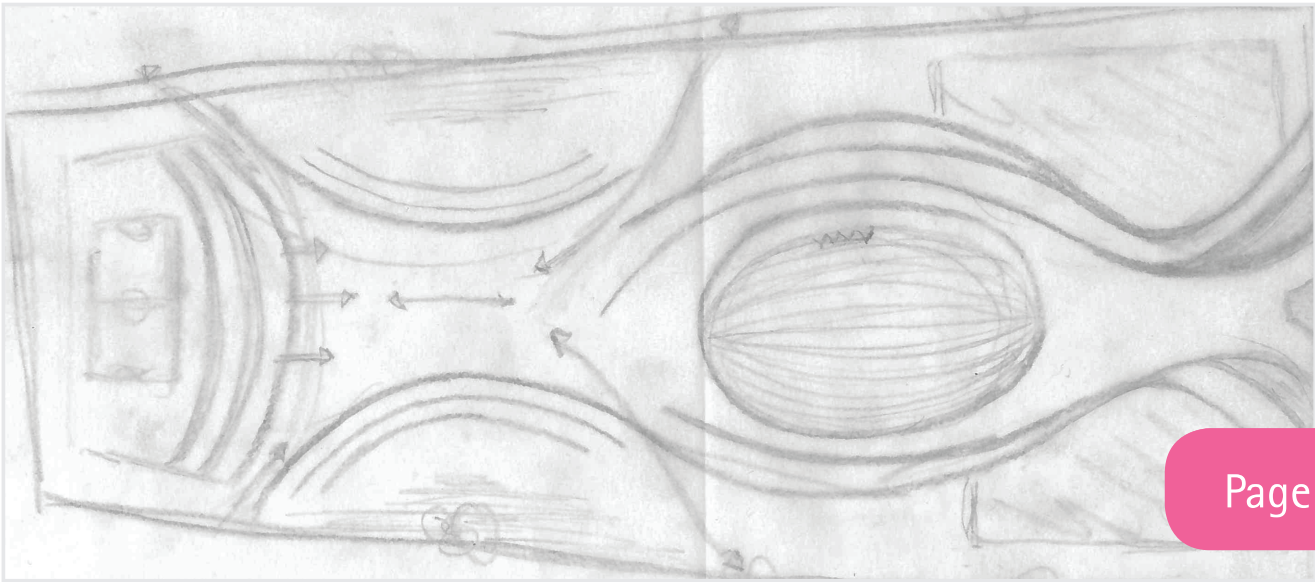




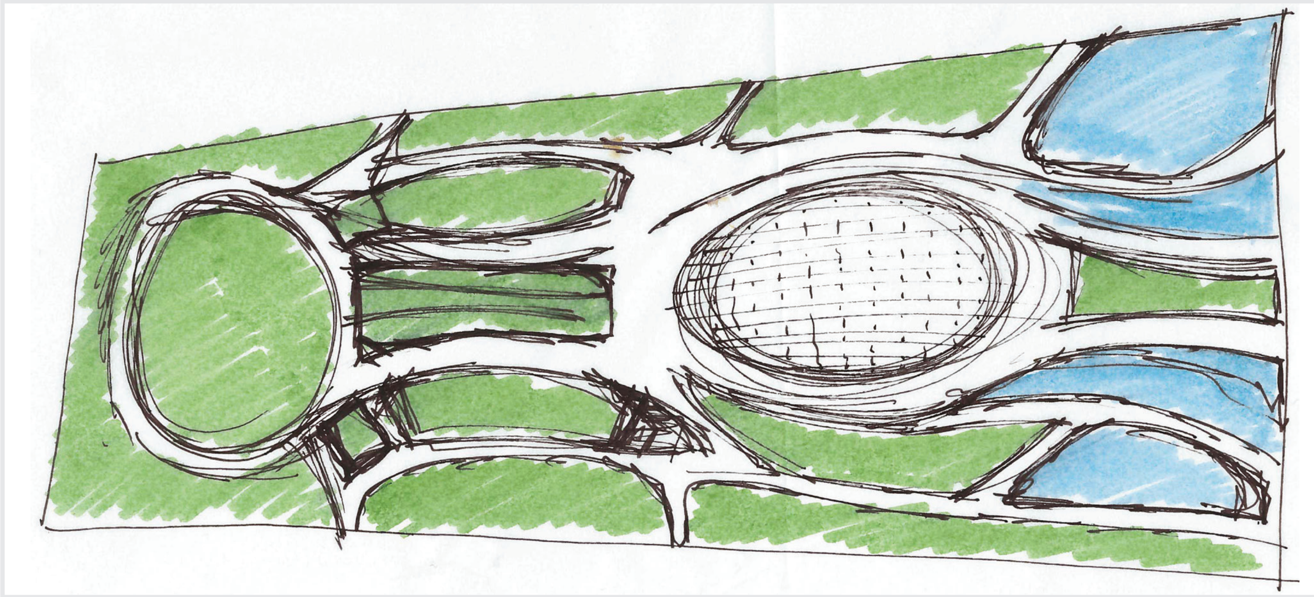
Formfinding

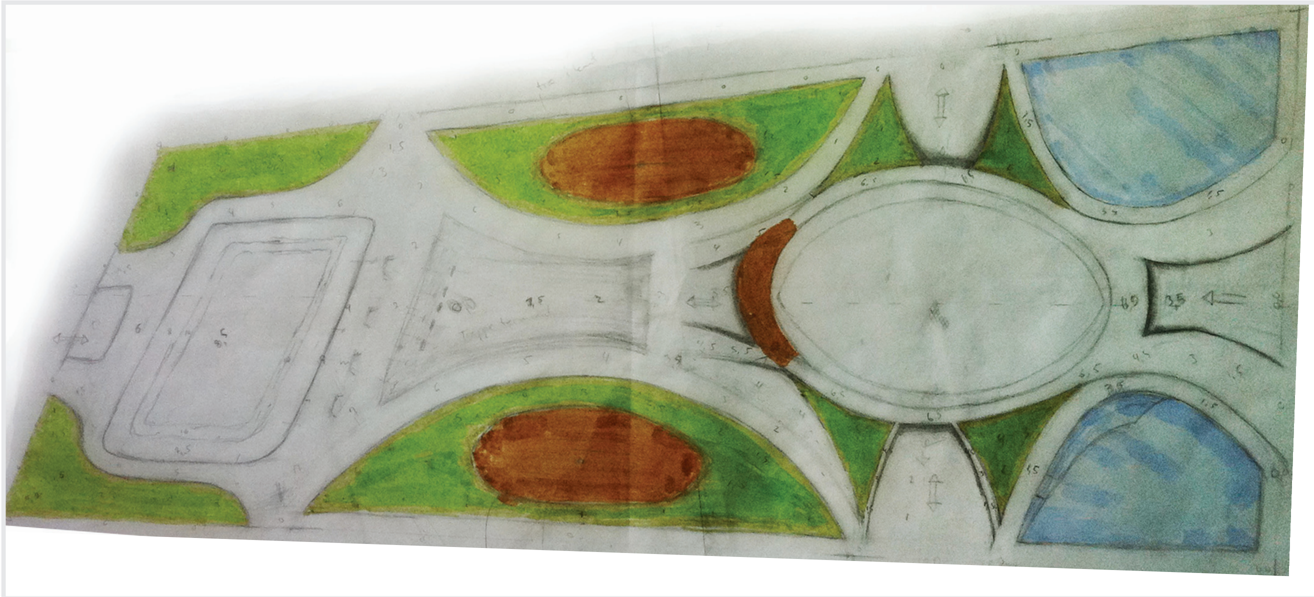
Masterplanning

These sketches show progress in that the functions are slowly starting to find their place in the landscape. The parking is placed close to the eastern edge of the plot in order to be as close to the motorway connection as possible. A central axis has begun to take form, it stretches from east to west, defining the placement of the building and how auxiliary functions are mirror around it. The sketches have different expressions where the top one seeks to subdivide the area into functions, the lower sketch searches to achieve a flow of unbroken lines through the plot.



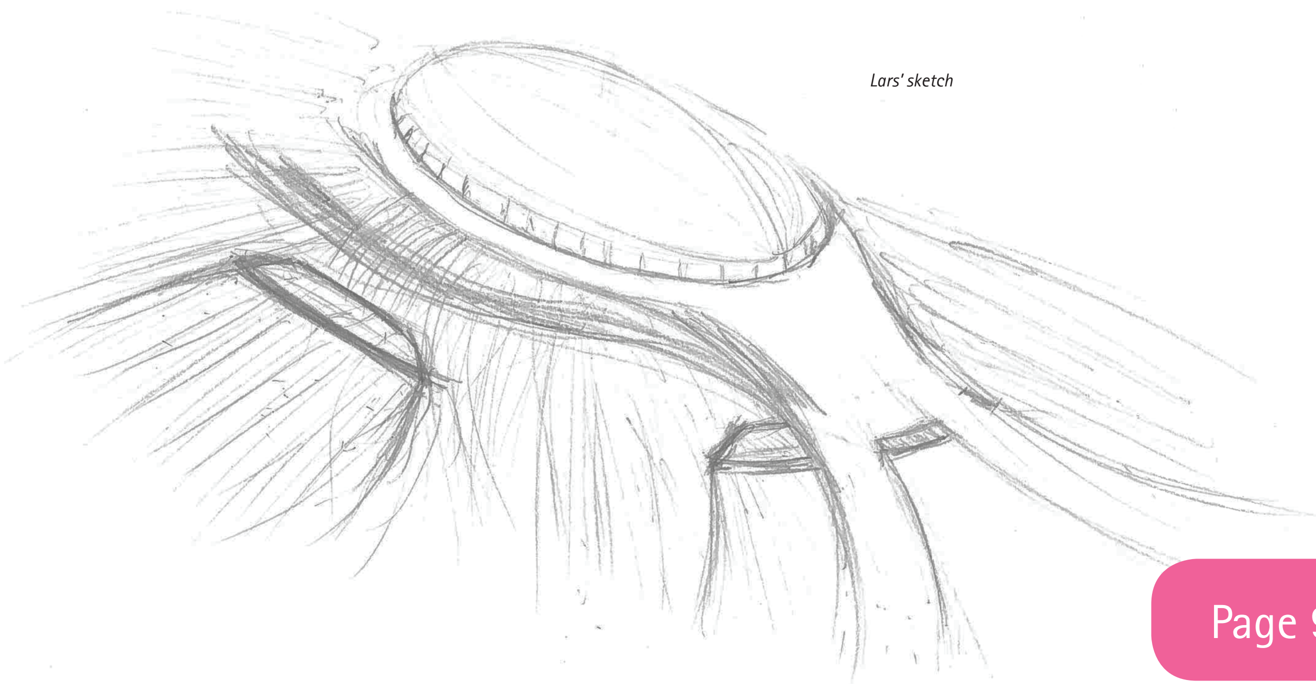
These to sketches are quite close to the final versions of the master plan design. We begin to have a clear idea of not only the placement of the building and the functions, but also the flow and placement of paths. Furthermore these last sketches we begin to reveal a sensation of the materials we intend to use in order to differentiate areas. Finally the masterplans begin to relate to changes in elevation between the plot and the building.





The two sketches on the right are the result of working intensely with sketching on the final shape, while simultaneously sketching on the masterplan, with the goal of ensuring the best possible synergy between context and building. The two sketches were created simultaneously as a test of our mutual understanding of the concept – and how we envisioned the masterplans interaction with the dome. As the sketches show, our understanding of the concept lines op quite well. Therefore we decided to continue on, returning to the interior of the building, improving the design – this time with digital tools.

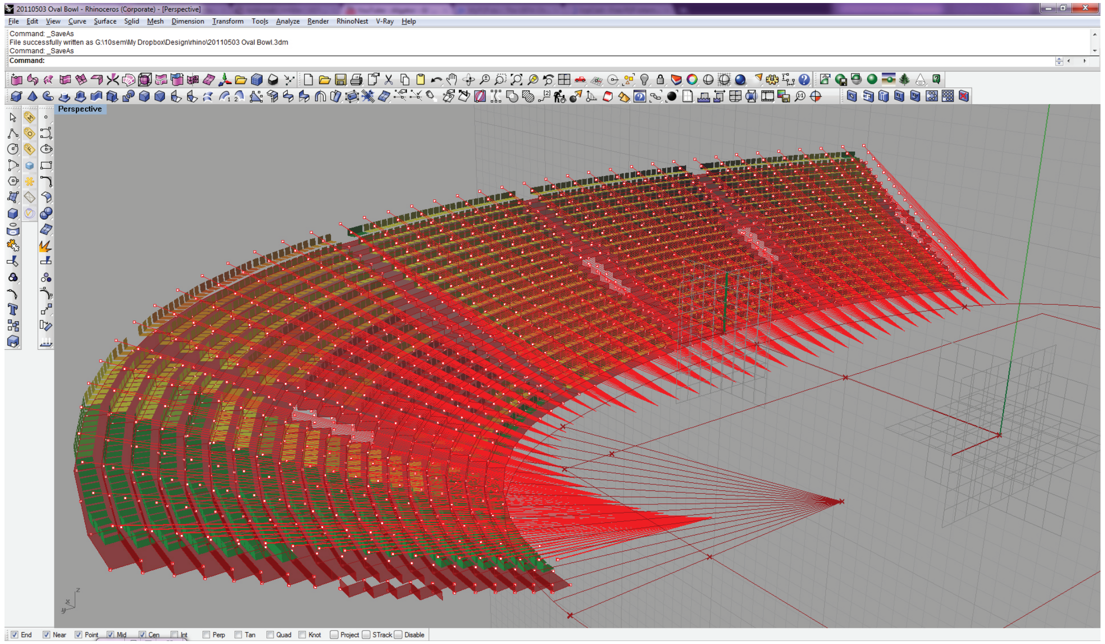
Andreas' sketch



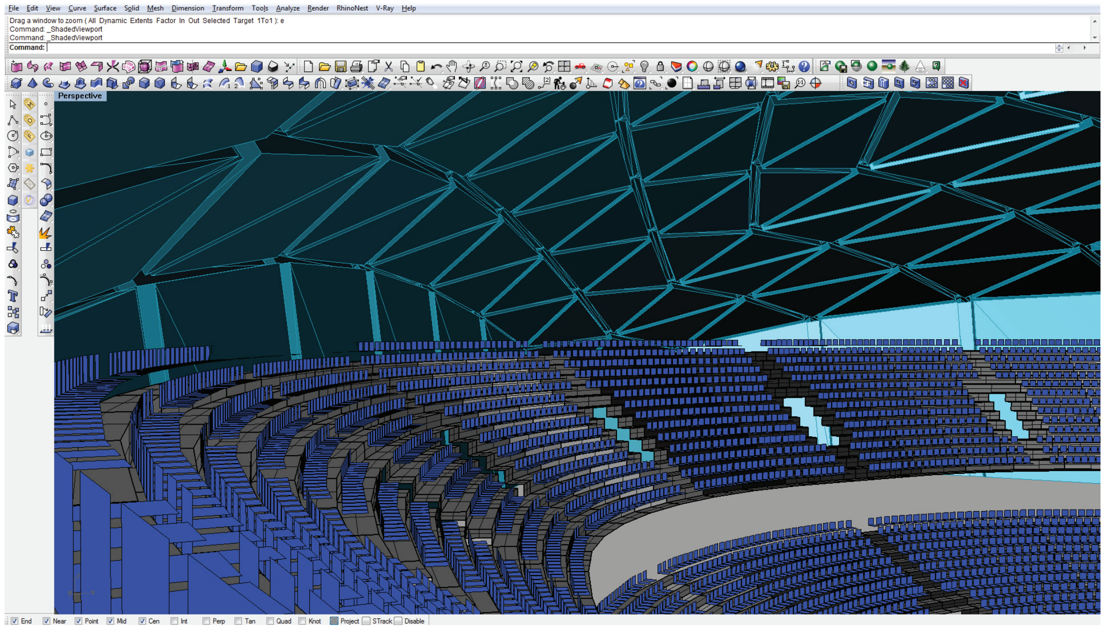
Lars' sketch

Digital tools

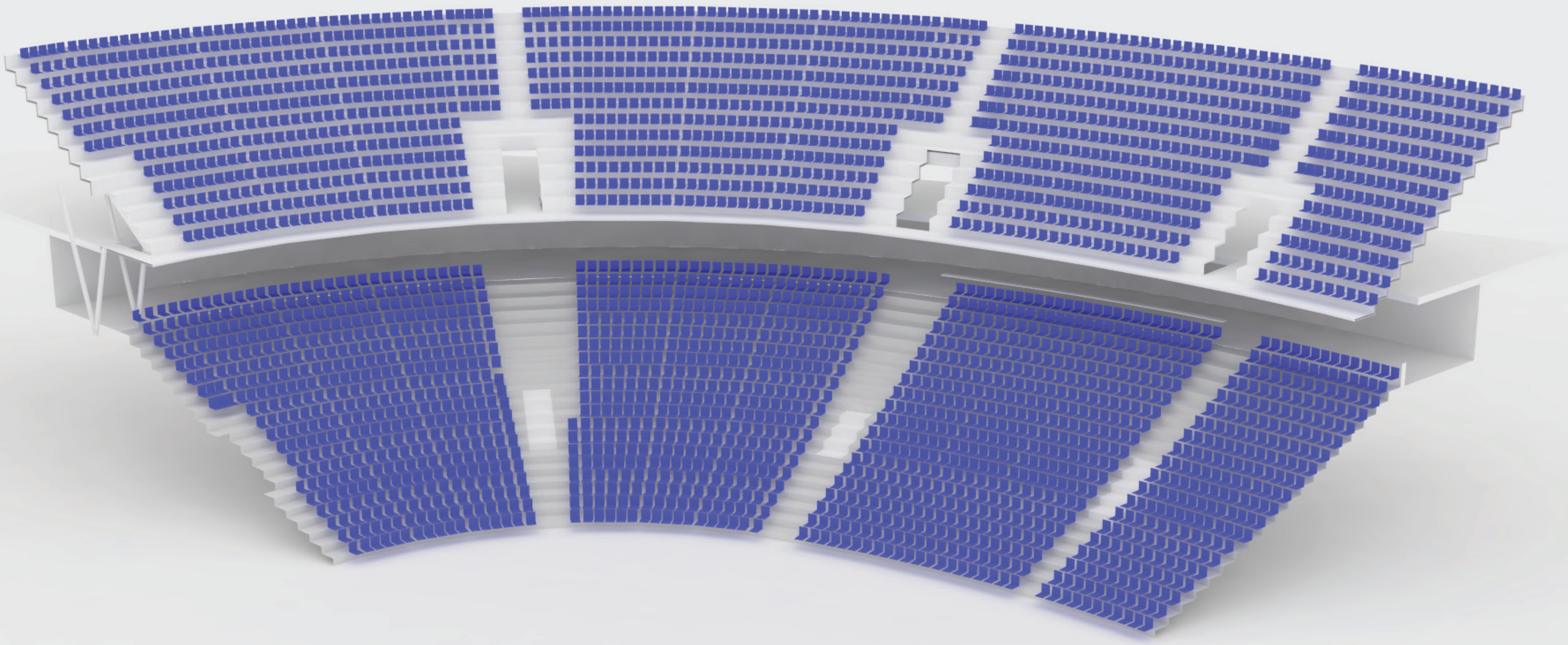
As the earlier sketching phase moved towards a more fluid design with a ellipsoid dome, so did we start another iteration regarding the interior setting. We began working in depth with new spectator tiers related to the ellipsoid design. The earlier spectator investigation took a long time to model, why we sought out new method of testing tier layout. For that purpose the parametric model plugin Grasshopper for Rhino was used. We found an already existing script which we altered to our demands (all credit for original grasshopper script goes to Roberto Molinos & R.J. Gonzalez) The script gave us the possibility to work intensely with the earlier mentioned C-value to optimize sightlines for every seat in the arena, the overall layout of tiers, rows, levels etc.



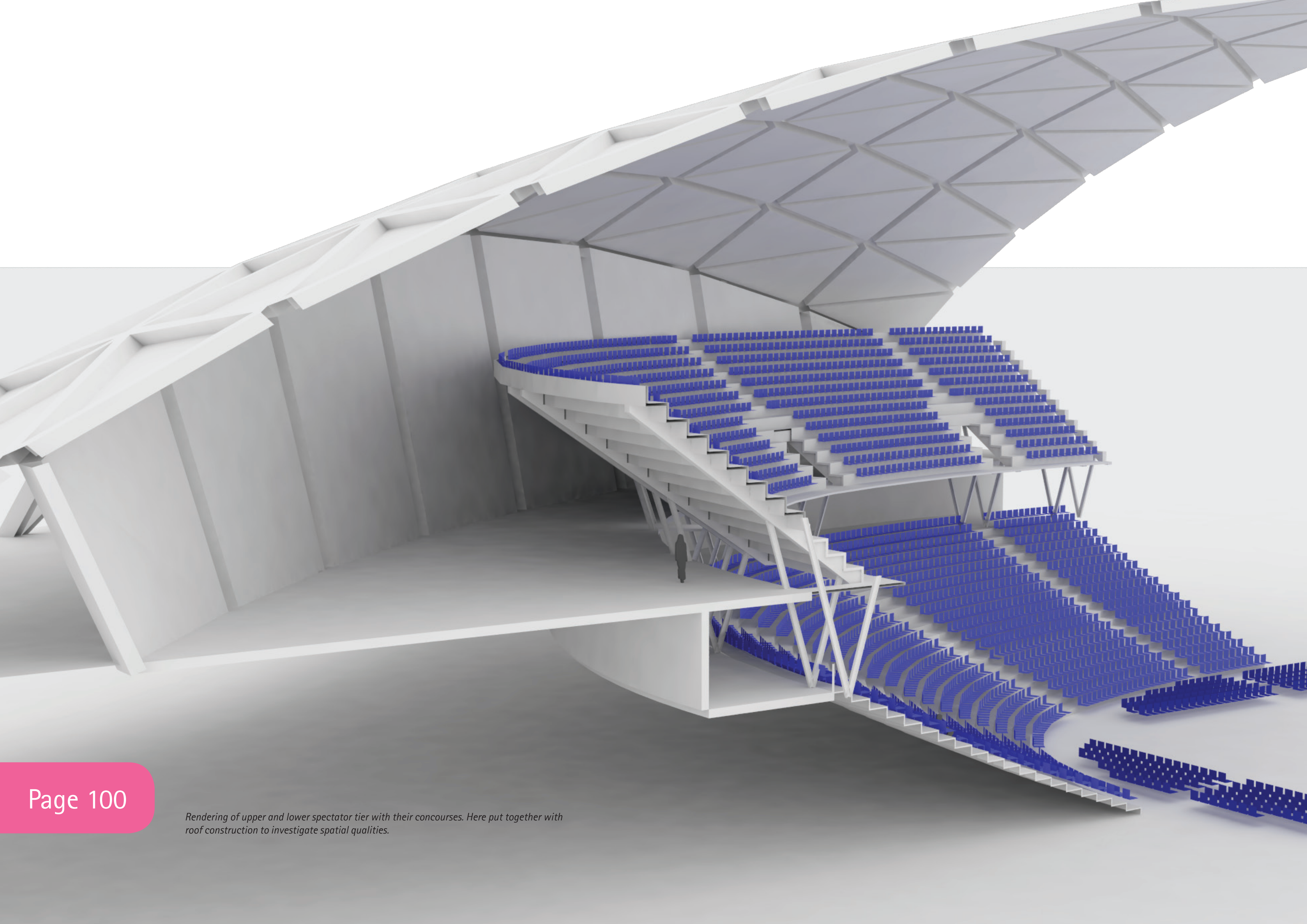
Digital modelling of spectator seating with optimized sightlines for as many as possible. Model made with Grasshopperscript for Rhino



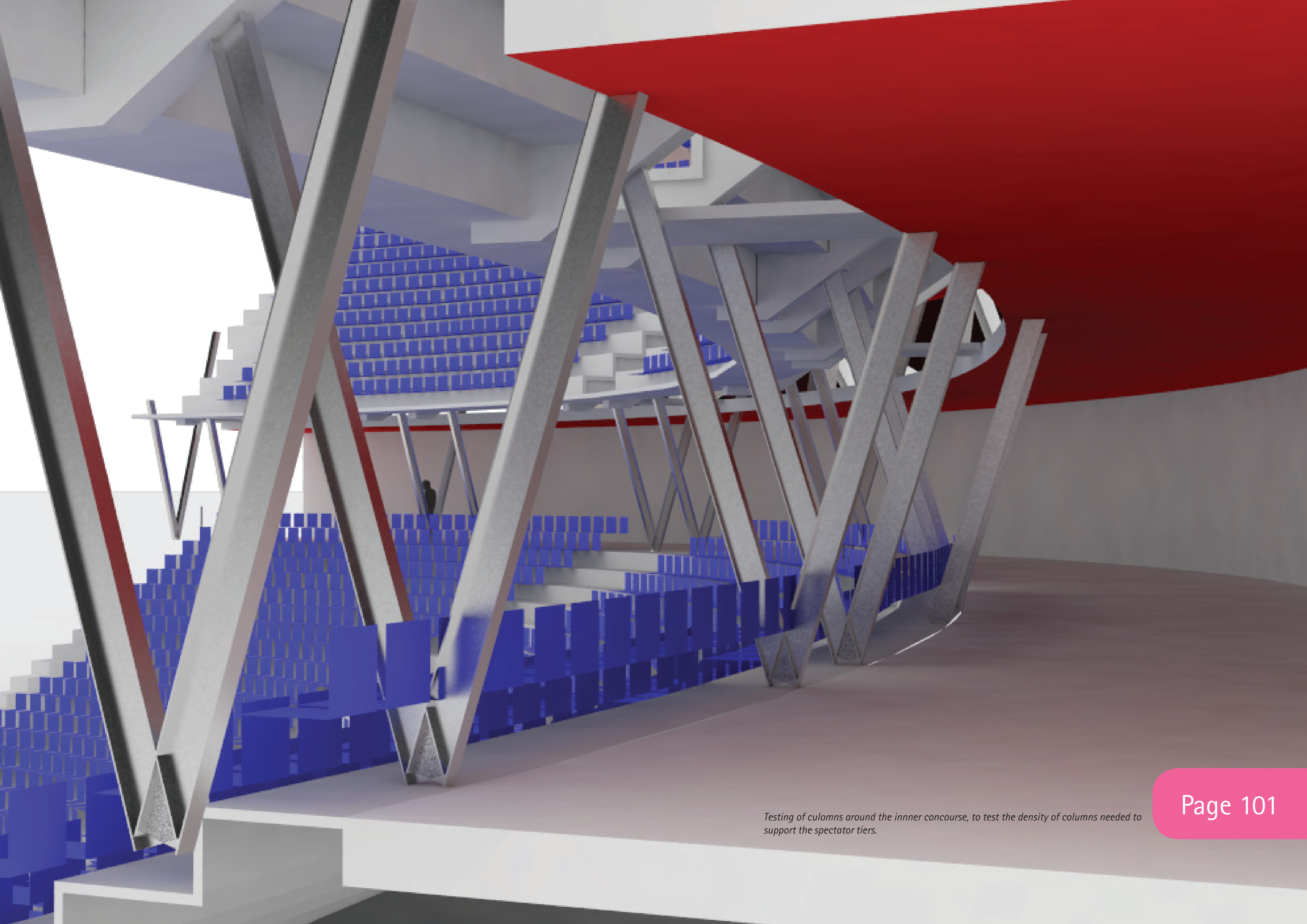
Screenshot from Rhino



Rendering of upper & lower spectator stamd. Lower spectator tier is directly connected to the circumpherial concourse on the main level turning inwards, while as the upper spectator tier is connectied to a outwards concourse one level above.



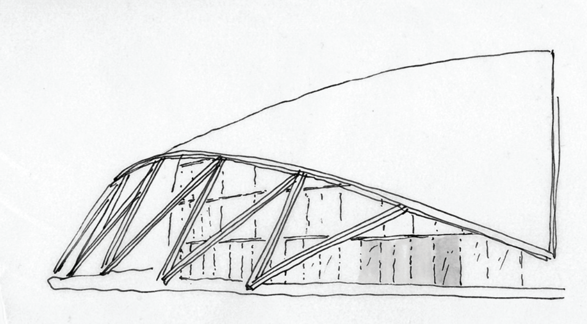
Rendering of upper and lower spectator tier with their concourses. Here put together with roof construction to investigate spatial qualities.

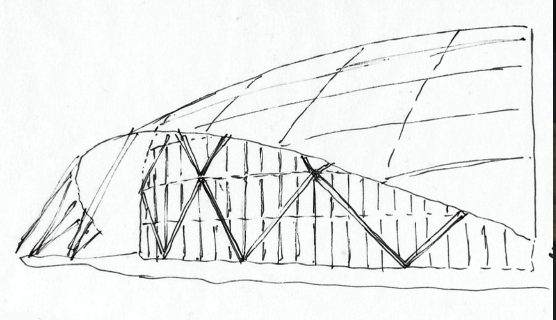


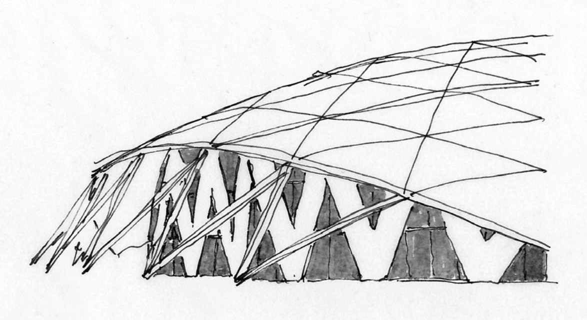
Testing of culomns around the innner concourse, to test the density of columns needed to support the spectator tiers.

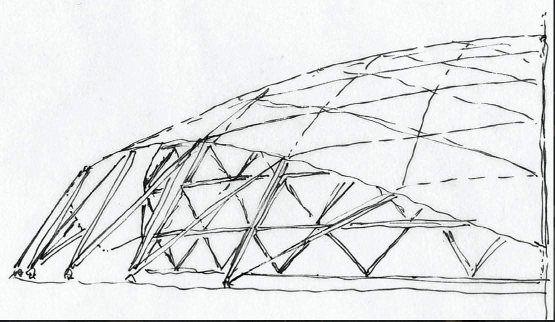
Facades

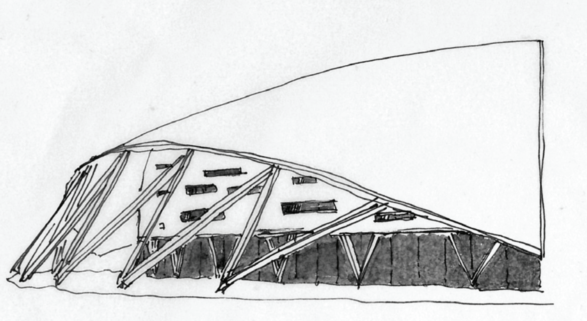
In order to facilitate transparency we started out with a glass facade. It appeared to work out well in earlier iterations, but as we started to add more detail such as latticework to glass façade, the elegance of the solution faded. Therefore we began to sketch on alternative façade solutions to see if it was possible to create a design for the façade that somehow had a greater degree of harmony with rest of the design. The sketching process showed that it was not the façade design itself that was the problem. Several other designs proved to be working against the bracing of the dome or even trying to overpower it. Therefore we went back to the original simple design, a glass façade divided with trusses. We then tried working with materials instead. A more stringent approach with a cleaner profile helped the design considerably. Furthermore we could use this as a way to fill out certain areas of the façade with a solid material giving the façade not only variation, but also solving to problems in the process: Helping to lower the heat loss of the large glass façade while also allowing privacy for those functions that need it.

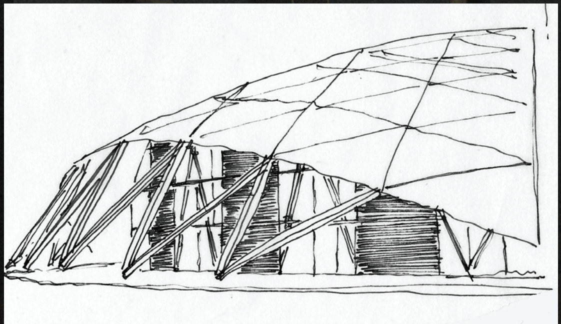


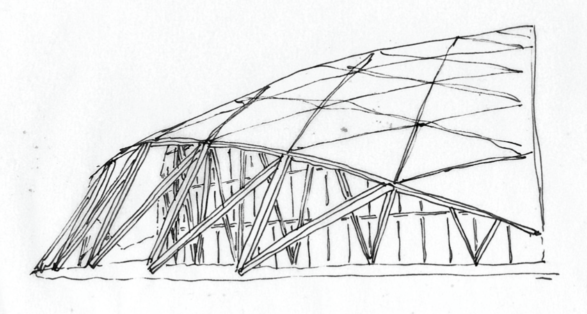


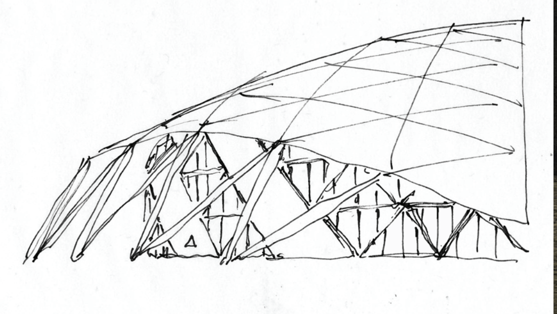


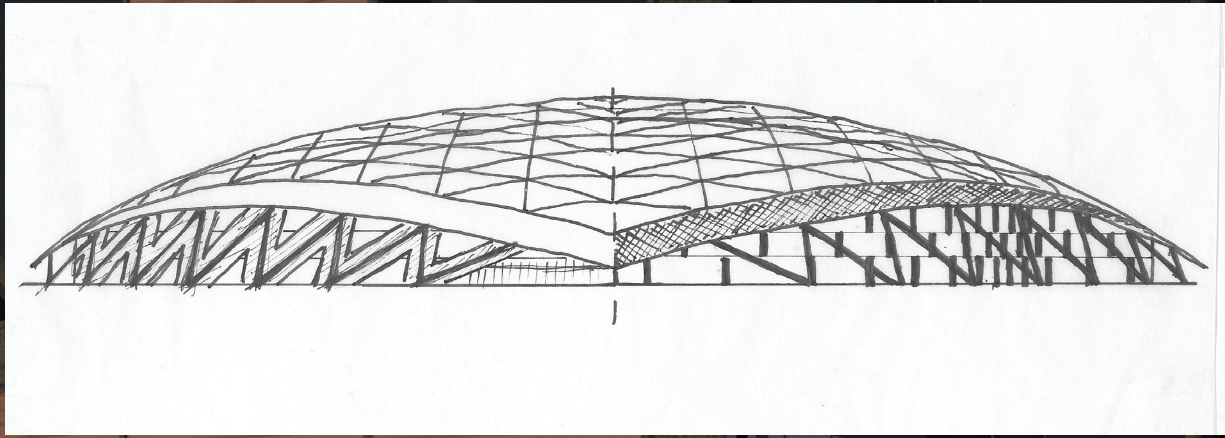


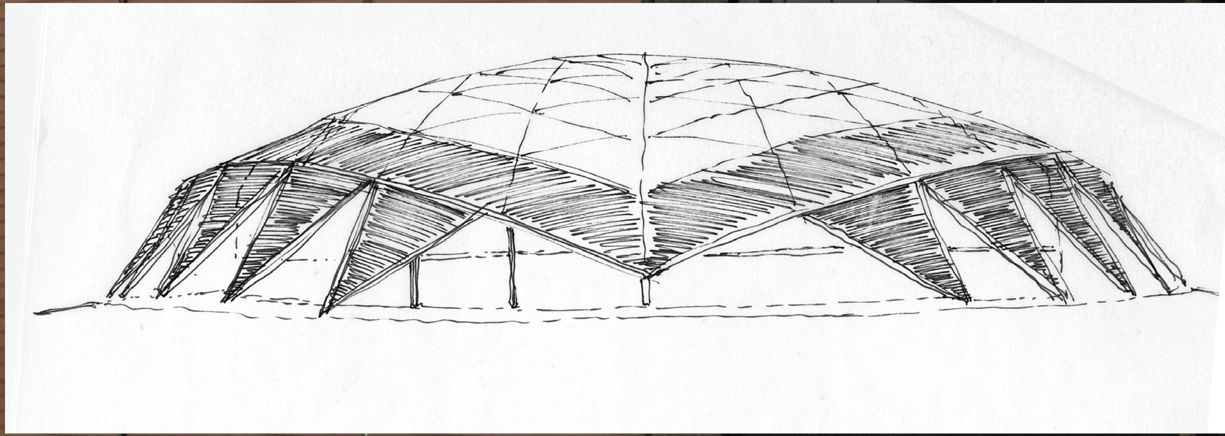


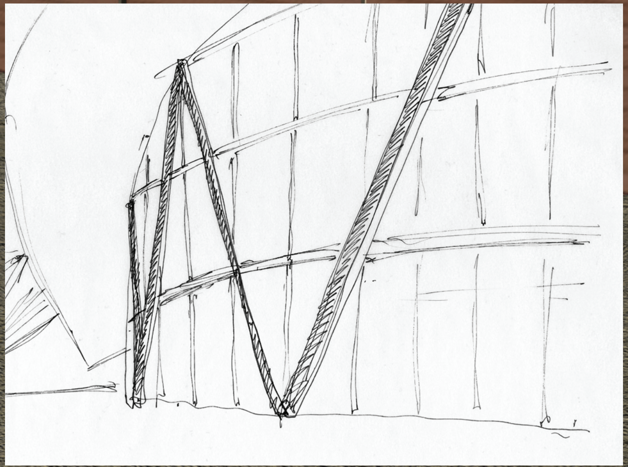


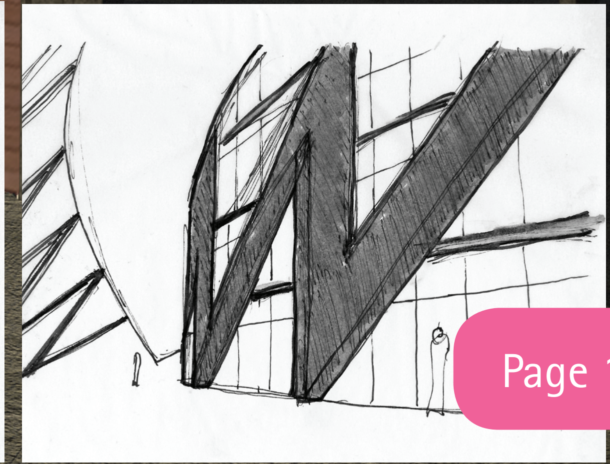








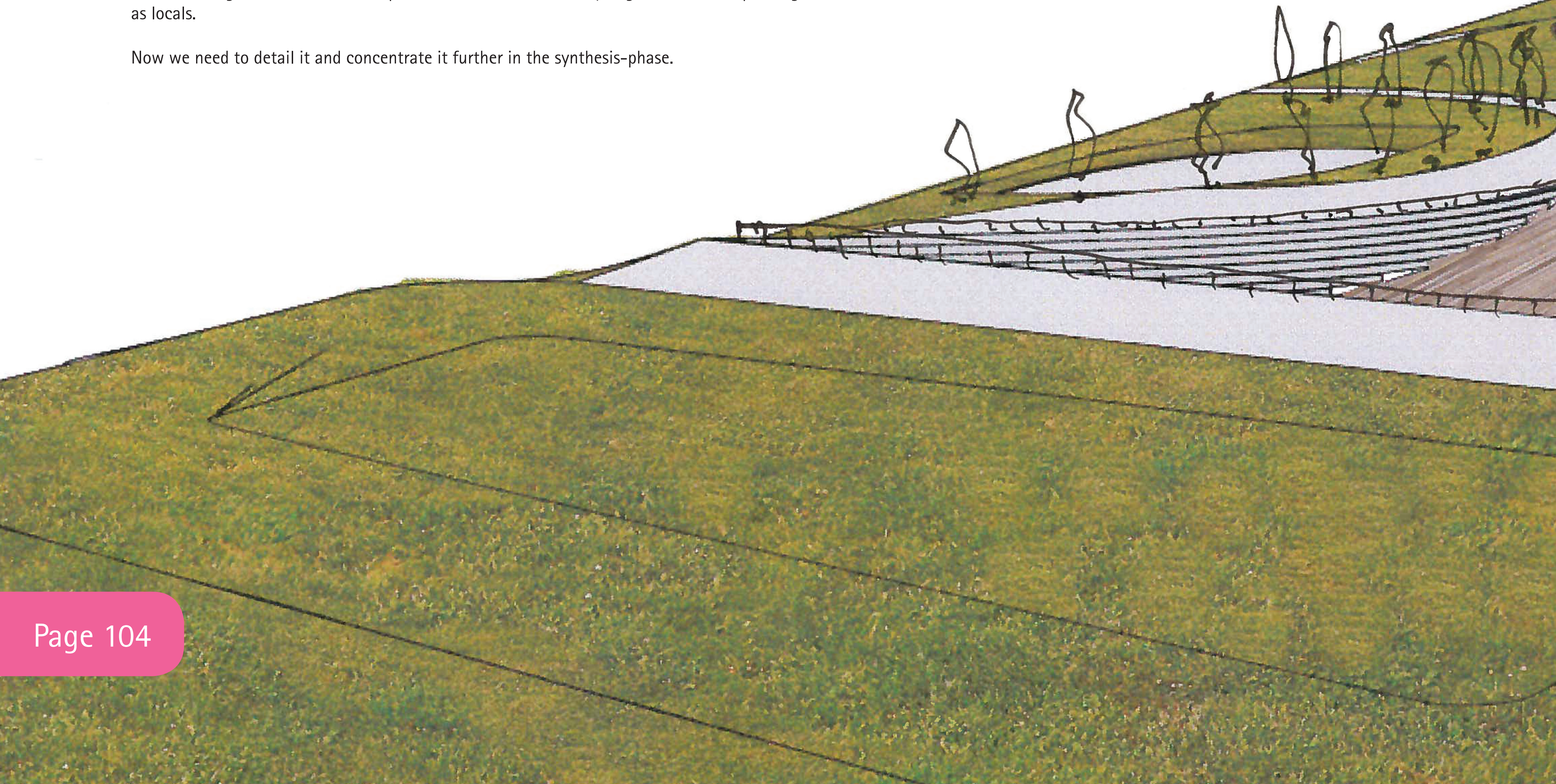


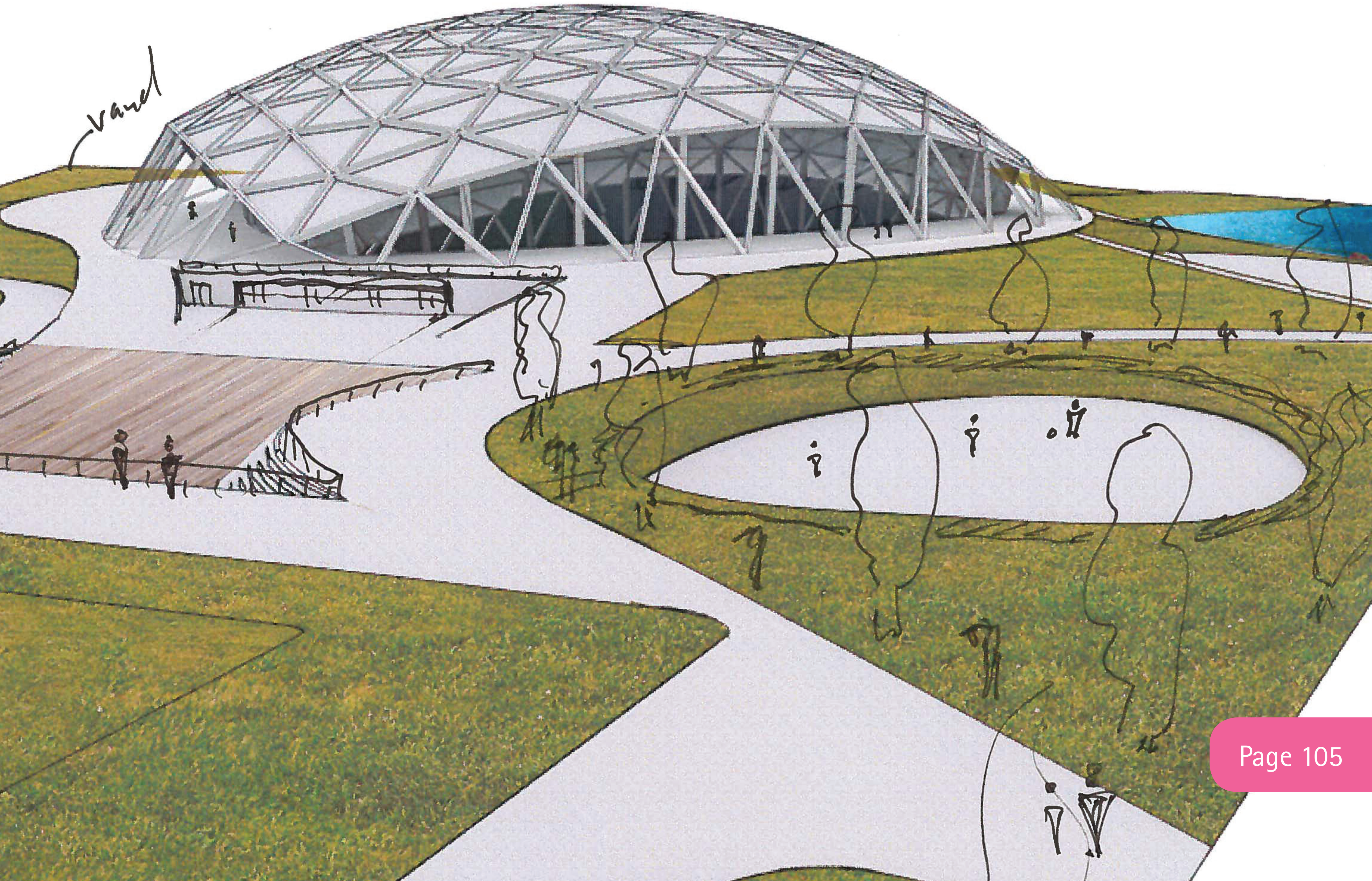


Formfinding phase - sum up

Rounding of the formfinding process we have created a design that in many aspects relates to the demands set in the problemformulation and vision.
We have created a dome structure that differentiates itself from the context through a powerful design language while remaining transparent visually and functionally.
We have integrated it into a masterplan with which it enters a synergetic relationship that gives value to visitors as well as locals.

Now we need to detail it and concentrate it further in the synthesis-phase.

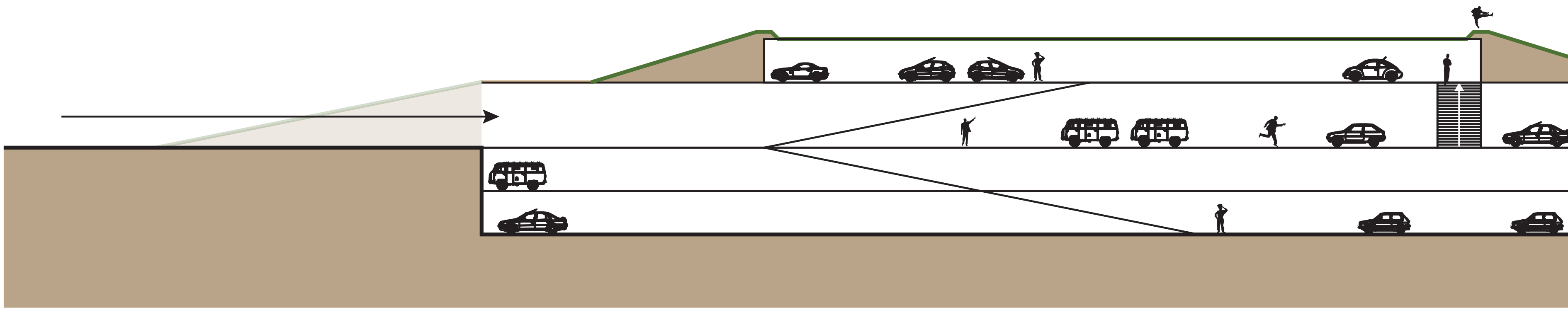


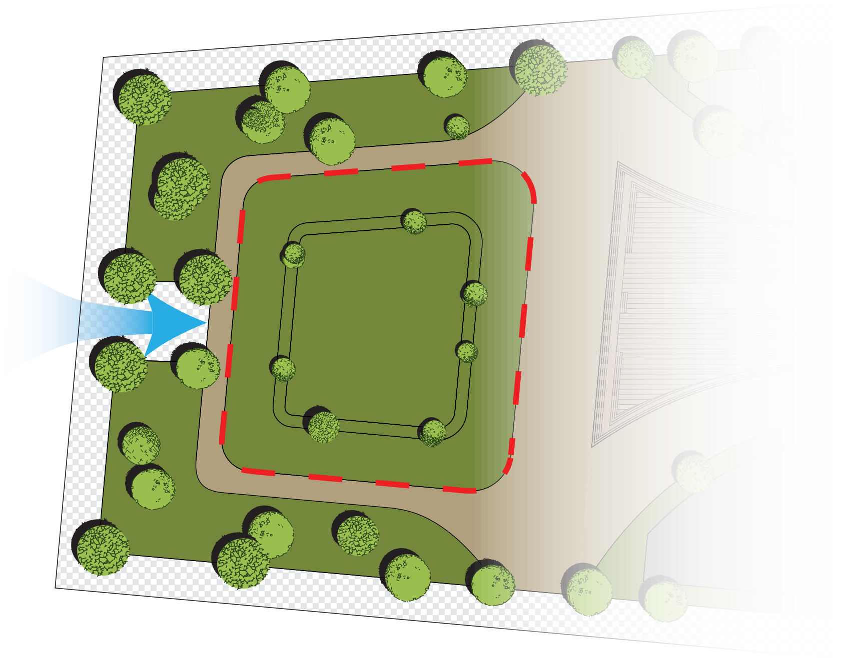

vand

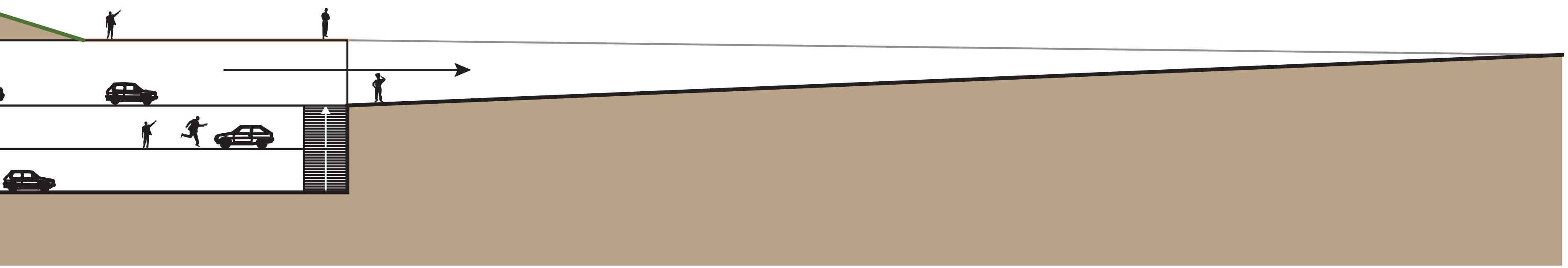
Synthesis

Parking

In this phase we take our existing design developed in the previous process and refine it further.
We start out with the parking structure on the west side of the plot. The section below demonstrates how people can drive directly inside the hill which is takes nature of a cave rather than a parking structure. After parking people exit on foot out in a artificial valley one level below the stadium. This is done to control the views of the arrival and as a means to strengthen the sensation of pilgrimage when arriving to a game.







Pitch sizes

We have said early in the process that we want to create a multi-functional indoor arena which alone gives a rough guide in relation to possible sizes. However, when we say that we want the stadium to be able to support a host of different sports we also need to define them.
Our original thoughts were to create a handball arena which has a pitch size of 40x20, but is usually has a boundary around the edges a few meters wide. Furthermore it needs space for courtside personnel such as the teams and officials. Therefore it did not require a great deal of extra space to be able to accommodate slightly larger pitches.
Our largest pitch size is 61x30 which is the size of in internationally approved ice hockey rink. The hockey rink does not have a wide edge like the handball court – it has a hard barrier right on the edge of the rink. Therefore it hardly takes up any extra space in addition to the 61x30.
With the hockey rink as our outset we can accommodate anything that is smaller than that as demonstrated by the diagram to the right.

ice hockey:
61 x 30

swimming:
50 x 25

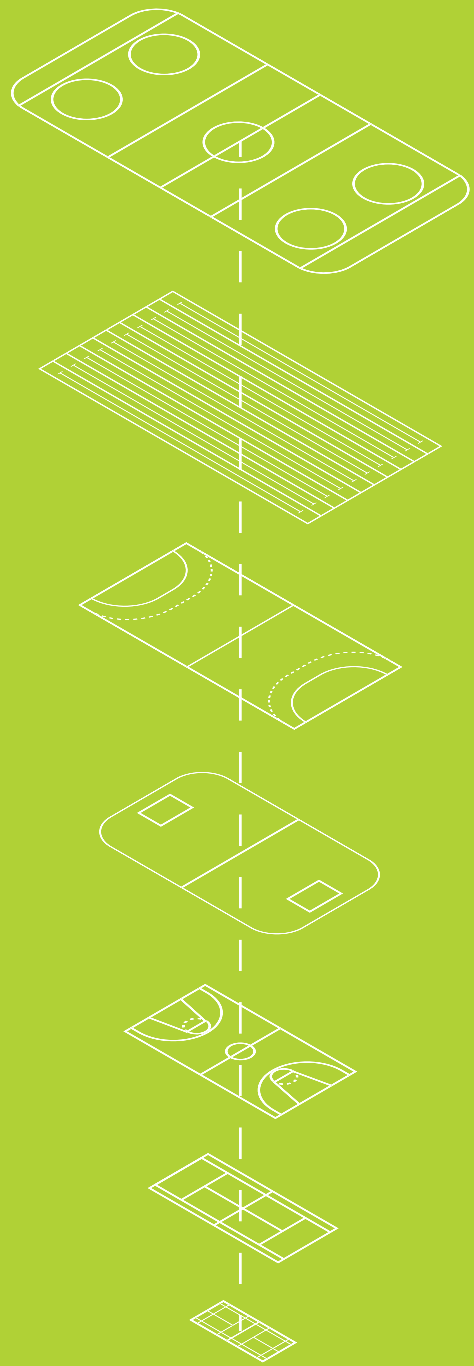
handball:
40 x 20

floorball:
44 x 22

basketball:
28 x 15

tennis:
24 x 11

badminton:
13½ x 6



Energy & ventilation

A multi arena is a complex building with wildly fluctuating peaks regarding use of the building and thus internal heat load ranging between a large empty volume in the middle, which will accommodate up to 15.000 spectators during curtain events to the small scale offices in the perimeter of the building. A project of this complexity requires advanced energy calculations to give a rightful prediction of the energy behavior of the building. During initial sketching, very rough month-average calculations was done in spreadsheets. Otherwise no calculations have been done regarding testing the energy consumption of the building.

In order to heat up the building and conserve energy a design proposal with a low surface to volume ratio is proposed. The building features a largely transparent glass facade and a semi transparent roof.

The roof construction which covers the arena is a double façade with two layers on inflated EFTE foil bubble skin foil similar to those used on the Beijing National Aquatics Center (Water Cube) and Allianz Arena in Munich.

During winter the skin acts like a highly insulated greenhouse. The skin is semi transparent and lets in light which heats up the cavity, the bubble and the thermal mass inside the arena.

During summer period, the cavity between the insulating bubbles can be naturally ventilated due to stack effect caused by the pressure difference of the air inside and outside. Pressure difference is caused by the temperature difference of the air being heated inside the cavity. An upening in top of the roof lets out the hot air and sucks in cold from the bottom of the cavity at the rim of the building facades.

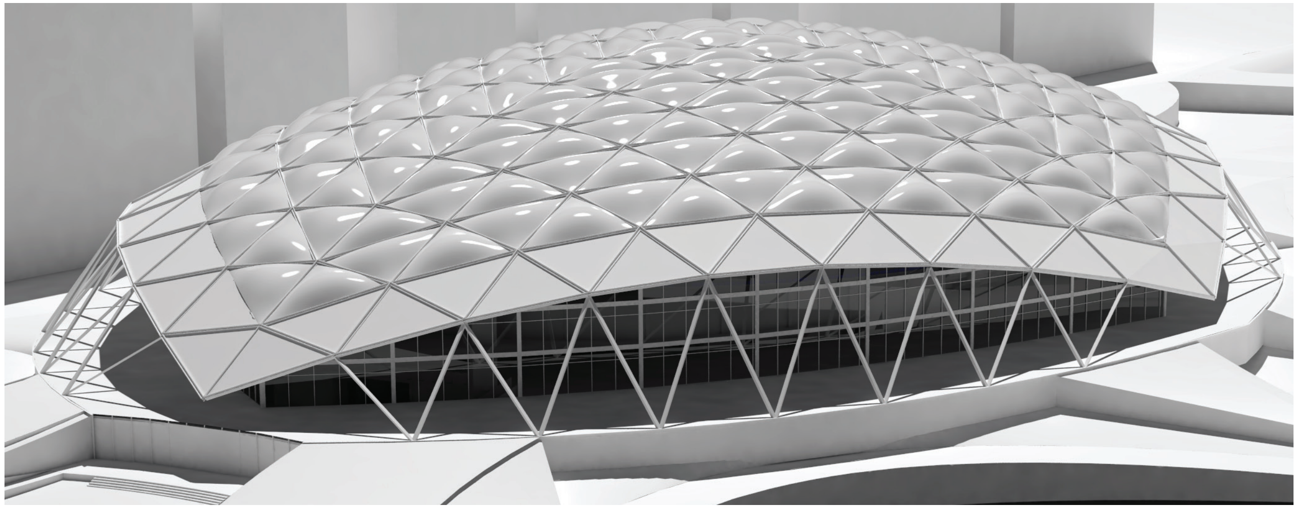
Construction

During the project structural analysis has been conducted on construction elements. For that purpose Finite Element analysis has been used both for iterative testing and verification of final structural layout. Structural testing has been focused on the large roof construction which spans across the whole building and is such the most critical structural element of the building.

Dead load:
Weight of structural beams is automatically calculated by the Finite element program StaadPro based upon the chosen geometry and beam profiles. In addition 0,25kN/m2 is added for the roof construction. This value is quite based upon the lightweight EFTE-foil facade.

Snow Load: 0,72kN/m2 is applied to roof surfaces with an angle less than 15 degrees.

Wind Load:
An approximate value of 1,5kN/m2 has been applied to the construction with a wind direction from west as this is the dominant wind direction with the strongest winds.



	member diameter	member thickness	max. deflection (< 750mm)	max. beam stress (> 230N/mm^2	Within limits
Joints have no degrees of freedom	114,3mm	3,6mm	206mm	92,2N7mm2 (axial)+213N/mm^2 (bending), total stress: 305N/mm^2	Yes/no
Joints released, removing bending stress in members	219,1mm	6,3 mm	293mm	194N/mm^2 (axial)	Yes/Yes

Ultimate limit state:
Ultimate limit state is conducted to test whether individual members yield stress is not surpassed.

Characteristic strength of steel:
approx. 230 MPa

Characteristic strength of concrete:
approx. 20-50 MPa

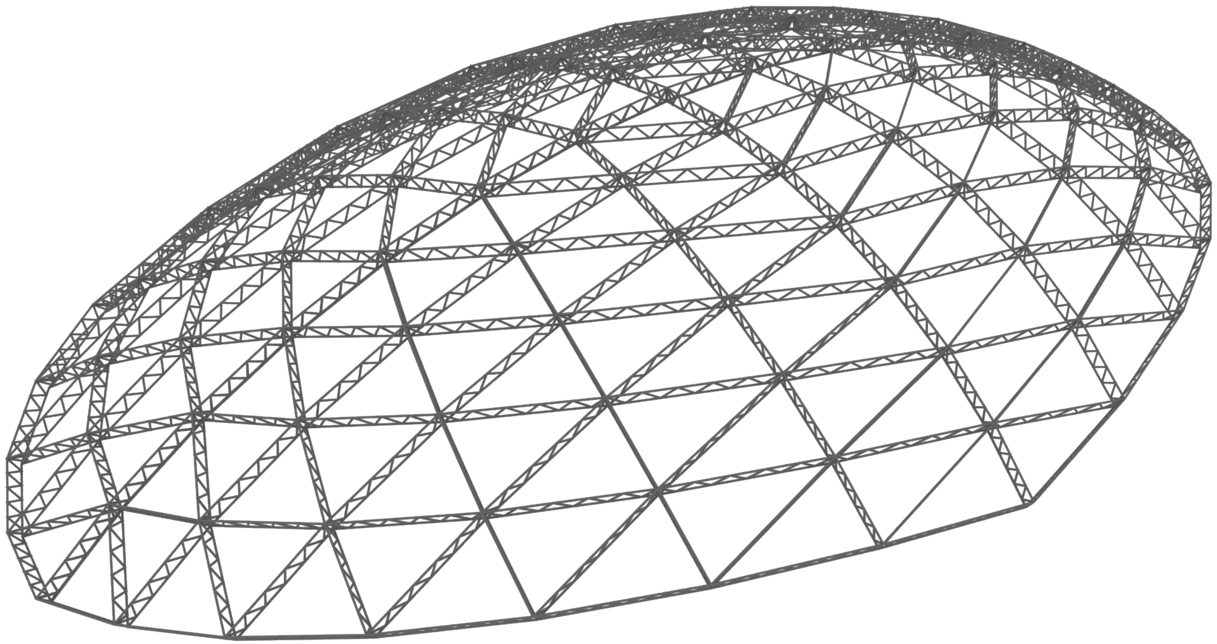
Serviceability limit state:

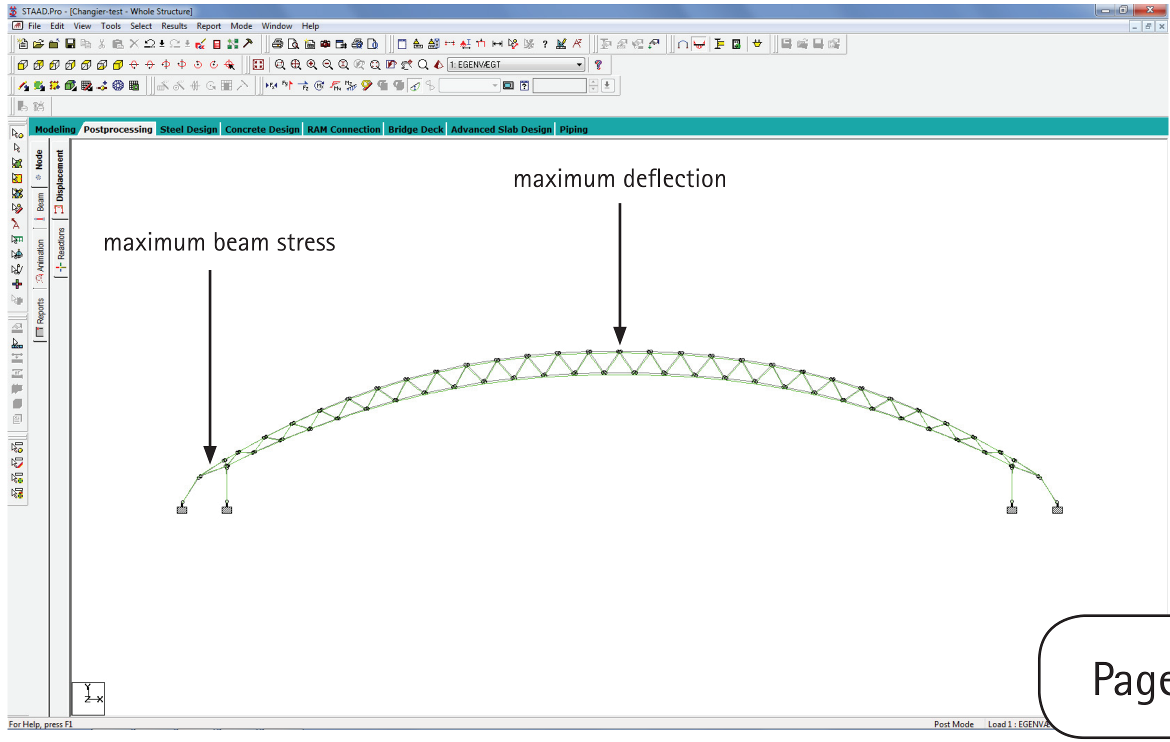
The whole construction is also tested for 'serviceability', if the deflection of the structure is sufficiently small to ensure the comfort of users in the building. The maximum deflection for a roof construction is 1/200 of the length.

Length =150m
Maximum deflection L/200, L=150m: 150m/200= 0,75m = 750mm

Since the sketching process the proposed construction for the large roof spanning approx. 150 meter x 105 meter is changed into a double truss like construction to emulate large beam while drastically decreasing the amount of steel used in the construction.

A number of test were conducted to find the approximate size of the member profiles. In the table the first test featured member profiles with no degrees of freedom. It was no apparent problem regarding the deflection of the roof. But with no degrees of freedom, the members were prone to high bending moments. Thus testing was done with members without moment in their joints. Releasing the members of their moment helped to sort out the problem. Though we had to find a bit stronger profile, ending up with a circular tube of 219 mm diameter and material thickness of 6,5 mm. The maximum deflection is at the middle of the large roof deflecting 293mm, coming well below our limit of 750mm. The maximum beam stress is found in members were the roof meets supporting concrete column and supporting angled columns at the perimeter of the building. Maximum stress hits 194N/mm2 which is within our design limits.

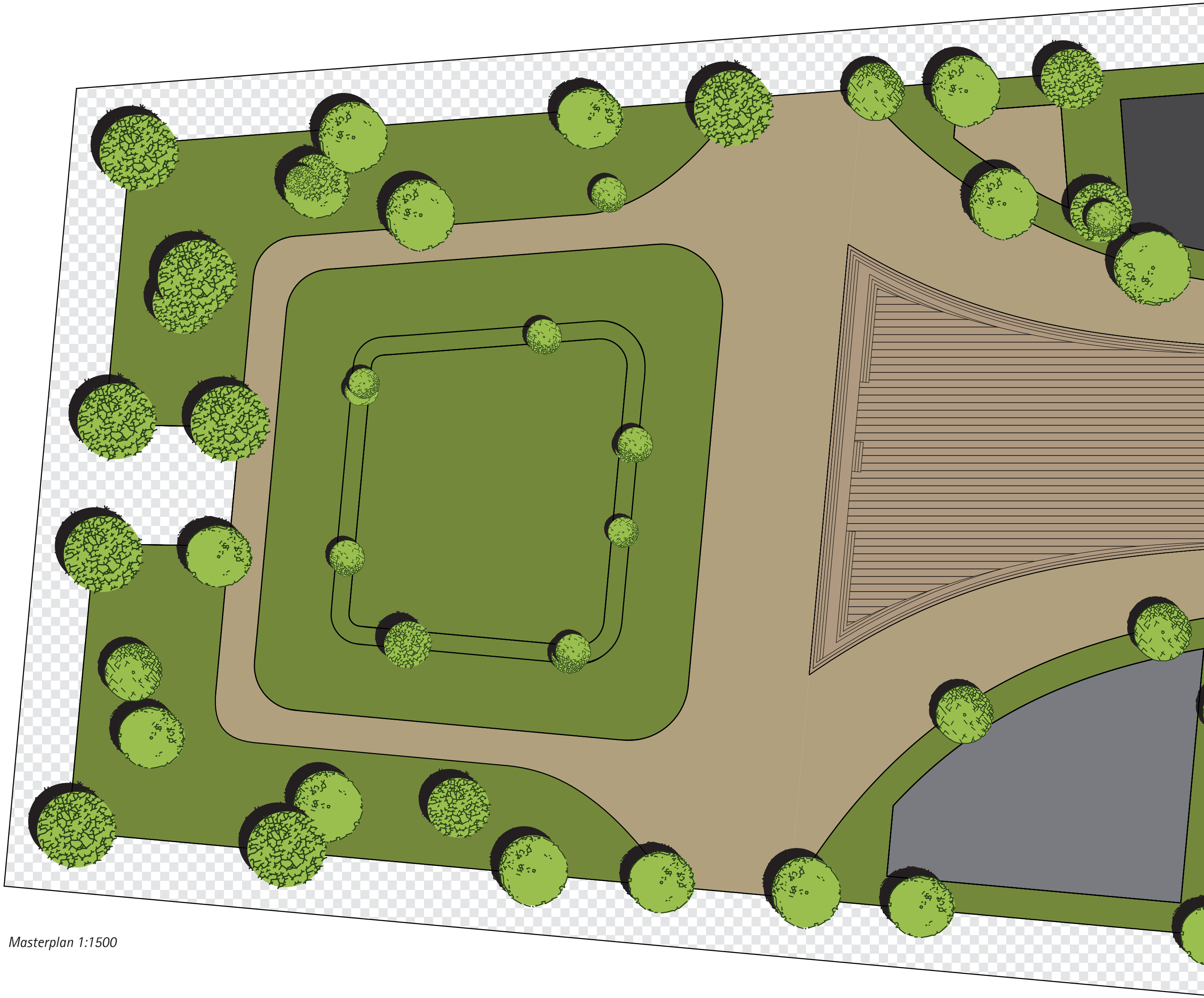




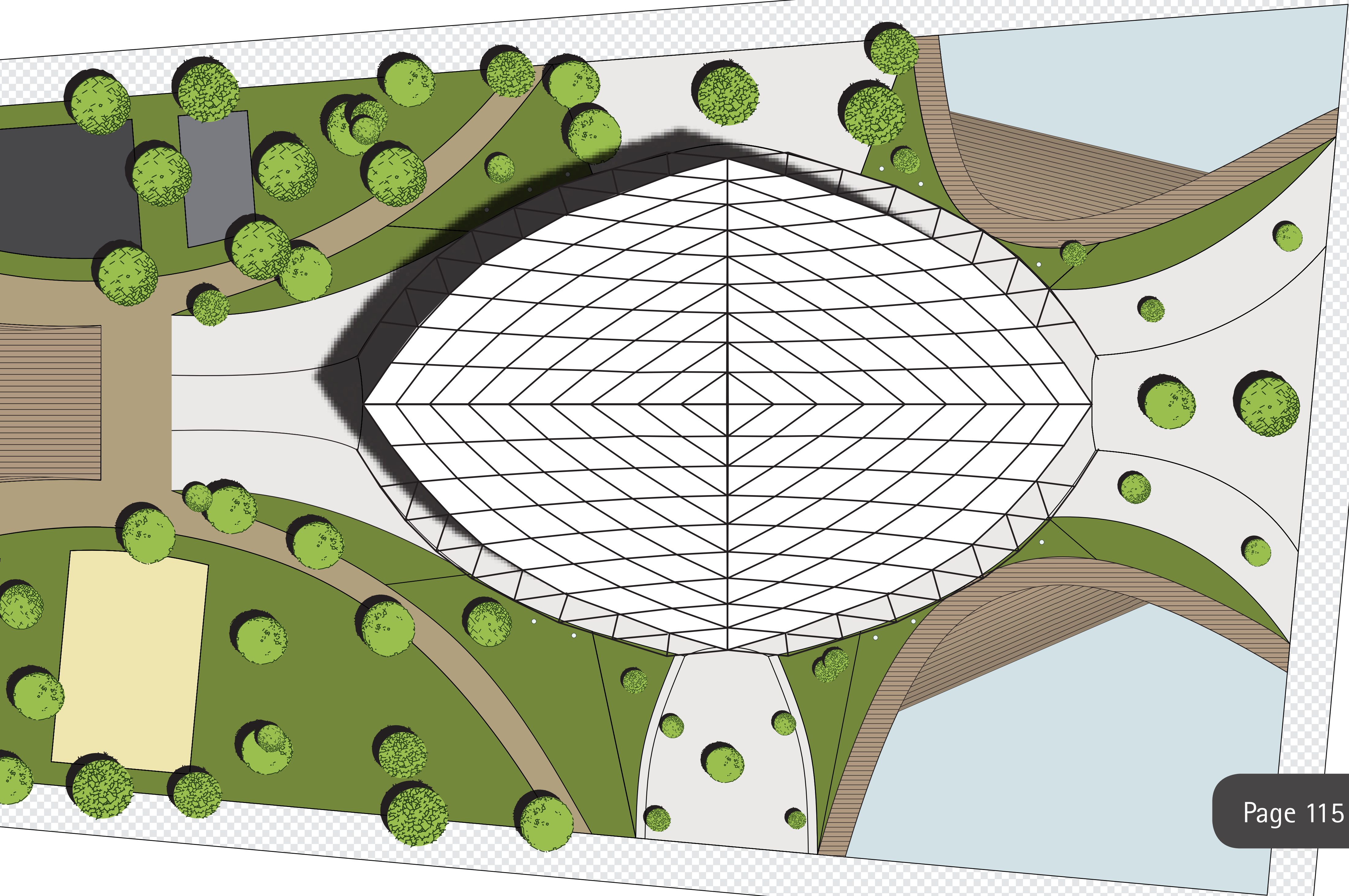
Presentation

Masterplan

The plot is framed by a paved mixed use-surface along the edge of the entire plot. This intended to be used by a mix of cars, pedestrians and bicyclists. It is paved for low speeds and allows for limited time parking. In the middle of the plot we have the activity zones which connect to the Plug-in Park to the south just off the map. The axiality of the plan is accentuated by lining it with trees and to the east we have to bodies of water with terraces so that people can relax and enjoy the café which faces out towards the water.

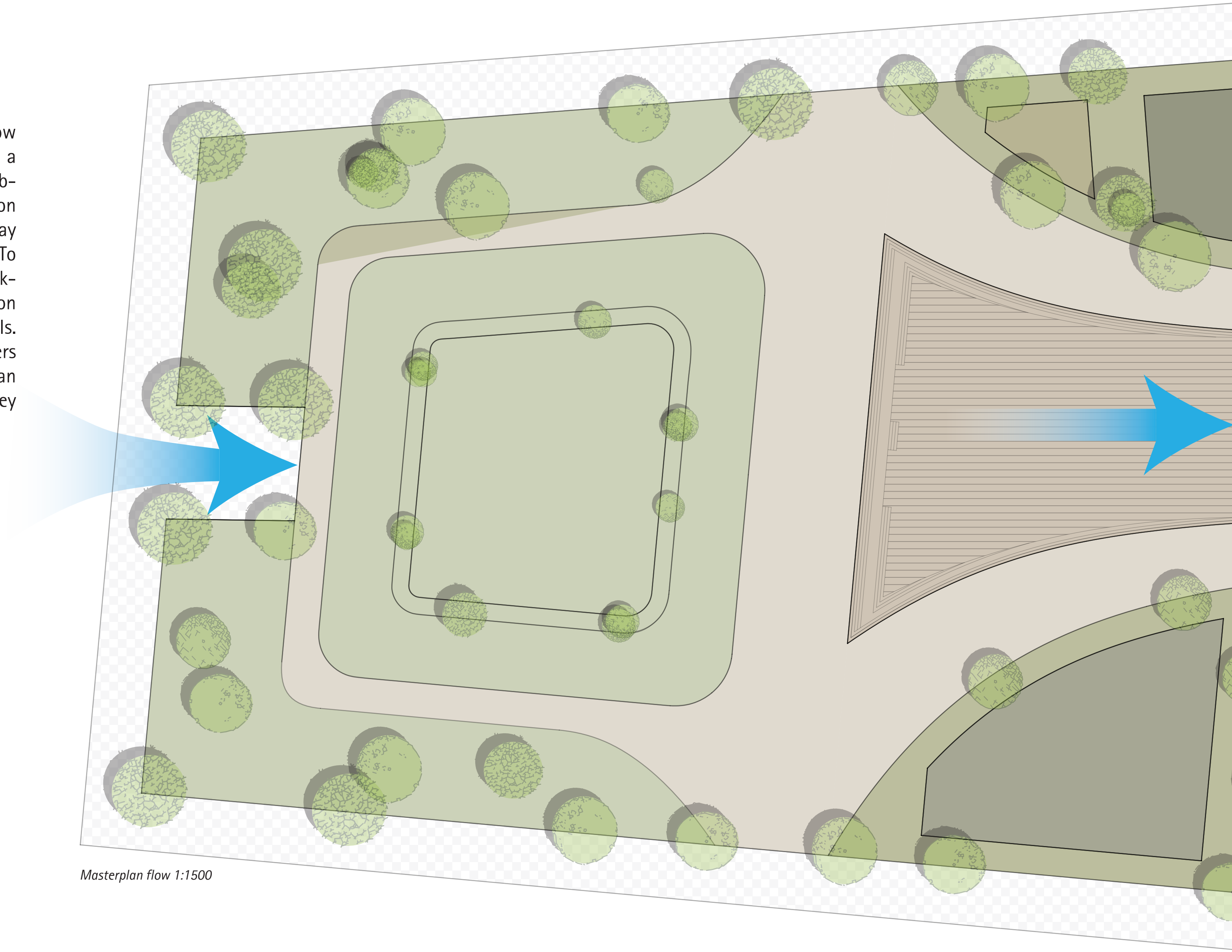


Masterplan 1:1500

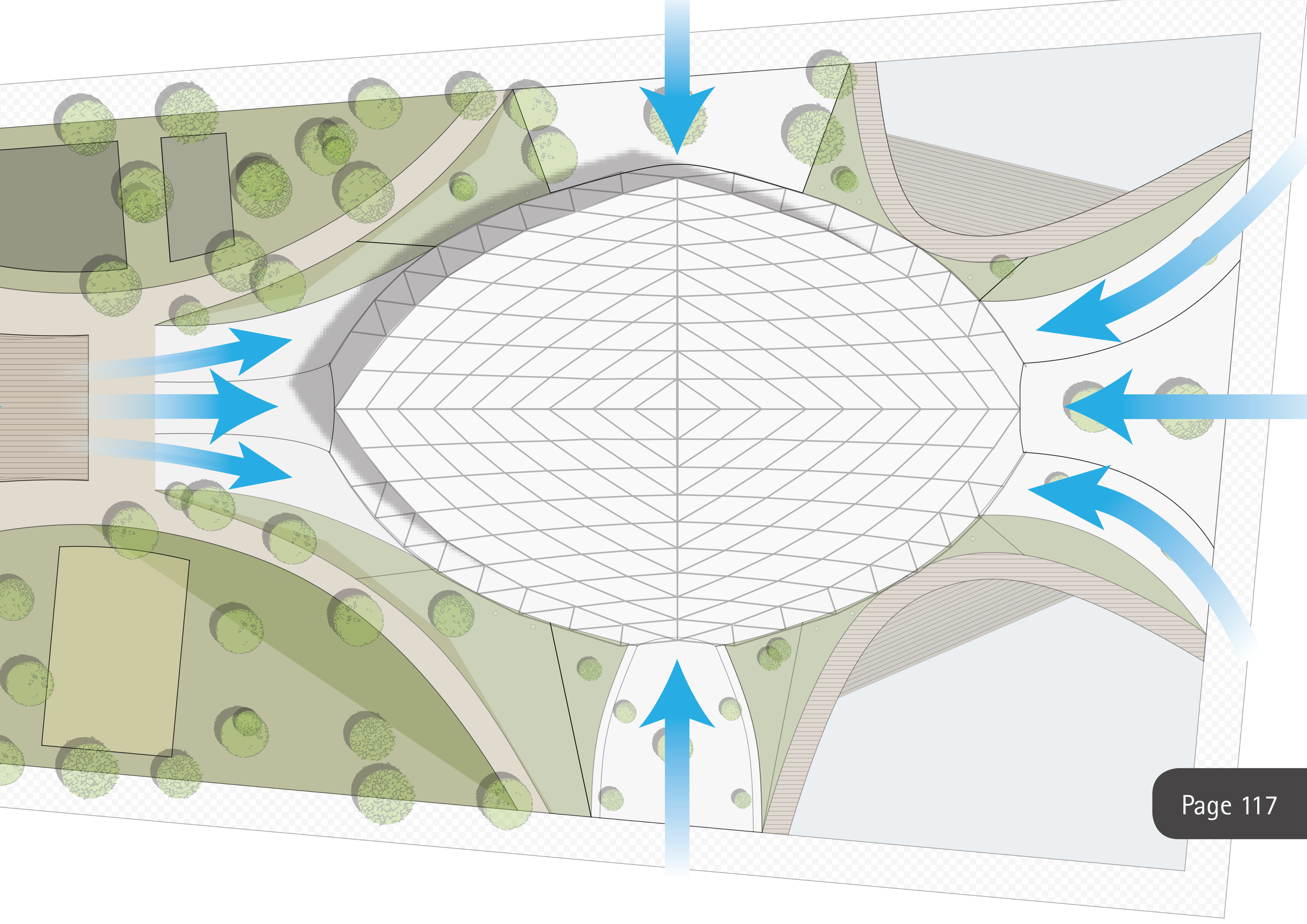


Masterplan flow

The arrows describe how we anticipate the flow of people on the area on a gameday. To the east a large portion of the spectators will arrive with public transportation. On this façade we offer access on two levels. To the south we have a smaller entryway in just one level intended for the near context. To the west we have our entryway to the buried parking structure. From there spectators will arrive on foot and be able enter the stadium on two levels. Finally we have the north façade where VIPs, players and other people with special needs arrive. They can arrive on foot and enter on the ground floor, or they can drive into the basement from the ramp.

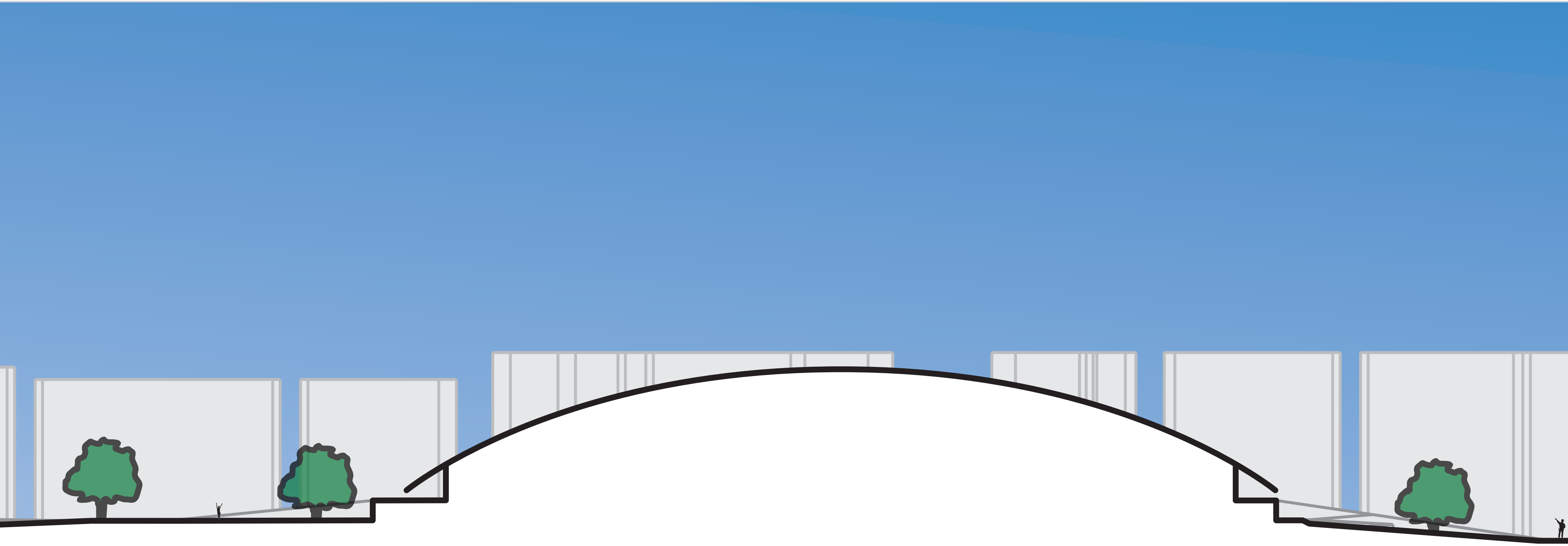


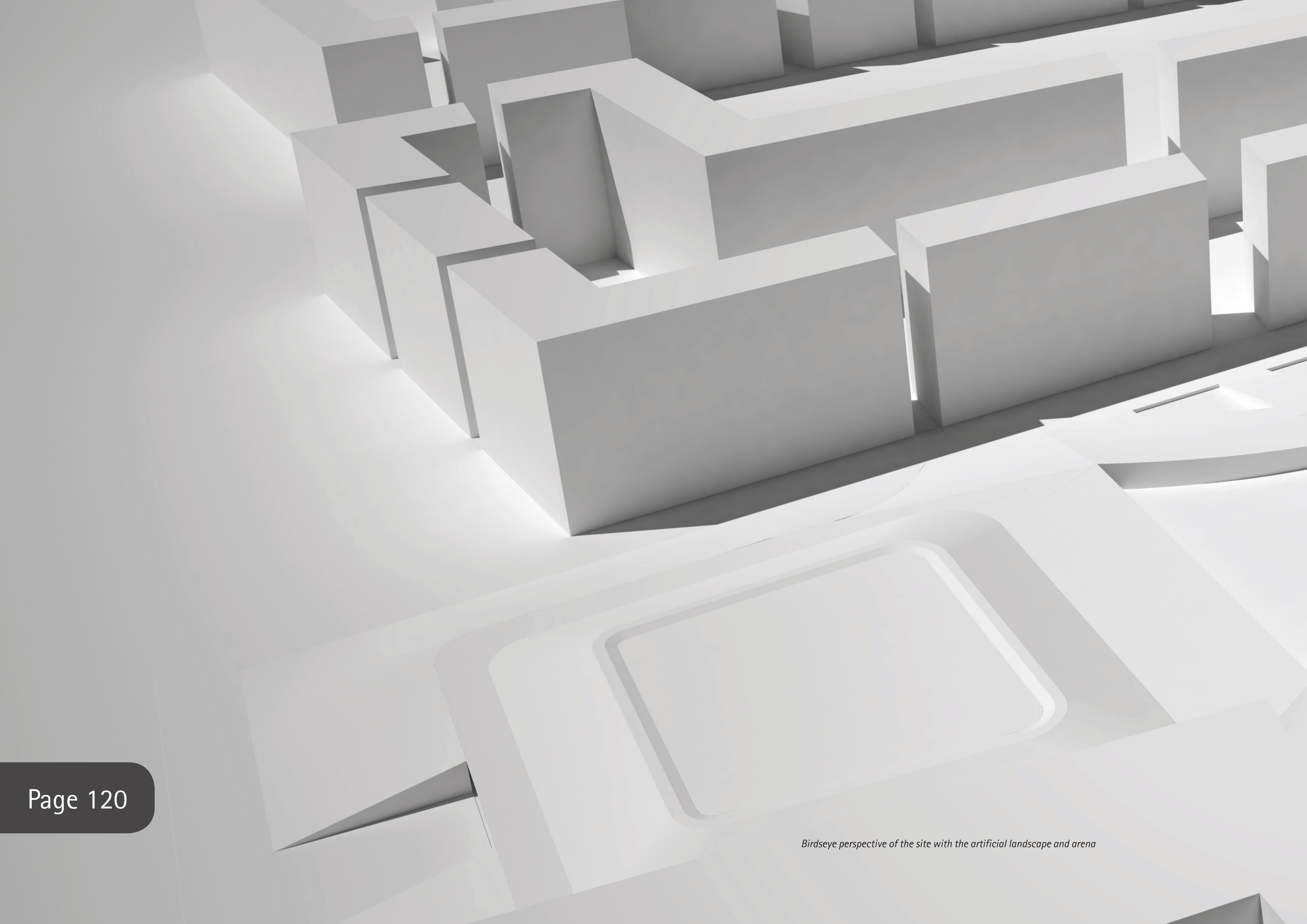
Masterplan flow 1:1500



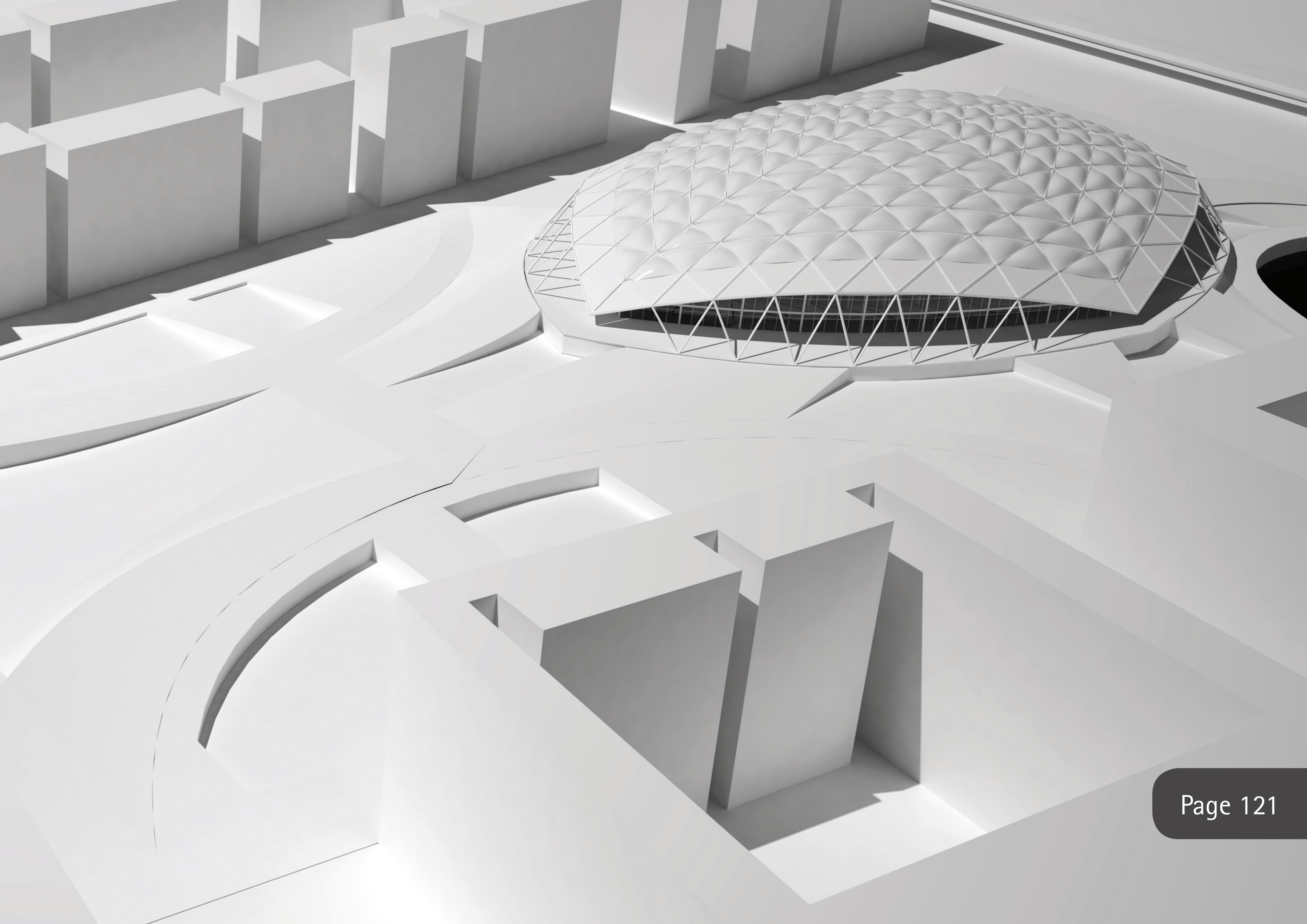
Masterplan section

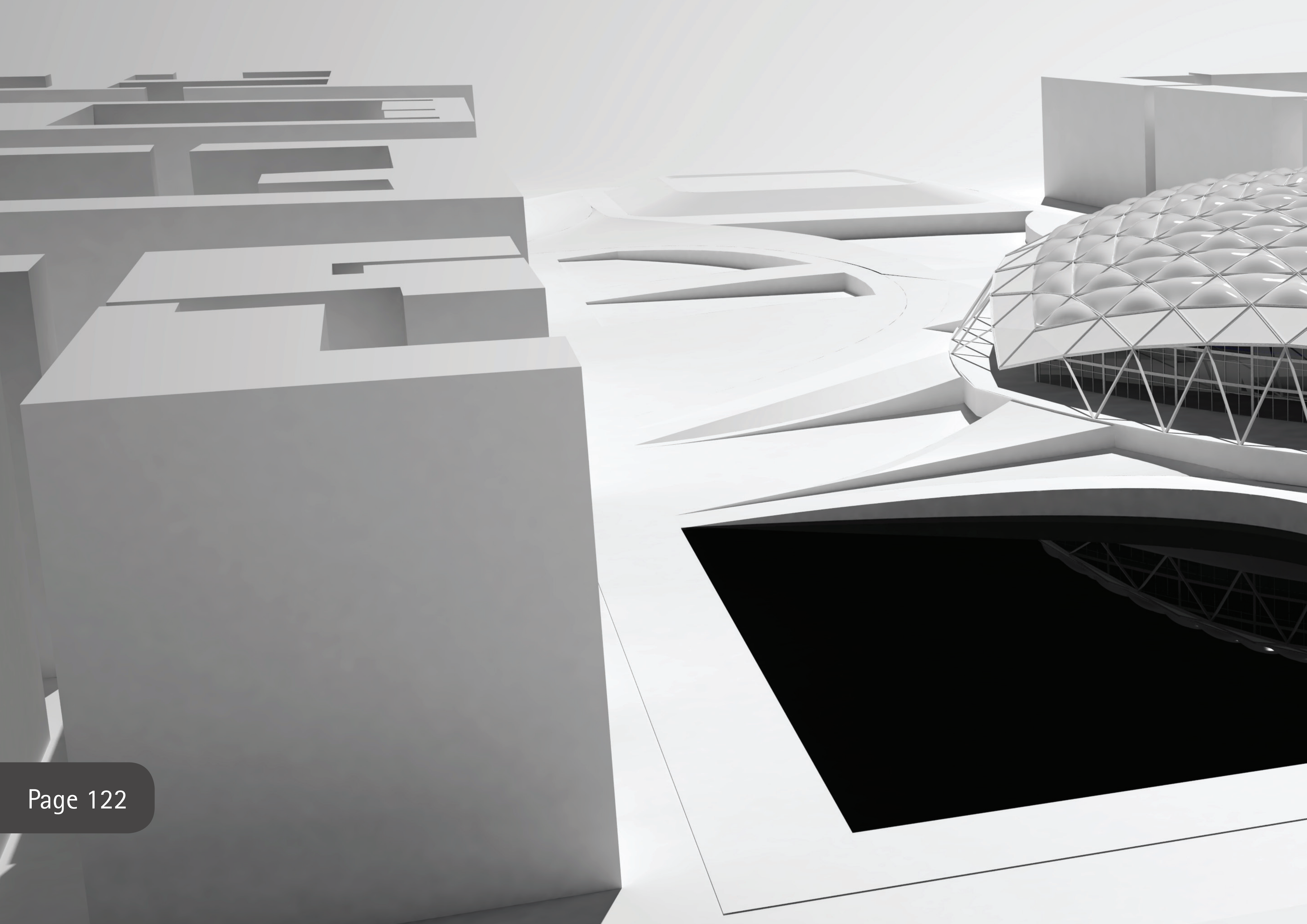
Section through masterplan 1:1500

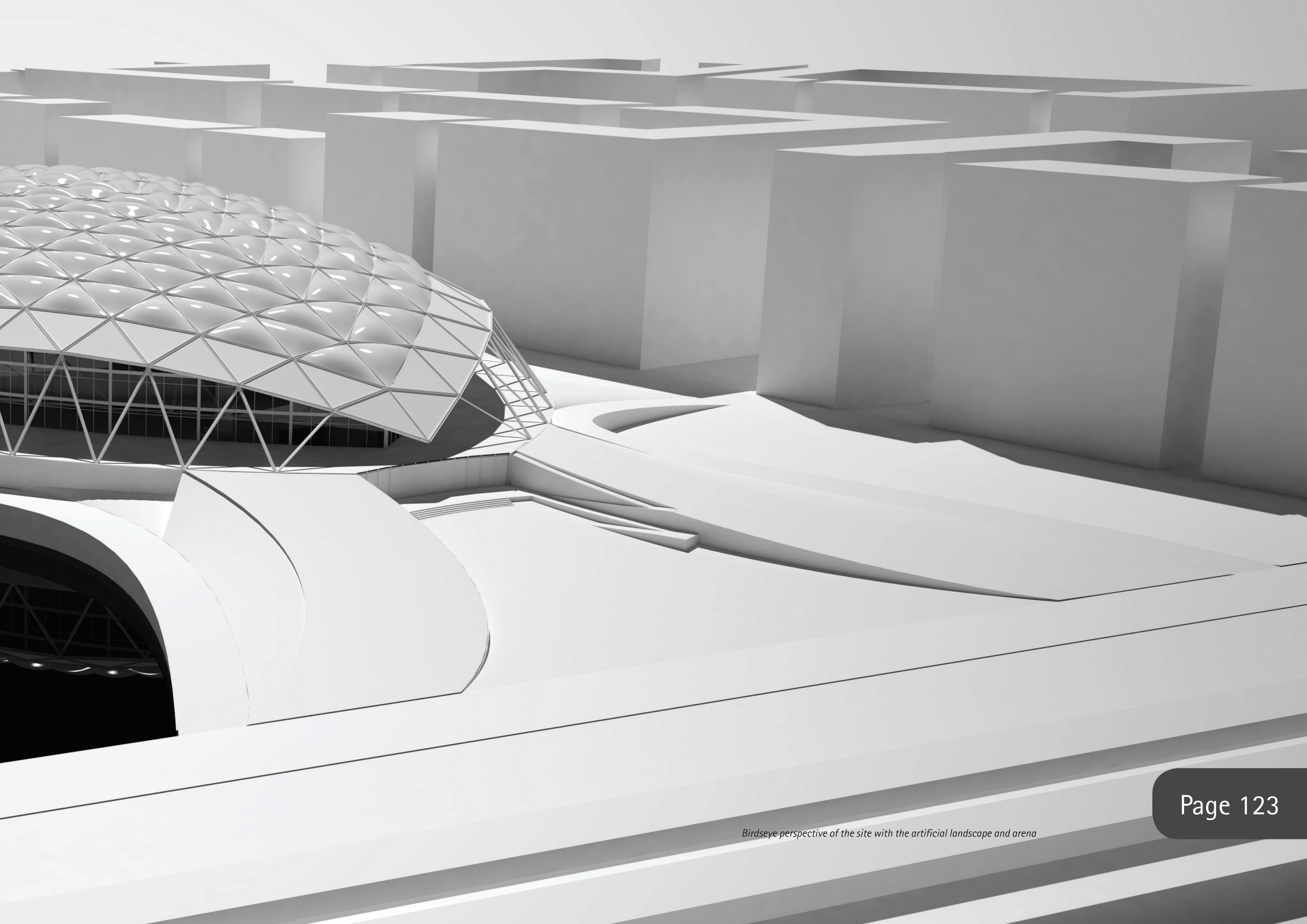




Birdseye perspective of the site with the artificial landscape and arena

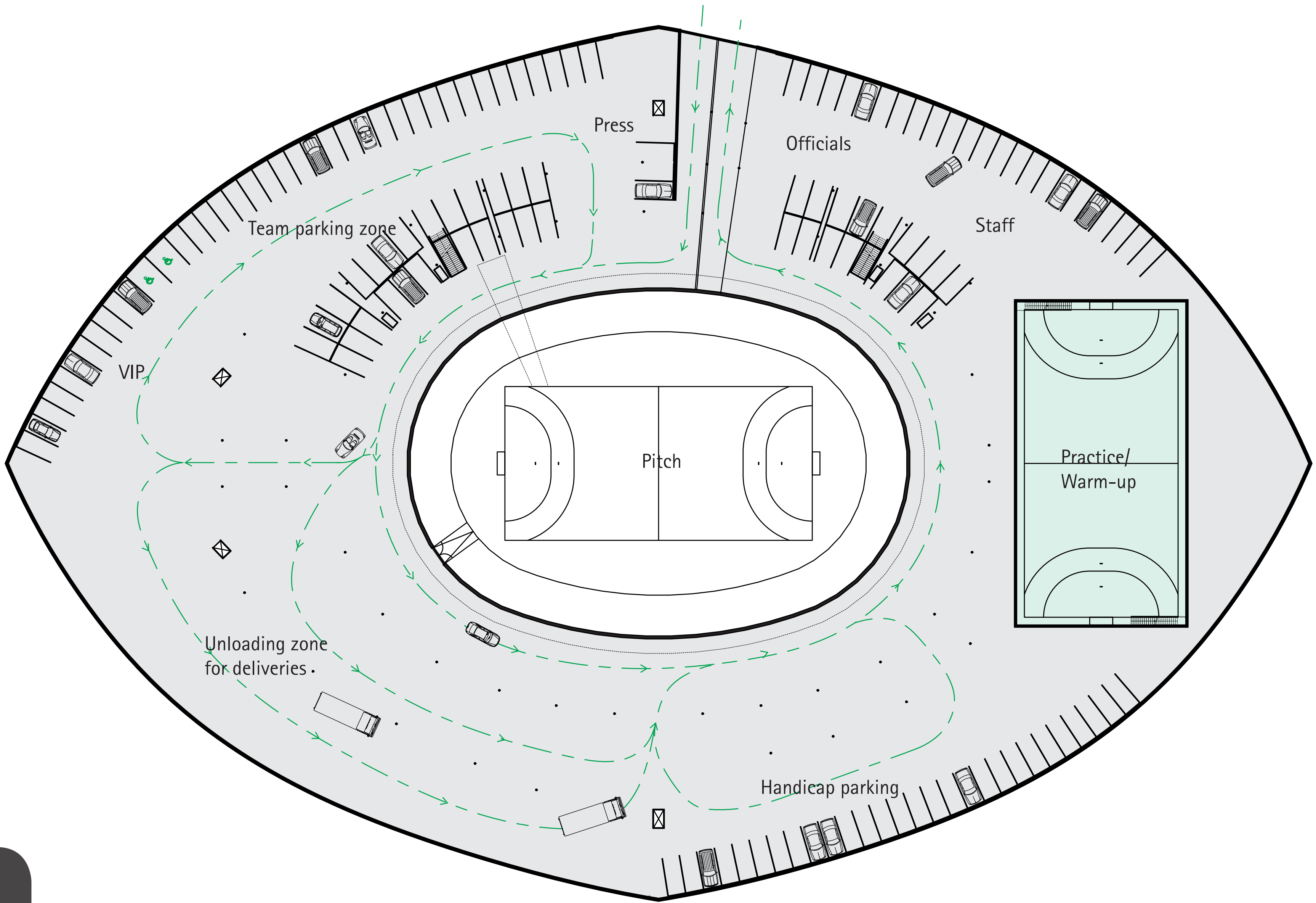






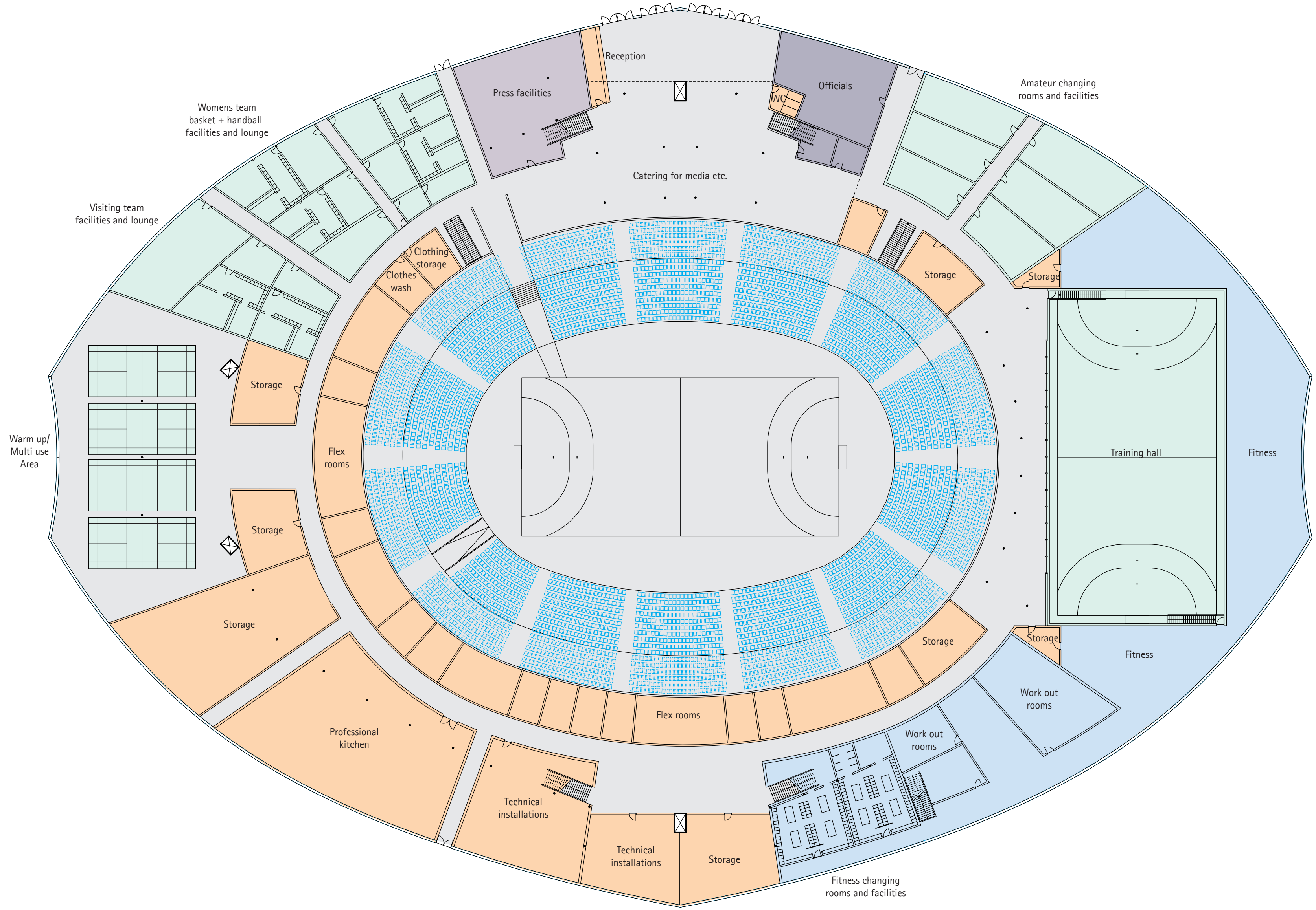
Birdseye perspective of the site with the artificial landscape and arena

Floorplan -1



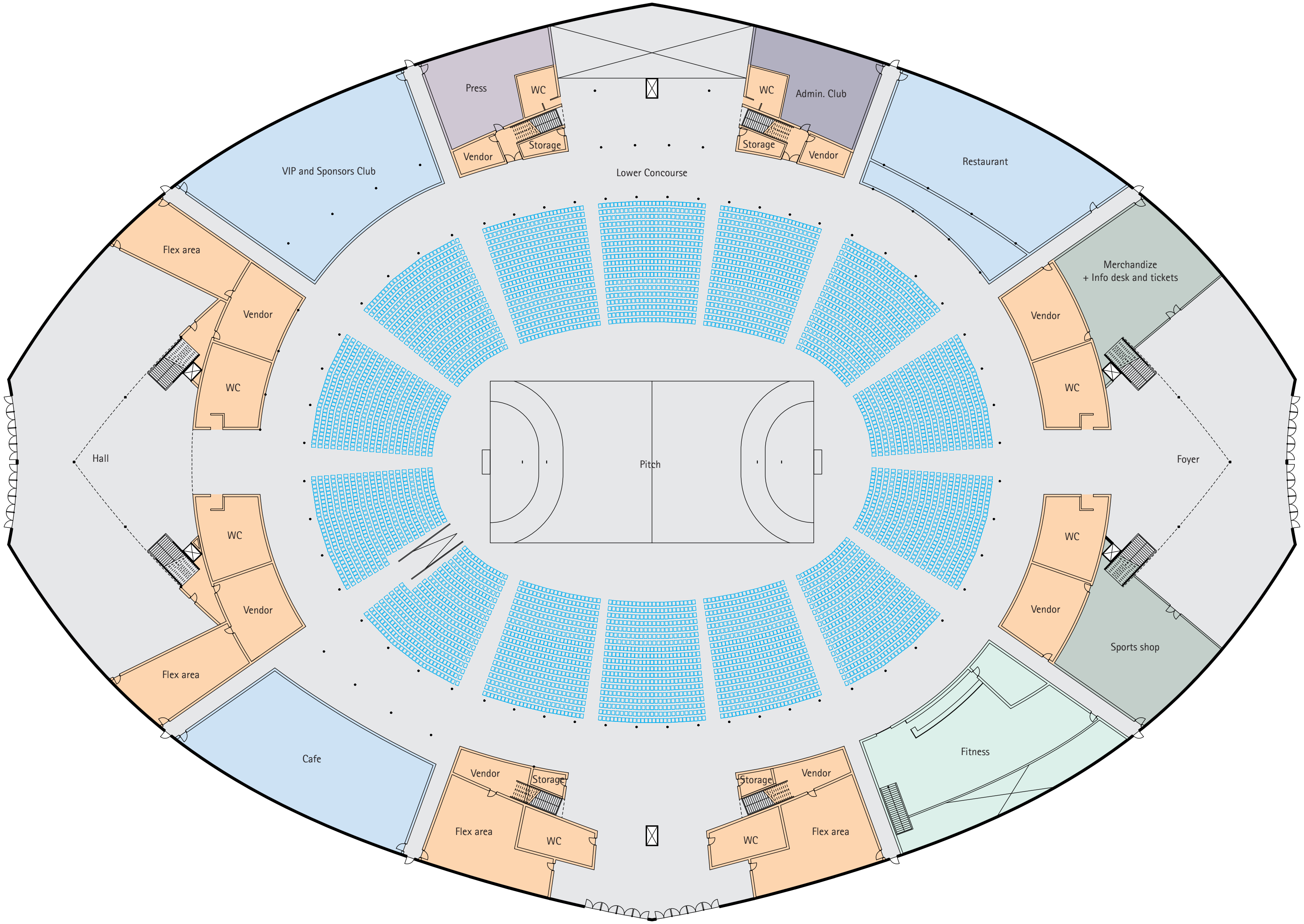
1:750 level -1 parking in basement and goods delivery and pitch in center

Floorplan 0



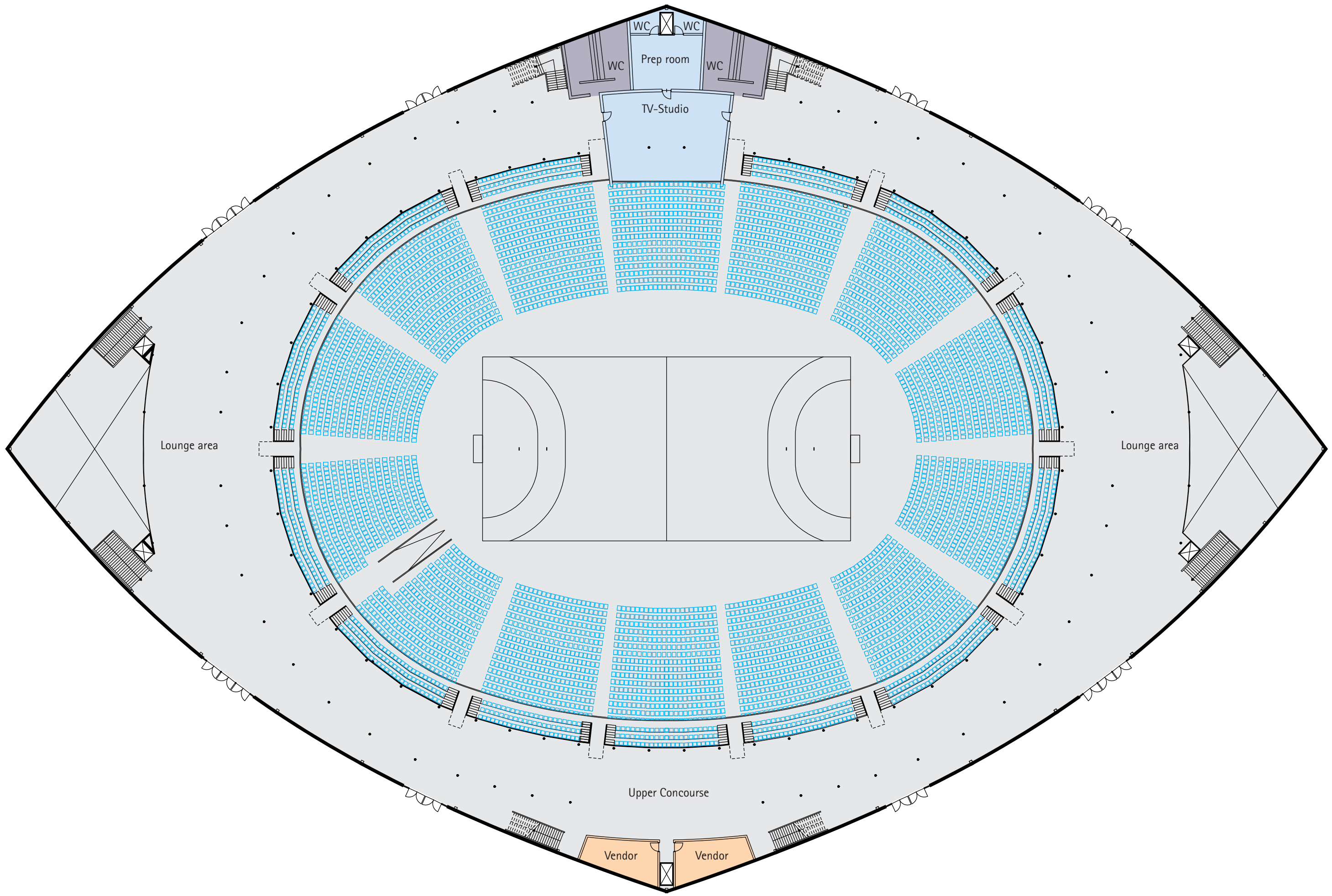
1:750 level 0 changing rooms for amateur, elite & officials, lower level of fitness center

Floorplan +1



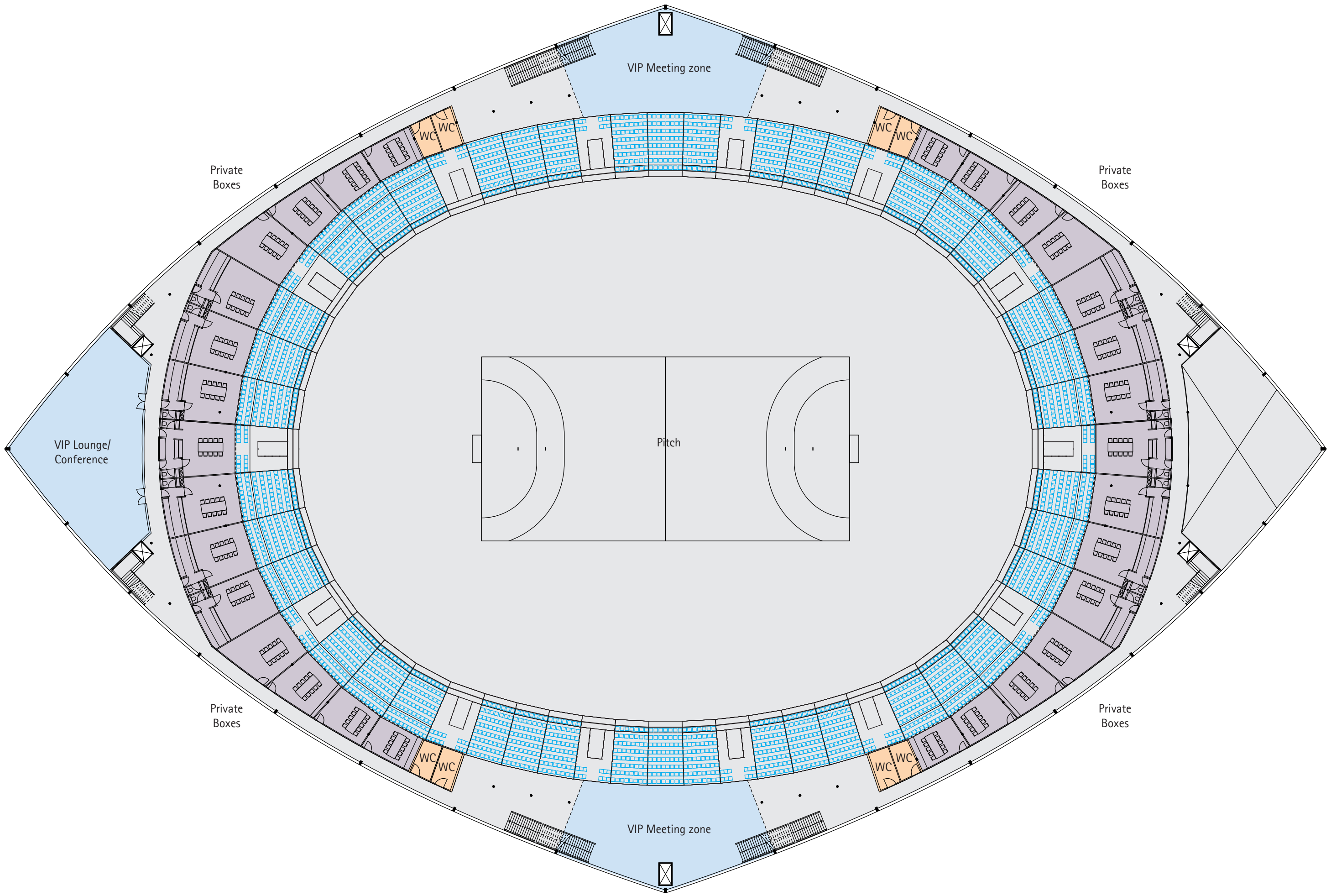
1:750 level +1 main level with foyer, hall, inner concourse which connect to lower spectator tier and ancillary functions. Main entrances on this level in either end.

Floorplan +2



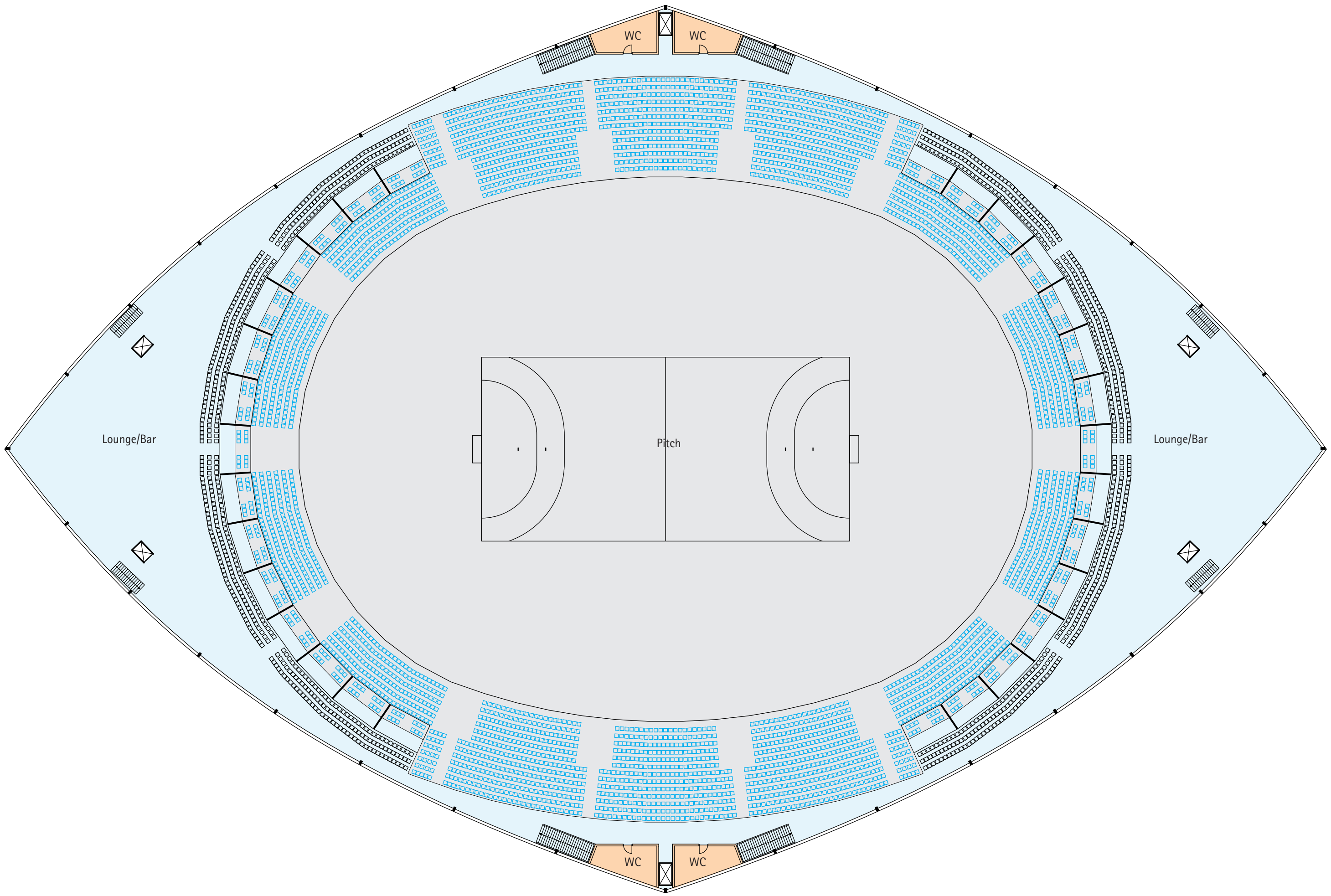
1:750 level +2 level with direct access to outside through the colonnade. Tv-studio for press. Acces to upper and lower floors.

Floorplan +3



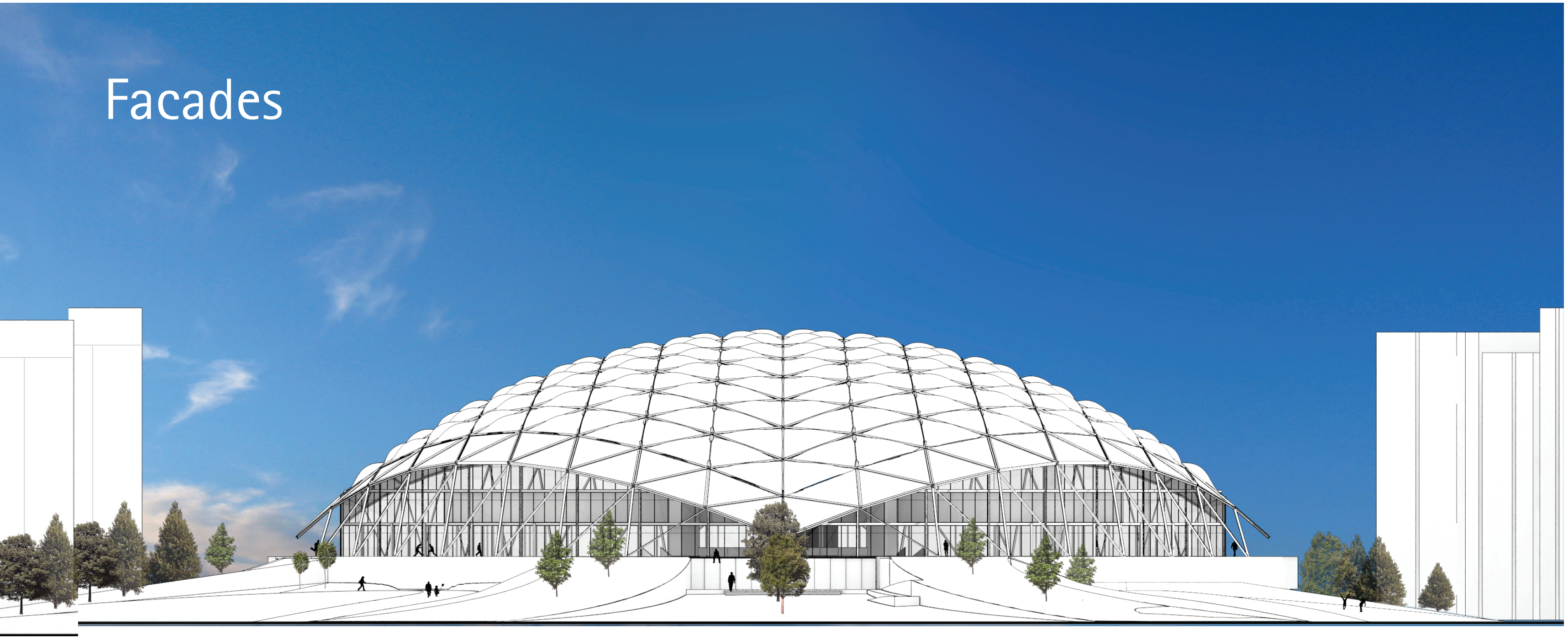
1:750 level +3 VIP level. VIP boxes are placed in both end of the upper tier in the arena with direct acces to VIP common lounges.

Floorplan +4

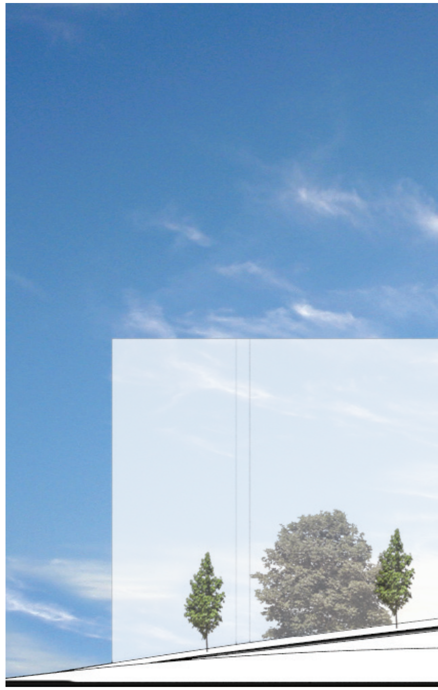


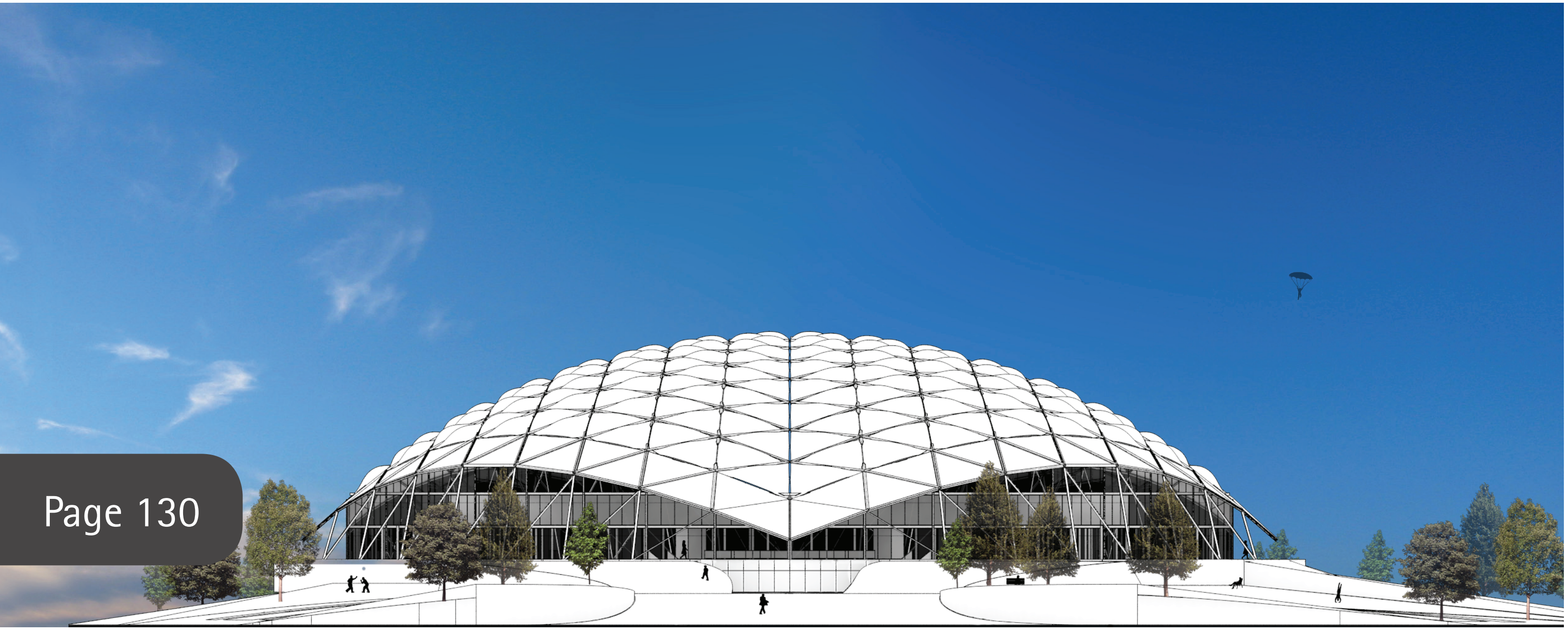
1:750 level +4 Uppermost floor in the building features lounge area in either end of the building. Direct acces from tier above VIP boxes.

Facades

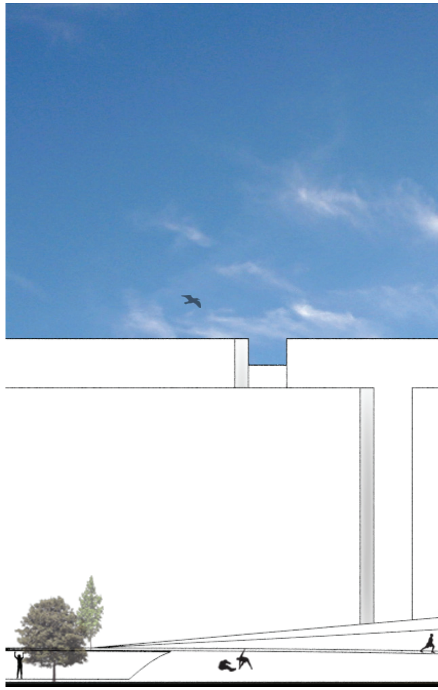


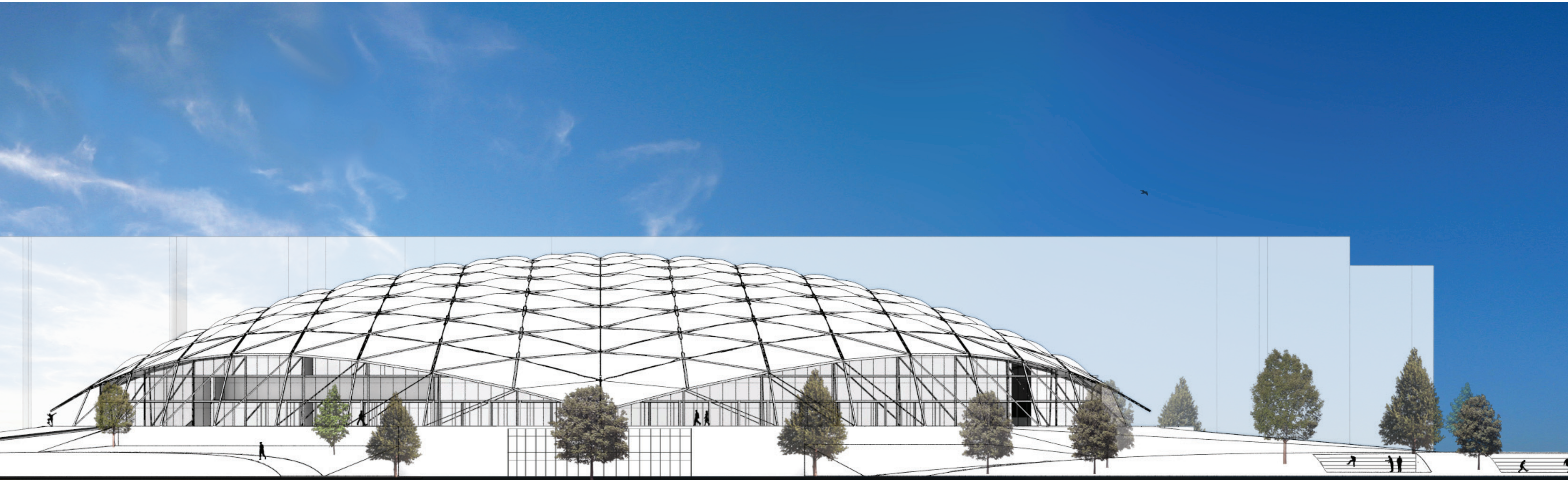
1:750 *facade, east*



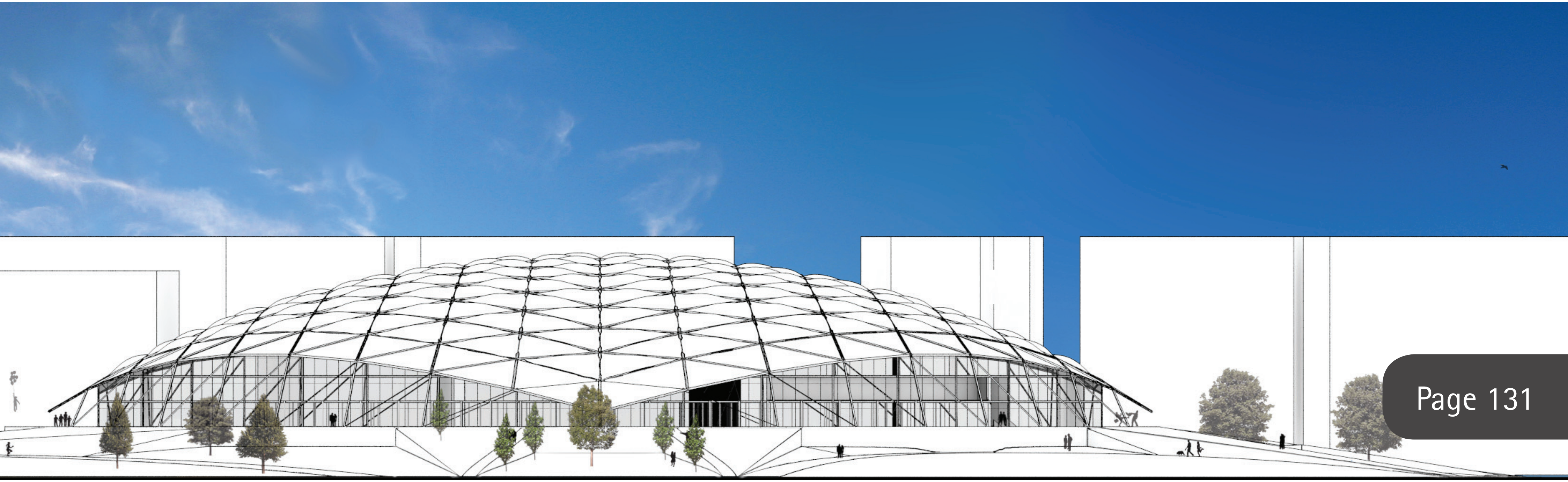


1:750 *facade, west*



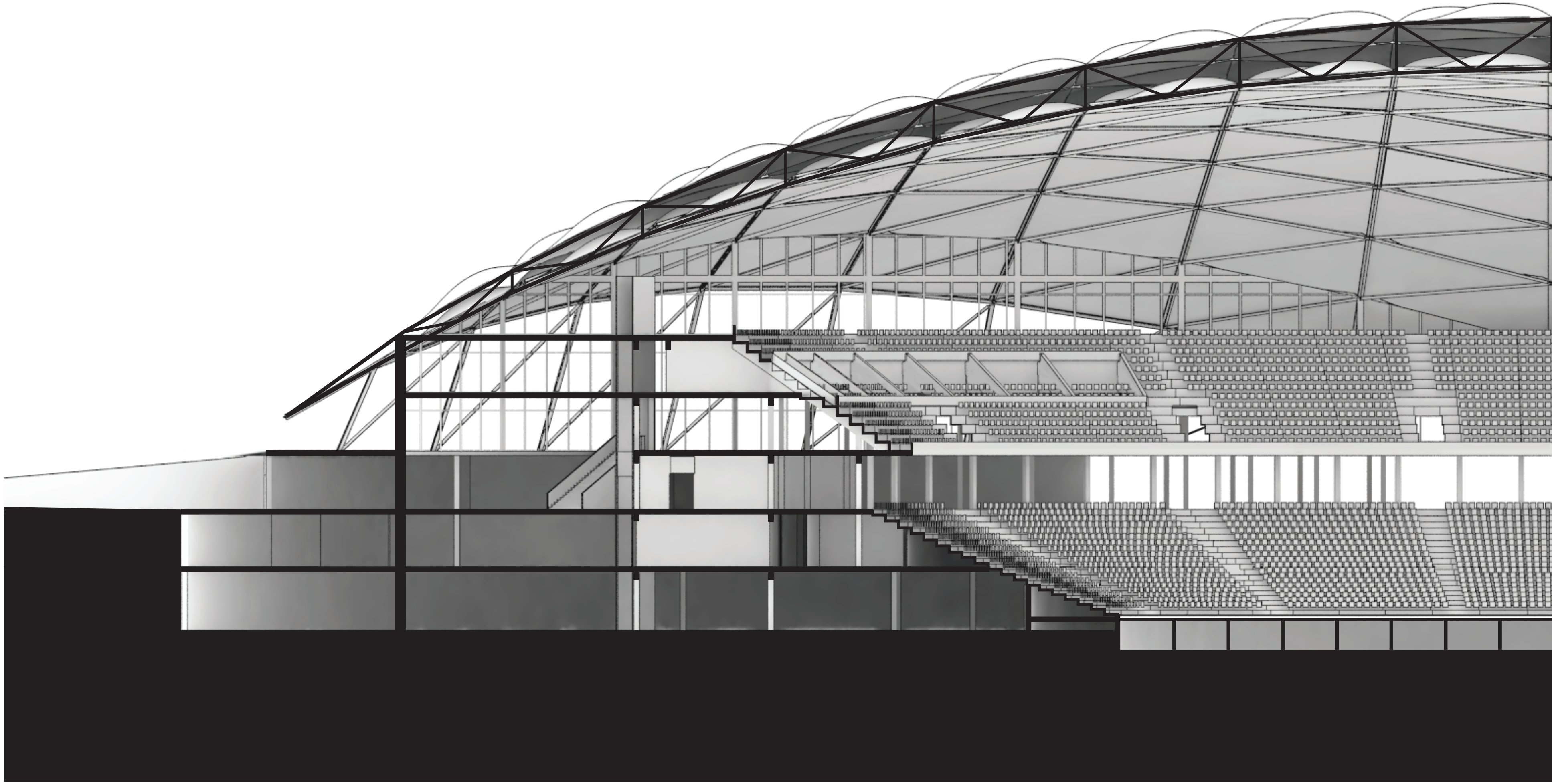


1:750 facade, south

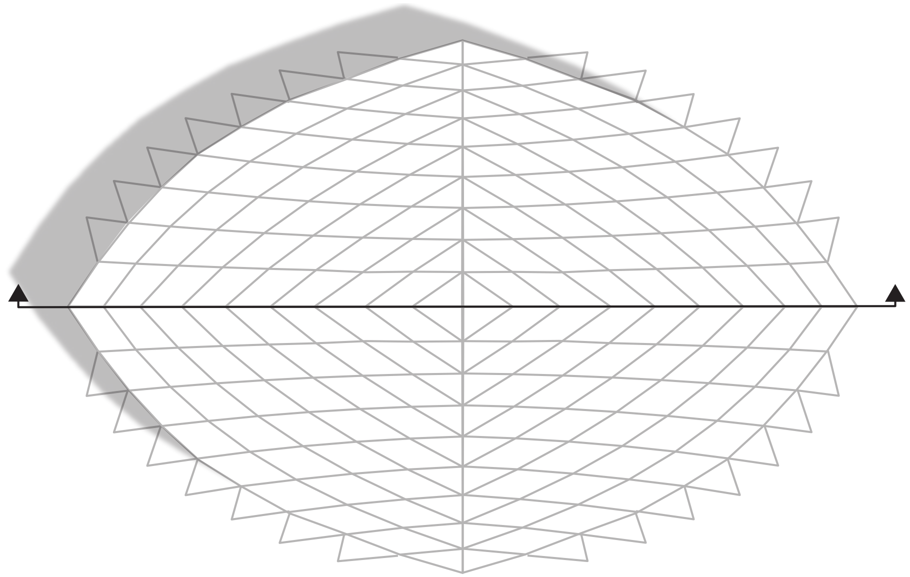


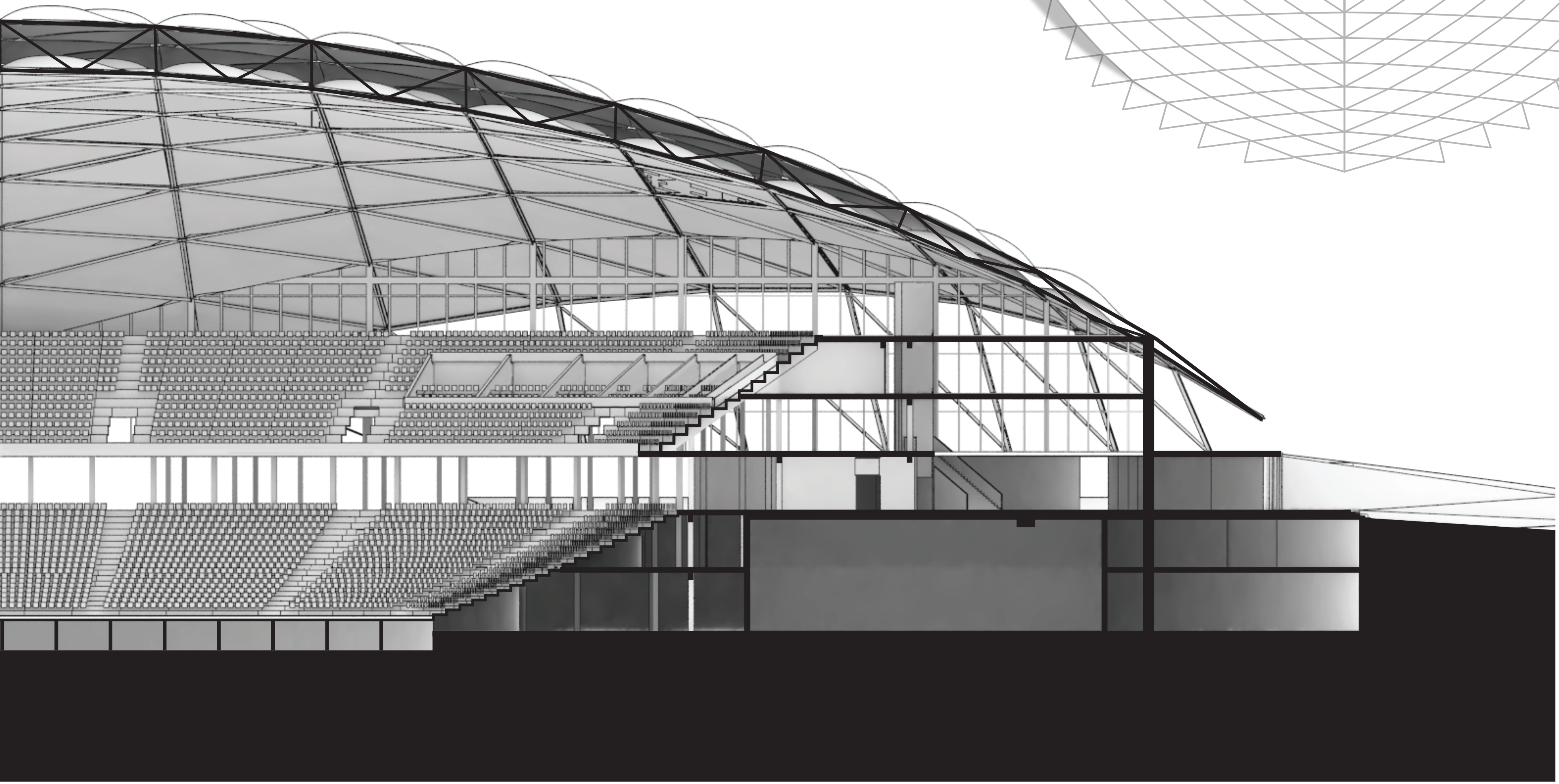
1:750 facade, north

Section

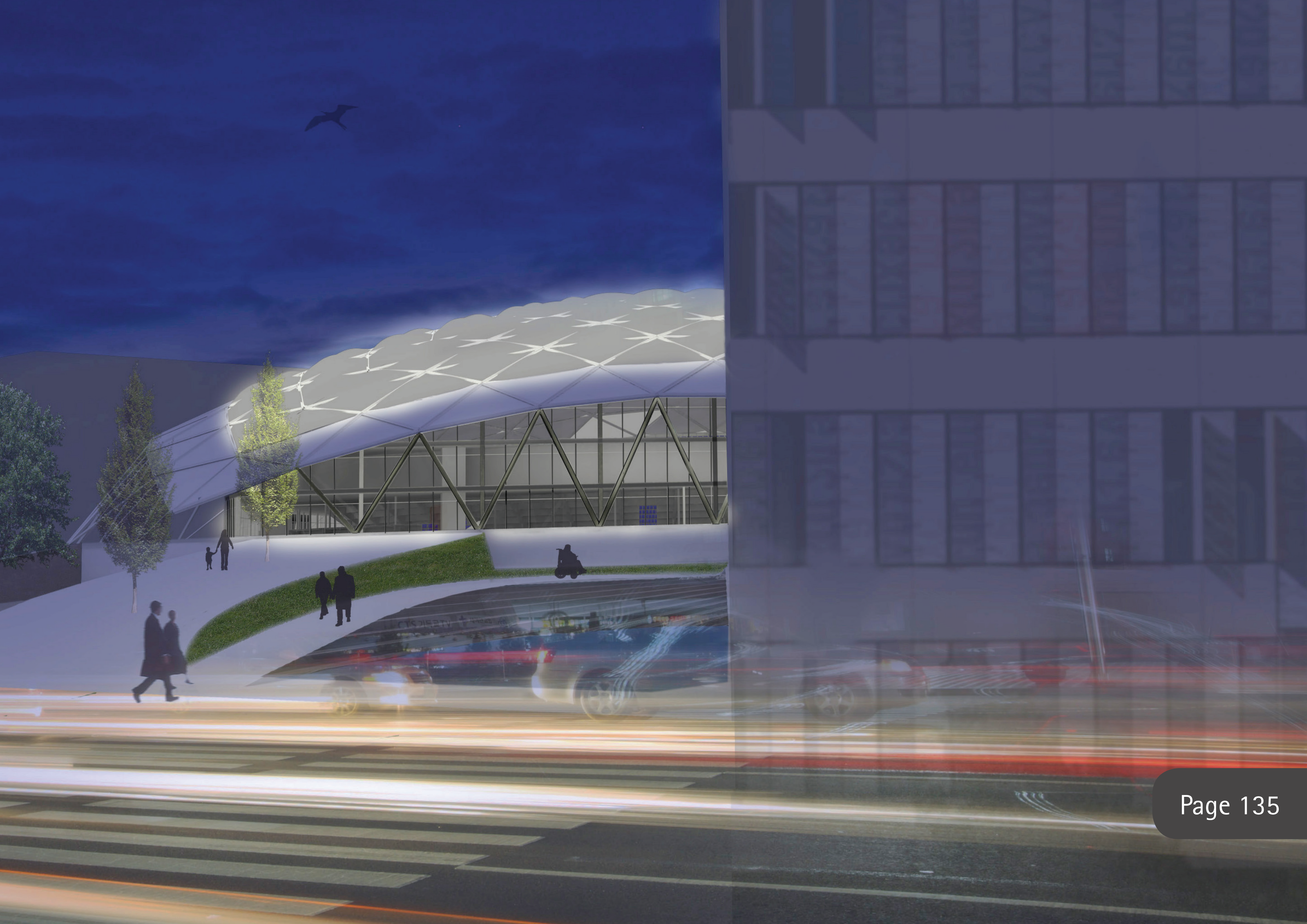


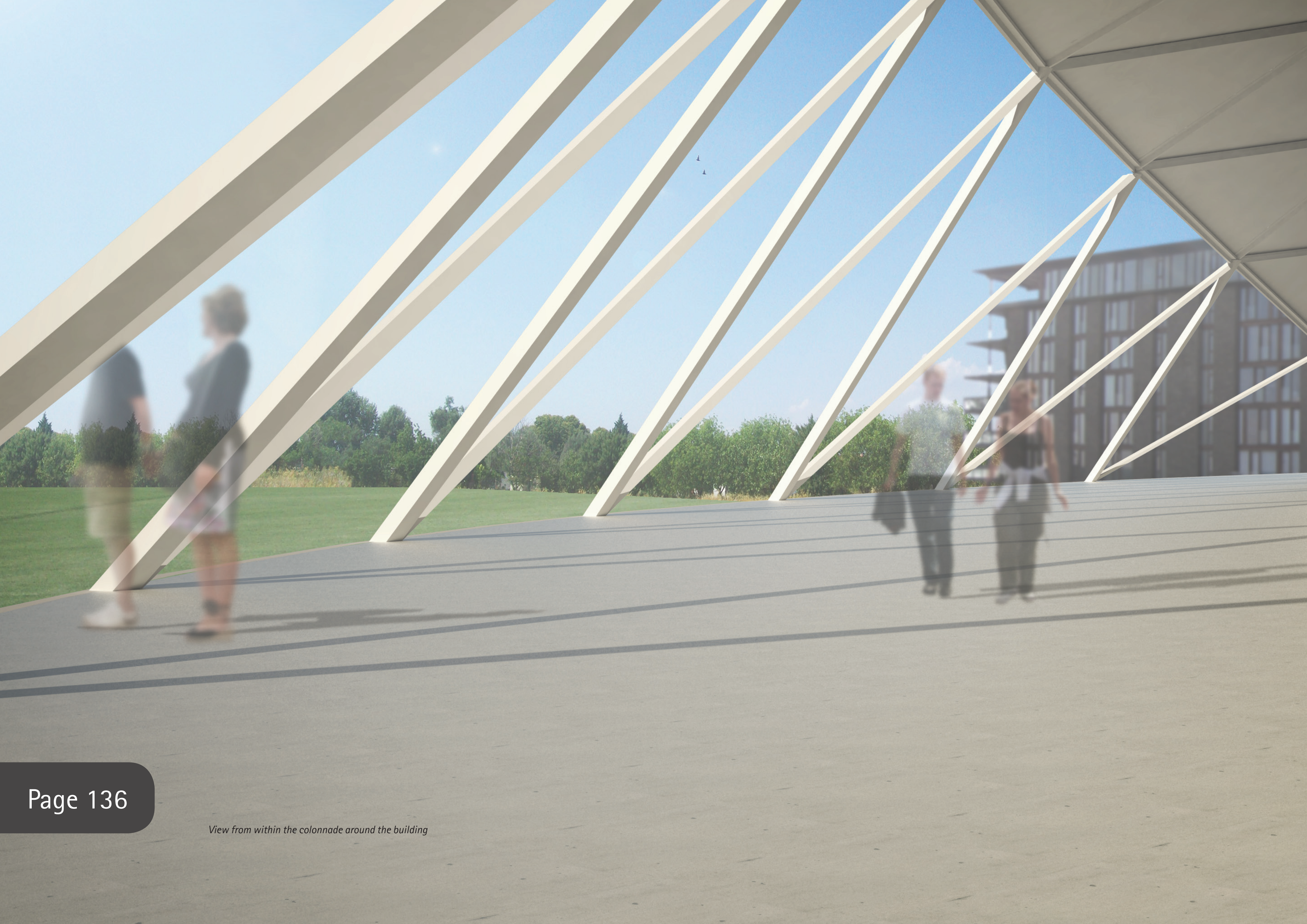
Section east-west through the building



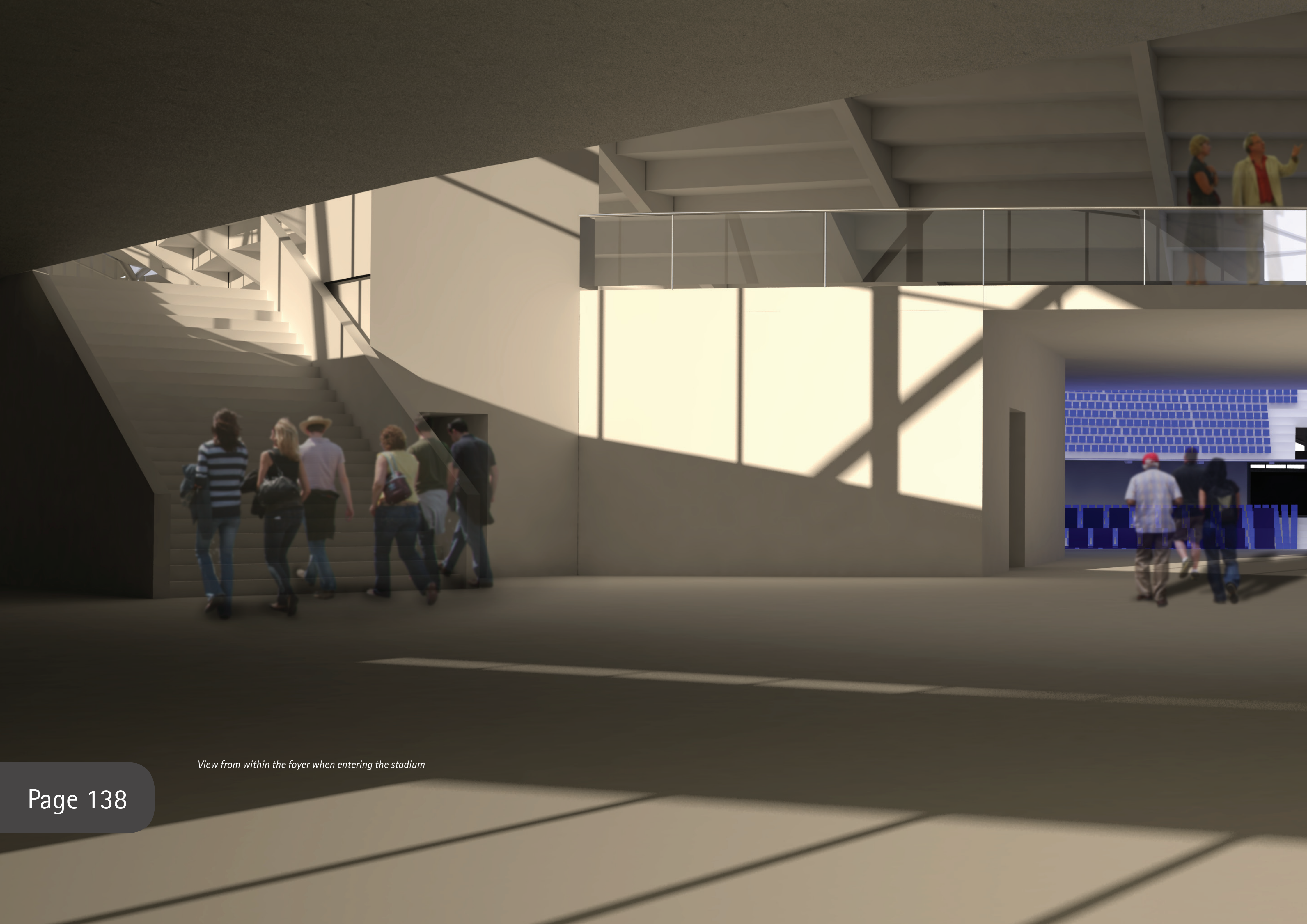


Approaching the stadium with the metro

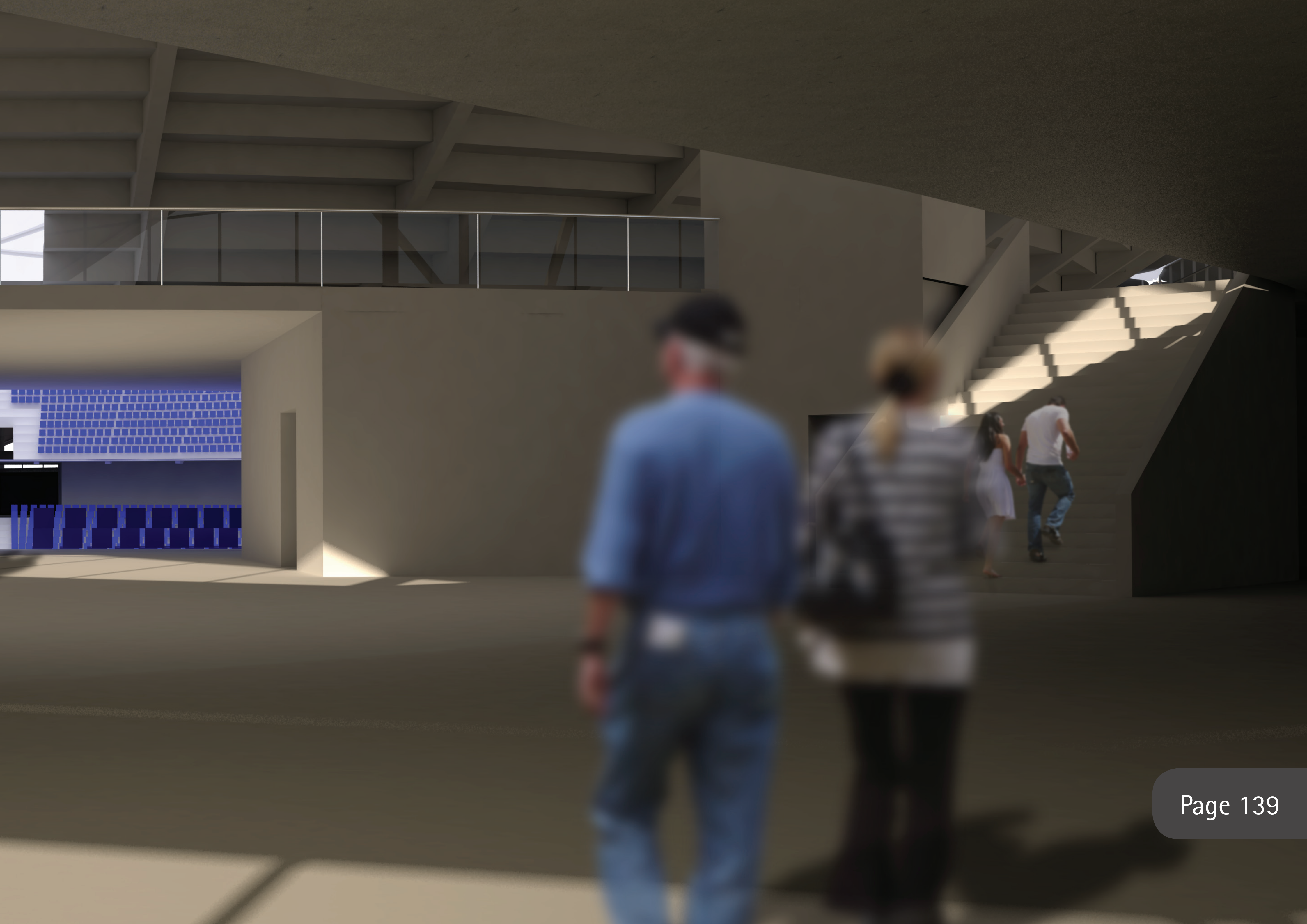


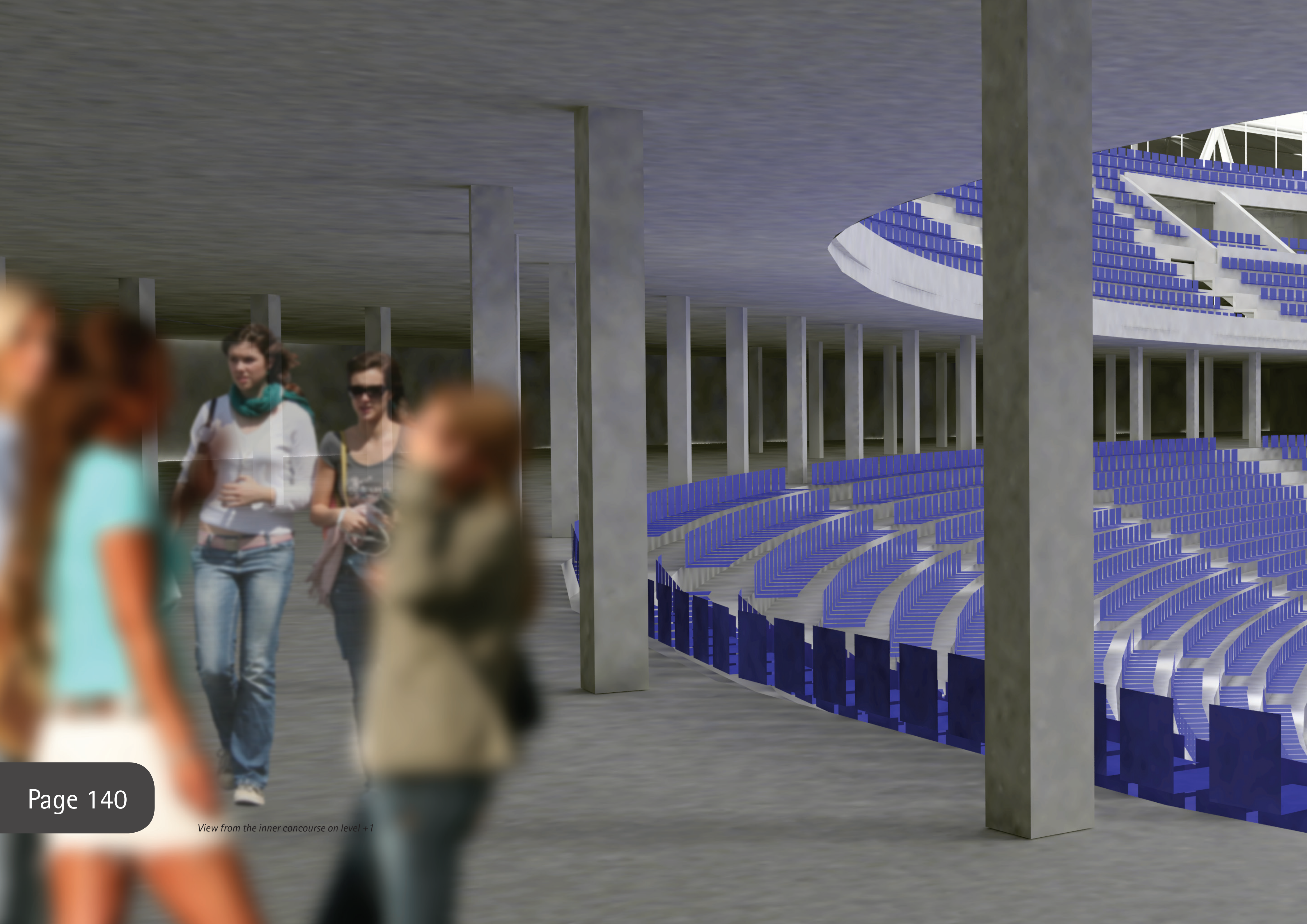


View from within the colonnade around the building

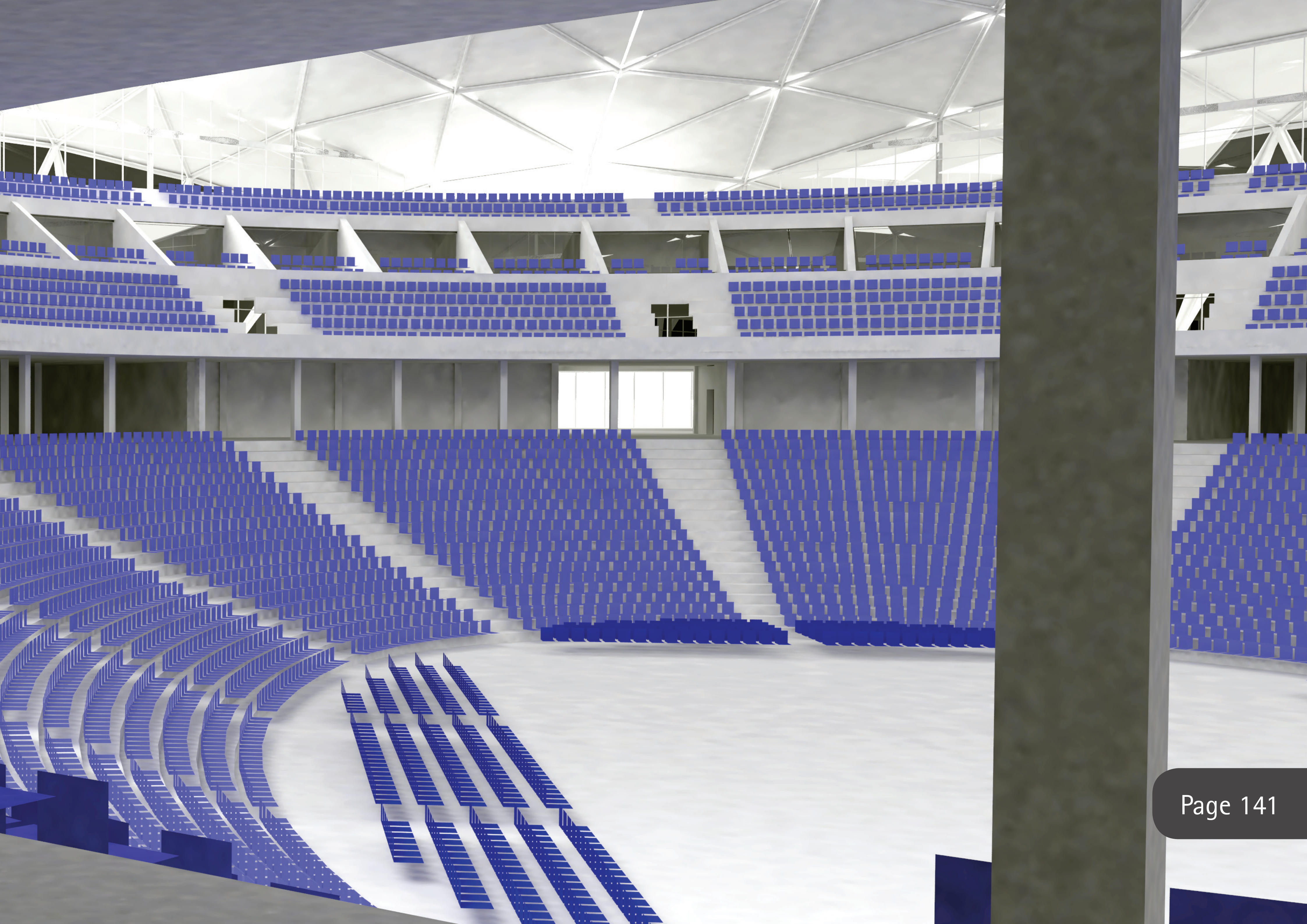


View from within the foyer when entering the stadium

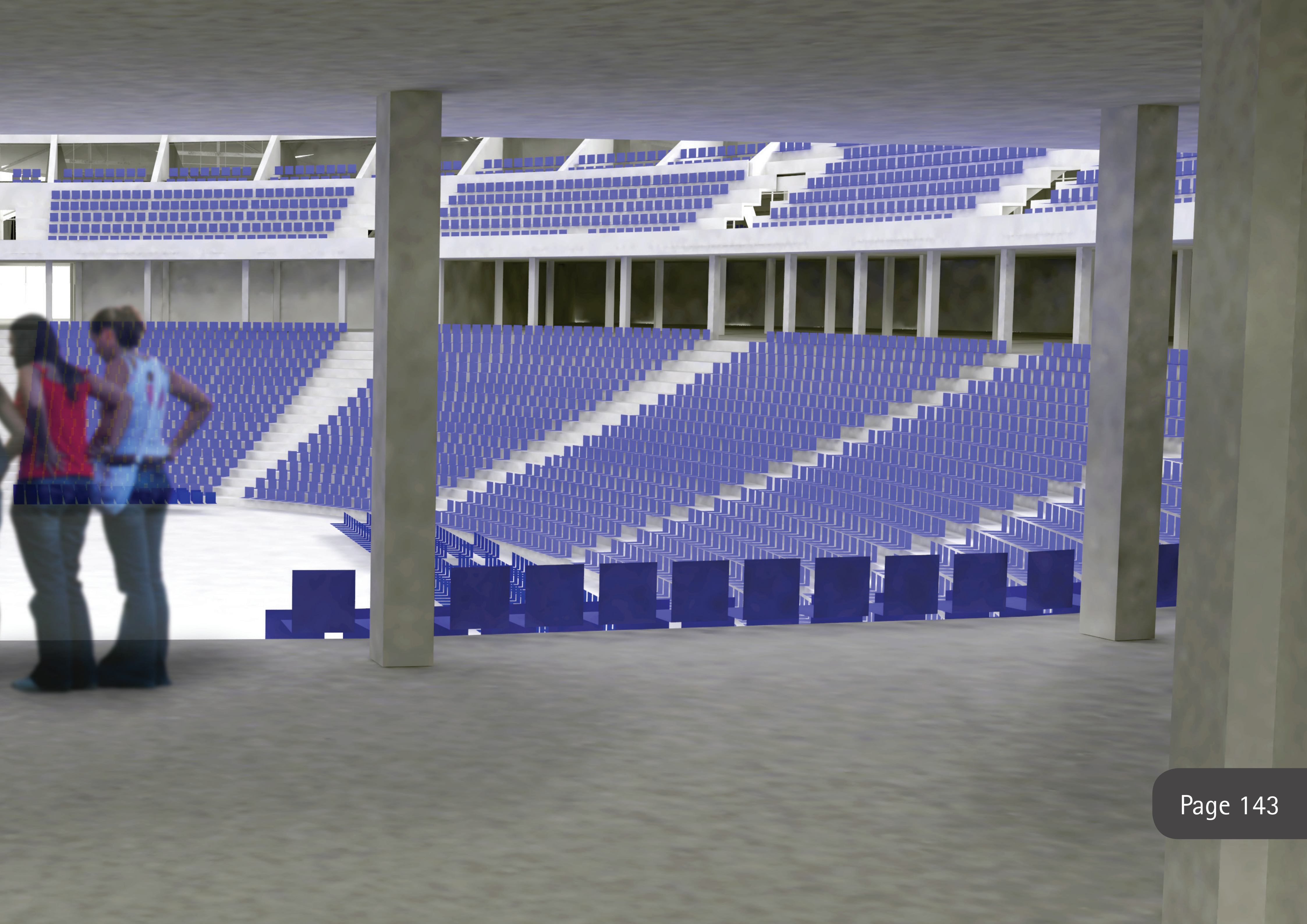


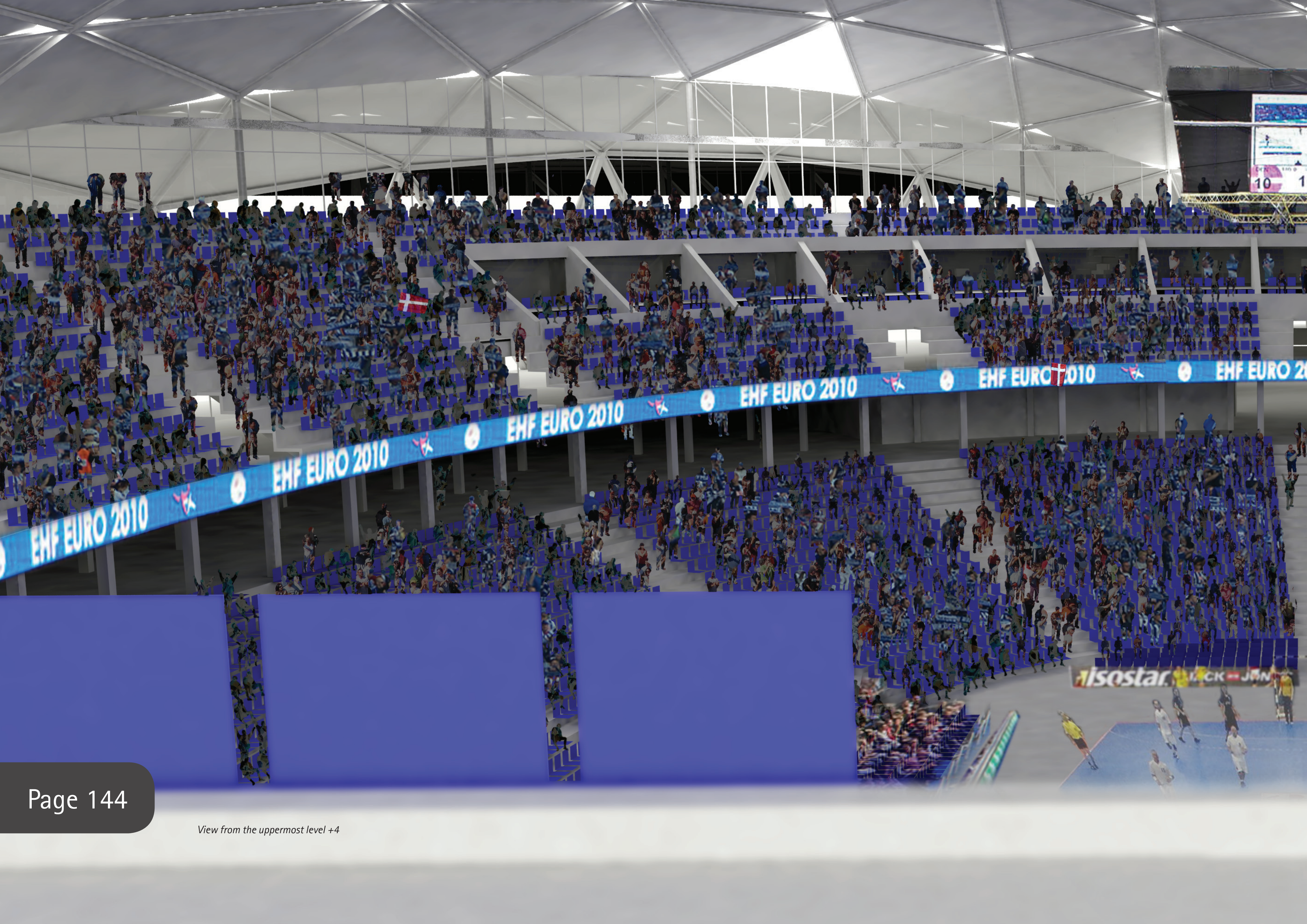


View from the inner concourse on level +1

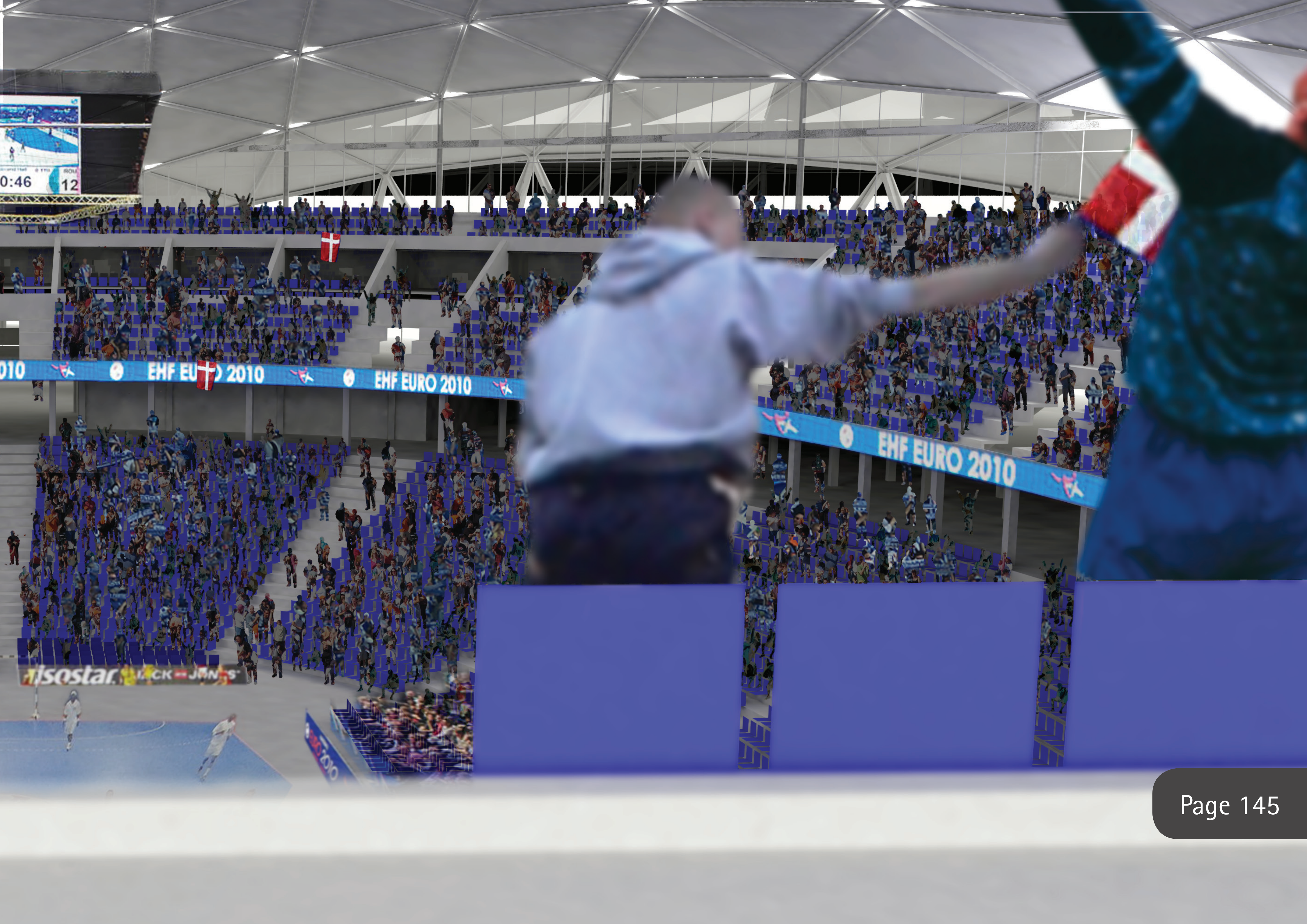


View from the inner concourse on level +1





View from the uppermost level +4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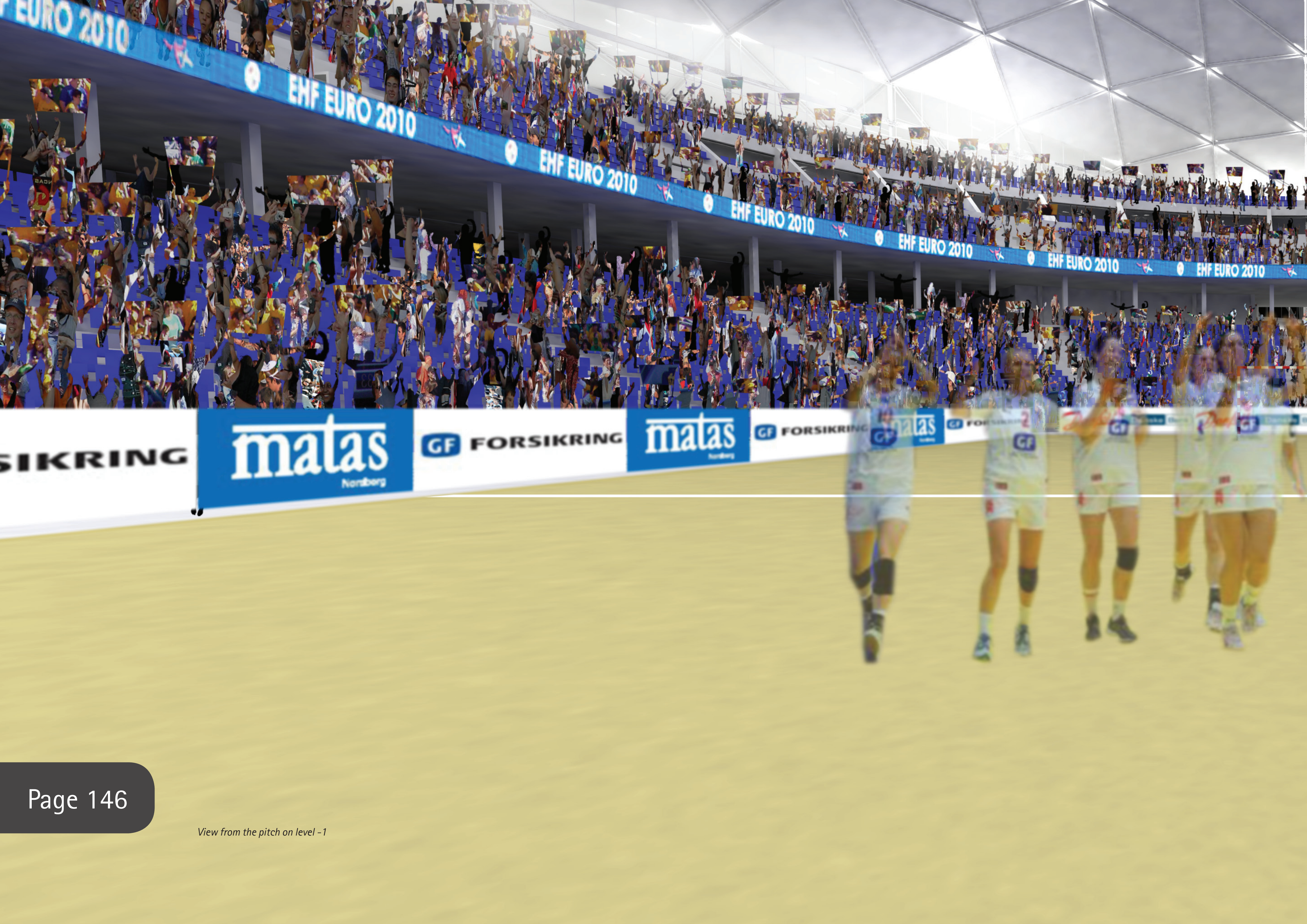

View from the pitch on level -1


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Academic summary

Conclusion

In this last chapter an overall summarizing conclusion is conducted upon the final design proposal. In order to enable this we compare the qualities of the final design with the criteria set in the problem statement and vision.

The problem formulation asks how we can design a multi-arena that can meet the needs of the context and major events, the vision describes a transparent tectonic stadium with an iconic design-language, combined with a masterplan that supports the stadium experience while offering value to the context.

We have strived to meet the demands of the problem formulation and vision on two levels; on the building side we made the appropriate facilities to host a world class sports event such as the handball World Cup – but we have also facilities for lower tiers of sport with extra changing rooms, showers etc. and an extra handball court. That way we can accommodate the local athletes as well as the professionals. Furthermore we added a restaurant, a café and a fitness center, thus creating active functions in otherwise quiet periods. On the context side we have created a landscape with the stadium on top of a hill, playing on our human desire to always climb the nearest top. The landscape is integrated with the buildings ramps, allowing easy access and exit from the building. Simultaniously the paths are designed to play on the arrival to the stadium in order to reinforce the sense of pilgrimage. For the locals, the landscape provides areas with activities and shelter from the strong winds. There are accommodations for a range of outdoor activities: Skating, basketball, petanque and others. Also there are large grassy areas for relaxing.

As a whole we have lived up to the demands of problem statement and the vision; the design would be an impressive host for any major event, while it adds value to the context for the rest of the year – both outside and inside.

Perspective

What is the future of our dome - a good question to think about when looking half a decade into the future. Obviously it is not possible to give a precise answer – but in this section we will speculate on just that question and some of those that it is connected to.

First off, the future of our dome is dependent on two significant factors:

A) The future of sports culture. Will the sports we have chosen to cater for grow or diminish?

B) The future of Ørestaden. Will the city grow in and develop a unique identity and fabric like the bridge areas or will it retain its sense of vacancy?

The answer to the first point has a tendency to become purely speculative, but clues lie in surveys that hint on the future trends in sports. Studies point towards a tendency where the 'large' established sports continue to enjoy popularity in the public and especially on the professional level. Another parallel tendency shows that traditional smaller sports are giving way for newer types of sports –most of these are not team based, which allows more personal freedom for the athlete [Kural, 2000]. For the stadia this is good news as it means it is likely to host large sports events in the future. Concerning the smaller sports, the building is based on an open plan layout with pillars which allows for great flexibility of use. Also we have flexible outdoor areas that cater to many types of sports. Furthermore the temporary Plug-in Park is quite close to our plot which caters to both new and established sports – perhaps some type of synergy effect with this could be achieved if it is allowed to stay.

Second point is a speculative as the first, but figures from By & Havn shows that people have moved to Ørestaden in large numbers this past year. Subsequently one could speculate that the sense of emptiness that dominates Ørestaden is not only due to poor city planning, but also due to the fact that this new part of the city was being built faster than it could be populated. If this is true, then it is likely to be populated in the coming years, and the few remaining building plots will be developed, which then is likely to alleviate the sense of emptiness.

Of course, if Ørestaden somehow remains frozen in its current state, it will most likely have a negative effect on the stadium, as there won't be enough users to give life to the building outside of major events. This would leave it standing as an empty for the greater part of a year.

So in summation, the stadium is suited to take into account some shifts in sports, and would be, if constructed, a popular venue for sports events many years to come. However, the stadium is dependent on the future growth in the area, but seen in the light of many newcomers last year, and the constant need for housing in the greater Copenhagen Area, Ørestaden is likely to be densely populated within a few decades. Therefore, the future for a project like ours is bright.

Reflection

Looking back on a project in order to try and examine the design process is interesting, because it can help us see flaws and errors that we may otherwise not have noticed.
We used an iterative design process throughout the project, which we have kept for the most part of the process.
A recurring theme for this project and semester is: 'if we had more time'. As mentioned in the conclusion we are generally pleased with the design and its ability to meet the requirements that we have set. However, living up to the demands we set for ourselves does not equal great design and a job well done. Even though the design has many positive qualities, there are also a number of elements that would benefit greatly from extra work, especially light-conditions and utilizations of space on the lower levels. On the master plan level, further detailing the activity zones would strengthen the concept.

Even though we knew from the outset that multi-arenas was the result of compromise, and we prioritized accordingly, we would still like to work further on the acoustic properties of the dome so that we could investigate its properties further and the effects of the bubble-roof. Furthermore we have also chosen not to examine energy-aspects in this project, but we still kept it in mind when designing - for example the dome shaped roof encapsulates the largest possible volume with the smallest possible surface and the fact that over half of the building is buried, should help keep energy consumption down. So the elements for a good result are in place. Further investigating energy and ventilation would be able to reveal this and be an interesting challenge as the usage patterns of the building would fluctuate wildly over a year.

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