POLITECNICO DI MILANO

VI School of Engineering (Ing.VI – EDA)

MASTER OF SCIENCE IN ARCHITECTURAL ENGINEERING

Library for the School of Architecture – Dubai (UAE)
Urban design, architectural design and sustainable technological design

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FIGURE 1 Inspiration for the design

The thesis examines issues of sustainability in relation with desert climates. The author first discusses the implementation of the Urban Design and its reflection to the various public, and later on continues to accommodate individual needs. The author then reflects on a micro concerns and continues with Architectural Design of the main complex of the site, the campus of School of Architecture, choosing the school's library as the focus project. In the last part of the thesis, the author explores the issue of sustainable consumption of the school's library and the link between harsh climate, discussing three questions: (1) What would be appropriate volume and its envelope?; (2) What are the levels of solar radiation, how that effects the environment and how that links the consumption levels?; (3) Autodesk Ecotect Analysis software and the main limits of it? The results reveal a positive conclusion, that the project has accomplished to be certified as an energy efficient non-domestic building, taking the C level (51-75 kWh/m2) – minimum energy standard.

La tesi esamina le problematiche relative alla sostenibilità in relazione alle strutture situate in luoghi contraddistinti da climi desertici. La candidata espone in primis l'attuazione di un particolare design urbano e la sua influenza sul vasto pubblico, per successivamente passare alla risoluzione di bisogni ed esigenze specifiche. Partendo dalla riflessione su diverse micro aree di interesse, continua illustrando il design architettonico del principale complesso del sito: il Campus della Scuola di Architettura, scegliendo la biblioteca della scuola come punto di partenza per spiegare la logica del suo progetto. Nella parte finale della tesi, la candidata esplora i problemi relativi alla sostenibilità dei consumi della biblioteca collegandoli alla particolare situazione climatica di estrema aridità. In che modo? Portando l'attenzione su tre questioni fondamentali: 1) Quali sarebbero i volumi appropriati e i loro "rivestimenti"?; 2) Quali sono i livelli di radiazione solare, come questa possa influire sull'ambiente e come si ricollega ai livelli di consumo?; 3) L'utilizzo di software come Autodesk Ecotect Analysis e i suoi principali limiti? I risultati rivelano una conclusione positiva, ovvero il progetto risulta idoneo ad essere classificato come un edificio non domestico energeticamente efficiente, usufruendo del livello C (51-75 kWh/m2) quale standard energetico minimo.

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URBAN DESIGN

The objective of Urban Design project is to extract the guidelines out of climate, cultural and geographic conditions of the location and to overlap them with stakeholder's project needs, which will lead to an urban design proposal for the new School of Architecture in Dubai, UAE. In the early stage, there will be introduced the methodology called NOOS, as a tool of research, which stands for the process of exploring Not Only One Solution. The results of the research reveal how such a harsh atmospheric environment could be overcome with passive and active urban installations and technology solutions and in the same time accommodate all the needs of wide pallet of users. For all projects details, refer to annexes 1 and 2.

Not Only One Solution

The methodology that is going to be introduced here, throughout the study project is called NOOS[1]. It is an acronym which stands for Not Only One Solution reiterating that urban design, like other design activities, not only permits but demands different answers, different solutions that can be given to a problem, regarding urban or development ones. The organization of a design process is not, therefore, an attempt to shape a deterministic process which would lead, given certain inputs, to only one output. To use a process means to employ a structure, a route strategy, which helps the designer to move towards the target, not necessary to get there earlier.

The NOOS process appears to be strongly systematic, roughly linear and highly optimistic. It assumes, for the sake of descriptive convenience and the necessary simplification, of a relative lack of conflicts between the actors involved, and a high level of honesty and competence by every party involved.

It should be notified that urban design processes and NOOS are not different, but are the same tools to be used and adapted due to needs of the project. They are not written on the stone or a wizard's wand that can easily solve the problem. The urban design process proposed here should be considered as a guide for managing an urban design project. The main ability of the designer should be to adapt the urban design process to that particular situation and to that specific task and mission.

In a figure 1, it's presented the full concept of this logistic approach, with the steps and undergoing processes that will process in the urban design projecting. These steps are: analysis, pre-project, project, execution.

[1] Methodology by course "Urban Design", MSc program Architectural Engineering, University Politecnico di Milano.

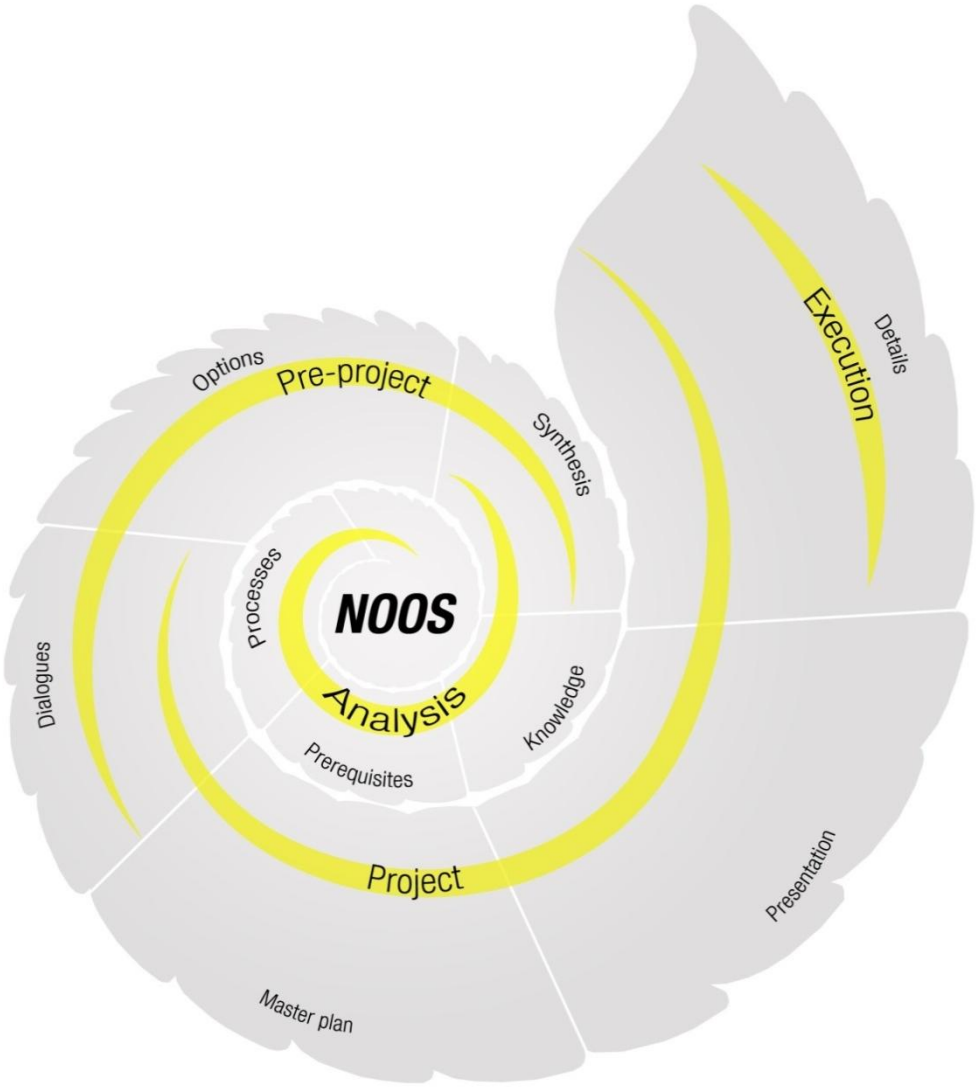

FIGURE 2 NOOS process analogy

Analysis, overlaps with the second stage on the step synthesis:

Processes: Data collection of existing conditions (natural, built and socioeconomic), identification of all opportunities and limitations, formulation of goals and objectives, translation of alternative solutions into policies, plans, guidelines and programs;

Prerequisites: fallows the environmental characteristics, techniques for listening the clients demands and the brief of the project needs through identification of stakeholders and their expectations, focusing on the achievable vision by presenting the precedents of the best practice from the local and abroad examples;

Knowledge: is the collection of data regarding the existing situation on and around the site of interest. It is studied through: survey and analysis, possible site visits, photos and sketches of the location, ecological planning methods, ecological footprints, collection and analysis of historical data, historic growth pattern map, urban morphology, socioeconomic analysis, study of transportation and urban mobility, studies of social facilities, public city spaces, think "outside of the box";

Synthesis: tools for interpretation of collected data from the previous step into synthesis techniques to produce the guide specific for that specific situation. It is composed by: SWOT analysis, map of opportunities and constrains, transects, sustainability analysis, geographic information system, awareness of the space and design task, case study and diagnosis.

Pre-project, overlaps with the analysis stage on synthesis step and with projecting stage on dialogues step:

Options: is a tool for making the choices, list of general goals, visualization of a concept plan and choices, using the "green" buildings, neighborhood, site ranking systems;

Dialogues: is meant to fallow the comparison of characteristics and risks within the planning program, including possible public participation, their types and techniques how to involve the people in design processes.

Project, comes as a third stage that shares the dialogues step with the previous one and details step with the execution stage:

Master plan (MP): visually interpreters the origins of the MP, its characteristics and goals, within the contents and structure;

Presentation: is a step containing the summary report, followed by any electronic type of presentation (.ppt, .pdf, etc.) or printed one.

Details: is a phase including the design guidelines and the mobility feasibility.

Execution takes place in details and continues in the implementation phase:

Implementation: is extracting the importance of the UD planning and designing actions, delivering the guidelines and rules for architectural design (AD). In some project, it might be including also the monitoring of the site and maintenance management.

The four phases of the NOOS methodology shall be explored acutely within the study example in the succeeding chapters, processing the facts and database into workable design strategies and prospects and programs.

Processes

Dubai (/duːˈbaɪ/ *doo-**BY***; Arabic: دبيّ *Dubayy*, IPA: [dʊˈbæj]) is the most packed city and emirate in the United Arab Emirates (UAE) and the second leading emirate by territorial size after capital, Abu Dhabi. It is located on the southeast coast of the Persian Gulf and is the one of the seven emirates that makes up the country. The city Dubai is located on the emirate's northern coastline and heads up the Dubai-Sharjah-Ajman metropolitan area, and it is roughly at 16m above the sea level. Dubai is positioned at 25.2697°N 55.3095°E and covers an area of 4,110 km^2, which represents a significant expansion beyond its initial 3,900 km^2 designation due to land reclamation from the sea.

Dubai lies directly within the Arabian Desert. However, the topography of Dubai is significantly different from that of southern portion of the UAE in that much of Dubai's landscape is highlighted by sand desert patterns, while gravel deserts dominate much of the southern region of the country. The sand consist mostly crushed shell and coral and it is fine, clean and white. East of the city, the salt-crusted coastal plains, known as Sabkha, give way to a north-south running line of dunes. Far East, the dunes grow larger and tinged red with iron oxide. Dubai as no natural river bodies or oases; however, it does have a natural inlet, Dubai Creek, which has been dredged to make it deep enough for large vessels to pass through.

Seismically, Dubai is in a very sable zone – the nearest seismic fault line, the Zagros Fault, is 200 km from the UAE and is unlikely to have any seismic impact on the city[2]. Experts also predict that the possibility of tsunami in the region is minimal; because of the Persian Gulf waters are not deep enough to trigger a tsunami. Sandstorms are only natural risk of the area, reaching sometimes the speed of 110km/h (68.3 mph), like in April 1st, 2015[3].

Dubai has a hot desert climate. Summers are extremely hot, windy and humid, with an average high around 41˚C and overnight lows around 30˚C in the hottest month, August. Most days are sunny throughout the year. Winters are warm with average high of 24˚C and over lows of 14˚C in January, the coldest month. Precipitation, however, has been increasing in the last few decades, with accumulated rain reaching 94,3mm per year[4]. Dubai summers are also known for the moderate to high humidity level, which can make it uncomfortable for many[5]. The highest recorded temperature in Dubai is 52, 1˚C, reached in the period of July 2002[6].

[2] Far enough from the fault lines. The National, 23rd April 2008.
[3] http://thewatchers.adorraeli.com/2015/04/02/massive-sandstorm-hits-arabian-peninsula/
[4] "Climate in Dubai across the year. Dubai Metrological office". Dubaiairport.com. Retrieved 2013.
[5] "Temperature and Humidity in Dubai". Godubai.com. Retrieved 2013.
[6] "UAE weather: temperature soars to near record level". Thenational.ae. Retrieved 2014.

Abu Dhabi and Dubai are the only two emirates to have veto power over critical matters of national importance in the country's legislature[7]. It has one of the world's fastest growing economies. Dubai has emerged as a cosmopolitan metropolis that has grown steadily to become a global city standing tall as a business and cultural hub of the Middle East and the Persian Gulf region as a whole. It is also a major transport hub for passengers and cargo. Although Dubai's economy was historically based on the oil industry, the emirate's Western-style model of business drives its economy with the main revenues now coming from the tourism, aviation, real estate and financial services. Dubai has recently attracted the world's attention through many innovative large construction projects and sports events. The city has become symbolic for its skyscrapers and high-rise buildings, such as the world's tallest Burj Khalifa, in addition to ambitious development projects including man-made islands, hotels, and some of the largest shopping malls in the region and the world.

Prerequisites

The initiative for this project was released to the public eye in October 2013, as an International Competition hosted by [AC-CA] to generate contemporary design ideas for the new campus of the School of Architecture in Dubai. The stakeholders were unnamed, but the project holds a social and public character, so therefore it will be treated as public project. In the competition brief there were given instructions on how the project should be handled and what qualities should be provided in the solutions. The guidelines, given by the leading team of experts were:

- Intelligent and appropriate use of all design principles;
- Use of the space and perceive traffic flow within the space;
- The Design's aesthetics and originality;
- The use of sustainable materials;
- Clarity and comprehensibility of the design.

The brief also allows the designer to choose its site of preference anywhere within the city boundaries in order to focus more on achievable vision for the new School.

Within the guidelines there were several functionalities to be included in the project:

Administrative zone: A zone designated for administrative staff including offices, meeting rooms, etc.

Academic zone: Teaching zone, library, Academic staff offices and research spaces, computer center.

Social and welfare zone: A zone allocated to students social and welfare activities with café, restaurant, Students Union area, students shop, careers adviser, student travel agency, events space, etc.

Professional practice zone: A zone destined for offices for a professional architecture practice linked to or affiliated to the architecture school where students may also undertake real life work experience, internships, work after graduation, etc.

[7] The Government and Politics of the Middle East and North Africa. D Long, B. Reich. p. 157.

Circulation zone: A zone of first contact with entrance hall, reception desk, security point, school exhibition foyer, waiting area, information desk, etc.

Service zone: A zone which includes general storage, loading area, plant room, etc.

External zone: An external parking, landscaping, emergency/fire escape meeting points, etc.

Knowledge

City area: 4,114 km^2

City population: 2, 106 million people

FIGURE 3 Dubai map

In the competition brief, there were no constrains on the location of the School project. In order to collect more efficiently the knowledge for the sites of interest to build on, the analysis will be based on the portion of the city that brings up the main qualities of this metropolitan city as well some factors important for integration of the project in the city's texture. The first qualities of the site must be:

- easily reached by public transportation (bus and metro);
- close to the center of the city, but not in the epicenter of it, for the privacy and security;

- enough large site, that could host not only the School needs, but also other activities that could attract more public - beneficiary for the School's gallery and extension of students activities after the class hours;
- a location where the green network could continue to expand and give all visitors a comfort from the solar radiation;
- well positioned and not surrounded by the skyscrapers in order to harvest the wind and solar energies;
- with an additional space for the open parking space;
- close to the business (companies) and institutional (libraries, high schools) facilities that could take interest in the work of the students.

The first analysis of the city showed in the figure 2 that it's the thin "ribbon" of the city fabric, closest to the seaside is the most suitable for the location search. This part of the city is found between the main road E11, or the metro line (dashed line) and the sea shore. On the West, the analyzed area will be till the Palm Jebel Ali, and on the East it will finish with the downtown of the Dubai.

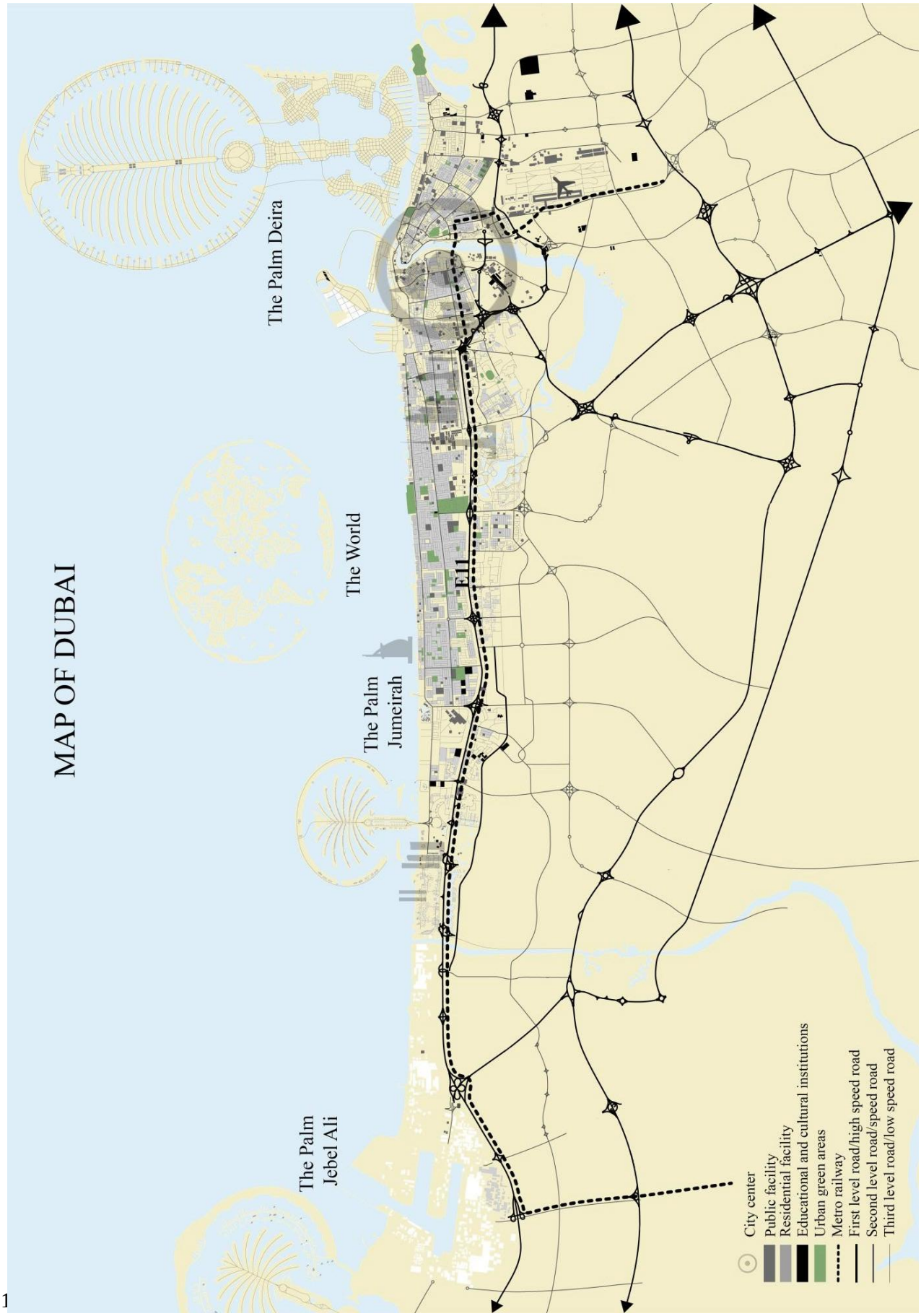

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FIGURE 4 the zone of interest

As showed in the figure 4, Dubai is a city with fairly dense constructed city blocks. This part of the city is constructed on a combination of the different blocks morphologies (orthogonal, curvilinear, radial, T-tree etc.), which all carry mix uses and different users programs, mostly based on hotels, residential and business facilities.

FIGURE 5 The block morphology

The inner city urban infrastructure, as demonstrated in figure 5, is based on the three levels of road sizes:

- First level roads for the heavy traffic placed mostly parallel to the sea line. Some of them are pointing to the lower parts of the city closer to the desert, as it's expected that the city grows in that direction. Along the main road, the metro line runs (black dashed line). This communication shall be one of the priorities in the site choosing.
- Secondary level roads are more perpendicularly distributed along the city, cutting the main roads. These communication lanes are also one of the important guidelines, because they carry most of the public transportation as bus lines.
- Third level roads are small streets creating the urban fabric. These roads are less important, since are mostly used by private transportation system, and therefore not interesting for a project of a public character.

It would be most desirable to situate the construction somewhere between the first and the second level of communications in order to obtain the efficient public transportation. This move would show most useful, since the facility will be mostly used by younger public o students that count around 1200 individuals.

FIGURE 6 transportation analysis

In the next phase, the project should be well communicating with other educational and cultural institutions, but should avoid being in a center of tourist attractions, because of its security and comfort qualities. Also it should be well situated in a close by of the business centers, as it could influence stronger relation of the school and the corporations who could have interest in the works of students. In addition to the functionality of the possible location choice, there should be also concern about the heights of the nearby facilities, since they can influence greatly the solar exposure of the zone of construction and possible sustainable technological installations. It would be a perfect balance if the school could have strong visual connection with the city's skyline panorama, but with a privilege to still stand tall among the constructions pattern around it.

In the map of functional analysis, figure 6, the locations are presented in rectangular portions.

This division shown on a map, figure 7, demonstrates clear division of the city. In the far west side, there

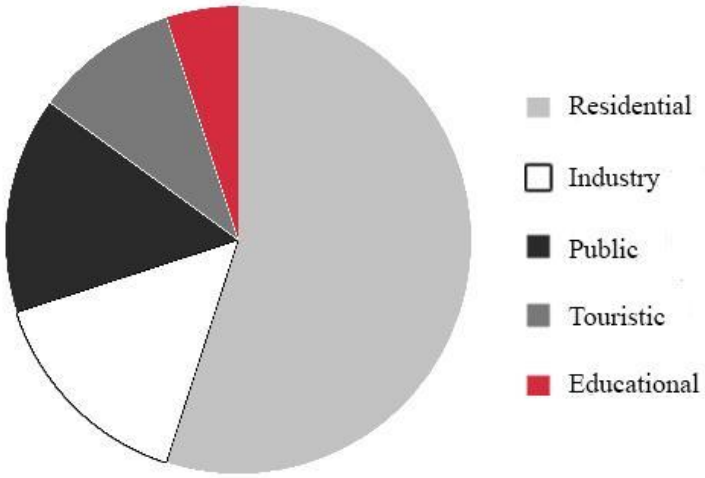


FIGURE 7 Development of different functions in the city

is a strict industrial zone, on the water front. On the far East side, around the city center, there are private / residential objects, public / retail / tourism / airport / religious facilities and several educational/university/ministry of culture and education facilities. In this zone, the weakness could be traffic overload and grand migration of the tourists in the seasons. Also, the sites are much smaller and it could be a sign of loss of strong visual connection of the future school with a surroundings. The middle zone of the city, along the seaside, seems more promising, since its composed mostly by residential buildings and educational centers and institutions. This may seem confusing at first, but it's promising for the wind energy collection strategies, since those facilities are not of great heights. It could also mean the increased flow of the users and visitors from a nearby, continuing on the extension of the activities and programs on the site.

Figure 8, has the urban green network extracted. As shown, it's not well connected and in abundance, but taking in the consideration the climate conditions, it is comforting. All these green areas are organized as parks. They are rich of palm trees and flowers, which can reduce the solar radiation effect in some areas and air pollution effects. In the middle zone of the city there is a more consistent pattern of the green areas, which narrows the map for a search.

FIGURE 8 functional disposition in the city

FIGURE 9 Urban green areas

Taken in consideration pros and cons for the site scouting, it has been concluded that the are below the man-made islands called the World, should be most compatible with the stakeholders guidelines as well with the designers priorities for achieving the project's vision.

FIGURE 10 diagram of virtues and needs

In the figure 9, stands the diagram of all qualities named by the stakeholders and design needs. In this schematic presentation we can see:

- Top circle pointing to the seaside;
- Far left circle pointing to the educational facilities;
- Middle left circle pointing to the metro line;
- Middle circle pointing the green area;
- Middle right circle pointing the Burj Khalifa, symbol of Dubai;
- Far right circle pointing the desirable visual skyline;

In overlay of that information with empty sites in nearby, we can extract four potential choices, figure 10.

FIGURE 11 Four site proposals

First choice

Second choice

Third choice

Fourth choice

FIGURE 12 Site choices

In order to bring the one out of the group as a best choice, each choice will be graded by the weaknesses that bring to the project quality:

First site: Missing out on solar and wind potential for energy harvesting. Possible shadow cast in winter period from the skyscrapers on South-West. Visual potential for the school as a new landmark is reduced by domination of skyscrapers.

Second site: Possible shadows drop on the block in the future, if the line of skyscrapers is continued along the main road. It is too large for the project needs.

Third site: Possible noise and air pollution from the main roads.

Fourth site: Site placed far from the metro line. Morphology of the block could turn on to be challenging for the projects functional and sustainable needs.

The site for the project has been selected, figure 12. It is located in between the Al Hadiqa Street and 7th Street, and between 12 A Street and 16 Street. The area has 56.250,00 m^2 or 0.05625 km^2 . This area is mostly residential, with High School and Hospital in nearby. The location on the North-East side, with a Street Al Hadiqa is the main communication lain. It belongs to the second road level and beside high frequency of private transportation it has as well a public transportation, bus no. 15. This street in its East part, just 200m away from the location of the project, connects to the biggest and most important road in the city, the road E11. As discovered earlier in the text, the road E11 also has the metro line fallowing it. As a addition to the Al Hadiqa Street, on its West side it's leading towards the seaside and on its North side is a boundary for one of the biggest parks in Dubai, Safa park.

FIGURE 13 Project site

Synthesis

One of the tools for site quality evaluation is a SWOT analysis and it stands for Strength, Weakness, Opportunity, and Tread. In the figure 13, is presented one of the forms of the SWOT analysis, extracting all processes and conditions on the site.

FIGURE 14 SWOT analysis

This table will help us locate all of the site factors that will enter in a process of designing. As shown in the figure 14, map of the site, it is easy to spot how the factors of SWOT analysis are distributed, indication from where each of the factors is influencing.

FIGURE 15 SWOT map

Options

The master plan of the site is a representing the location with a new layout. In its context it includes six building volumes, predicted for Universities needs and additional program buildings and public spaces.

In the initial competition brief, the School should be located in the form of a skyscraper. Site and sustainable perspective for that kind of architectural form are showing that it would be much more efficient to divide the School in several, smaller facilities, and here is why:

- Not all functions of the concept are used equally through the day and year – probable lose of energy;
- The public and users of the space are expected to be in a great number, since just expected number of the students is 2000, so it was better to divide the functions in different volumes to provide comfort and safety for all. The additional plus is possibility to evacuate more quickly the public in a case of emergency;
- The energy performance can be improved by increasing roof surface making it available for the solar panel needs;
- Creating narrow passages between the buildings creates more shadow on the site, and it can create more comfortable open spaces around the buildings;
- Paralleling the volumes and making them cascade in one direction can coordinate the wind flow and bring natural ventilation of the passages;
- The general composition of the elements is not higher then 60m, so it's not dominating the surroundings and it's not shadowing the surrounding objects. This is a point of transition from skyscrapers of the business center to a residential zone, so it can create nice doping line in city panorama;
- It gives opportunity for pedestrians to cross over the land in more optimized and accommodating environment;
- The volumes are not monumental, and can be easily manipulated to accommodate additional program like mosque that we would like to offer to wider public of this neighborhood.
- It can have lightweight, movable constructions for exposition area on the open space, through the garden that can be followed by all visitors, since the site is floodable with its many elements, and not just concentrated in one volume.

The site is also compatible to be as an extension of existing green net of the Safa park, on the other side of the road. It can improve image of the city and performance of the site on extreme weather conditions of Dubai.

The site will be organized so that it can support the technological sustainable solutions and strategies that will improve temperature and humidity issues.

In order to engage the community of the neighborhood in using more frequently site, but not just for crossing over it, the project will incorporate another unit on the north side of the land. In a zone of that in its narrower content contains the hospital, schools, libraries and residential buildings, and in its wider one has business centers, it seems logical to embrace as a new additional function that can serve all that public. As a result, the additional program on the site will include a mosque, covered flea market during weekend and flower covered resting and relaxation area during the working week, park with pond, pavilion of architecture and external exposition space. In a further development of the project and site, the primary key words in shaping this volume will be: functionality, light solutions, sovereignty and integrity in a respect to other buildings on the site.

Dialogue

In order to improve the image, community vision and a vivid sense for all the predicted users of the space, it would be interesting to add that the project should be cared and protected not only by stakeholders investments and municipality polices, but also by local citizens and institutions who are in nearby and can benefit from the new program on the site. This dialogue will present potential users, their needs; characteristics of the site and possible risk in the absence of interest the target groups.

The target publics for the urban design project are:

- *Students*: users of School of Architecture, users of the High School in the 7th Street;
- *Residents and citizens*: local public interested in program and activities offered by project;
- *Merchandisers and shoppers*: traditional flea market for citizens and tourists;
- *Religious groups:* residential and business groups are able to enjoy a mosque on the site;
- *Daily migrating public*: residents and occasional visitors in transition using the space for more comfortable and quicker way to cross the site.
- *Pavilion and exposition visitors:* lovers of Art and Architecture.

For those concerned that green spaces may foster crime and illegal activity, evidence now exists that the opposite may be true. When adjacent to residential areas, green spaces have been shown to create neighborhoods with fewer violent and property crimes and where neighbors tend to support and protect one another. These are the findings of scientists at the Human-Environment Research Laboratory of the University of Illinois at Urbana-Champaign who studied green space alongside public housing in Chicago.

The factors that explain these findings emphasize the importance of greenery in community and personal wellness. Time spent in natural surroundings relieves mental fatigue, which in turn relieves inattentiveness, irritability, and impulsivity, recognized by psychologists as precursors to violence. Green spaces also support frequent, casual contact among neighbors. This leads to the formation of neighborhood social ties, the building blocks of strong, secure neighborhoods where people tend to support, care about, and protect one another.

Master plan

The master plan has a local character and is concentrated on the improvement several lacks of the zone:

- Extension of the green net;
- Creating new program for the public and dominant visual point in the neighborhood;
- Additional parking area;
- Revitalization and adaptation of a void in urban texture of the city.

The figure 15 is a representation of a Master Plan of Urban Design and its correlation to the existing city infrastructure and content.

In the figure 16 is represented the map of the Master Plan for the Urban Design. The map indicates the disposition of architectural solutions and the landscape architectural diversity.

The figure 17 shows sections of the site and how the ambient flows from existing city context to a new architectural and urban adaptation of the block.

FIGURE 16 The new vision for the site

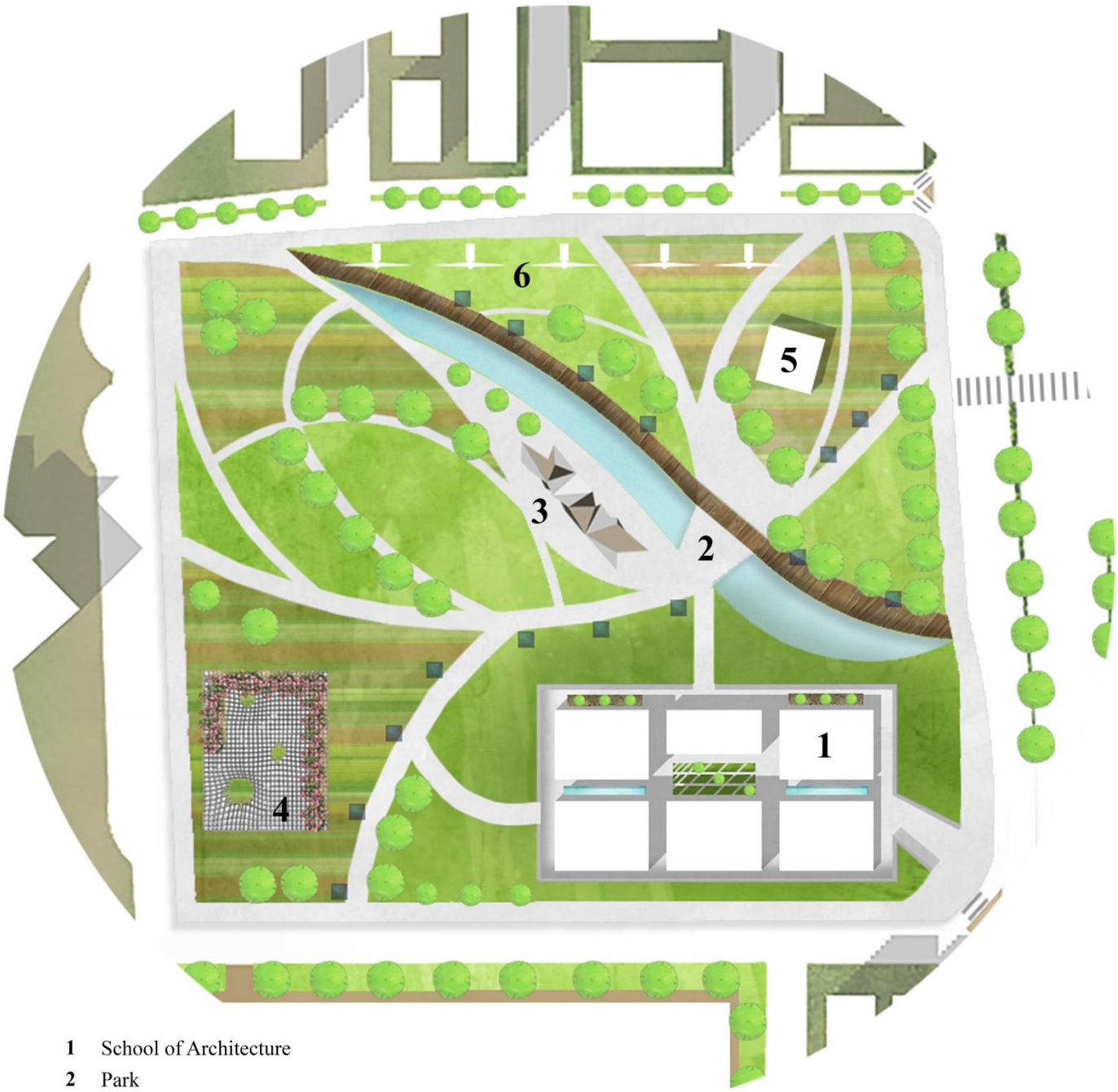


FIGURE 17 Master Plan

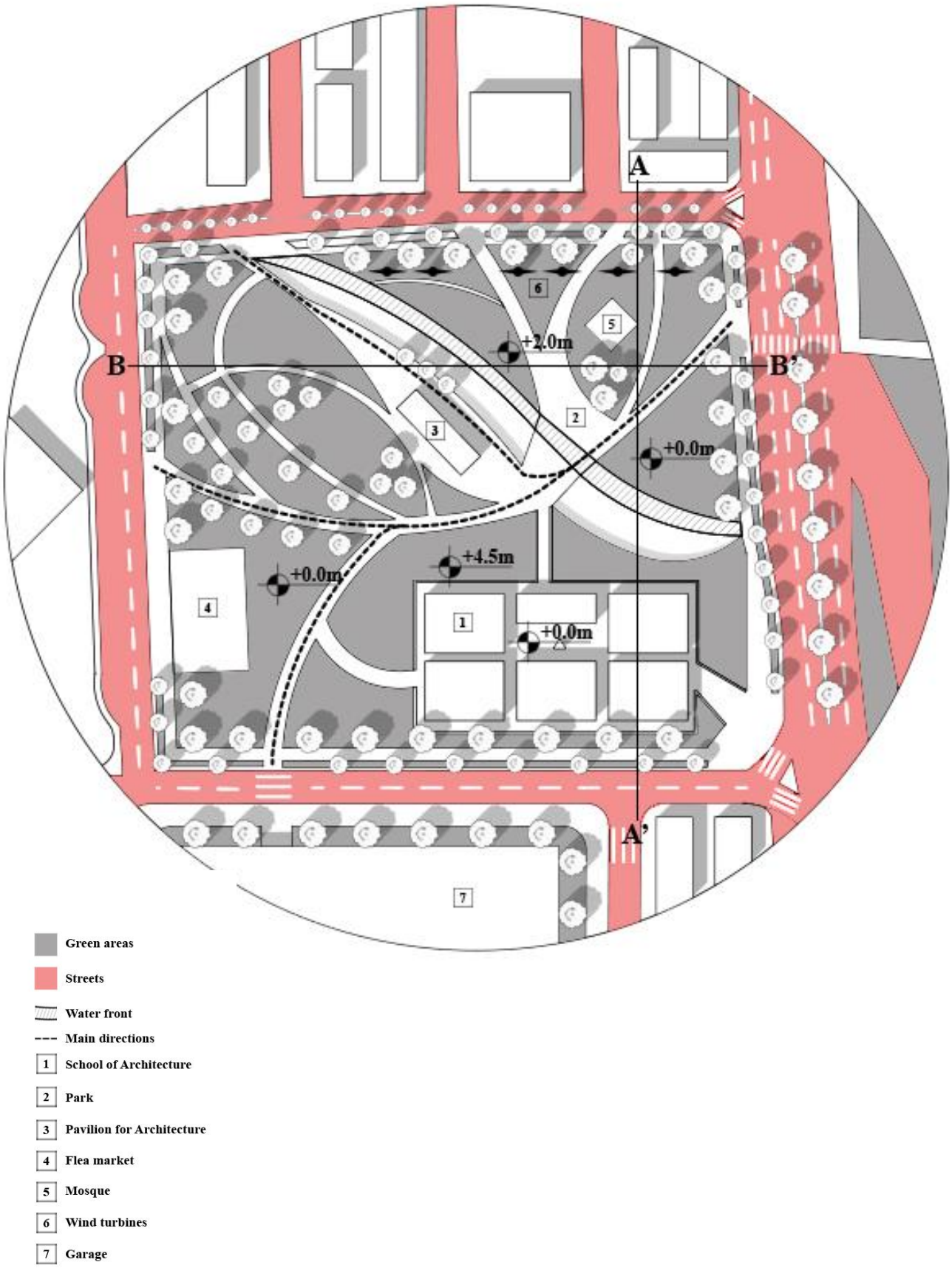


FIGURE 18 Master Plan (technical drawing)

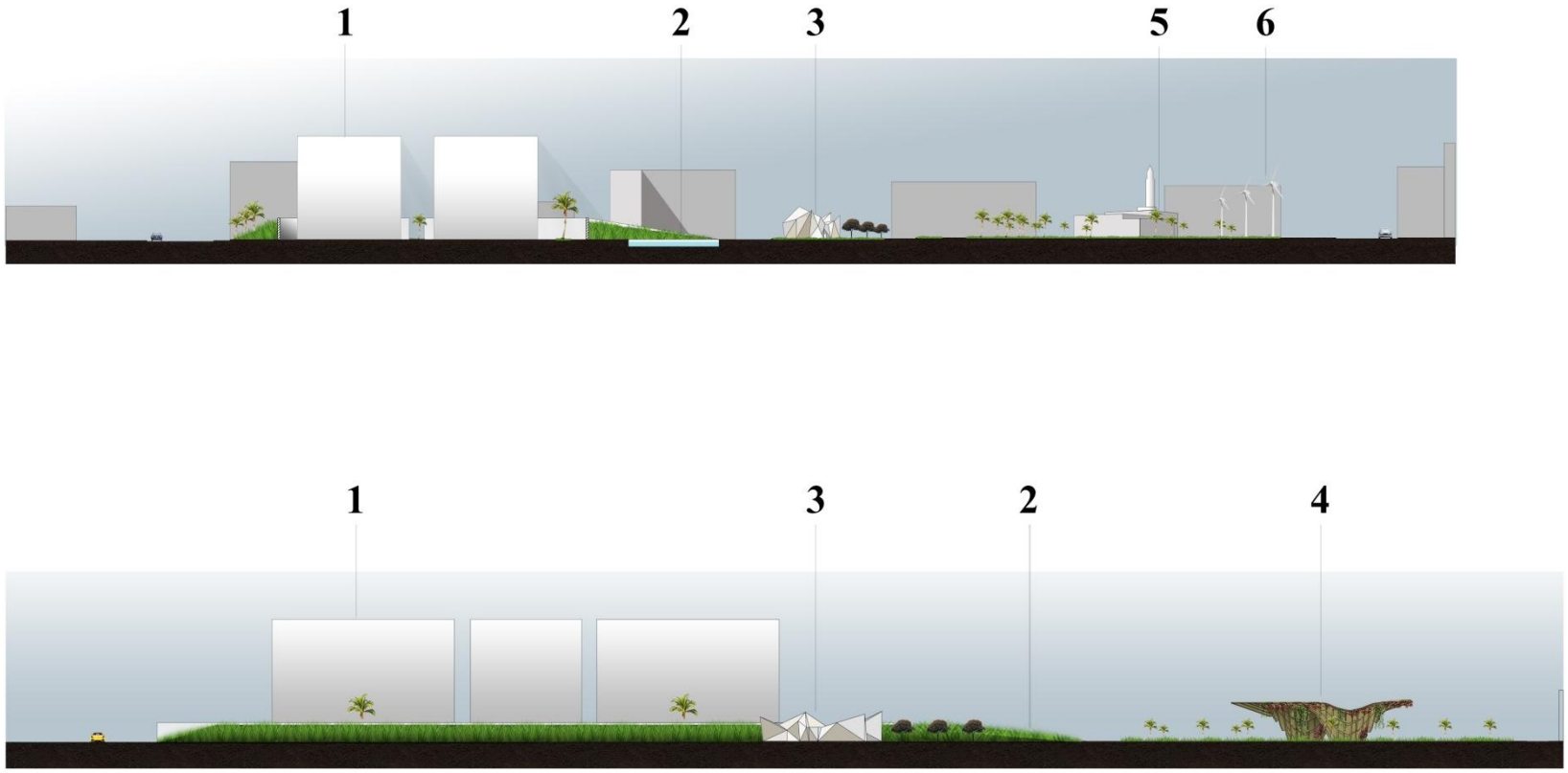


FIGURE 19 Sections of the Master plan

1 School of Architecture
2 Park
3 Pavillion of Architecture
4 Flea market / covered resting area
5 Mosque
6 Wind turbines

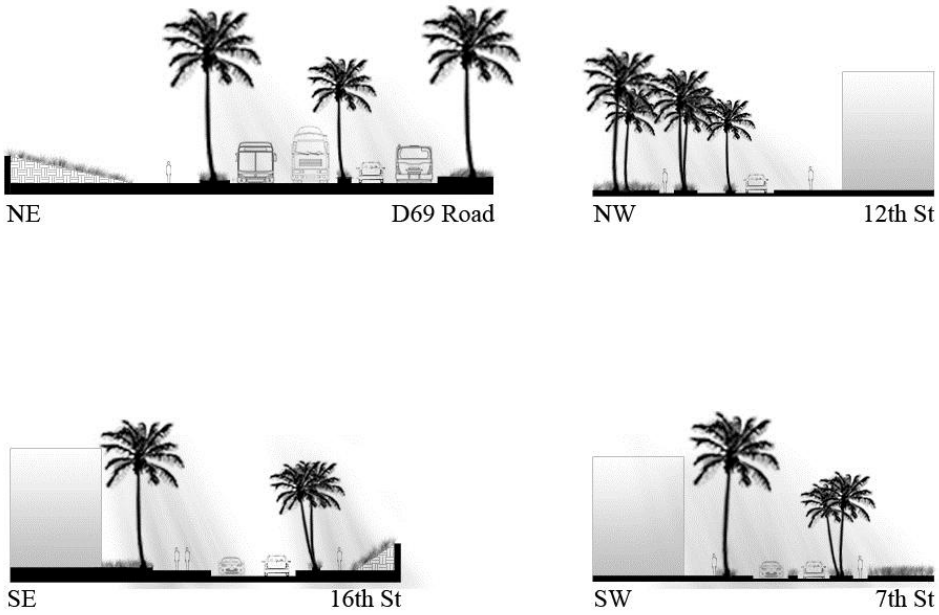


FIGURE 20 Sections of the streets

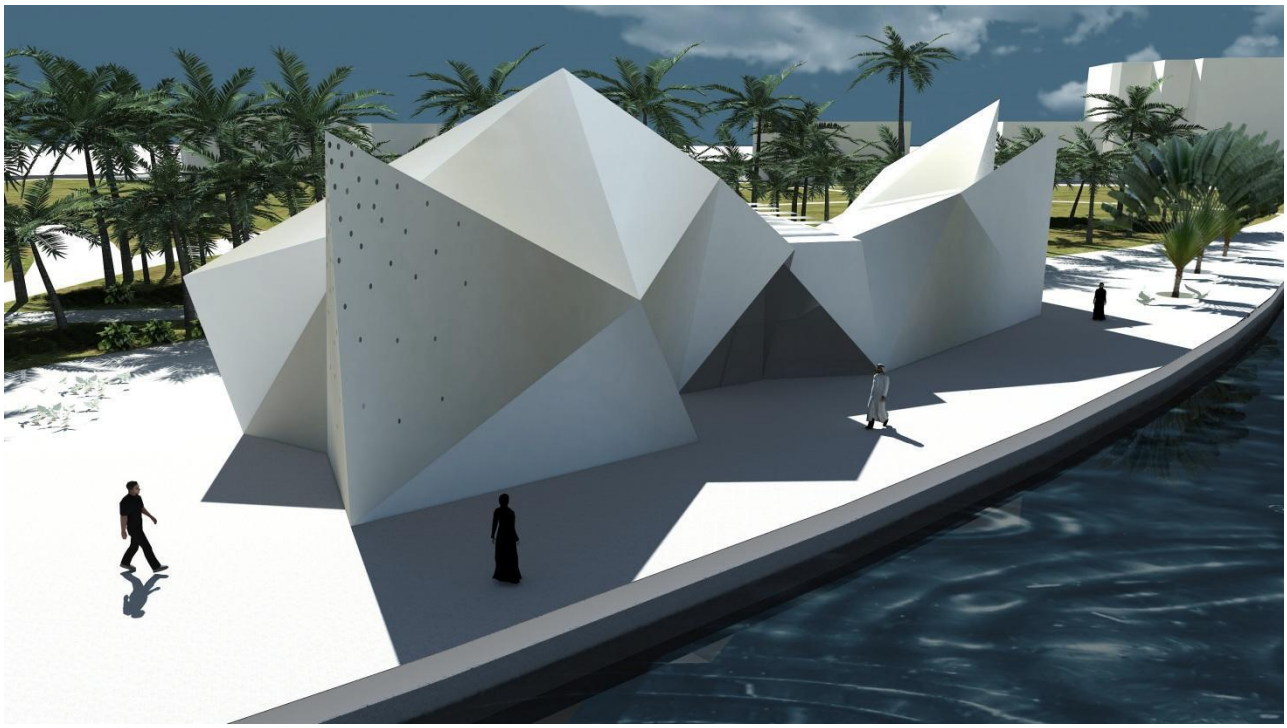


FIGURE 21 Pavilion of Architecture for student's expositions (render)

FIGURE 23 Market (render)

FIGURE 22 Mosque (render)

Implementation - Guidelines for Architectural Design

Urban design project involves the arrangement and design of buildings, public spaces, pedestrian walkways, services and facilities for cultural, religious and trade needs. Urban design is the process of giving form, shape, and character to groups of buildings, to whole neighborhoods, and the city itself.

Urban design is about making connections between people and places, movement and urban form, nature and the built fabric. Urban design draws together the many strands of place-making, environmental stewardship, social equity and economic viability into the creation of places with distinct beauty and identity.

Expectation for the next phase, Architectural Design, are to promote a more beautiful environment to live in, to start point in helping a community to think about visual environment and its connection to natural processes within the surroundings, to protect the values and vision of the urban structure.

ARCHITECTURAL DESIGN

The objective for the Architectural Design project is to generate an architectural solution for the needs of School of Architecture in Dubai, UAE. In the Prerequisite chapter listing the stakeholder's expectations, there were several functions required in such a facility, while in the chapter Options, of the Urban Design, was introduced the idea of dividing the School in several buildings, mostly to accommodate energy needs and studies of each of functional segments most efficiently. Development of the project will be focused on one facility only, chosen by preference of the designer, and will represent the projecting activities for the needs of Students Library. For all projects details, refer to annexes 3 until 14.

Concept of the site

The School of Architecture is planned to be a complex of six separated volumes, dwelling in area separated from the rest of the architectural program planned in Urban Design project. This campus was first envisioned as set in a "hole" of a ground, protected by walls on which external sides the gardens are falling on a steep soil. This configuration has for a purpose to change the state of the mind and soul of the users and visitors, since the character of the project is educational institution that should demand a respect and order from the occupants.
That hole will be constructed from a 0.0m ground level, as a concrete vessel, on which external sides will be placed gardens slowly dropping from a top level of 4.5m again till 0.0m. Dramatic tall walls that will circle the site have a buffer role as well, and will be a noise pollution protection strategy from a busy transportation around the site and it will give the School possibility to secure the zone during the night by closing just the gates at entrances.

In a figure 23, sketches are fallowing the genesis of the concept:

- The first drawing is explaining in section the geometry of the new topology and what are the expectations form it;
- The second is explaining the experience level in which the concrete vessel should open towards the street and park, collecting the visitors and directing them in a new special experience;
- Vista is the third sketch exploring several levels of visual potentials and how that new shape of the site can be useful for the users;
- Relation is introducing first models as inclined volumes in two lines, surrounded by two gardens and narrow passage in the middle. Gardens are created for the student's needs, but depending on the season, solar radiation and temperature will be used in different seasons;
- The geometry is giving the insight in geometrical possibilities for a volume definition.

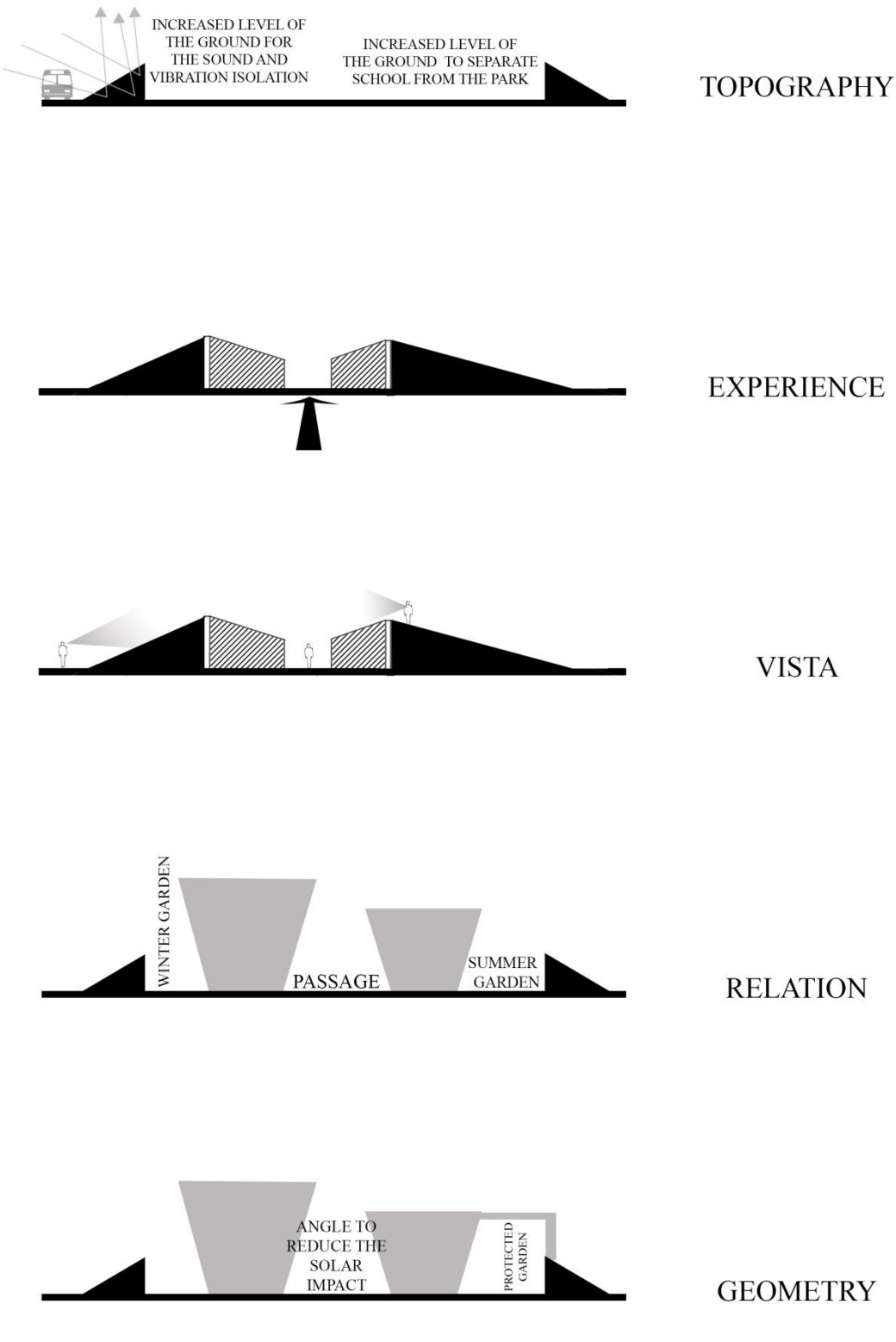


FIGURE 24 Concept sketch

Concept of the building

The volume of the building will be composed by two shapes, one the external and the other one as internal one. Figure 24 is a demonstration of the geometry planned for the project and in a purpose of the aesthetics will be multiplied for all other facilities in the camp further on in the work.

FIGURE 25 Volume of the facility

The external shape will be used as light envelope and a solar protection layer, followed by a second volume, more compact and solid in nature of the materials, creating a volume for the library's needs.

FIGURE 26 Second façade concept – from a tree to geometry (sketch)

Relationships with existing built environment

The project is architectural extention of the Urban Design project. It will overlook over the park for public use proposed by Urban design, but will have also its own gardens as well. It will dominate in the landscape of the new block arrangement with its hight, but with the the sloped gardens surrounding it, will simply melt into the environment not trying to overwelm it, but rather become one with it.

FIGURE 27 Library (back building) with another facility of the campus (front building) (render)

Below and above

The building will be in two ways in connection with the ground levels, from a street and from inside the concrete vessel. The mass has a firm connection with the ground, since it will give an optical illusion from the ground to be slinked into the soil, but lines at the top, imitating the tree structures, that are airy, light and give more sense of transparency. This image will change in the core of the project by experiencing the site and stepping into solar protected passages with gardens and water installations, converting the understanding, from an exposed structure (outside the vessel), into protected and more intimate oasis, where instead it will appear more ground connected.

FIGURE 28 Entrance to the campus (render)

FIGURE 29 View from the top of the concrete vessel (render)

Materials and the structure

Materials used in the project exterior design are based on the idea of immitation of organic shapes, but trough new components and forms. In this project there are two types of the facades, internal ones - solid ones covered with wavy pettern pannels, and external ones - fabricated concred ones with wooden brise soleil. The contrast of materials is a posibility to seek a new forms beween organic and technological styles, within textures, layers and light.

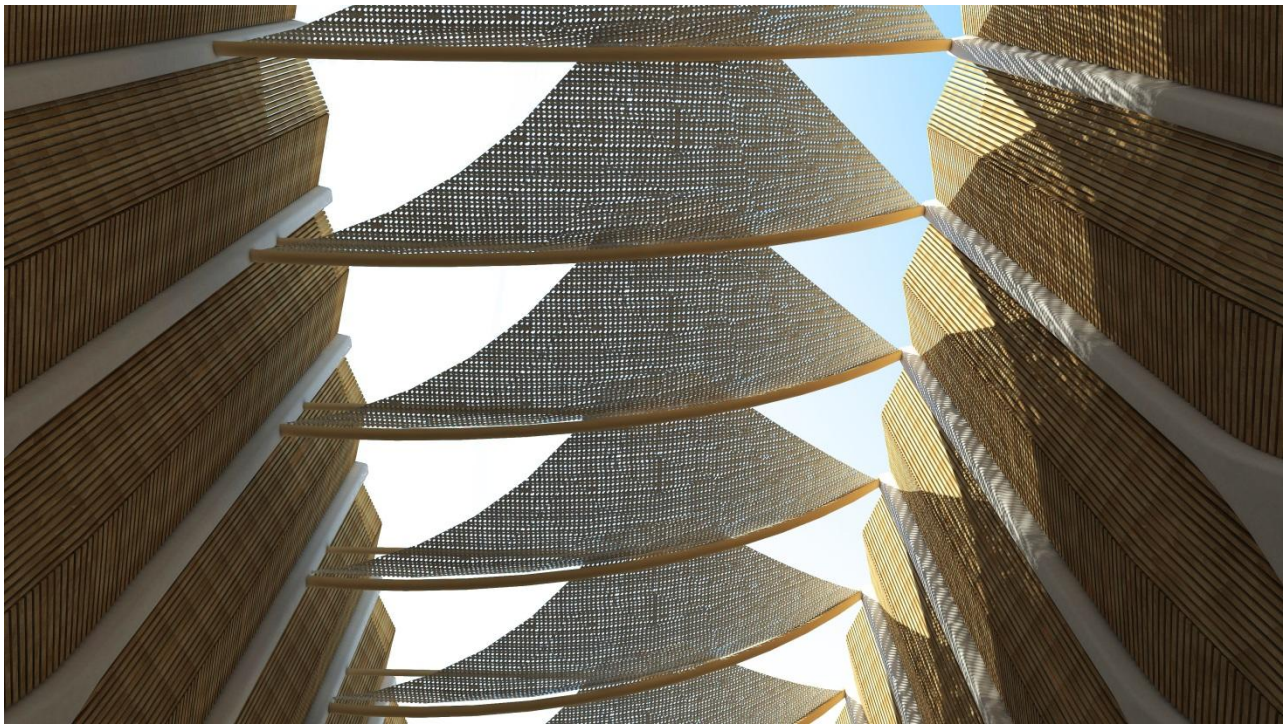


FIGURE 30 Passage between buildings, view from the ground (render)

Functional layout, hierarchy and movement

The use of space has been oriented towards the reading rooms divided in group reading area, individual reading/studying area and periodicals reading lounge. These functions are based on the first and second floors. On the ground floor, the area is collective and divided in information receiving area (info desk, electronic catalogue area), service are (cloakroom and copy room). On the basement level, the books are storage, as well as the technical room, for the building service systems. All floors capacities are expressed and connected in the figure 29 with staff and public vertical connections (elevators for the book, elevators for the visitors, stairs for the book storage space, stairs for the visitors).

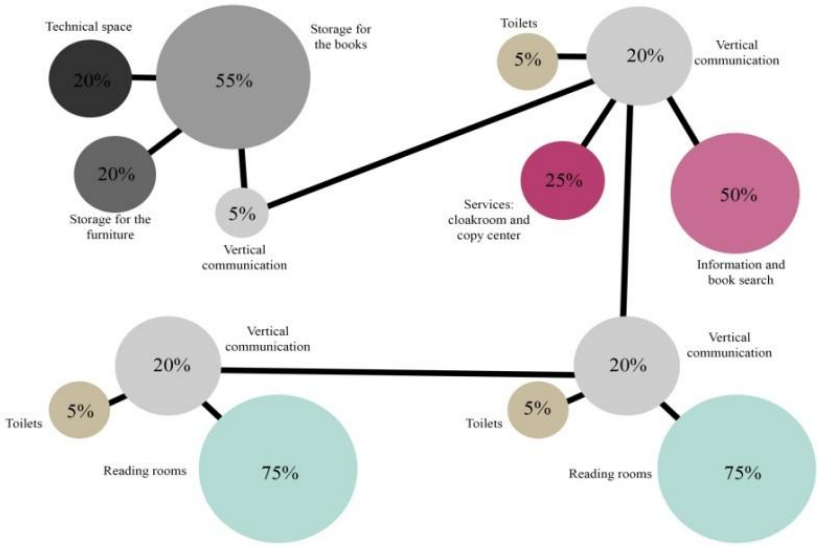


FIGURE 31 Hierarchy of the spaces

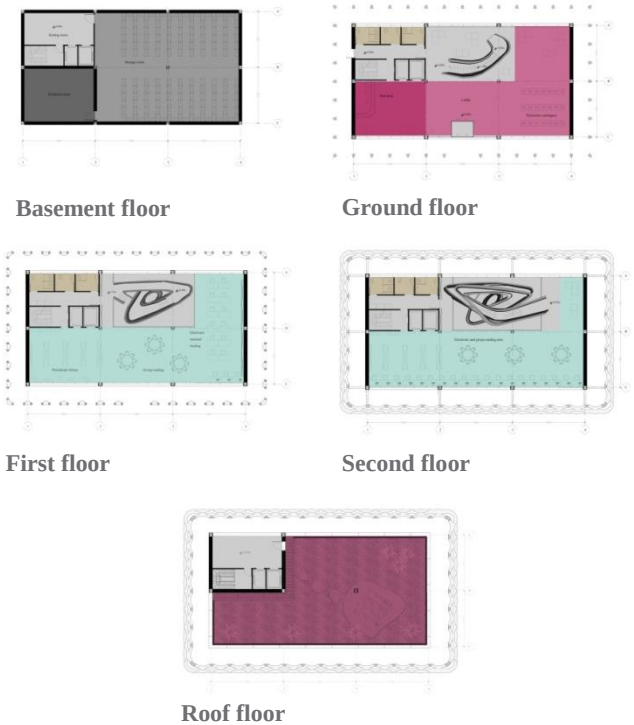


FIGURE 32 Layout of the Library plans (scheme)

Inside and out

The building will have stronger visual connection from the inside towards the external environment. It will achieve that with its large window openings overlooking the second façade. The best visual spot will be on the roof top, which is an oasis created to host student during break time. The second experience of the space will be through the window openings looking fist on the secondary façade and onto the external space.

FIGURE 33 Roof top/oasis and relaxing space (render)

FIGURE 34 View through the window of the second floor

SUSTAINABLE TECHNOLOGICAL DESIGN

The sustainable technological design is a chapter based on the reducing the environmental impact with architectural program and increasing the comfort of the users and clients, by implementing solutions and strategies that deal with solar radiation, harsh climate and temperatures, air pollution and vibrations of the soil created by the frequent road nearby, by using several technological installations. Some effects of these implementations are going to be analyzed with Autodesk Ecotect Analysis 2011 software, which is an environmental analysis tool that allows designers to simulate buildings performance from earliest stages of the conceptual design. It is based on specific climate conditions and thermodynamic laws are providing an analytical result directly within the context of the building model. For all projects details, refer to annexes 15 until 18.

Location data using Ecotect software

The basic settings for the Ecotect software analysis, Weather Tool, are going to be adjusted to the Kingdom of Saudi Arabia, city Riyadh, since it is the only location with a desert climate and the closest location to the Dubai listed on a Weather Data in the software. For the purpose of clarity, the location will be further considered as Dubai, and not as Riyadh.

The Library for the School of Architecture, under the consideration, is located on the Northern part of the city of Dubai. The geographical location is 25˚10’54’’N and 55˚14’39’’E having an elevation of 261 m from the sea level.

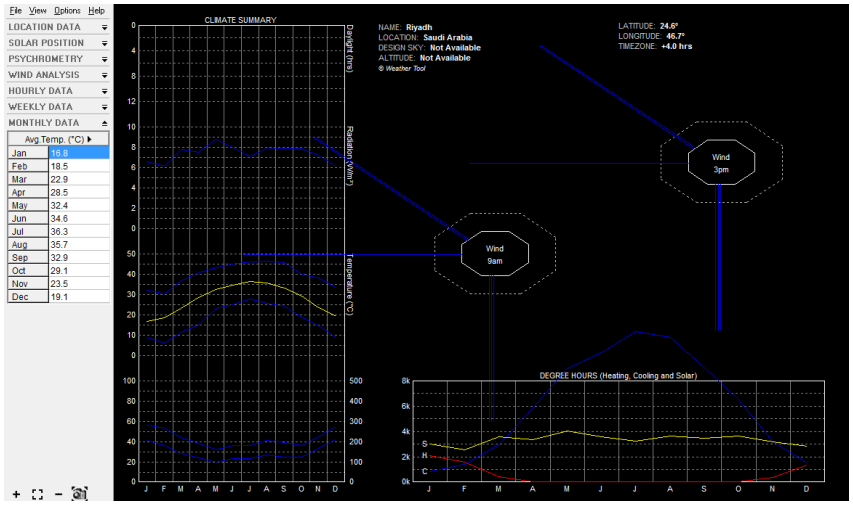


FIGURE 36 Monthly data: Average temperatures

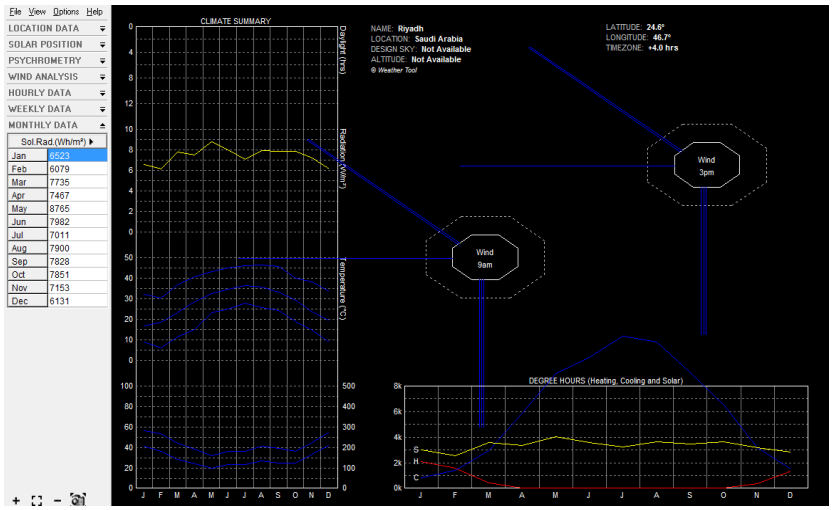


FIGURE 35 Monthly data – average solar radiation

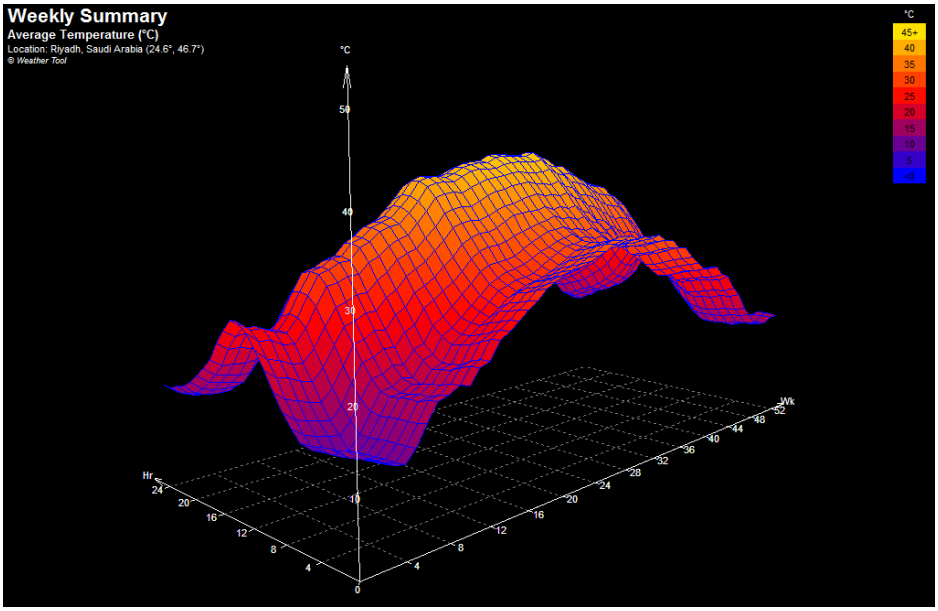


FIGURE 38 Weekly data – average temperature

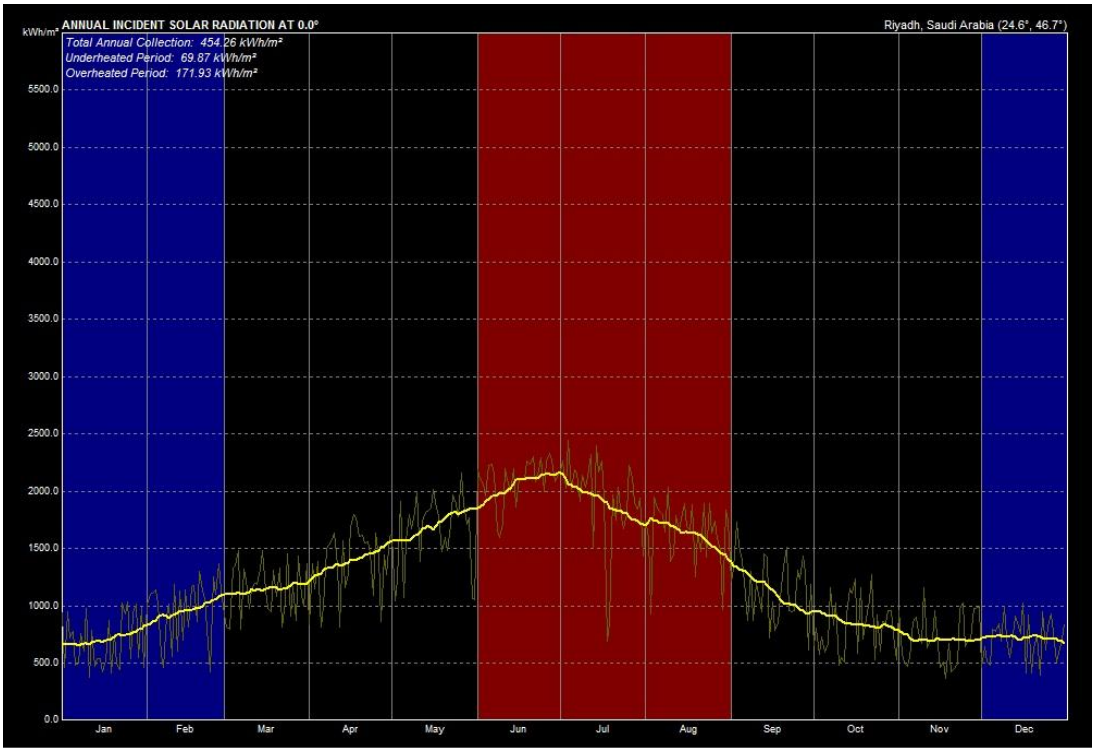


FIGURE 37 Annual incident solar radiation

Selecting shape of the building using Ecotect software

The study comprises of developing different shaped buildings having the volume but each time only changing the shape of the building. Thereafter, the thermal analysis is made for all the proposals (including the design proposal) using the ECOTECT software and comparison is made between the surface to volume ratio and heating/cooling loads of the buildings.

The 3 Dimensional Views of different options:

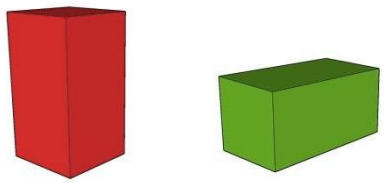


FIGURE 39 Options 1 and 2

Different shaped buildings were made to analysis the shape to volume ratio versus the heating and cooling loads. The thermal analysis is made using the Ecotect software for all the building shapes keeping the volume constant. The following represents one by one discussion of all the samples including the designed building shape for the purpose of analysis and thereafter plotting the values on graphs for ease of comparison:

Option 1

This option comprises of a simple rectangle made for the analysis representing the simplest of shapes, in a vertical position. Thus, the analysis made there with Ecotect is also presented for better understanding of the Heating and Cooling loads. This sample was also developed as a comparison to other models.

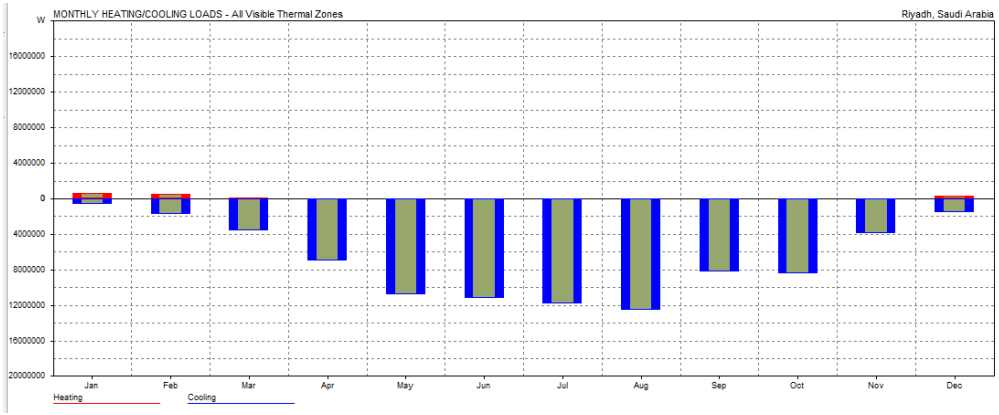


FIGURE 40 Heating and cooling loads

Option 2

This option comprises of also simple rectangle made for the analysis representing the simplest of shapes, in a horizontal position. Thus, the analysis made there with Ecotect is also presented for better understanding of the Heating and Cooling loads. This sample was also developed as a comparison to other models.

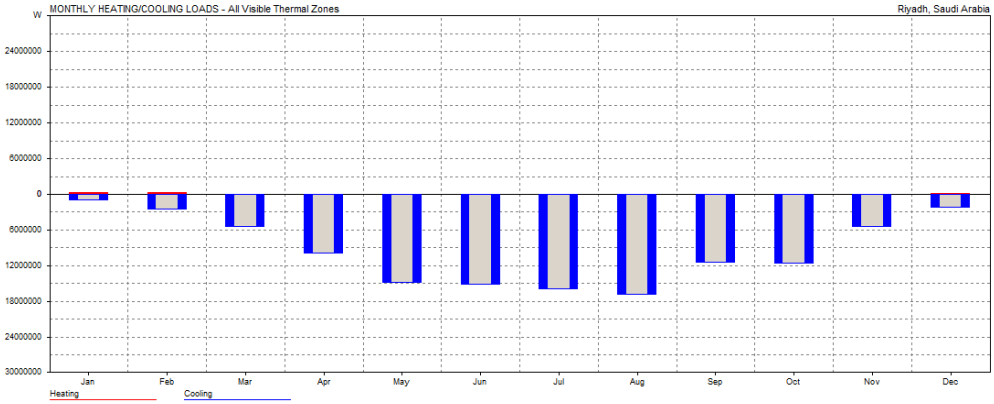


FIGURE 41 Heating and cooling loads

In the light of a fore mentioned discussion, here under the calculation regarding the same is represented with a graphical comparison separately for the heating and cooling loads. The Table below shows the values of loads, surface areas, and surface to volume ratios. The same values have been used to make the graphs underneath via which a vivid comparison may be made for all the options.

Shapes	Option 1	Option2
Shape factor (surface/volume)	0.32	0.29
Heating load(KWh)	1362	916
Cooling load(KWh)	82607	113559
Volume(m^3)	5103	5103
Surface area(m^2)	1674	1485

Table 1 – Shapes 1 and 2: analysis

The graphs for heating and cooling loads from above table are presented below:

Conclusion

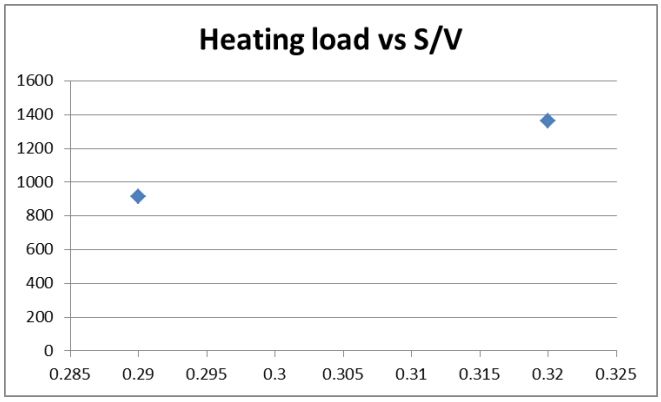


FIGURE 42 Relationship between Heating Loads and S/V ratio

From the above analysis it is revealed that the shape of the building has an important effect on the heating and cooling loads of the building. The values of table are used to make the graphs for heating and cooling loads versus the increasing surface to volume ratios (S/V) which have a trend as represented by the trend line. From the graphs it can be observed that for increasing values of S/V the loads (heating and cooling) usually increase but with some exceptions which might be due to:

1. The shape (geometry) of the building;

2. Its orientation;

3. Exposed surface to the solar radiations; and

4. Surface in contact with the ground.

The Option 2 performs less effectively in the analysis of cooling loads, but will have greater success in the direct solar gain, where the S/V ratio, being smaller, will have more advantage.

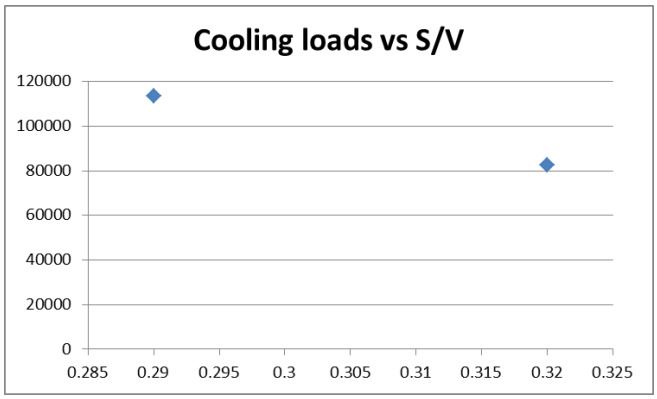


FIGURE 43 Relationship between the Cooling Loads and S/V ratio

Solar and shadow analysis using Ecotect software

The Solar analysis will be based on two objects of the complex, since the Library of School of Architecture is located directly in front of one the facilities if the campus that is casting the shadow on it, since is more south positioned. The simulation is based on two critical dates in the calendar year, 21st of June and 21st of December, as the dates of longest and shortest solar radiation periods. The first date will be further addressed to as summer solar position and the second will be winter solar position.

Summer analysis

Summer period is most aggressive time of solar radiation, since the radiation is almost vertical in respect to the ground, which means that the facilities on the site will have direct solar radiation, and will not have shadow casting on each other.

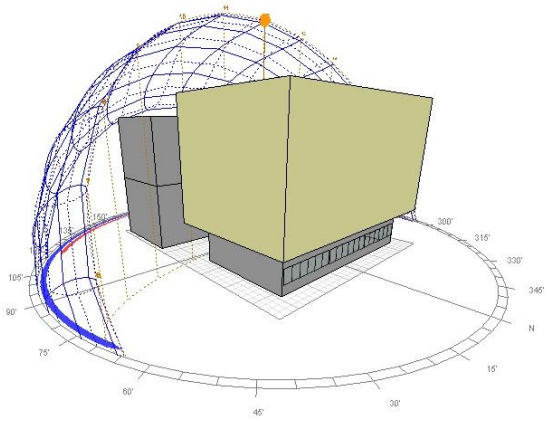


FIGURE 45 Summer Sun position

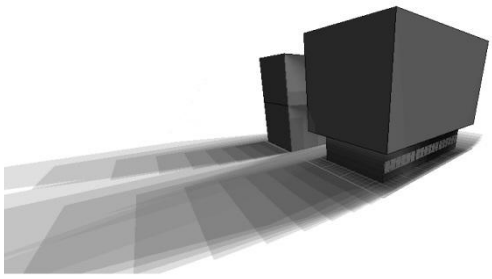
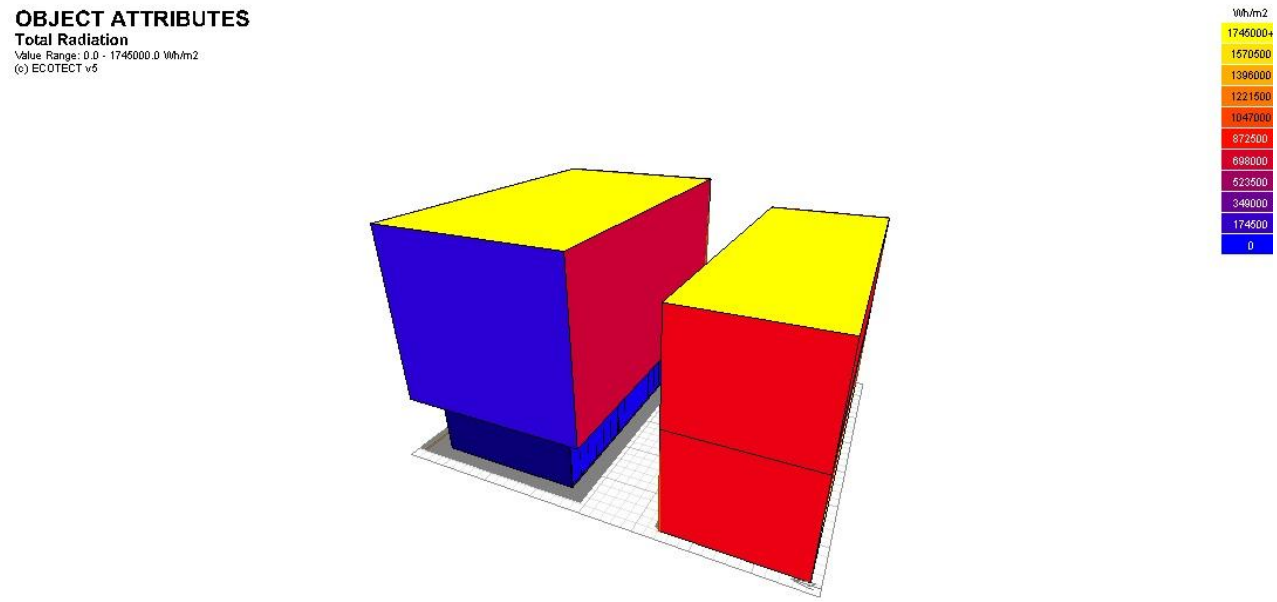


FIGURE 44 Summer shadow range



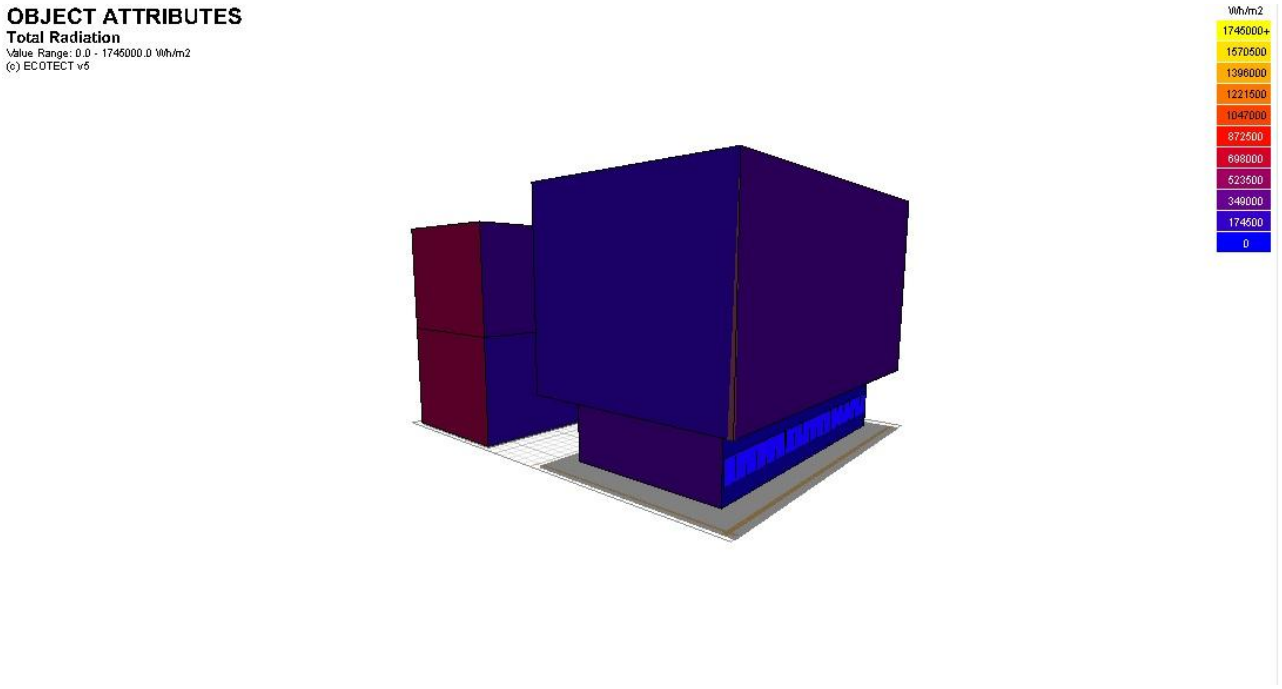


FIGURE 47 21st of June, direct solar radiation – north and east facades

Winter analysis

Winter period is least aggressive time of solar radiation, since the radiation is less vertical in respect to the ground, which means that the facility on the site will have direct solar radiation but with casted shadows of the building around it, and will have longer shadow range.

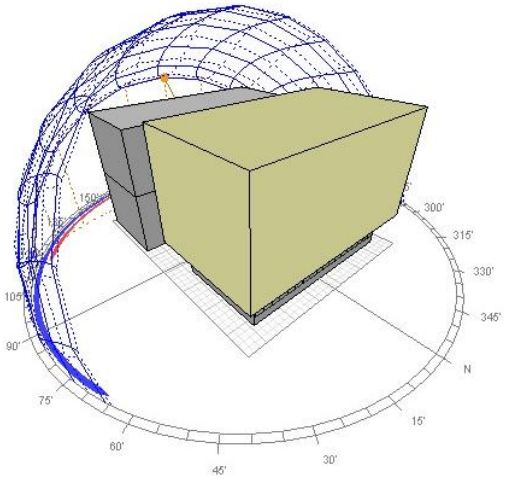


FIGURE 48 Winter Sun position

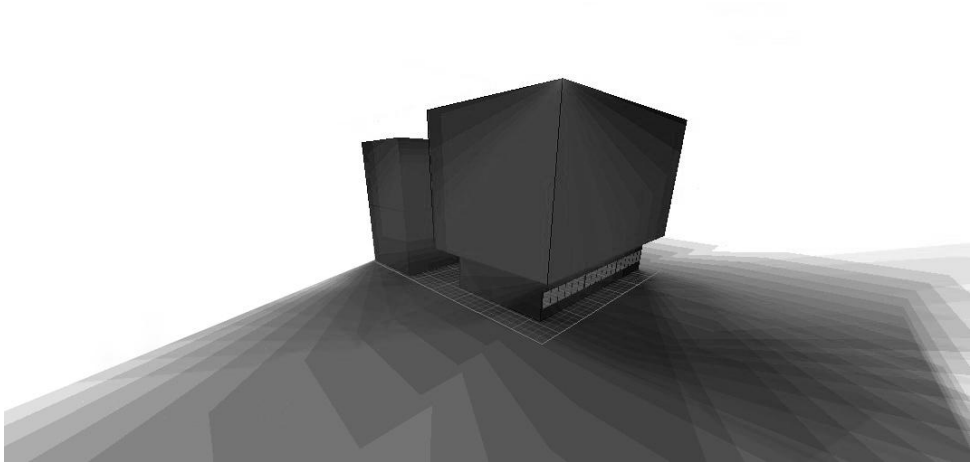


FIGURE 49 Winter shadow range

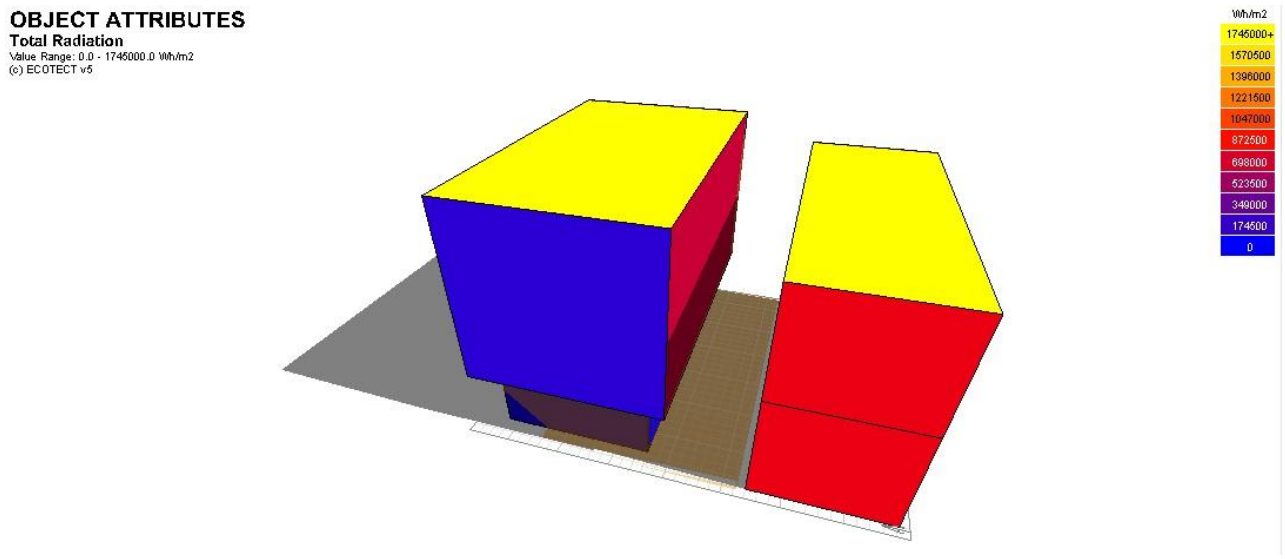


FIGURE 50 21st of December, direct solar radiation – south and west facades

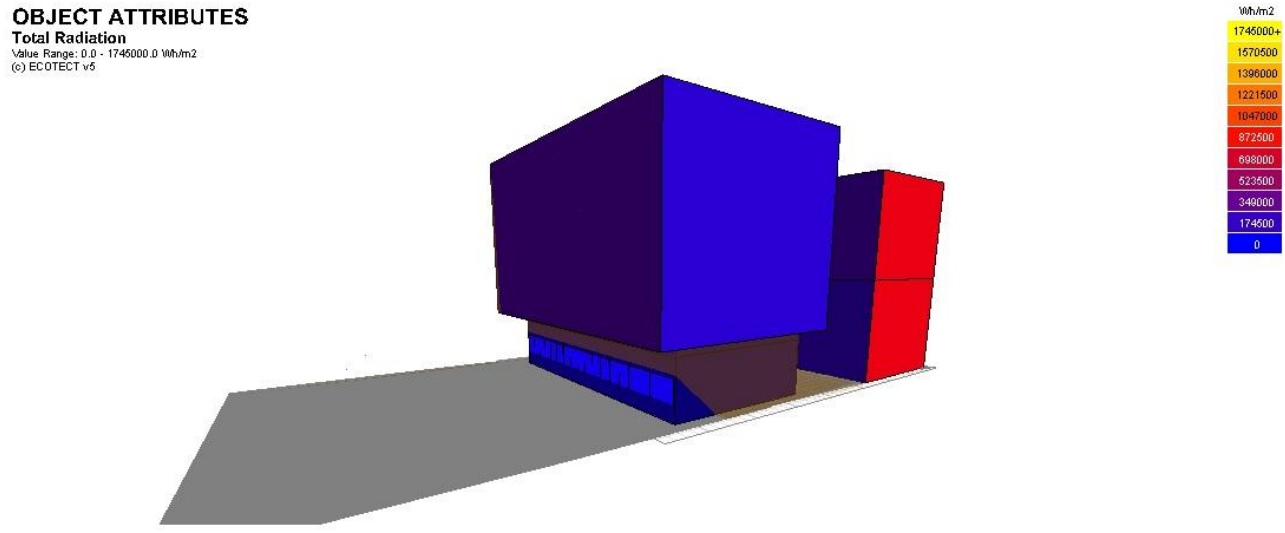


FIGURE 51 21st of December, direct solar radiation – north and west facades

Variance of heating and cooling loads by changing U-values using Ecotect software

U-value comparison

In order to manage the heat fluxes, to analyze the parts of the buildings that directly interact with the external environment. The building elements will be divided in four categories: walls, roof, floor and windows.

	Minimum value (W/m^2K)	Optimum value (W/m^2K)	Best value (W/m^2K)
Opaque wall	0.27	0.18	0.10
Roof	0.24	0.19	0.10
Floor	0.30	0.25	0.15
Window	1.80	1.30	0.90

Table 2 U-value comparison

In order to proceed with the calculations, the first values will be graded in three categories depending on the decreasing factor

		Categories		
		Step 1	Step 3	Step 4
Wall	U-value	0.27	0.18	0.10
	Decreasing factor	0.5	0.5	0.5
Roof	U-value	0.24	0.19	0.10
	Decreasing factor	0.4	0.4	0.4
Floor	U-value	0.3	0.25	0.15
	Decreasing factor	0.5	0.5	0.5
Window	U-value	1.8	1.3	0.9
	Decreasing factor	1	1	1
	G-value	0.7	0.5	0.2

Table 3 U-values and decreasing factor

Heating season

During the heating season the average temperatures are at a comfortable level, between 20°Cand 30°C °F on average, which is during months March, April, October, November and December. These temperatures are not demanding any heating during the day time, but may demand the system on during the night time at some facilities. Since the library will not work at night, there will be no proposal for the heating loads depending on the U-values of the elements.

The figure bellow is showing the lowest temperature values throughout the year.

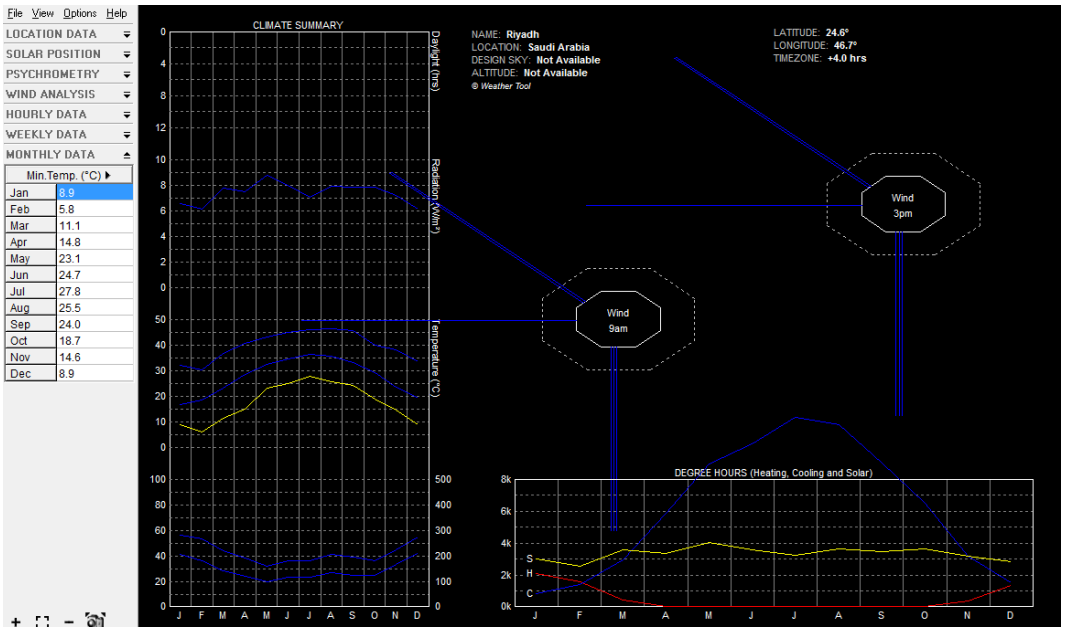


FIGURE 52 Lowest temperature values

Cooling season

To calculate the average u-values, in this case we used the following relation:

$$U_{din} = \frac{\Sigma_i \times U_i \times F_d \times S_i}{\Sigma_i \times S_i}$$

Where:

S_i - Surface of every element exposed to outside;
U_i - Thermal transmittance of the element;
F_d - Decrement factor;

First of all we calculated the surfaces of every element exposed to the outside, with the help of the Ecotect Software:

Walls: 825.52 m^2

Roof: 441 m^2

Floor: 378m^2

Windows: 420.48m^2

Next, the U-values are multiplied with corresponding surfaces, obtaining:

	SU-values		
Walls	222.89	148.59	82.55
Roof	105.84	74.97	44.10
Floor	113.40	94.50	56,70
Windows	756.86	546.62	336.38

Table 4 SU-values

Calculation, with Ecotect, for the heating thermal load of the building, making the hypothesis that only one category varies at time. In this way it's possible the estimation of material influences, on its own, the heating load of the building.

U_{din} and cooling load expression:

	U_{din}	Relative U-value	Cooling loads (kWh/m2a)
Wall opt 1	0.135	0.05	105.93
Wall opt 2	0.09	0.035	104.86
Wall opt 3	0.05	0.018	103.86
Roof opt 1	0.096	0.023	92.22
Roof opt 2	0.068	0.018	91.87
Roof opt 3	0.04	0.014	91.50
Floor opt 1	0.15	0.036	85.16
Floor opt2	0.125	0.03	85.07
Floor opt 3	0.07	0.018	84.87
Windows opt1	1.8	0.027	81.41
Windows opt 2	1.3	0.0199	76.07
Windows opt 3	0.8	0.0122	69.74

As shown in the table above, in the first column there are the total U-values, calculated as sum of all the product of U-values by surfaces. In the second column are inserted the u-values relative only to the element that was changing in that calculation, and in the last column the cooling load as a result of a thermal analysis made with Ecotect software.Therefore, the synthesis will include the steps 3 of each element in a relationship cooling loads vs. U-values:

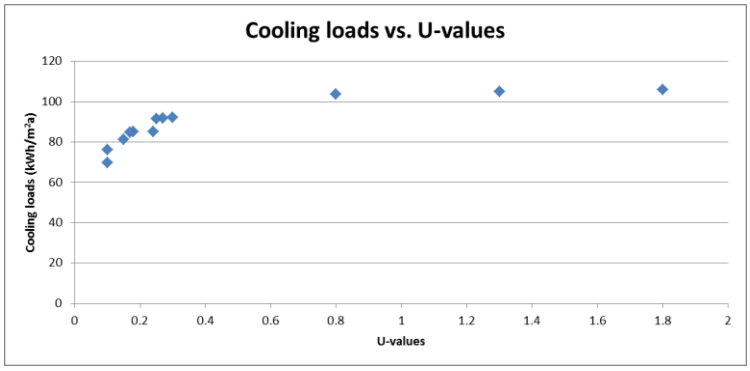


FIGURE 53 Cooling loads vs. U-values

Ventilation analysis using Ecotect software

Special environmental conditions, like the one in Dubai, must depend on the Full Air Conditioning system, because it includes constant cooling loads and unpredictable hating ones, and excludes other systems because:

- Natural ventilation is excluded because of the hot outside air (Heating loads– too cool to contribute and Cooling loads – too hot to contribute) ;
- Mix-mode system is including exceeded values of the heating season, which counts on the drop of the temperatures during the winter seasons at night, when the facility is not in use;
- Heating only system is not needed;
- Cooling only system is not including the incidental drops of the temperature in winter seasons;

Full Air conditioning is variable due to Air Change Rate. In the table below it is demonstrated how the quality of the system is variable due the rate:

Full Air conditioning system

Operating time: 9am-7pm

Thermal comfort: 23-25˚C

From 7am till 7pm	Heating loads (kWh/m^2a)	Cooling loads (kWh/m^2a)	Total area (m^2)	Air Change Rate (ACH)	Wind sensitivity (Air changes/h)
Full Air Conditioning	0.001	69.74	1197	0.25	0,25
	0.037	79.39	1197	0.5	0,25
	0.2.15	89.14	1197	0.75	0,25
	0.447	98.70	1197	1.0	0,25
	1.17	11.86	1197	1.5	0,25

Table 5 Full Air Conditioning with Air Change Rate

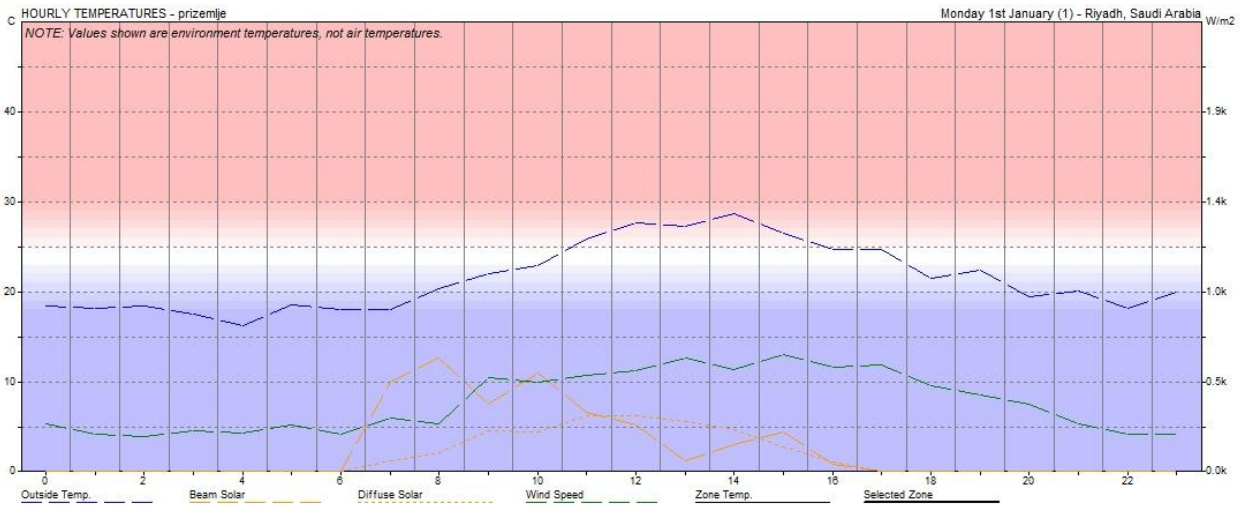


FIGURE 54 Hourly temperatures profiles

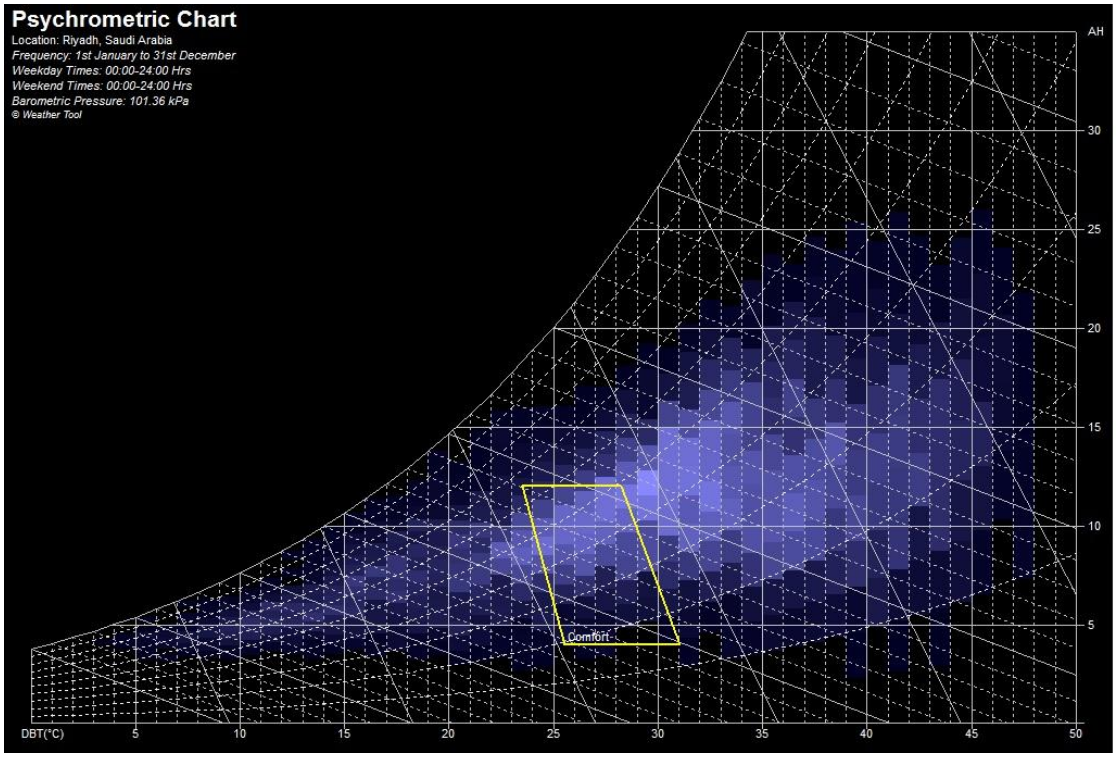


FIGURE 55 Psychometric chart with comfort zone marked

The results reveal a positive conclusion, that the project has accomplished to be certified as an energy efficient non-domestic building, taking the C level (51-75 kWh/m^2) – minimum energy standard, by reaching the 69.74 kWh/m^2. This verification has been certified by the UK standard, below represented:

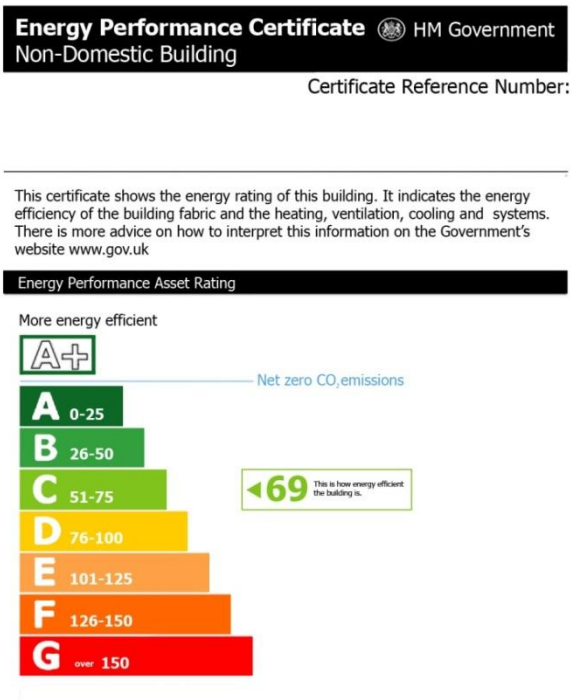


FIGURE 56 Energy Performance Certificate

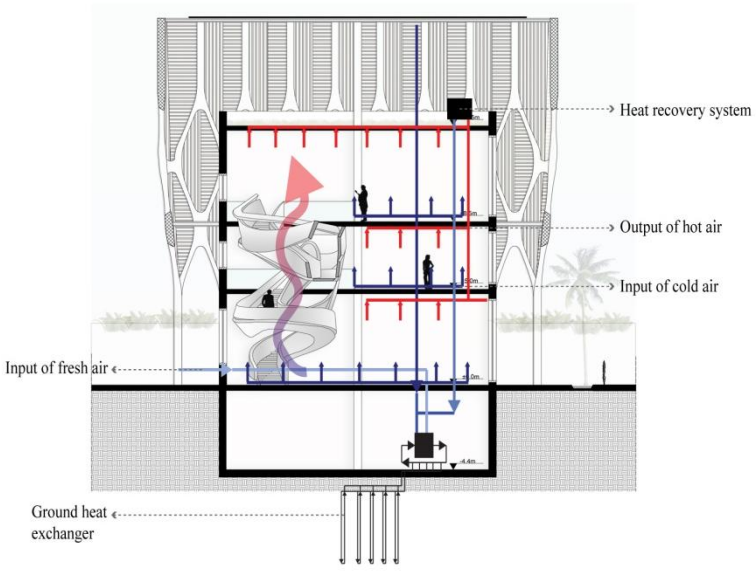


FIGURE 57 Ventilation strategy

Shading device analysis using Ecotect software

This analysis will be based on the Shading Device Wizard tool within the Ecotect environment, which can help in understanding the design better and to identify the most important areas for shading. Results interpretation: Colors reflects the importance of the direct beam solar radiation on summer and winter solstice. The yellow dots represent the spots exposed the longest time during the day while the blue dots represent spots that are less exposed.

June 21st:

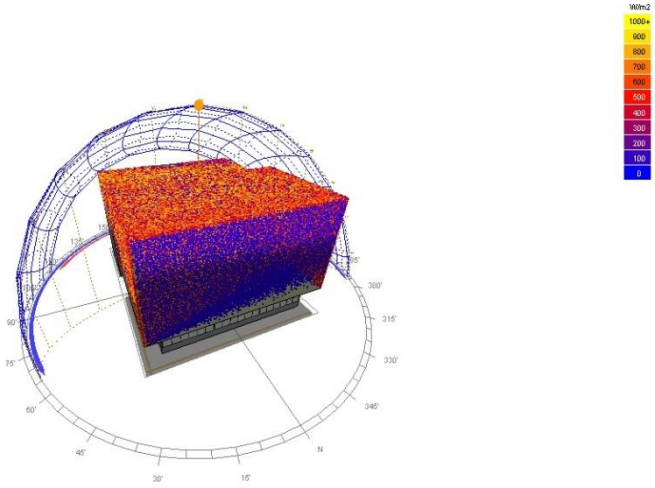


FIGURE 58 Shading device - north facade

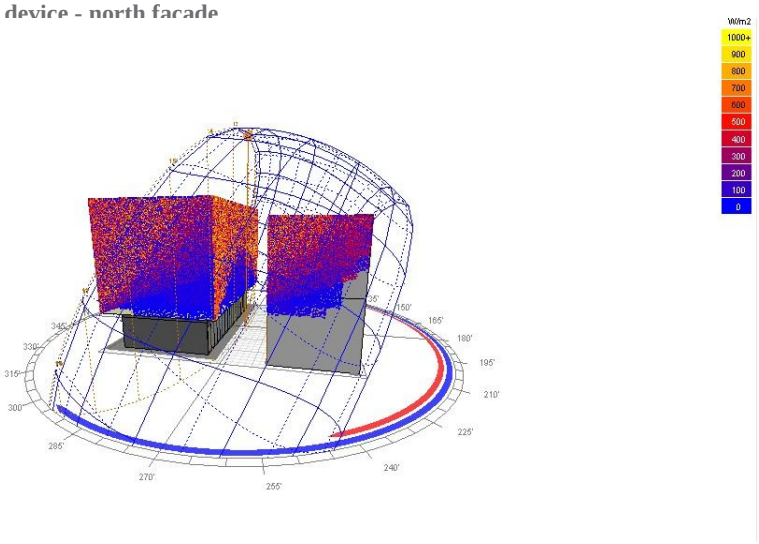


FIGURE 59 Shading device - south and west facades

December 21st:

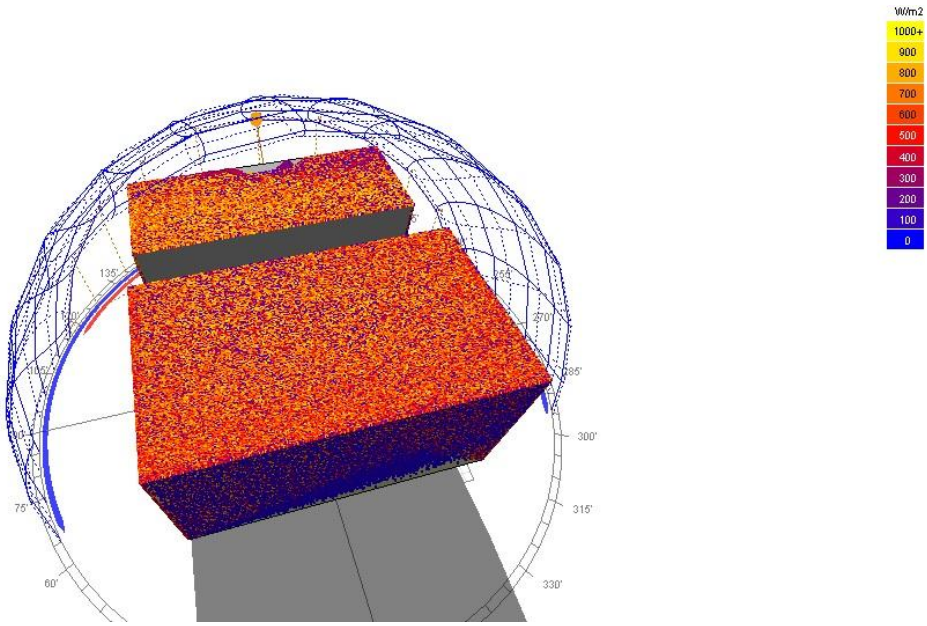


FIGURE 60 Shading device - roof top

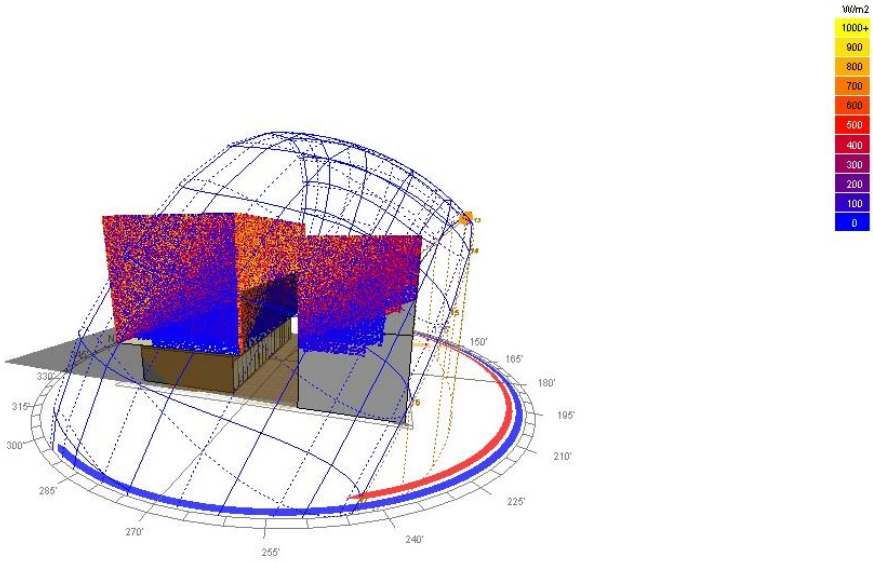


FIGURE 61 Shading device – west facade

Natural day lighting analysis of the facility using Ecotect software

The fraction of spaces having access to daylight can be easily computed via Ecotect. One can observe that a daylight factor of 5% on internal surface means that it received 1/20th of the maximum available natural light. For reference, a room that has a daylight factor of less than 2% is considered poorly lit. Rooms with daylight factor between 2% and 5% are considered ideal for the indoors.

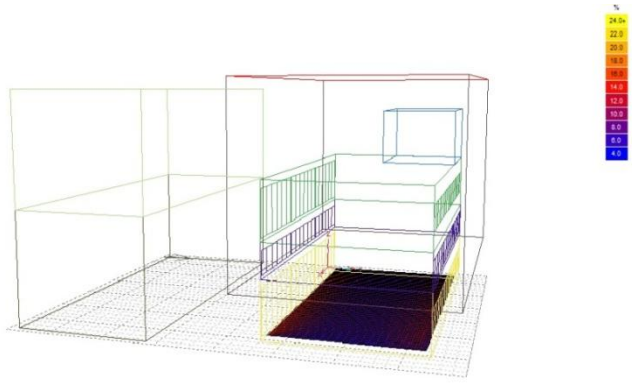


FIGURE 62 Daylight Analysis – ground floor

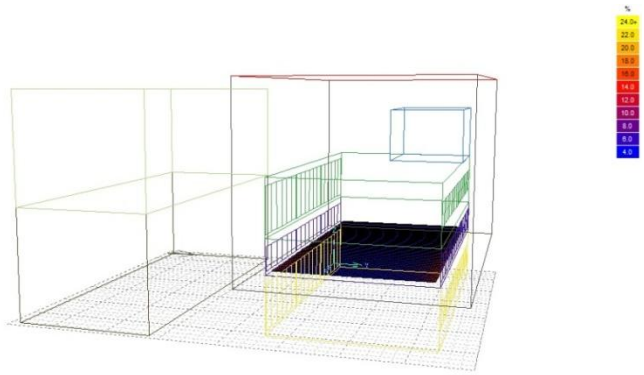


FIGURE 63 Daylight Analysis – first floor

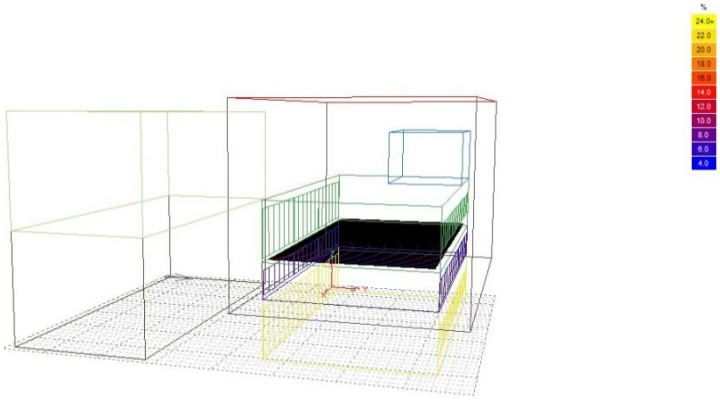


FIGURE 64 Daylight Analysis – second floor

Solar panel strategy

The Arabian Peninsula lies in virtually rainless sunny belt with a typical daily average solar radiation exceeding 6 kWh/m2 (Alnaser and Alnaser, 2011) and 80-90% clear skies throughout the year. Among all forms of alternate energy, solar power therefore is a preferred choice, for its seemingly limitless potential in the GCC region and relatively well-developed technology and profitability. There is a host of existing and upcoming solar energy projects in the region with diverse applications, primarily in the form of technology clusters, utility-scale solar power plants, solar desalination projects and solar panel manufacturing industry.

In the year 2008 annual solar irradiation exceeded 2100 kWh/m2 in the southernmost region of the country. Unfortunately, this region is uninhabited. Elsewhere in the country the values ranged from 1800 to 1950 kWh/m^2, except for the Northeastern coastal region of the country where the values drop below 1800 kWh/m^2. [8]

Sizing photovoltaic panels "Sunpower E20"

$$E_{pv} = \eta_{pv} \times A_{pv} \times H$$

E_{pv} - Energy produced by the photovoltaic system;
η_{pv} - Efficiency of the photovoltaic system;
A_{pv} – Surface of the photovoltaic panel;
H - Annual solar irradiation.

The choice for the system was reduced on Sunpower model: E20 for the panels and series 3000 for the inverter.

[8] http://www.mesia.com/wp-content/uploads/UAE-Solar-Resource-Atlas.pdf

SUNPOWER® MODULI FOTOVOLTAICI E20/333 E E20/327

20% DI EFFICIENZA

I moduli SunPower E20 sono ad oggi i più efficienti disponibili sul mercato e offrono una maggiore potenza installata a parità di spazio disponibile

COMPATIBILITÀ CON INVERTER SENZA TRASFORMATORE

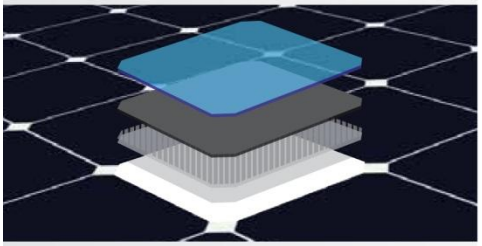
La totale compatibilità con gli inverter senza trasformatore assicura al cliente l'abbinamento di moduli della massima efficienza a inverter di pari grado, massimizzando l'energia prodotta dal sistema

TOLLERANZA DI POTENZA POSITIVA

La tolleranza positiva assicura per ogni modulo una resa di potenza quantomeno pari al suo valore nominale, se non superiore

DESIGN AFFIDABILE E RESISTENTE

L'esclusiva tecnologia delle celle Maxeon™ di SunPower e un avanzato design modulare garantiscono un'affidabilità ineguagliata nel settore



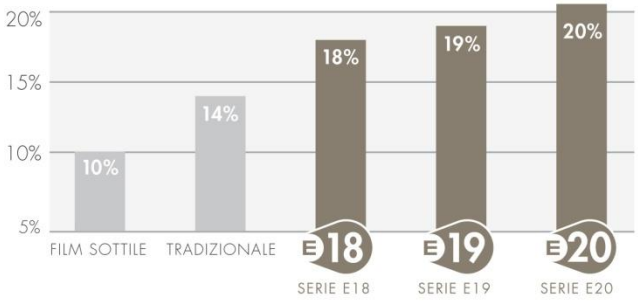
TECNOLOGIA CELLE MAXEON™

Cella solare brevettata con tecnologia back-contact, con la massima efficienza ed affidabilità del settore.

THE WORLD'S STANDARD FOR SOLAR™

I moduli fotovoltaici SunPower™ E20 assicurano efficienza e resa energetica ai massimi livelli odierni. Basati sulla tecnologia delle celle SunPower Maxeon™, i moduli della serie E20 offrono efficienze di conversione per modulo fino al 20,4%. Il coefficiente ridotto di tensione-temperatura del modulo E20, il vetro anti-riflettente e le straordinarie prestazioni in condizioni di bassa luminosità garantiscono una produzione energetica eccezionale per watt di picco di potenza installata.

IL VANTAGGIO DELL'ALTA EFFICIENZA SUNPOWER



www.sunpowercorp.it

FIGURE 65 Sunpower solar panel, page 1 of the brochure

SUNPOWER MODULI FOTOVOLTAICI E20/333 E E20/327

MODELLI: SPR-333NE-WHT-D, SPR-327NE-WHT-D

DATI ELETTRICI

Misurato in condizioni di prova standard (STC): Irraggiamento 1000 W/m², AM 1,5 e temperatura della cella 25°C

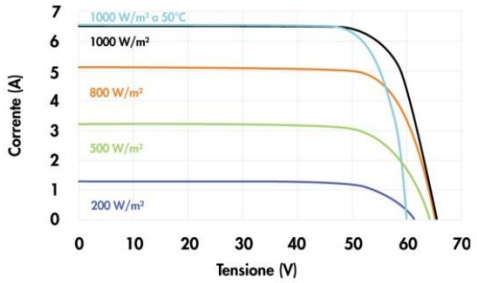
Potenza nominale (+5/-0%)	P_{nom}	333 W	327 W
Efficienza della cella	η	22,9 %	22,5 %
Efficienza del modulo	η	20,4 %	20,1 %
Tensione di punto di massima potenza	V_{mpp}	54,7 V	54,7 V
Corrente di punto di massima potenza	I_{mpp}	6,09 A	5,98 A
Tensione a vuoto	V_{oc}	65,3 V	64,9 V
Corrente di cortocircuito	I_{sc}	6,46 A	6,46 A
Tensione massima del sistema	IEC	1000 V	
Coefficiente di temperatura	Potenza (P)	– 0,38 %/K	
	Tensione (V_{oc})	– 176,6 mV/K	
	Corrente (I_{sc})	3,5 mA/K	
NOCT		45° C +/– 2° C	
Corrente nominale del fusibile		20 A	
Limite di corrente inversa (3 stringhe)	I_r	16,2 A	
Messa a terra		Messa a terra positiva non necessaria	

DATI ELETTRICI

Misurato alla temperatura operativa nominale della cella (NOCT): Irraggiamento 800 W/m², 20°C, vento 1 m/s

Potenza nominale	P_{nom}	247 W	243 W
Tensione di punto di massima potenza	V_{mpp}	50,4 V	50,4 V
Corrente di punto di massima potenza	I_{mpp}	4,91 A	4,82 A
Tensione a vuoto	V_{oc}	61,2 V	60,8 V
Corrente di cortocircuito	I_{sc}	5,22 A	5,22 A

CURVA I-V



Caratteristiche di corrente/tensione a seconda dell'irraggiamento e della temperatura del modulo.

CONDIZIONI OPERATIVE DI PROVA

Temperatura	Da -40° C a +85° C
Carico max	550 kg/m² (5400 Pa), fronte (es. neve) nelle configurazioni di montaggio specificate
	245 kg/m² (2400 Pa) fronte e retro (es. vento)
Resistenza all'impatto	Grandine: 25 mm a 23 m/s

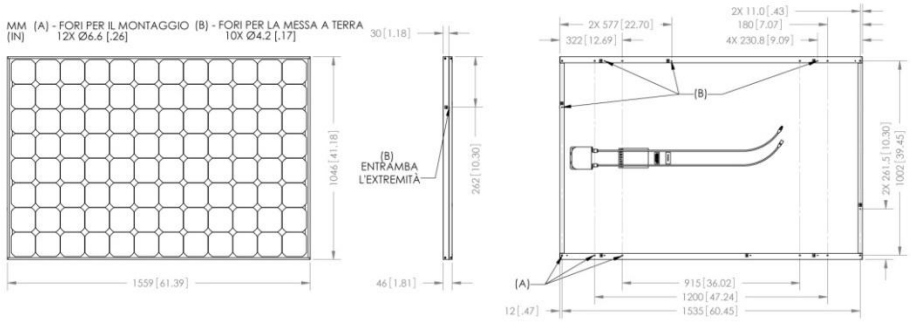
GARANZIE E CERTIFICAZIONI

Garanzie	25 anni di garanzia limitata lineare sulla potenza
	25 anni di garanzia limitata sul prodotto
Certificazioni	IEC 61215 Ed. 2, IEC 61730 (SCII)

DATI MECCANICI

Celle solari	96 celle solari SunPower Maxeon™	Cavi di uscita	Lunghezza dei cavi 1000 mm / connettori MultiContact (MC4)
Vetro anteriore	Vetro temperato anti-riflettente ad alta trasmittanza	Telaio	Lega di alluminio anodizzato tipo 6063 (nero)
Scatola di giunzione	IP-65 con 3 diodi bypass	Peso	18,6 kg
	32 x 155 x 128 mm		

DIMENSIONI



Prima di usare il prodotto leggere attentamente le istruzioni relative all'installazione e alla sicurezza. Per ulteriori informazioni visitare il sito www.sunpowercorp.it.

www.sunpowercorp.it

Documento #001-65483 Rev E / A4_IT
CS 12_447

FIGURE 66 Sunpower solar panel, page 2 of the brochure

Therefore:

$\eta_{panel} = 20.4\%$

$\eta_{inverter} = 90\%$

$\eta_{pv} = \eta_{panel} \times \eta_{inverter} = 20.4 \cdot 90 = 18.4\% = 0.184$

The energy for the system can be calculated multiplying the electrical demand of a square meter for the total number of square meters that have ti be served by electricity. Electrical needs for the Library, per square meter:

$E_{pv} = 90 KWh/m^2$

$S = 1197 m^2$

$E_p = 90 \cdot 1197 m^2 = 107730\ KWh$

$$A_{pv} = \frac{E_{pv}}{\eta_{pv} \times H} = \frac{107730}{0.184 \cdot 1800} = 325.27 m^2$$

Single module has surface of:

$A_{panel} = 1.046 \cdot 1.559 = 1.63 m^2$

Number of modules needed:

$$N_{pv} = \frac{A_{pv}}{A_{panel}} = \frac{325.27}{1.63} = 199.55 \rightarrow 200 \text{ modules}$$

In the total energy need it could be introduced the calculation for the cooling system. The energy needs for newer libraries are 104.6 KWh. There are several reasons why newer libraries need more than usual 70 KWh per square meter per year. These reasons are as follow:

- The large area of building;
- Rely on mechanical ventilation to get fresh air;
- Basically maintain the indoor air quality by the central air conditioning or heating;

Therefore:

$E_{pv} = 104.6 \cdot 1197 = 125206.2\ KWh$

From here it can be obtained the total surface of the panels necessary to cover all electrical needs:

$$A_{pv} = \frac{E_{pv}}{\eta_{pv} \times H} = \frac{125206.2}{0.184 \cdot 1800} = 37.8m^2$$

The number of modules needed:

$$N_{pv} = \frac{A_{pv}}{A_{panel}} = \frac{37.8}{1.63} = 23.19 \rightarrow 24 \text{ modules}$$

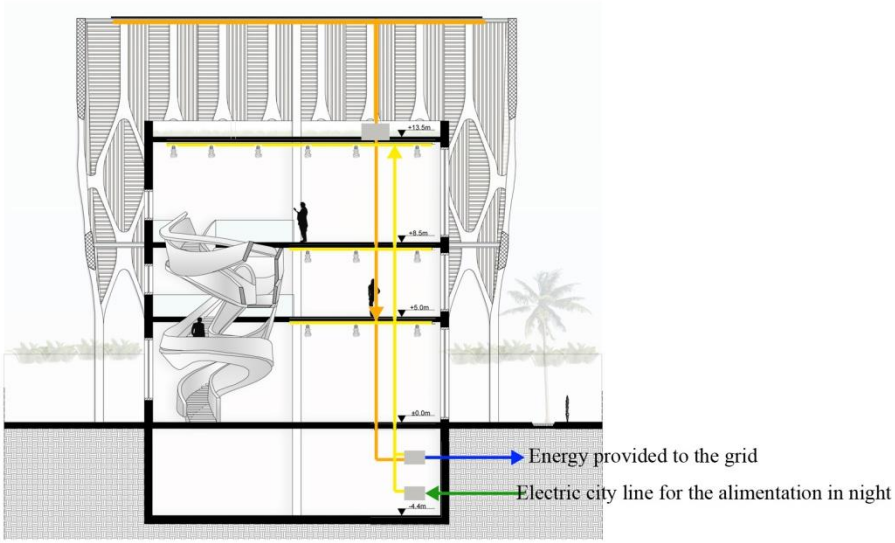


FIGURE 67 PV sustainable strategy

Geo-thermal heat exchanger

Type of the system:

- Closed loop – vertical ground coupled.

Advantages:

- Small are required for the installation;
- Stable deep soil temperature;
- Adoptable too many sites.

Meeting the energy needs of:

- Space cooling;
- Possible space heating.

Level of application:

- Communal system – the most efficient.

System configuration:

- Probes (vertical ground pipes) up to 60m deep;
- Heat exchanger, “Chiller”, a unit considering condenser, pumps and auxiliary boilers;
- Energy providing system – PV panels.

Main construction materials

West and east facades:

- Full concrete wall 300mm thick
- Knauf XTHERM TH31 insulation
- Panel ALUCOBOND system;
- No window openings.

North façade:

- Ytong cellular block 300mm thick;
- Knauf XTHERM TH31 (extruded polystyrene) 130mm thick;
- Panel ALUCOBOND system;
- SCHUCO AWS 75-RL thermal break aluminum frame with double glass.

South façade:

- Structural elements 300mm thick
- Knauf XTHERM TH31 (extruded polystyrene) 130mm thick;
- Panel ALUCOBOND system;
- Fixed SCHUCO AWS 75WF.SI windows.

Green roof:

- Predalles Structural deck 250mm thick;
- Knauf Polyfoam Xtaplus C-50 (extruded polystyrene) 120mm;
- Slope screed (1%) 50mm thick;
- DAKU green roof system.

Slabs:

- Predalles structural deck 250mm thick;
- Sheet for sound insulation from vibration;
- Knauf floating floor system.

The project is including blow-up drawing of the south façade, its structural elements, joints and details. For more information on the structure, please consult the annex.

Limitations of the Ecotect software and design

In spite of many capabilities, Autodesk Ecotect software also has limitations.

The first limitation is probably due to the conditions under which results are obtained. Indeed, the model's geometry quickly becomes very complex, so that tradeoffs have been made between the speed and accuracy.

Secondly, like most software of its kind, Ecotect still suffers from instability which frequently leads to unwanted program termination.

The third limit is lack of interaction of Ecotect with other modeling programs, which leads to creation of poor models in Ecotect itself and lack of accuracy of analysis.

Fourth limit is material library, which means that the designer has to create all materials from scratch.

Fifth limit is Weather Data that's lacking of key locations in the world, that like Dubai, could be the new hot location for analysis.

It's should be also mentioned that the Autodesk Ecotect Analysis software has been discontinued on March 20th 2015, and it will be integrated in Revit.

ANNEX

The annex is a chapter containing all necessary drawing documentations, which further explains all thesis project specifications. It is composed by: (1) plan and sections for Urban Design; (2) plans, sections, and elevations for Architectural Design; (3) blow up of south façade and three details of the same. This chapter should be used as an addition to each topic, as instructed by the author.

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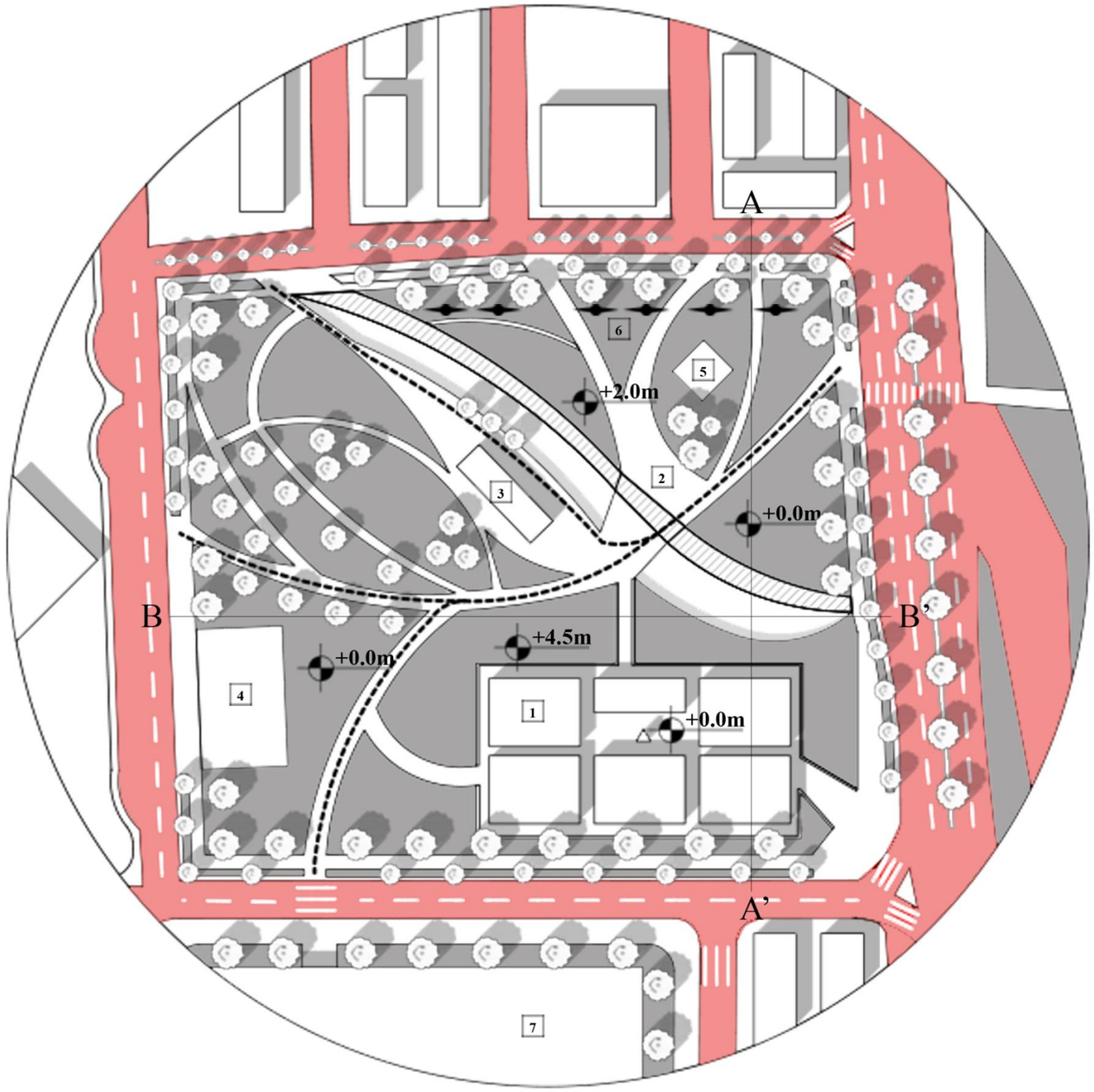

- Green areas
- Streets
- Water front
- Main directions
- 1 School of Architecture
- 2 Park
- 3 Pavilion for Architecture
- 4 Flea market
- 5 Mosque
- 6 Wind turbines
- 7 Garage

Situation urban design

S 1:2000
0 4 8

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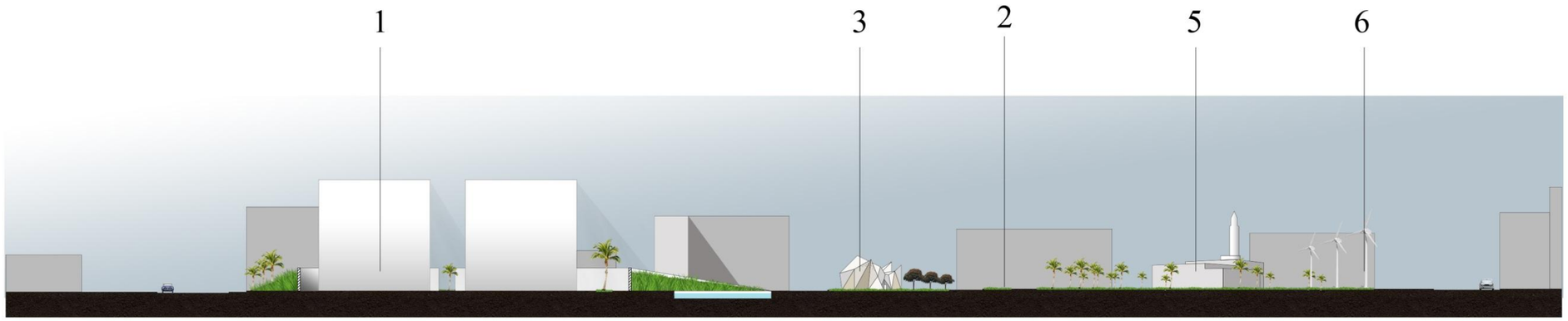
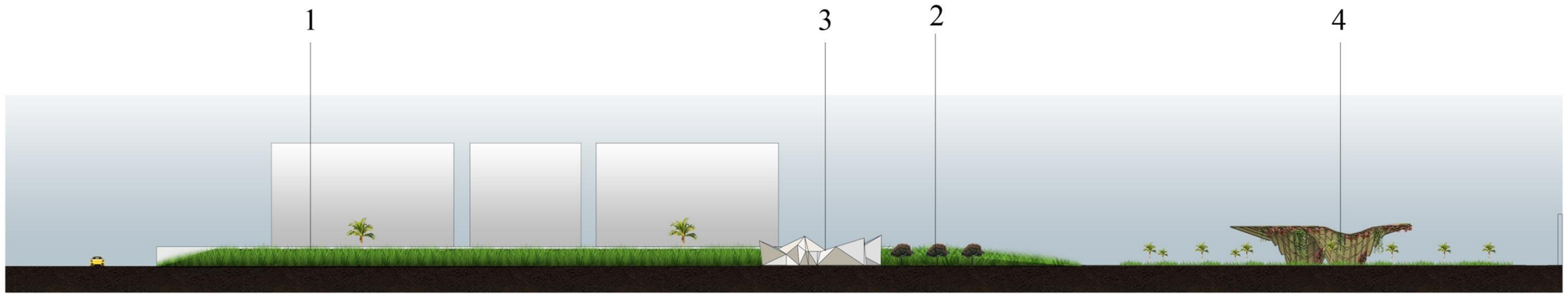


Section A-A'



Section B-B'

1 School of Architecture
2 Park
3 Pavillion of Architecture
4 Flea market/covered resting area
5 Mosque
6 Wind turbines

Sections urban design

S 1:1000
0 4 8

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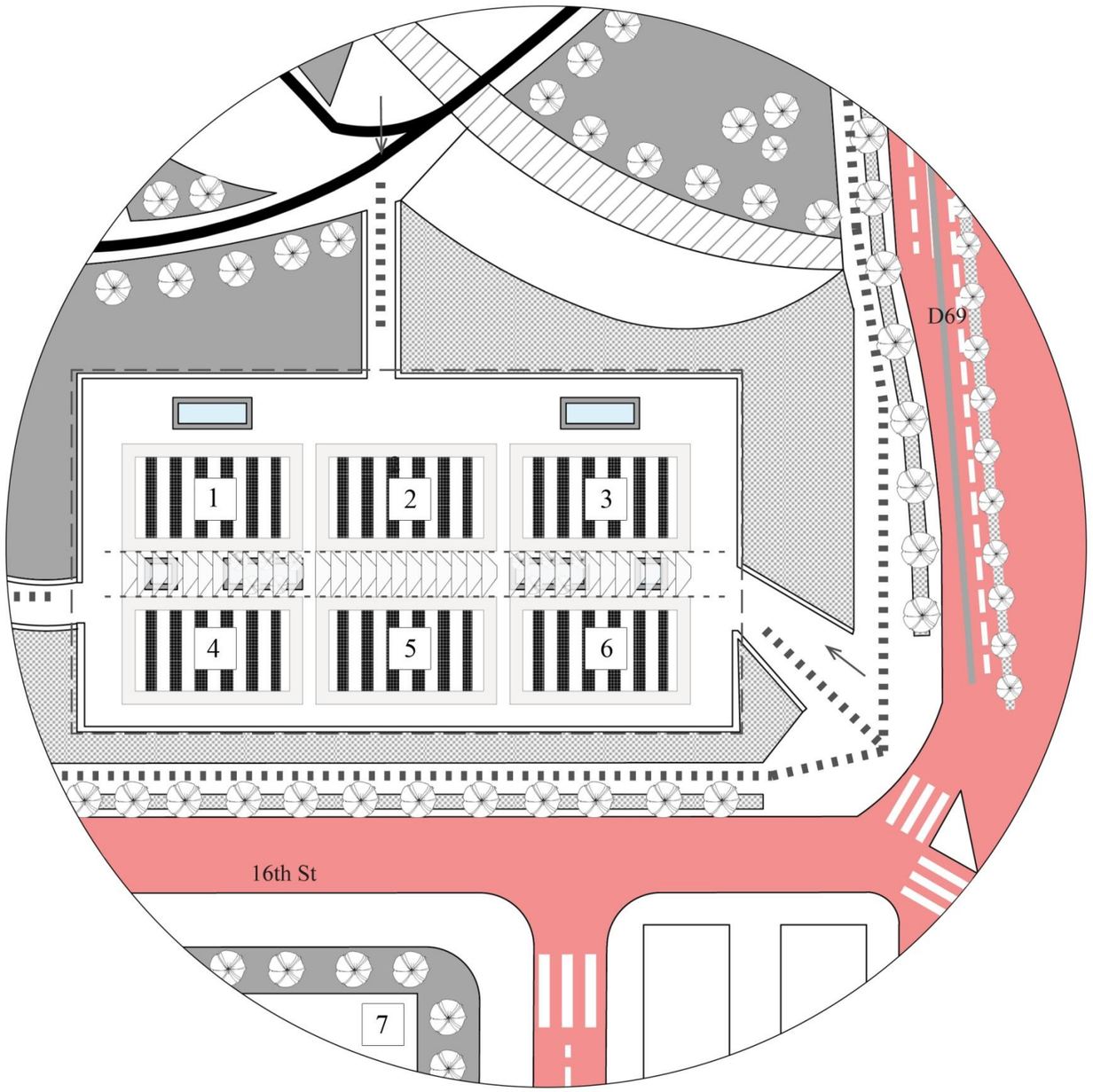

- Street
- Green areas with installations for public use
- Water installations
- Green buffer area
- Walkways
- Dominant views
- Aliment of trees
- Aliment of the buildings
- Perimitted building area
- 1 Academic yone
- 2 Circulation zone
- 3 Library
- 4 Academic zone
- 5 Social and welfare zone
- 6 Professional practice zone
- 7 Garage

S 1:1000
0 4 8

Situation architectural design

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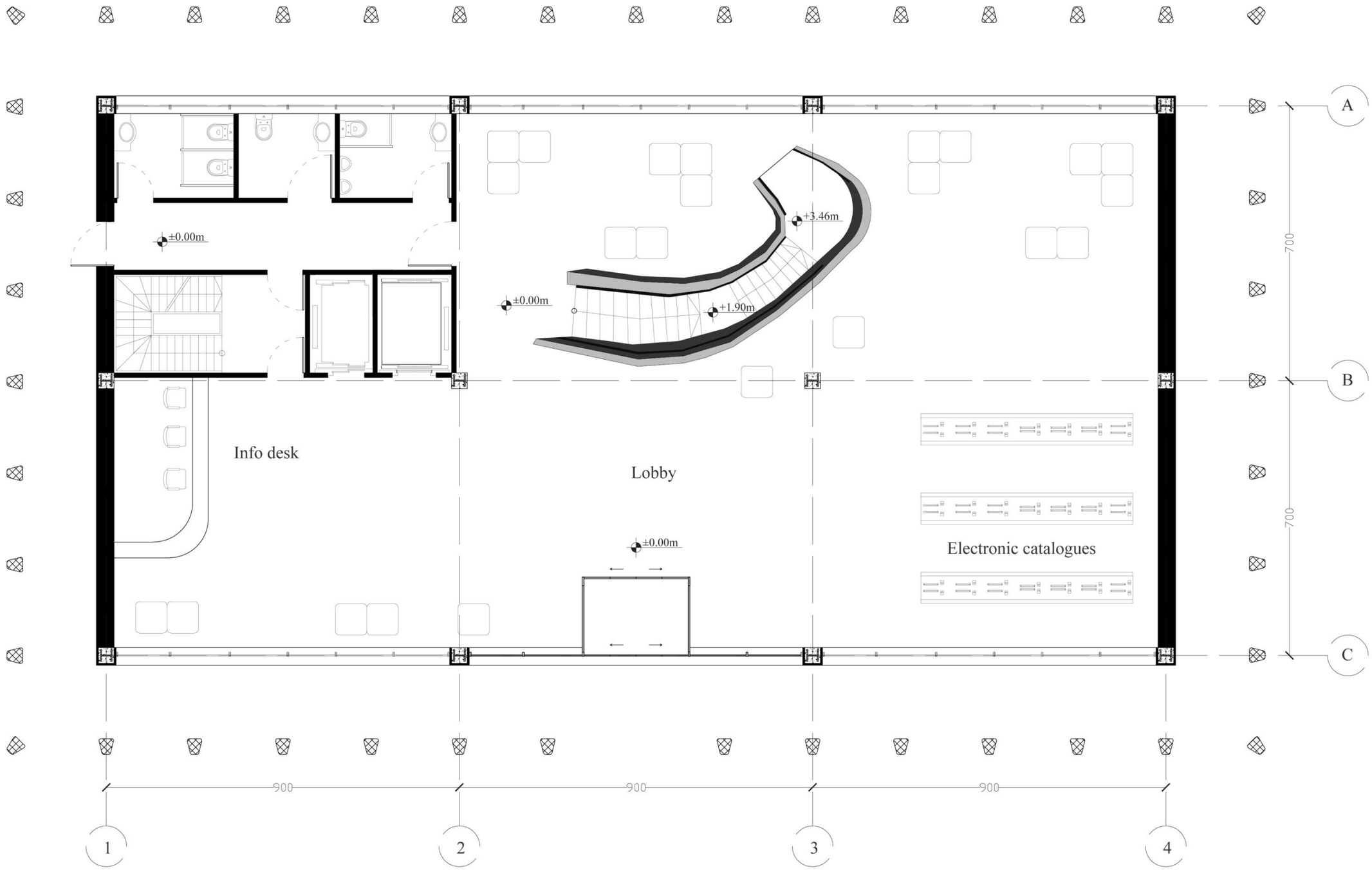

0.00m Ground floor

S 1:100
0 2 4

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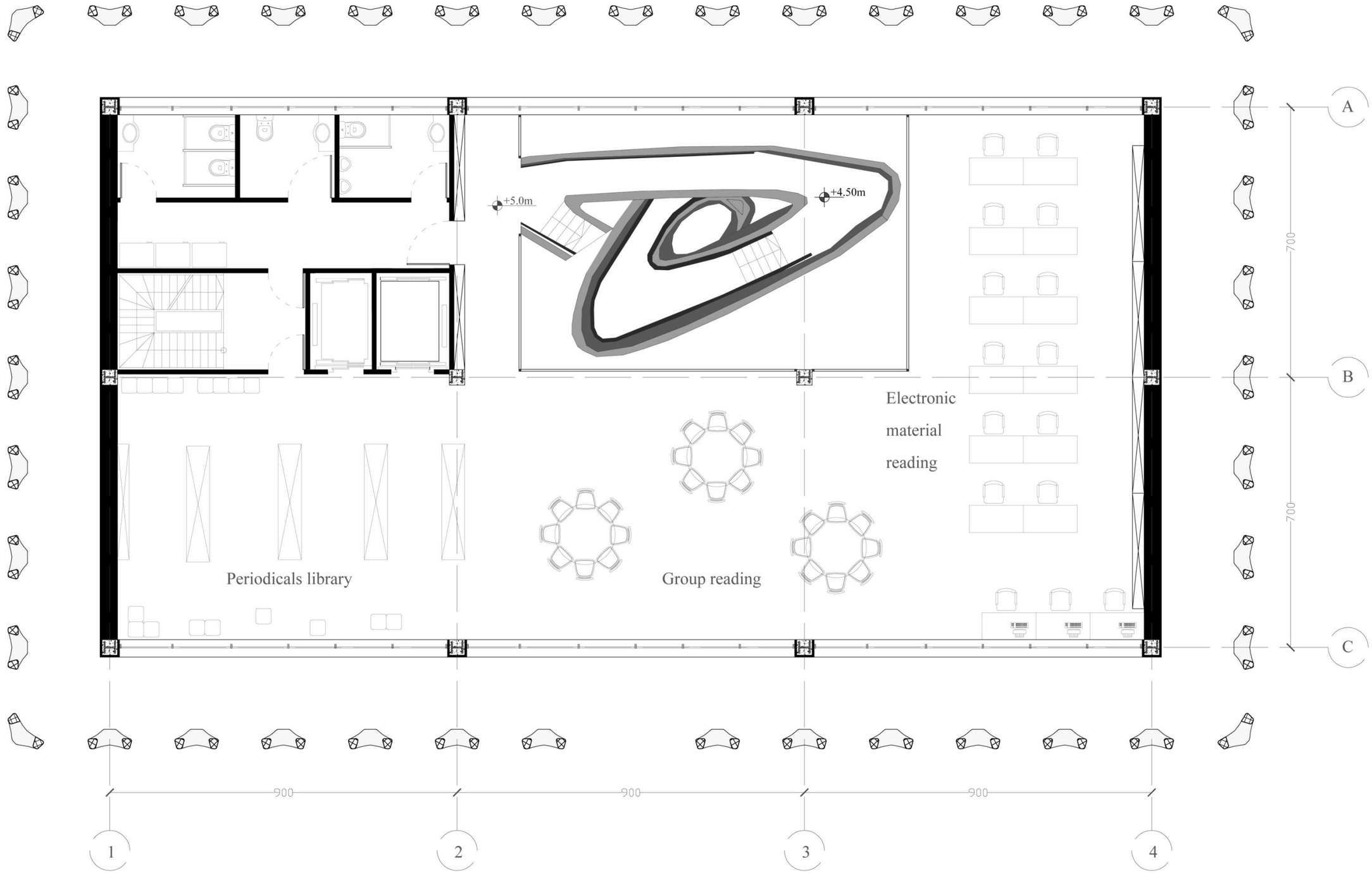

+5.00m First floor

S 1:100
0 2 4

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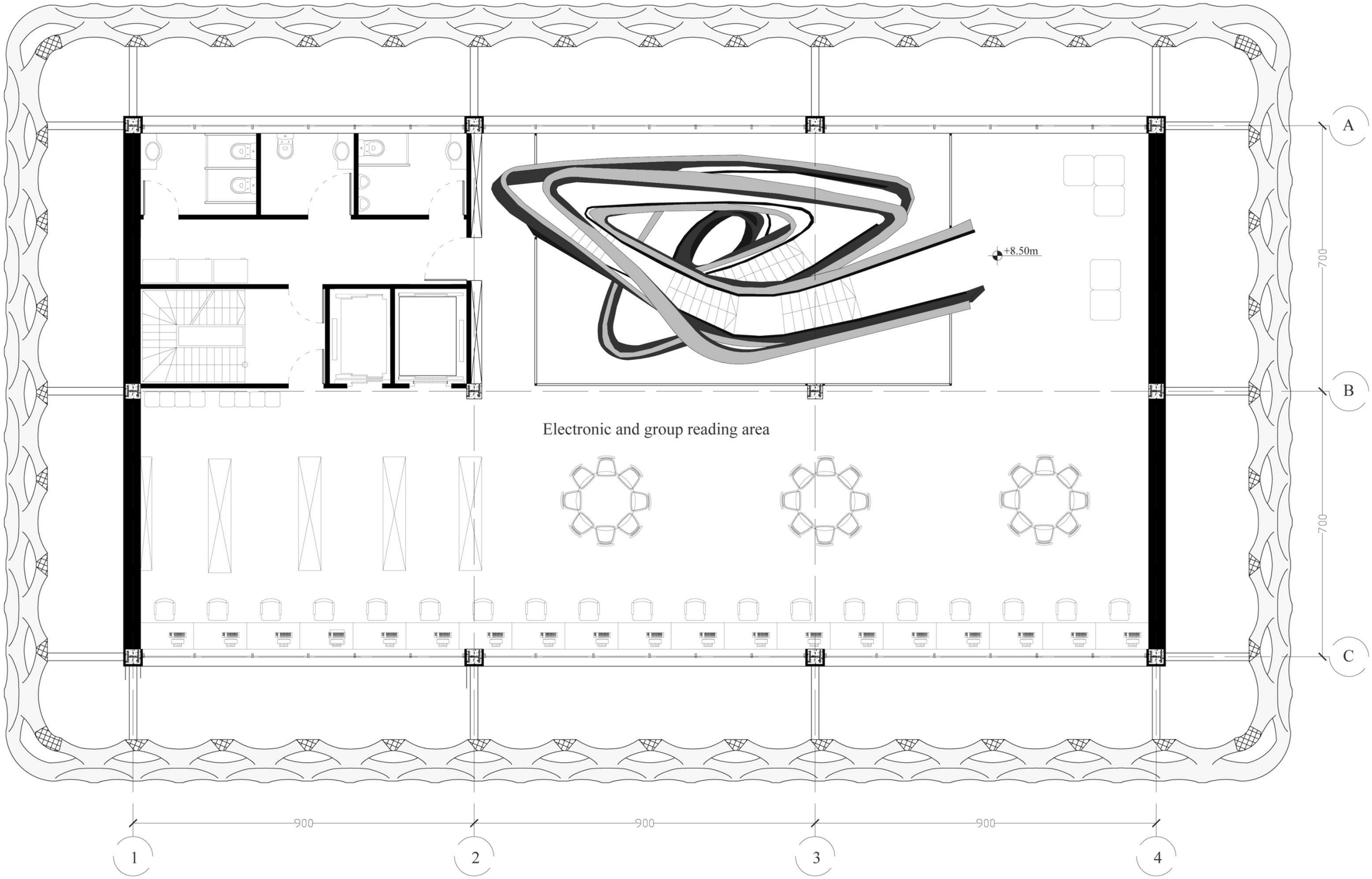

+8.50m Second floor

S 1:100
0 2 4

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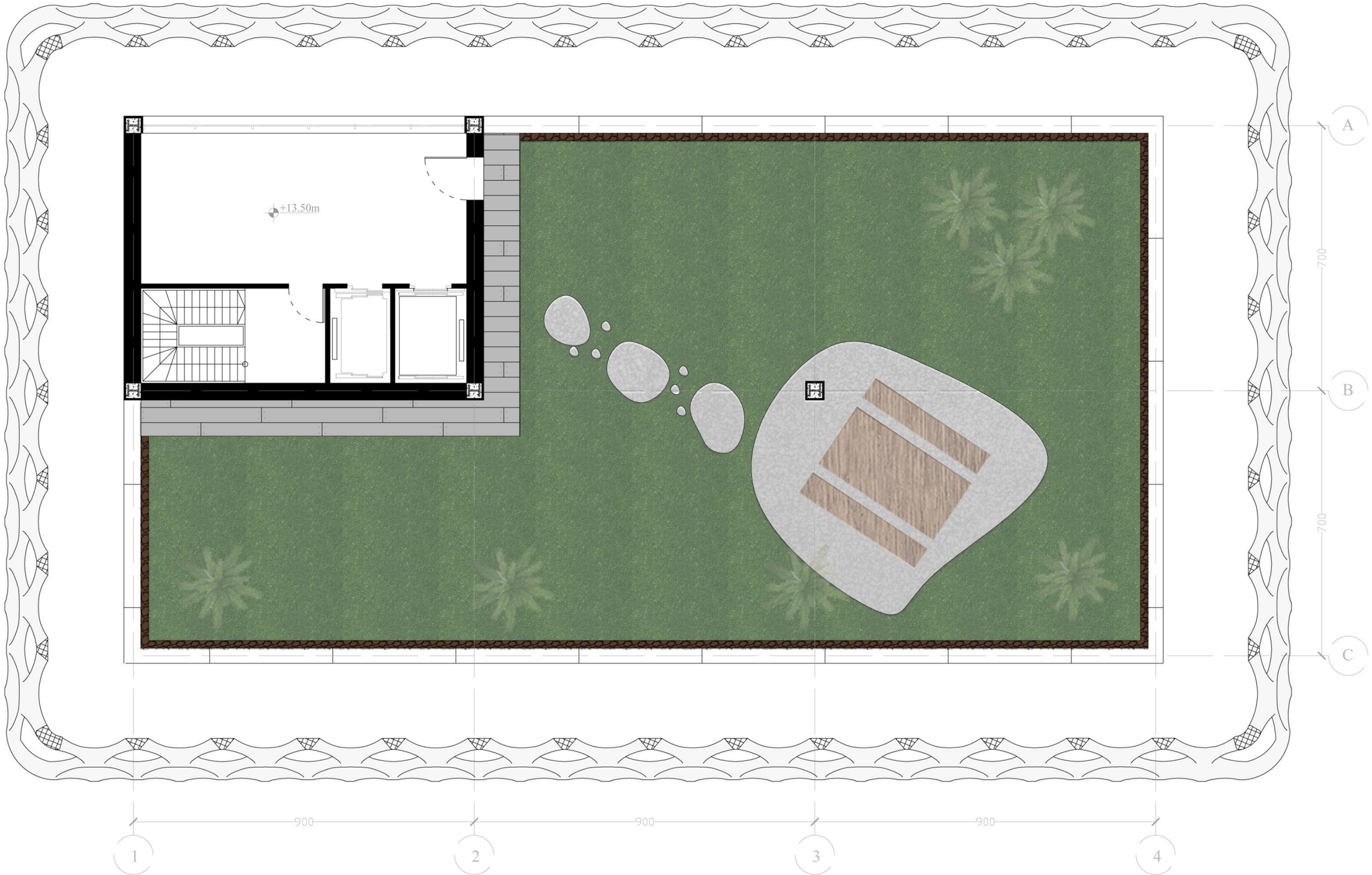

+13.5m Roof garden

S 1:100
0 2 4

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+16.5m Roof top

S 1:100
0 2 4

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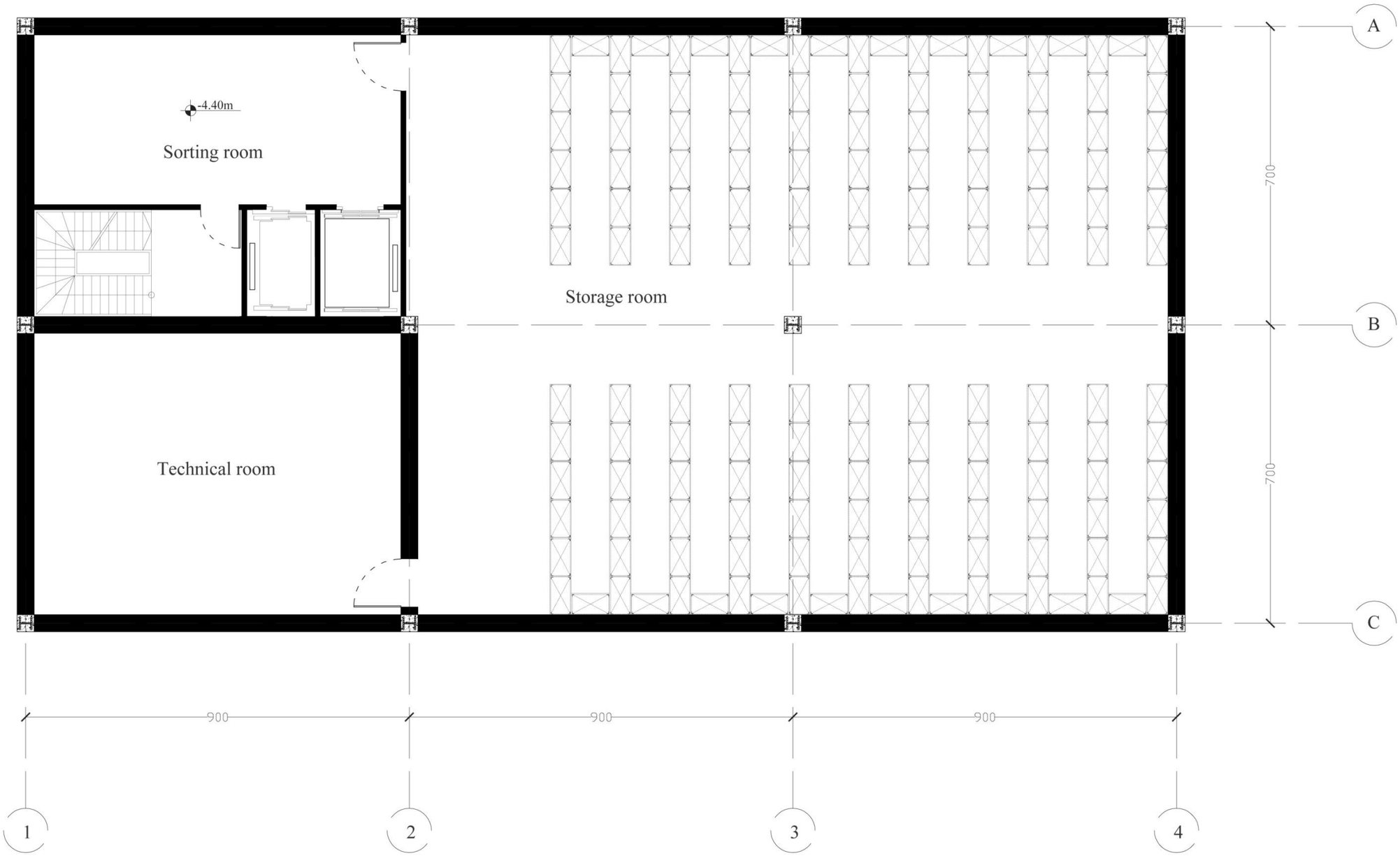

-4,40m Underground floor

S 1:100
0 2 4

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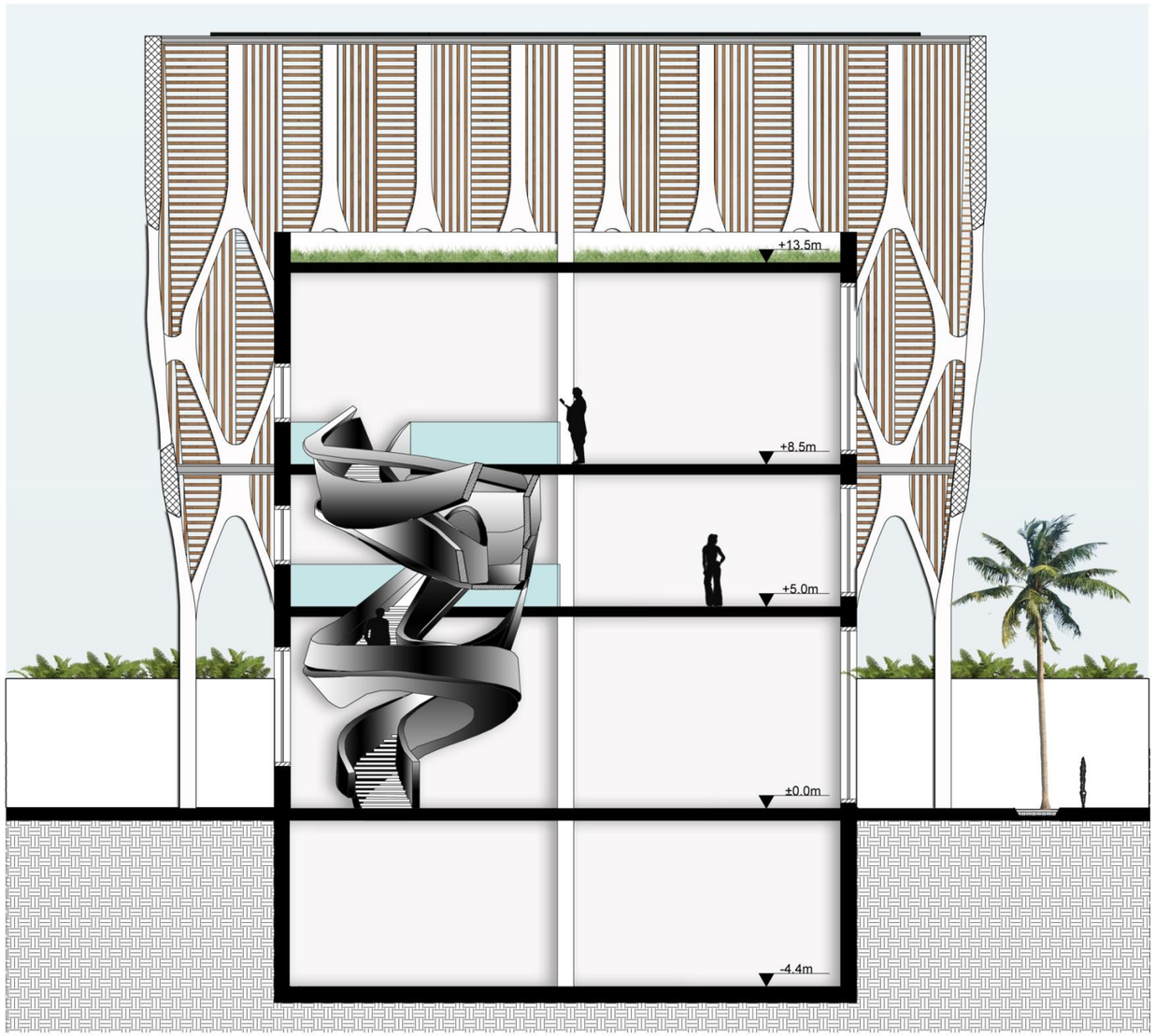

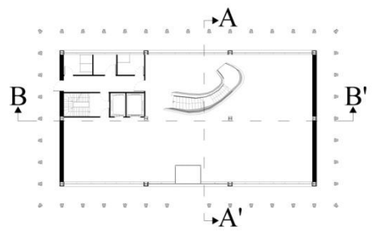

Section A-A’

S 1:200

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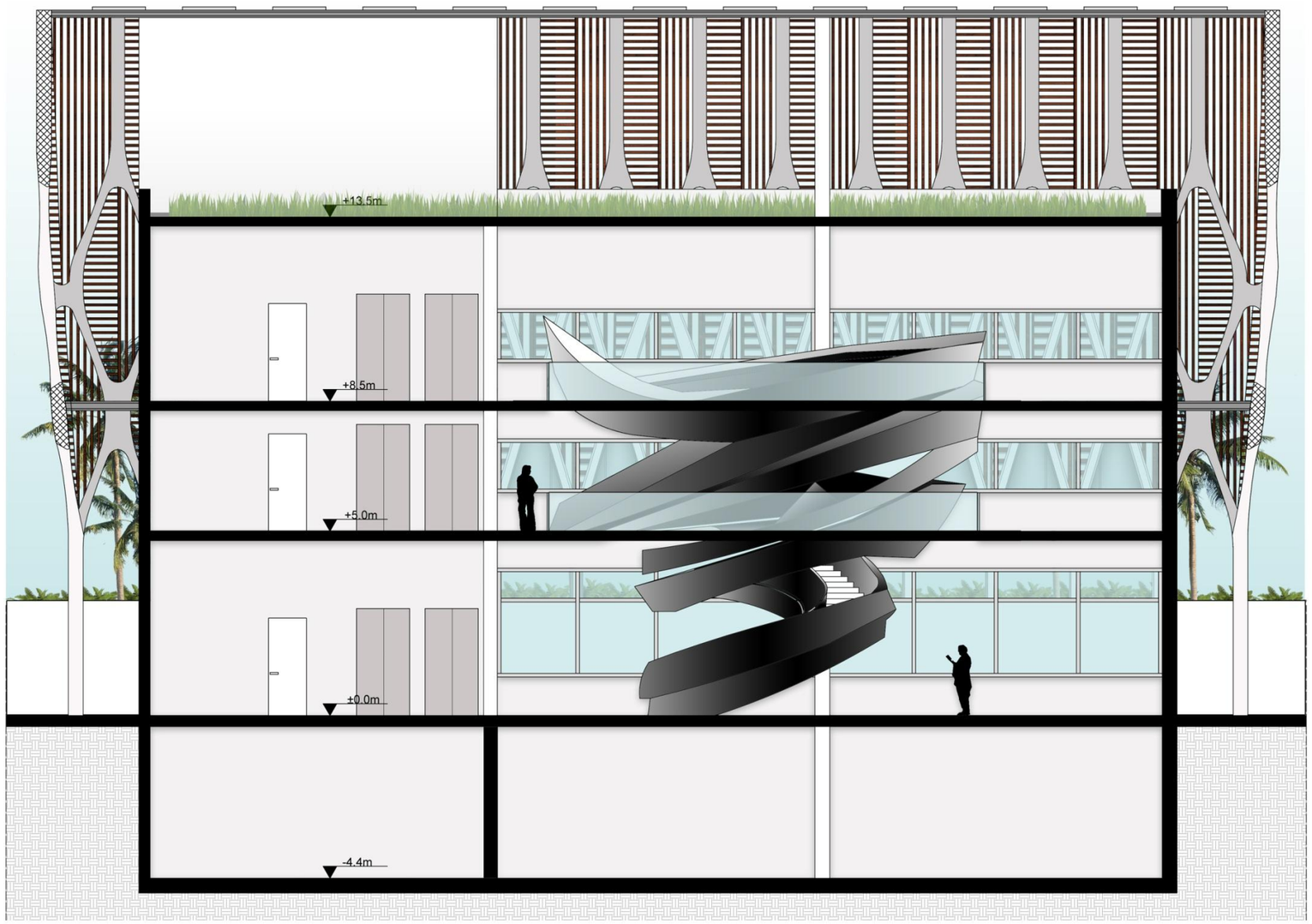

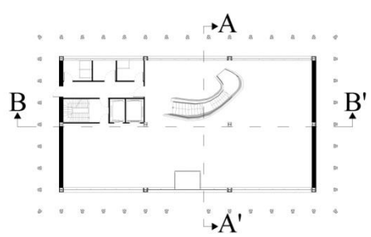

S 1:200

0 4 8

Section B-B’

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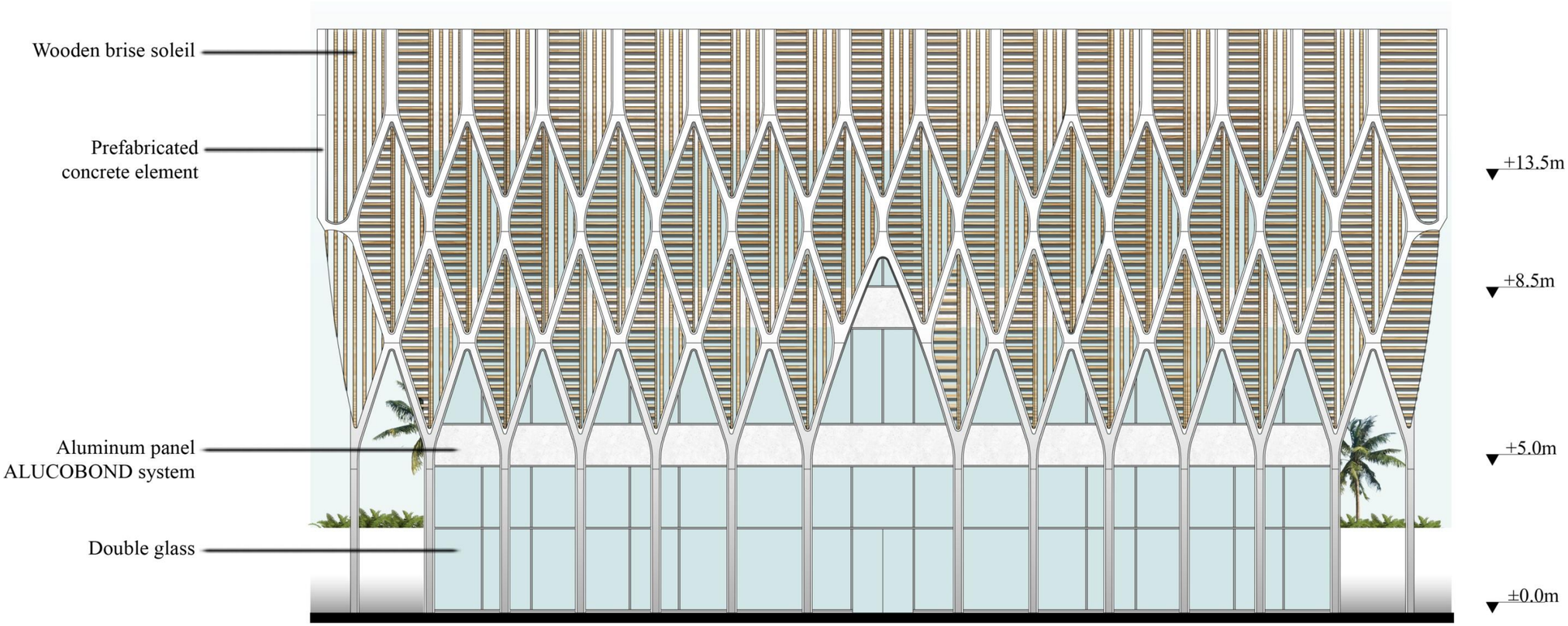

South elevation

S 1:200
0 4 8

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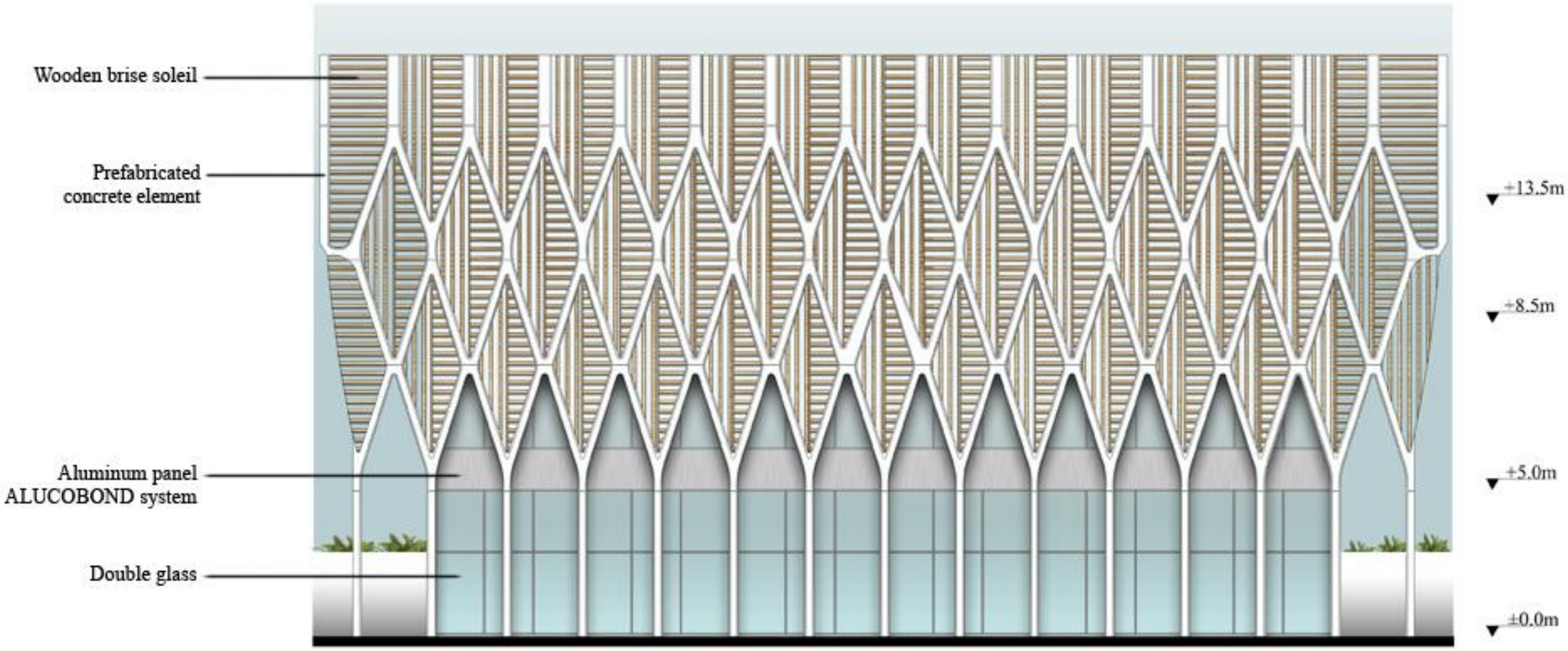

North elevation

S 1:200
0 4 8

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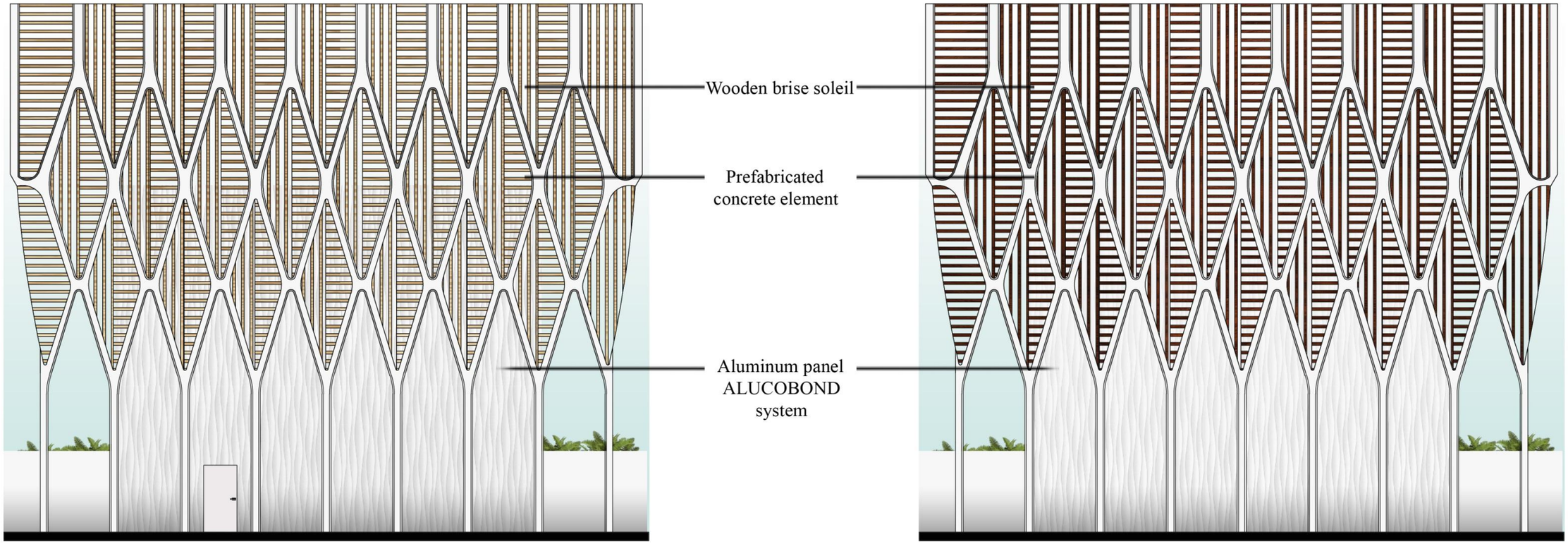

West elevation

East elevation

West and east elevation

S 1:200
0 4 8

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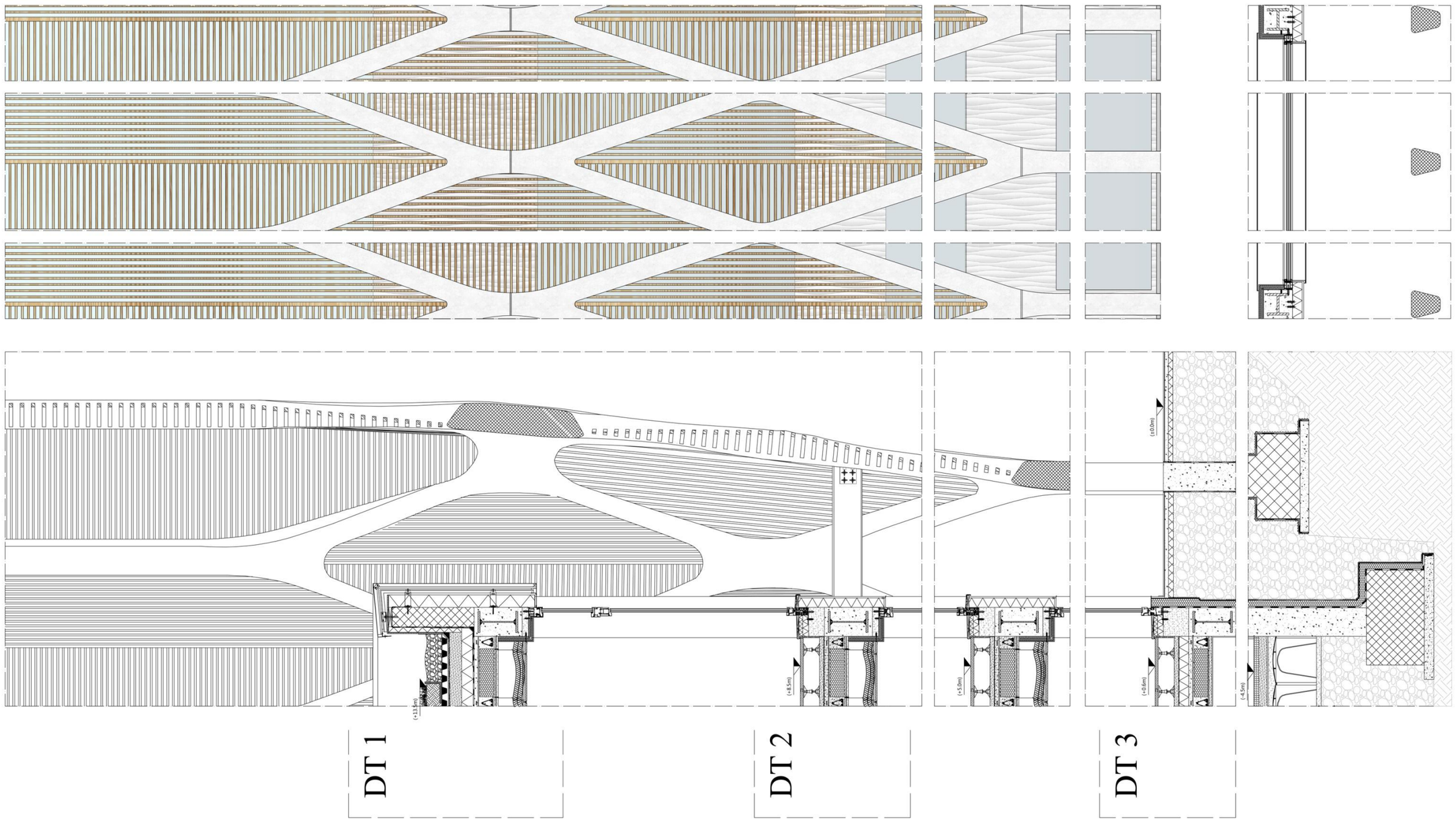

Blow up - south facade S 1:160

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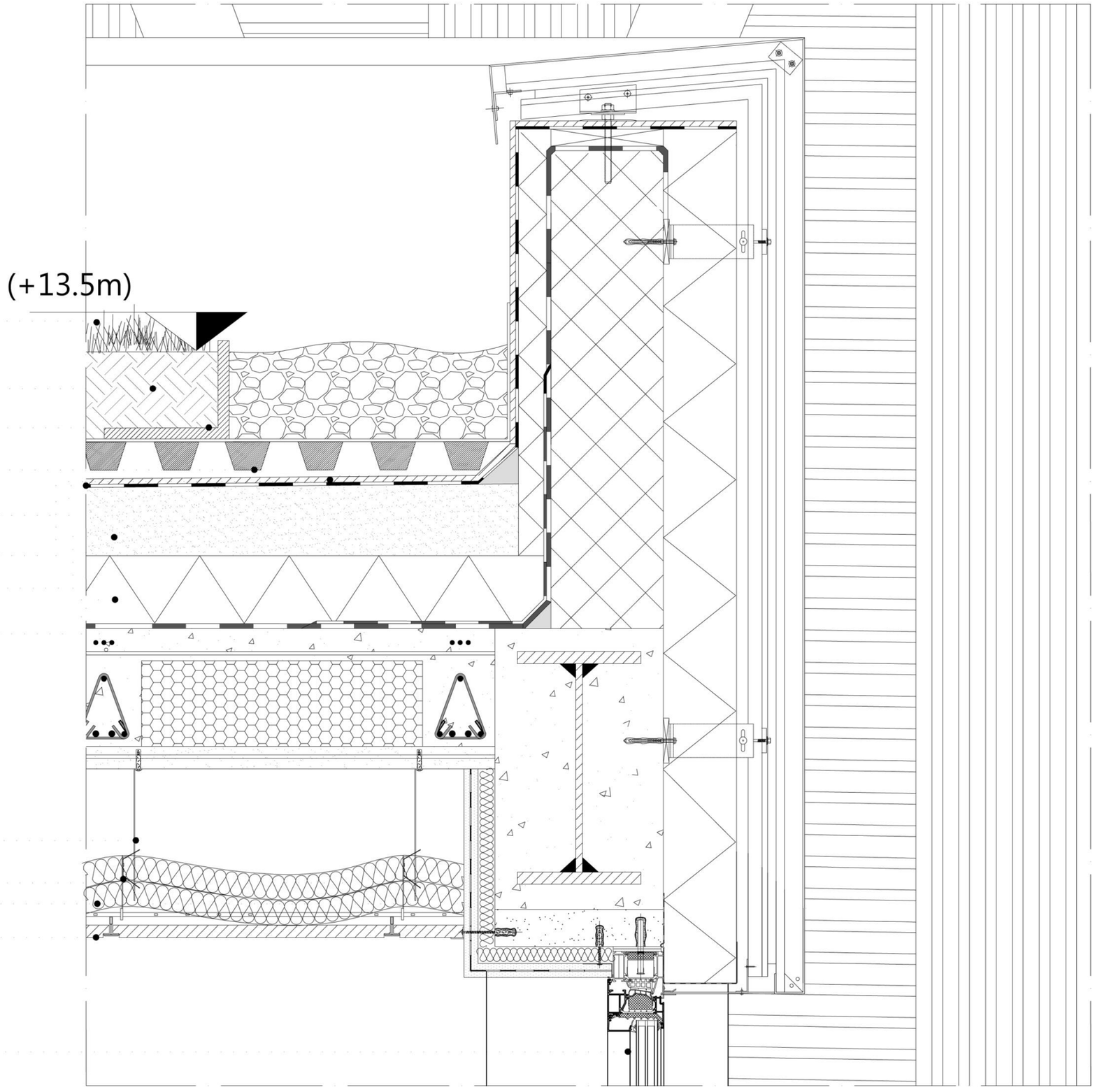
DT 1

S 1:10



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DT 2

S 1:10

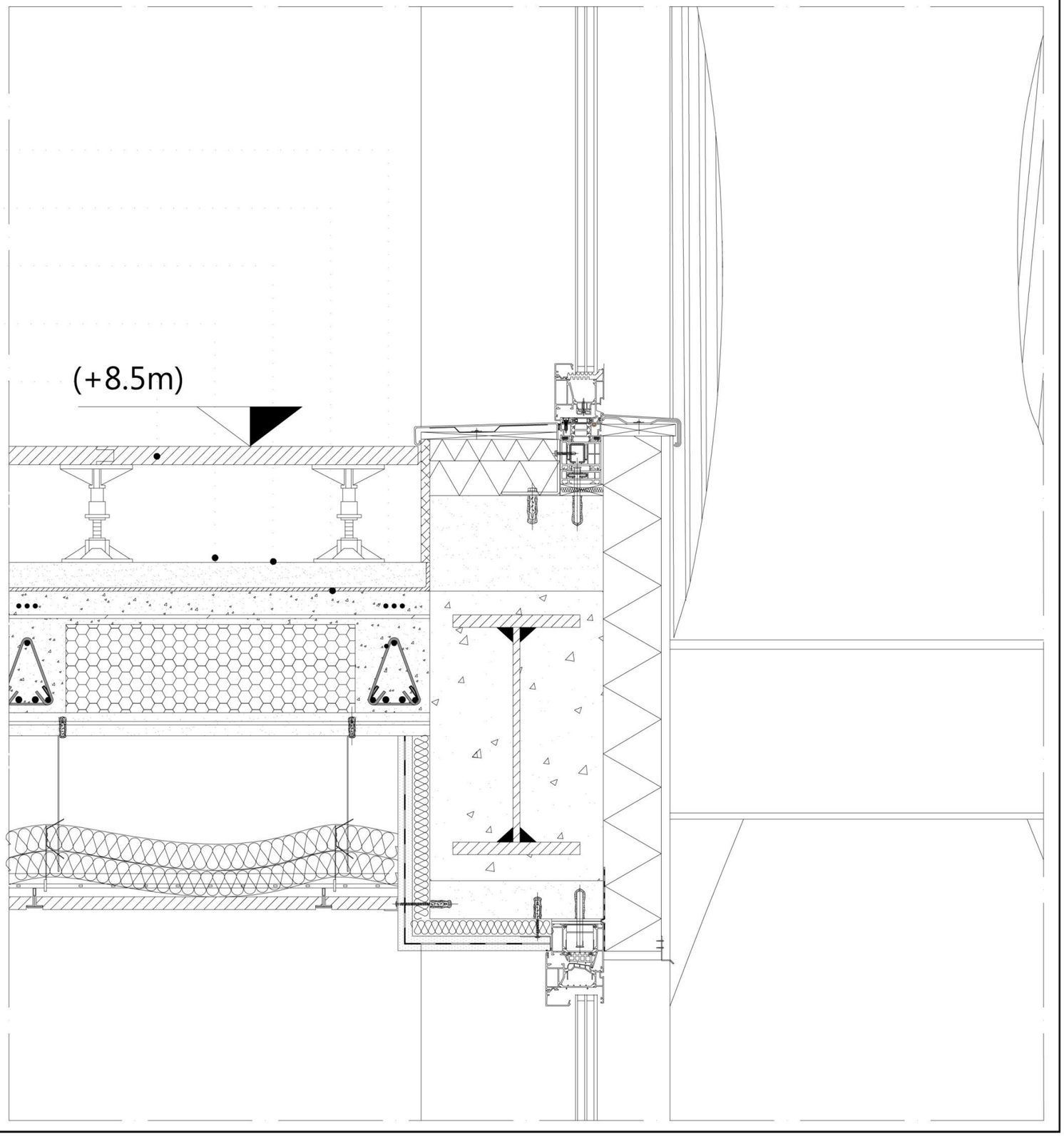
Predalles structural deck 250 mm thick

Sheet for sound insulation from vibration

Self-levelling screed 50 mm thick

Knauf support for floating floor 160 mm hight

Knauf flooring



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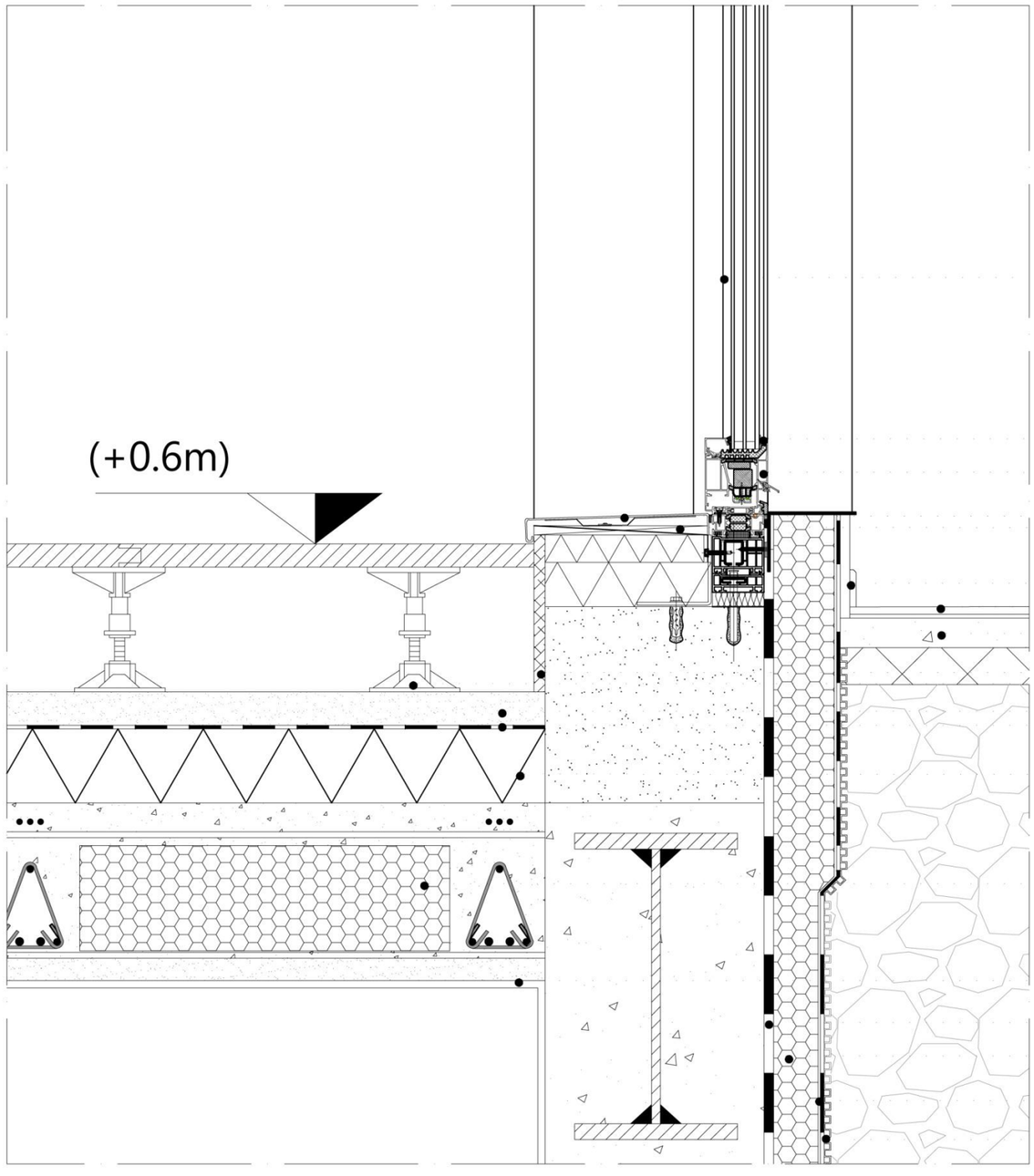
DT 3

S 1:10



Triple glass 3+3/14/2+2/14/3+3

EPDM gasket
Schuco fixed frame AWS 75WF.SI

Aluminum cover
Wooden support

Stone skirting
External paving 20mm thick
Self-levelling screed 40mm thick

Knauf mineral felt
Knauf floating flour
Self-levelling screed 50mm thick
Vapor barrier
Knauf Polyfoam Xtraplus C-500 (extruded polystirene) 120mm thick

Calandra Predalles structural deck 250mm thick

Mortar-cement plaster 15mm thick

Double waterproof membrane
Rockwoll ROCKACIER C SOUDABLE ENERGY 130mm thick

Waterproof membrane 3mm thick

Protective sheet for waterproof membrane