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Master's Thesis

TURIN TO SMART GREEN, MIRAFIORI SCIENCE PARK

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DECLARATION

I hereby declare that this dissertation, submitted to Politecnico di Milano as partial fulfillment of the requirements for the degree of Master has not been submitted as an exercise for a similar degree at any other university. I also certify that the work described here is entirely my own except for excerpts and summaries whose sources are appropriately cited in the references. This thesis may be made available within the university library and may be photocopied or loaned to other libraries for the purpose of consultation.

July 2014 Amin Moazami

ABSTRACT

In order to assure a bright future to Turin, we need to consider transforming or to replacing the current models of urban management, life and development. The ways we manage the urban areas, the planning of other transformations and regeneration, involving citizens, adapting to the climate and social changes will need to be considered as the main inspiring principles: resilience, sustainability and integration. One of the possible models refers to of the concepts of agro - housing and urban - farming, which are becoming more and more widespread: the use of open spaces. In future years the southern area of Turin and particularly the neighborhoods in South Mirafiori are to be the target of several transformations, which have already started or will happen in the near future. FIAT factory areas have been partially already dismissed a part of them have an uncertain future. Definitely the property values of these plots due to their strategic infrastructural location and their sizes make them one of Turin's most interesting opportunities for regeneration and development. In this Thesis it has been tried to achieve certain objectives that defined in order to come out with a proper proposal for this area.

The proposal focuses on creation of a long term sustainable transformation with application of latest technologies and strategies in Urban and architecture scale. Chosen strategies all adopted to be most efficient by using as passive strategies as possible. Techniques inspired by nature were the most desirable in decision making process throughout the design.

In this regard, methods such as; Natural Ventilation (NV), Earth Tubes and surfaces with Capillary tubes system is designed to realize a building with highest standards in terms of energy consumption and CO_2 emissions.

ESTRATTO

Al fine di assicurare un futuro luminoso a Torino , dobbiamo considerare trasformare o sostituire gli attuali modelli di gestione urbana , la vita e lo sviluppo . I modi gestiamo le aree urbane , la pianificazione di altre trasformazioni e rigenerazione , che coinvolga i cittadini , adattandosi al clima e cambiamenti sociali dovranno essere considerati come i principali principi ispiratori : la resilienza , sostenibilità e integrazione. Uno dei possibili modelli si riferisce a dei concetti di agro - Housing and Urban - l'agricoltura , che stanno diventando sempre più diffusa : l'uso degli spazi aperti . Nei prossimi anni la zona sud di Torino e in particolare i quartieri di South Mirafiori devono essere il bersaglio di numerose trasformazioni , che hanno già avviato o accadrà nel prossimo futuro . Aree dello stabilimento FIAT sono state in parte già respinto una parte di loro hanno un futuro incerto . Sicuramente i valori delle proprietà di questi terreni a causa della loro posizione strategica infrastrutturale e le loro dimensioni li rende una delle più interessanti opportunità di Torino per la rigenerazione e lo sviluppo fanno . In questa tesi si è cercato di raggiungere determinati obiettivi definiti , al fine di venire fuori con una proposta adeguata per questa zona .

La proposta si concentra sulla creazione di una trasformazione sostenibile a lungo termine con l'applicazione delle più recenti tecnologie e strategie di scala urbana e dell'architettura . Strategie scelte tutte adottate per essere più efficiente , utilizzando strategie passive possibile. Le tecniche ispirate alla natura sono stati i più desiderabili processo decisionale in tutto il disegno.

A questo proposito , metodi come ; Ventilazione naturale (NV) , Tubi Terra e superfici con capillare sistema di tubi è progettato per realizzare un edificio con standard più elevati in termini di consumi energetici ed emissioni di CO_2 .

DEDICATION

This thesis is dedicated to my beloved family; Mehdi Moazami, Maryam Shabannejad and Abdolreza Moazami. There is no doubt in my mind that without their continued support I could not have completed this process. I would also like to dedicate this thesis to my uncle, Shamsoddin Esaei and his lovely family for their encouragements throughout my study in overseas.

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CHAPTER 1

INTRODUCTION

1.1 Competition in Turin[1]

The massive transformation of the global economy, the redistribution of wealth and rights, new locations and methods of production of goods and services are transforming the boundaries of the contemporary city; the fragile balance between rural areas and urban settlements is quickly evolving. Younger generations from the rural areas in the whole world continue to move into the cities, claiming the right to share the benefits supplied by joint services, wealth and employment, peculiarities of the city even if they imply unacceptable life conditions. This has already led to an increase in urban population that generates the demand for new architectural solutions ensuring dignity and integrated living conditions. Turin knows these phenomena very well from its history. In more than one occasion in recent Italian history the city has been the home for many people and families coming from other parts of the Country.

1.1.1 The Vision

Imagine a neighborhood that connects the city with the fields not only physically but also from the cultural, philosophical and environmental perspective. The area will be one the main gates to Turin, strengthened by the Corso3 Marche project. The underground line 2 (still in development) will allow people to change transportation means right here. This will be the agriculture and food production district in the city, where people will be living in a farming oriented urban realm.

There is a huge amount of free unused green space in between and around the complex geometries of the motorway junction, with a high potential as landscape and agricultural resource. There are chances to create new connections to pursue the integration between Mirafiori and Beinasco, a small village now integrated with Turin, right on the main road to the south west. The ring road junction as a barrier might itself be turned into a landscape opportunity.

The narrow area of the FIAT production area car parking (that has been a second barrier to the expansion and integration of the neighbourhood) will be the chance to provide Turin with a new model of urban life. Dwellings integrated with food production, in traditional (surface field) or innovative (vertical) models; housing for low income people and immigrants, with agricultural skills; spaces, services and features to let the younger generation reinvent their own way to work; urban farming that opens towards a new economy, including education, documentation, food retailing, agricultural and zoo-technical services.

1.1.2 Competition site

Turin, Italy. South Mirafiori, Circoscrizione 10 (45°1'30.71"N, 7°36'22.92"E) trada Antica di ollegno, Strada della Manta, Via Anselmetti, Strada del Drosso.

Figure 1-1 Competition Site

The competition site area is private, owned by the FIAT group and other companies. The main function of the area has been devoted to a parking lot for the stock of new cars produced. On the west side one of the main entrances to the ring road and the motorway network makes this one of the natural gates to Turin. One of the two cemeteries of the city is located right besides this infrastructure. On the east side of the competition site, along Via Anselmetti, there two very different images: on the upper side, north to Via Plava, the FIAT manufacturing plants still in use; the lower east side is the South Mirafiori neighbourhood, with a narrow green strip facing Via Anselmetti, where the limit of the city is visible, there are high rise residential buildings and several community services. The southern limit of the plot has a wide agricultural area already targeted for different projects [www.miraorti.com), bounded by Via Miratiori and Sstrada del Drosso. At the very north, the plot has a triangular area vvith several abandoned industrial warehouses, today often used by homeless people to take shelter during the night.

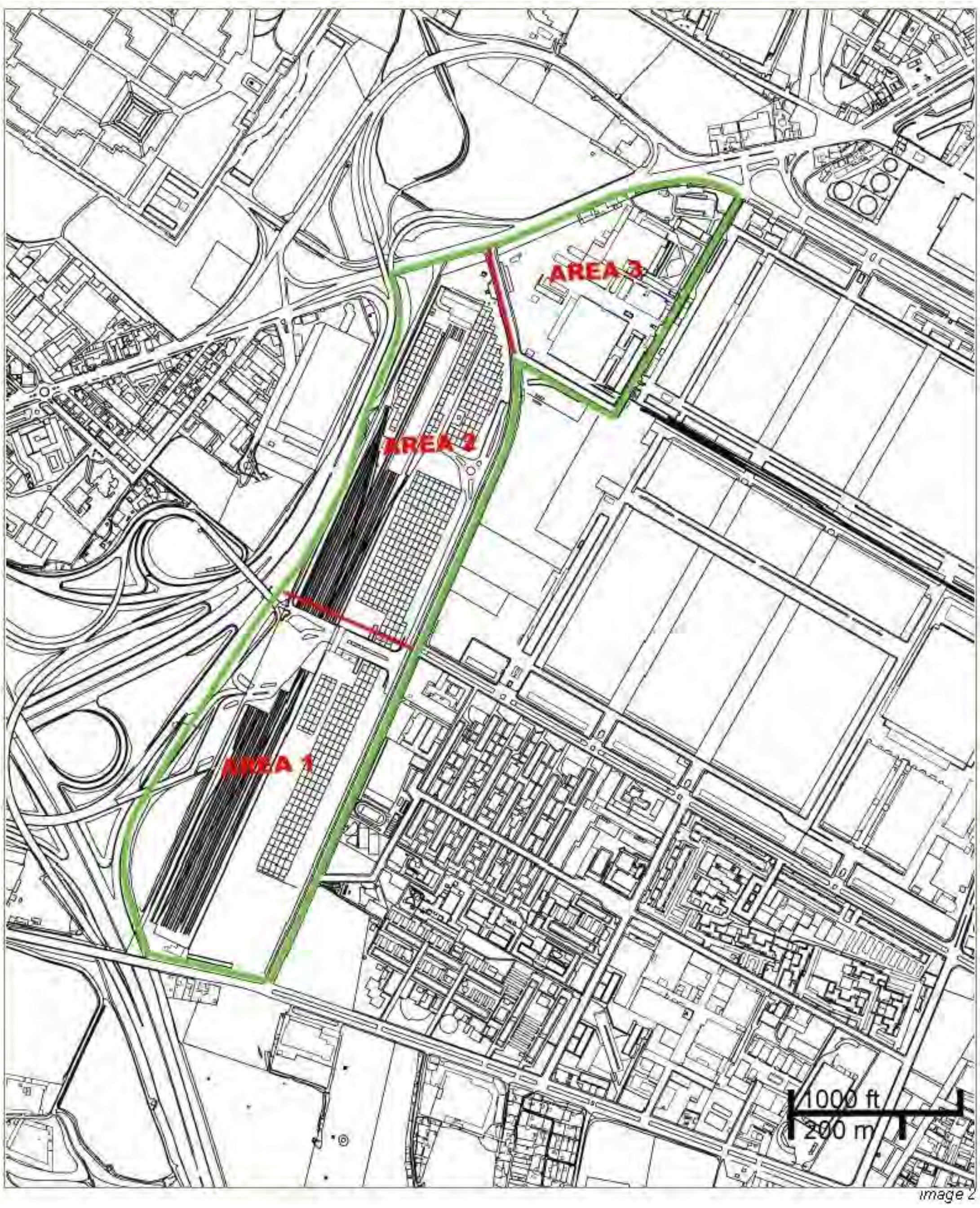

Figure 1-2 Site Borders and Areas

1.1.3 Project Scope

Participants are invited to apply their talent and to reflect on the following general objectives, related with the key issues of the area:

- To repopulate the neighborhood making it an attractive and vibrant area for younger generations, students, young couples, and the first employed.

- To foster the weaker strata of society, the new citizens, unemployed, seasonal and irregular workers, to settle in the area.
- To constrain the conditions that might lead to speculation, gentrification and social eviction.
- To contribute to increase employment in the area at urban level, starting from its natural green inclination, integrating agriculture, handicraft, and ICT.
- To suggest new lifestyle formats to live the job (flexible time frame, home based, delocalized...), new models of community, new participatory processes to the construction or the maintenance phases not exclusively money based.
- To introduce models of design, construction, management, maintenance and control that engages (partially or totally) the inhabitants.

1.1.4 Design Tasks

The scope of the competition brief refers to an idea of neighborhood in south Mirafiori where dwellings, occupation and nature are not only drawn close, but strongly integrated with an innovative approach related with the contemporary scenario. The program will include:

- New facilities, services and spaces for casual, odd, handicraft, displaced, seasonal workers. These may include spaces for temporary jobs, shared spaces and workshops, public ICT facilities.
- Dwellings with high quality of life delivered at an affordable standard for young and low income people, designed with a community orientation in mind.
- Low cost and low carbon buildings with parts for self-construction and/or self-maintenance.
- Dwellers should have a certain degree of freedom in shaping their own place, moving within given general rules.
- Integration between residential and agricultural activities, also through the definition of new building typologies and innovative schemes and integrated solutions. Vertical farms, hydroponic cultures, integration of ICT with agriculture; here agriculture is at the scale of the home or small local business.
- Employment opportunities for people migrated from rural regions around the world to engage with others in new forms of social enterprise.

- Integration of residential requirements and waste with the agricultural productive process (waste cycle, water cycle, renewable energies, bio integrated microclimatic systems).
- To make effective use of motorway junction spaces and landscape/agricultural resource [Fig1-1].

The competition site has been divided in 3 areas [Figure1-2] named 1, 2, 3 from south to north. Participants need to submit a general master plan for the whole site; then choose one of the 3 areas and develop a design – according to the requirements – only for that area. The competition advisory board provides the following general guidance, about the density and the land use of the 3 areas.

Area 1: 60 % agriculture; minimum distance from motorways: 10 meters
Area 2: 40 % agriculture; minimum distance from motorways: 10 meters
Area 3: 20 % agriculture
Maximum people settled: 1500

The structure of the south side of Turin has been strategically planned according to the scheme below:

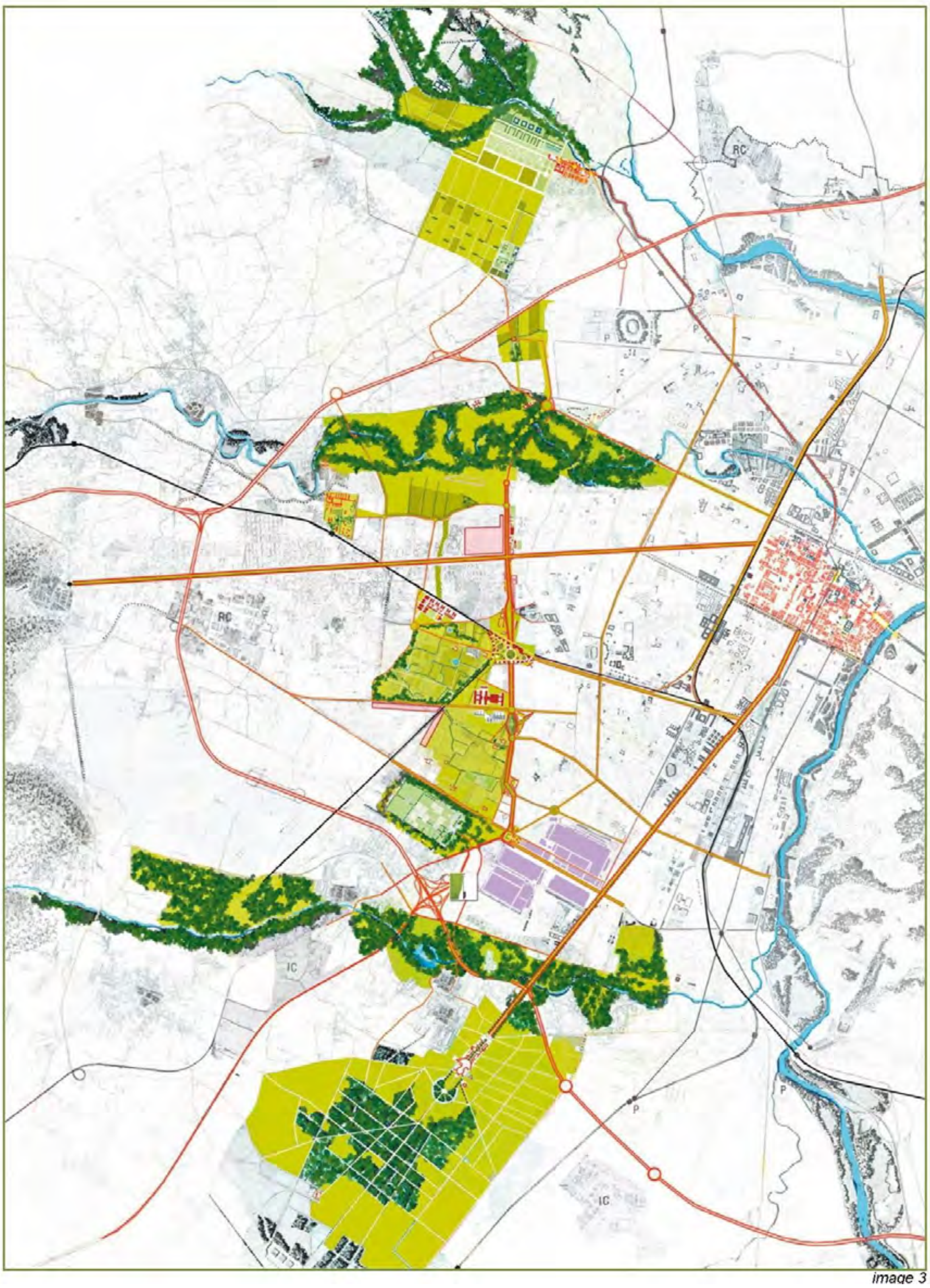

Figure 1-3 South side of Turin

1.1.5 Ongoing projects

This area of the city, where the competition site is included, is today one of the most active in terms of regeneration programs. Different private and public stakeholders are running many projects addressing a new vocation and image for the area and aiming to consolidate the social fabric, to create a new local economy, to foster the southern district of Turin to become the leading sustainable community.

1.2 City Scale Analysis

1.2.1 Turin

Turin is a city and an important business and cultural centre in northern Italy, capital of the Piedmont region, located mainly on the left bank of the Po River, in front of Susa Valley and surrounded by the western Alpine arch. The population of the city proper is 911,823 (December 2012) while the population of the urban area is estimated by Eurostat to be 1.7 million inhabitants. The Turin metropolitan area is estimated by the OECD to have a population of 2.2 million.

Figure 1-4 Coat of arms

Figure 1-5 Torino

1.2.2 The city history

Turin’s story is that of a city that has been largely an ‘industrial town’ for the past 100 years, and yet it had retained the institutional and social ingenuity to know that change would come and that preparation would be everything. “Always on the move” is Turin’s new organizing slogan.

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The Taurini were an ancient Celto Ligurian Alpine people, who occupied the upper valley of the river Po, in the centre of modern \Piedmont.

In 218 BC, they were attacked by Hannibal since his allies were the Insubres. The Taurini and the Insubres had a long-standing feud. Their chief town (Taurasia) was captured by Hannibal's forces after a three-day siege. As a people they are rarely mentioned in history. It is believed that a Roman colony was established in 27 BC with the name Castra Taurinorum and afterwards Julia Augusta Taurinorum (modern Turin). Both Livy and Strabo speak of the country of the Taurini as including one of the passes of the Alps, which points to a wider use of the name in earlier times.

The tribe of the Taurini is the origin of the city of Torino: Celtic in origin, they joined the ligurian tribes peacefully. The city symbol and coat of arms is the rampant bull – Torino literally means "young bull". The Salassi, another Celtic Italian tribe, was also part of the Piemonte area which was eventually destroyed by the Romans. The language of the Piemonte region, Piemontese, still to this day contains many words of Celtic origin and is more than a dialect: it is indeed a separate language spoken to this day by the people of Torino and the Piemonte region, giving them a unique sense of identity and affinity with their ancient ancestral heritage.

Figure 1-6 Turin in the 17th century

Figure 1-7 A view of Turin in the late 19th century

1.2.3 City growth and evolution

In the postwar years, Turin was rapidly rebuilt. The city's automotive industry played a pivotal role in the Italian economic miracle of the 1950s and 1960s, attracting to the city hundreds of thousands of immigrants, particularly from rural southern regions of Italy.

The population soon reached 1 million in 1960 and peaked at almost 1.2 million in 1971. The exceptional growth gains of the city gained it the nickname of the "Automobile Capital of Italy" and the “Detroit of Italy" (Turin has been "twinned" with Detroit since 1998). In the 1970s and 1980s, the oil and automotive industry crisis severely hit the city, and its population began to sharply decline, losing more than one-fourth of its total in 30 years. The long population decline of the city has begun to reverse itself only in recent years, as the population grew from 865,000 to slightly over 900,000 by the end of the century. In 2006, Turin hosted the Winter Olympic Games.

1.2.4 Geography and Climate

Turin is located in north-west Italy. It is surrounded on the western and northern front by the Alps and on the eastern front by a high hill that is the natural prosecution of the hills of Monferrato. Four major rivers pass through the city: the Po and two of its tributaries, the Dora (later changed to "Duria Minor" by the Romans, from the Celtic duria meaning "water"), the Stura di Lanzo, and the Sangone.

The city is located in a humid subtropical climate zone. This is in contrast to the Mediterranean characteristic of the coast of Italy. Winters are moderately cold but dry, summers are mild in the hills and quite hot in the plains. Rain falls mostly during spring and autumn; during the hottest months, otherwise, rains are less usual but more strong (thunderstorms are usual). During the winter and autumn months banks of fog, which are sometimes very thick, form in the plains but rarely on the city because of its location at the end of the Susa valley.

Its position on the east side of the Alps makes the weather drier than on the west side because of the foehn wind effect. The highest temperature ever recorded was 37.1 °C (98.8 °F), while the lowest was −21.8 °C (−7.2 °F).

Figure 1-8 Turin with Alps

1.2.5 Population

1.2.5.1 Population dynamics

The variation of the population in the Province of Turin, analyzed along the period related to the decennial investigation by the general Census on the population from 1971 to 2001, shows a growth of population data in 1971 and 1981 and a gradual population decline in population surveys of 1991 and 2001; while for the city of Turin is the progressive demographic decline has been recorded since the 1971 Census. From 1971 to 1981 there has been a redistribution of the population between the city and the surrounding metropolitan area, with an overall population growth of the territory, as recorded in the two censuses of 1971 and 1981, while in the following censuses of 1991 and 2001 the population decline has occurred on the total Provincial territory, with a decrease of -3.18%.

The period of greatest demographic depression for the Province of Turin is identified withe first half of the 80s, coinciding with the phase of restructing of the industry. The analysis of the major demographic components of long period (1981- 2005) shows that, after years characterized by a negative population growth (-7.6% in the period 1981-2001), the latest data indicate a reverse trend of our territory, which started since the second mid-nineties. In fact in 1995 the population was of 2,220,724 inhabitants, while on the 1st January 2006 was placed at 2,242,775 inhabitants living in the province. In the last four years the resident population has increased from 2,165,299 to 2,242,775 inhabitants, with a trend of steady growth.

To the significant trend of the positive migration balance contributes the demographic component related to foreign countries, with particular emphasis on migra- tion from countries outside Europe. In fact, the foreign residents on the 1st Janu- ary 2005 are 106,276 units, with an increase of 19,548 residents with respect to 2004, while on the 1/1/06 there are 118,284 foreign inhabitants with an increase of 12,008 residents compared to the previous year, contributing to the overall improve- ment of the master budget of our territory.

AREE TERRITORIALI	1971	1981	1991	2001
Provincia di Torino	2.287.016	2.345.771	2.236.765	2.165.619
Città di Torino	1.167.968	1.117.154	962.507	865.263

Figure 1-9 Population variation in the Province of Turin[2]

In the European Union, Italy is the country with the older population. On 1/1/06 the proportion of the population with more than sixty-five years overcomes the 19% of the total population. The Province of Turin, as all the highly developed areas, Reflects this condition with greater emphasis than the national datum, in fact, the elderly population in our region represents the 22% of the total population. Focusing on the municipal data of the Province of Turin, we can see that in 2005 there was an increase of population in 182 municipalities, a population declines in 126 municipalities, while in 7 municipalities the population remained unchanged, on the total of 315 municipalities. In the following image is reported the distribution of municipalities in relation to the number of inhabitants.

DATI ED INDICATORI DEMOGRAFICI	PROVINCIA DI TORINO	ITALIA
Superficie	6.830 kmq	301.336 kmq
Densità demografica (ab./kmq)	328,37	194,97
Popolazione residente al 31 /12/ 2005	2.242.775	58.751.711
Variazione popolazione periodo 1991 - 2005 (%)	0,31	3,47
Famiglie - numero	999.878	23.600.370
Numero medio componenti per famiglia	2,2	2,5
Tasso di natalità (per mille ab.)	8,89	9,50
Tasso di mortalità (per mille ab.)	9,99	9,70
Saldo naturale (per mille ab.)	- 1,1	- 0,22
Saldo migratorio (per mille ab.)	3,7	5,20
Popolazione con meno di 25 anni (%)	22,20	25,58
Popolazione con 65 anni e più (%)	21,77	19,77
Indice di vecchiaia	172,68	140,85
Indice di dipendenza	53,38	50,18
Stranieri residenti anno 2005	106.276	2.402.157
Stranieri residenti per 100 abitanti (%)	4,7	4,08
Elaborazione Ufficio Statistica su dati INPS		

Figure 1-10 Comparison of demographic data and indicators between Province of Turin and Italy[2]

1.2.6 Transportation

1.2.6.1 Transportation network in the Province of Turin

Torino, thanks to its position and a dense road network that extends throughout the Piedmont region, lies at the heart of Europe and represents an important gateway to and from major European cities.

The highways that connect Turin to other Italian cities are: A4 (Turin - Milan), A5 (Turin - Aosta), A6 (Torino - Savona) and A21 (Torino - Piacenza).

The chief town is also well connected with France and Switzerland through important passes: the Frejus tunnel (connected to the city through the A32), the Tunnel of the Great St. Bernard and the Mont Blanc one.

1.2.6.2 Highway Network

Turin is the third Italian railway junction. The main railway lines which radiate from Turin are those towards Genova (via Asti and Alessandria) to Milan (via Novara and Vercelli) and to France (via Bardonecchia and the Frejus rail Tunnel) and (Via Cuneo and railway tunnel Tenda). There are other lines to Ivrea-Aosta, Mondovi-Savona, Pinerolo-Torre Pellice, Trofarello-Chieri, Cirie-Lanzo Torinese-Ceres and Rivarolo Canavese-Cuorgnè-Pont Canavese.

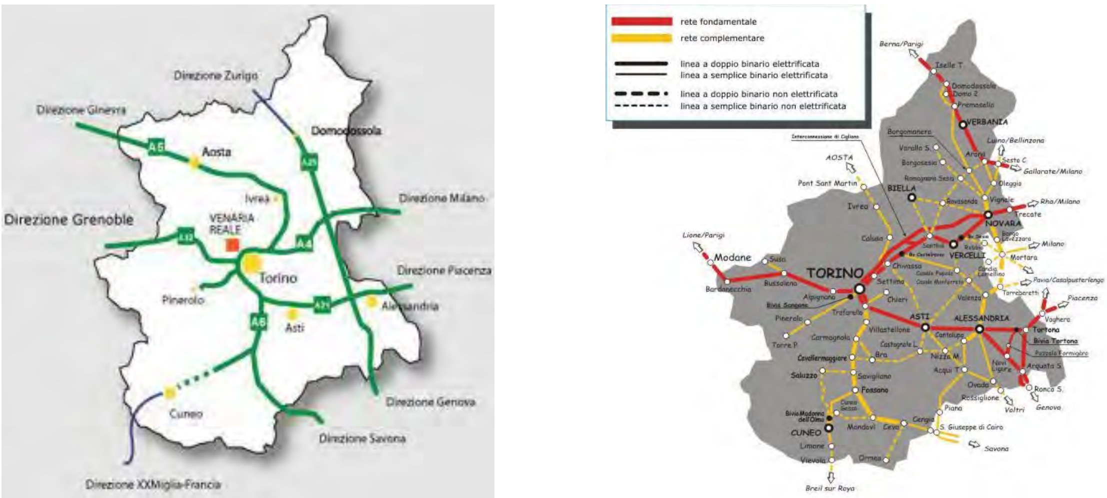


Figure 1-11 Railway network in the Province of Turin[3]

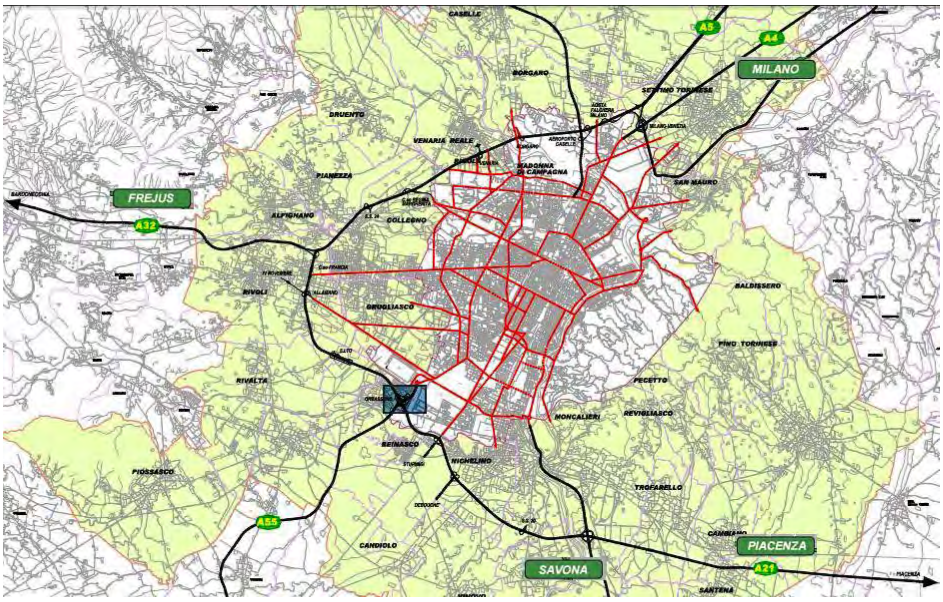


Figure 1-12 Highway network in the Province of Turin[3]

1.2.6.3 Subway System

In the map the blue color represents the stretch in operation. With red color is indicated the part whose opening took place on March 6 and September 9 (Porta Susa) in 2011; the green stretch has been approved and funded but the work has not yet started while in pink are described the extension under study.

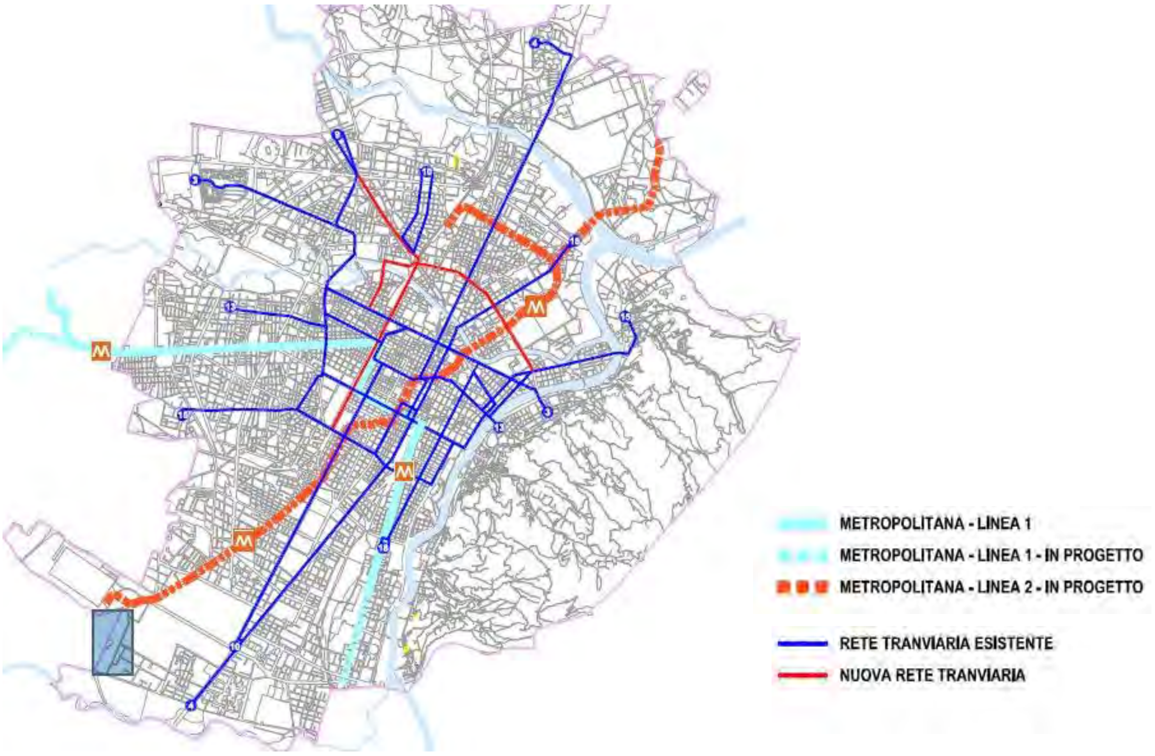


Figure 1-13 Expansion plan of the track[3]

1.2.7 Economic activities

Turin is a major industrial centre, where the headquarters of the car company FIAT is located. The industrial sector in the province of Turin has therefore always been characterized by a strong dependence on the mechanical sector, which, since the eighties, has entered a fluctuating phase of crisis and recovery. The progressive decrease of employment in the heavy industry (mechanical, components and informatics) caused the start of the process of redefinition and redistribution of the large urban areas, historically characterized by the presence of heavy industry, even through the distribution of population over large areas.

The automotive sector, pin of the provincial economy, since 2000 has entered into a serious crisis involving also other sectors, such as the heavy transport industry and the construction of metal products. As consequence of this crisis now among the driving forces of the industrial sectors of the province we must report those about the construction of tools machine and the sectors related with food.

1.2.8 Agriculture

Being the thesis based on a project of reintroduction of agriculture, we want to give a framework of the trend of this sector in the last years in the Province of Turin.
For a detailed study on purely agricultural aspects of the Piedmont and Turin have been taken into account, the difference of agricultural productions between 1999 and 2007 which are provided by ISTAT. [Figure1-14]

Coltivazioni di ortaggi in complesso nella Provincia di Torino - produzione raccolta (valori in quintali)									
Coltivazione	1999	2000	2001	2002	2003	2004	2005	2006	2007
Asparago	2.533	2.736	2.768	2.518	858	858	814	843	843
Cetriolo da mensa	1.600	2.450	1.700	2.325	0	0	0	0	0
Fagiuolo e fagiolino	2.190	2.051	2.231	2.071	1.870	6.400	6.450	8.000	8.000
Fragola	2.010	2.115	2.172	2.154	2.418	2.091	2.336	2.295	800
Lattuga	37.250	27.691	35.280	32.109	26.200	26.400	26.326	26.332	41.515
Melanzana	8.750	8.775	8.855	8.907	9.440	9.403	2.400	4.800	4.800
Popone o melone	0	0	0	0	0	0	0	0	0
Peperone	45.420	43.389	47.000	46.241	80.500	50.500	50.600	50.000	53.000
Pomodoro	37.640	43.340	43.763	42.667	40.000	45.499	32.050	59.160	37.470
Zucchina	56.980	59.000	57.150	57.350	69.000	21.200	21.300	36.000	34.275
Barbabietola da orto	-	0	0	0	0	0	0	1.000	0
Bietola	1.200	1.200	1.170	2.140	950	950	950	950	0
Carota	4.430	4.338	4.504	4.054	4.050	4.275	0	4.163	4.163
Cocomero	0	0	0	0	0	0	0	0	0
Finocchio	4.060	3.998	4.048	2.700	3.000	3.000	3.000	3.000	3.000
Indivia	9.557	8.350	9.315	8.459	7.700	8.076	0	7.888	7.888
Radicchio	6.560	6.395	6.527	1.000	600	600	513	578	573
Pisello	3.345	3.345	3.340	3.340	250	250	250	235	245
Prezzemolo	200	200	200	200	0	0	0	0	0
Ravanello	1.000	1.000	980	993	800	943	943	1.695	510
Sedano	2.400	2.400	2.400	4.900	5.000	5.000	5.000	5.000	2.160
Spinacio	16.100	16.600	16.393	2.000	2.000	2.000	2.000	2.000	0
Valeriana	-	-	-	-	-	-	0	0	0
Basilico	-	-	-	-	-	-	0	0	0
Altre ortaggi	-	-	-	-	-	-	0	0	0

Figure 1-14 Whole cultivation of vegetables in the Province of Turin[2]

1.2.9 Ecological analysis

Turin has a great environmental heritage and one of the highest urban standards of green space per inhabitant: more than 18.000.000 square meters of green areas, under continuous expansion; more than 60.000 trees along 300 km of trees lined streets, and other 100.000 in the hilly forest.

The green heritage of Turin is not only extended, but it's also different and complex. There are parks, urban gardens, historic gardens (such as Giardini Reali), hilly parks, the secular trees, protected regional areas.
One of the prerogatives of the green heritage of the city of Turin is to be designed and build over time according to typological systems.

Since the '70 the green areas grew from 4.000.000 to 18.400.000 square meters, achieving a standard of 19.05 square meters for inhabitant.

Actually there is an important project, called Corona Verde, involving 93 municipalities, that has the aim to integrate all the green areas of the province in a unique ecological system connected through cycle paths.


Figure 1-15 Sangone Park


Figure 1-16 Giardini reali

1.2.9.1 Corona Verde

Corona verde (Green Crown) is a strategic project regional direction that affects the metropolitan area and the hills of Turin involving the territory of 93 municipalities well. The project intends to implement a green infrastructure that integrates the Crown of Delitie of royal residences with green belt, represented by the natural heritage of parks metropolitan of rivers and rural areas still little altered, to redevelop the Turin metropolitan area and improve the quality of life. The project aims to highlight the values, opportunities and potential of this area, which has experienced rapid and intense processes of economic and productive development, promoting intervention that, in addition to the redevelopment, should come to reconstruct the image and identity values.

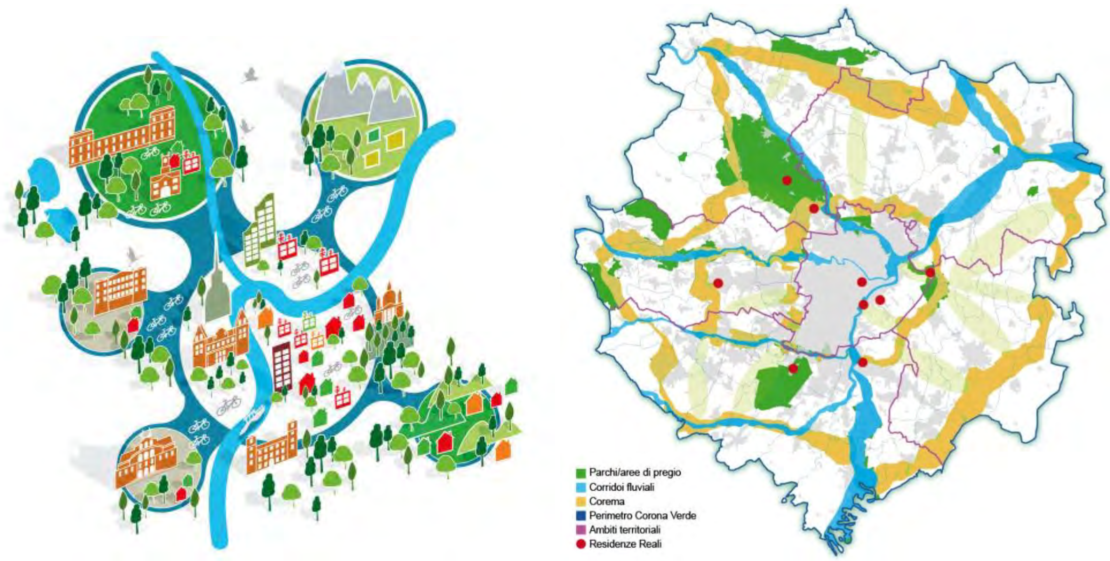


Figure 1-17 Corona Verde[4]

The portions of land which contain the most important resources or critical situations that require key interventions have been highlighted in a design brief, outlining a COREMA overall network environment (ecological and fruition). Besides being a great system of green spaces capable of safeguarding and connect to larger values that still characterize the Torino area, the project aims objectives such as:

- environmental protection and regeneration of valuable ecosystem components;
- strengthening the role of the ecological corridor of rivers and canals;
- enhancement of the use of an integrated system that is able to connect natural resources and historical and cultural systems;
- enhancement and redesign of urban edges and open areas to safeguard the combat use of land;
- Custody of peri-urban agriculture a central role in the management and maintenance of the system of open spaces and cultural landscapes.

1.2.10 Culture

Turin, as the former capital of the Kingdom of Sardinia, is home of the Savoy Residences. In addition to the 17th-century Royal Palace, built for Madama RealeChristine Marie of France (the official residence of the Savoys until 1865) there are many palaces, residences and castles in the city centre and in the surrounding towns. Turin is home to Palazzo Chiablese, the Royal Armoury, the Royal Library, Palazzo Madama, Palazzo Carignano, Villa della Regina, and the Valentino Castle. The complex of the residences of the royal house of Savoy in Turin and in the nearby cities of Rivoli, Moncalieri, Venaria Reale, Agliè, Racconigi, Stupinigi, Pollenzo and Govone was declared a World Heritage Sites by UNESCO in 1997. In recent years, Turin has become an increasingly popular tourist destination, ranking 203rd in the world and 10th in Italy in 2008, with about 240,000 international arrivals. The Egyptian Museum of Turin specializes in archaeology and anthropology, in particular the Art of Ancient Egypt. It is home to what is regarded as one of the largest collections of Egyptian antiquities outside of Egypt. In 2006 it received more than 500,000 visitors. The Museum of Oriental Art houses one of the most important Asian art collections in Italy.

Figure 1-18 The royal palace of Turin

Figure 1-19 The inside of the Egyptian museum

1.3 FIAT Mirafiori Factory

By 1910, Fiat was the largest automotive company in Italy—a position it has retained since. That same year, a new plant was built in Poughkeepsie, NY, by the newly founded American F.I.A.T. Automobile Company. Owning a Fiat at that time was a sign of distinction. The cost of a Fiat in the US was initially $4,000 and rose up to $6,400 in 1918, compared to $ 825 for a Ford Model T in 1908, and $ 525 in 1918, respectively. During World War I, Fiat had to devote all of its factories to supplying the Allies with aircraft, engines, machine guns, trucks, and ambulances. Upon the entry of the US into the war in 1917, the factory was shut down as

US regulations became too burdensome [citation needed]. After the war, Fiat introduced its first tractor, the 702. By the early 1920s, Fiat had a market share in Italy of 80%.

After only one decade of activity the FIAT Lingotto factory became under sized for the production demand and in in 1936 a new design for a bigger plant started:3 years later it was already operative.. The company chose the southern district of Mirafiori, west of Lingotto. The most famous part of the complex is still the office building [gate 1], built with the Finale Ligure white stone. Along with Lingotto complex, this isone of the symbols of the FIAT group. Car production only started after 1947 due to the World War II damages as during the conflict the factory was heavily bombarded.

The concept of an integrated factory was completed during the booming ‘60s, when a new complex was built south of the original core, called “Mirafiori-Sud”. With 2.000.000 square meters it’s still today the largest factory in Italy.

Mirafiori started experiencing a strong downturn from the late ‘90s: FIAT began to relocate productions to other sites, in Southern Italy and abroad, due to cost cutting. Along with the models’ reduction in the FIAT range -once the group’s largest factory and now surpassed by the plants located in Brazil and Poland - began to be reduced as well.

*The number of workers dropped from 40.000in the 80’s to the actual 5.400. It’s time for Mirafiori neighborhood to return to be vibrant, now with agriculture and dwellings as an option for the city.

Figure 1-20 FIAT Mirafiori Sud- Site photos

1.4 Urban Agriculture [5]

Definition: The expression "Urban Agriculture" is originally used only by scholars and the media, and then been adopted by a lot of agenda. It has been broadly defined as:

"All agricultural activities located within (intra-urban) or on periphery (peri-urban) of a settlement, city or metropolis, independently or collectively developed by people for self-consumption or commercialized purpose".

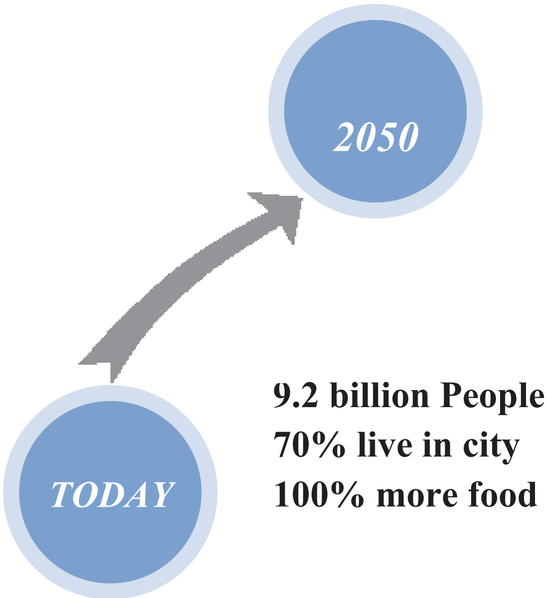
Main Actors: Many actors are involved in Urban Agriculture; they are the suppliers of resources, inputs services, the producers, the transporters, the retailers, the consumers, the promoters and the managers. These actors pertain to the public and private sectors, the formal and the informal economy.

Suitable Areas: Areas used for agriculture are of all sizes, from tiny home spaces (windowsills, containers, fences, rooftops, basements, walls) to recreational grounds, utility and transportation rights-of-way (stream or roadsides), to suburban public or private estates. On the other hand, those areas are used in a complementary way.

1.5 Why Urban Agriculture? [6]

Food supply:

World population is expected to increase by 1.8 billion as of 2030 and by 2.5 billion as of 2050, reaching 9.2 billion. Food demand is expected to increase by 50 percent by 2030 and 100 percent by 2050, because of continued population growth and higher incomes.



Limited Recourses:

People are accustomed to being able to find whether domestic or exotic foods all the year around in the supermarket. Thanks to the technologies of farming and distribution, people are enjoying this convenience and easiness of urban life. However, when this pattern of food consumption is being formed, few people know that such a common daily habit bring a whole range of costs.

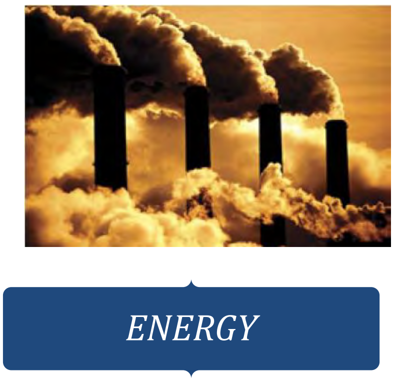


Figure 1-22-Energy Crisis

Figure 1-21- Deforesting

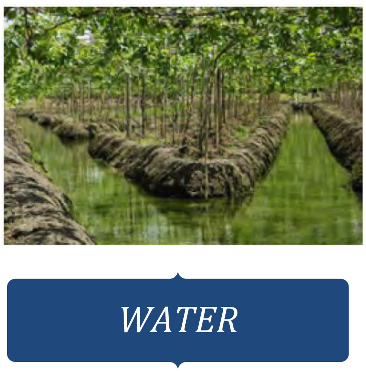
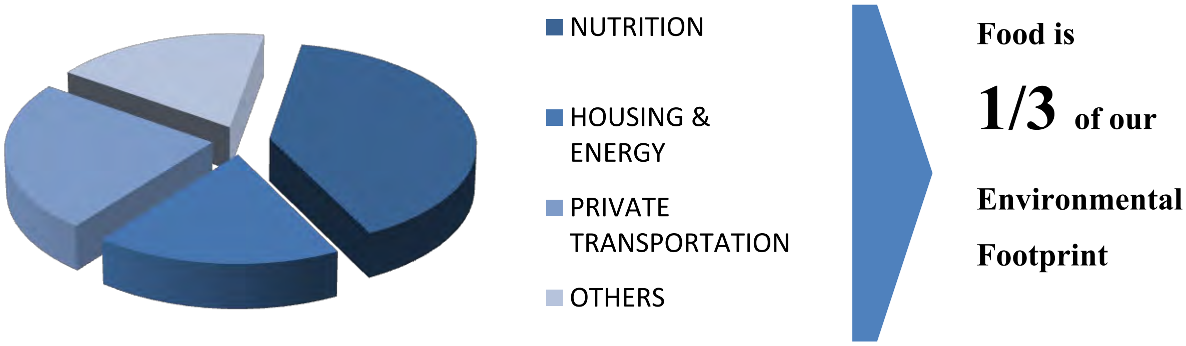


Figure 1-23- Water scarcity

Environmental Footprint [7]

Worldwide, agriculture and related up-stream activities such as fertilizer manufacture plus land use change are responsible for about one third of the world's greenhouse gas emissions.



Water

On average, agricultural products use 70% of all freshwater withdrawals and this is only 20% of all water used in agriculture. The rest comes from rainfall, and therefore it is clear that the dry regions of the world tend to rely on vast amounts of water for irrigation. For millions of people it is a challenge to produce sufficient amounts of food when dealing with periods of drought.

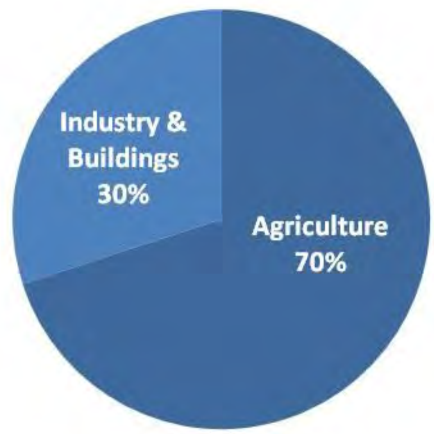


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Figure 1-24- Global fresh water withdraw

Energy [8]

There is dependence on energy throughout the food chain: from the manufacture and application of agricultural inputs, such as fertilizers and irrigation, through crop and livestock production, processing and packaging, distribution services, cold storage, disposal equipment in food retailing and in home kitchens. It was estimated that vegetables have traveled 2000 kilometers on average before them arrive the store where people buy it.

1.6 Urban Agriculture advantages

As cities continue to grow, more and more resources will be channeled into them generating more waste in the form of urban wastewater. The larger the growth in population, the larger the volume of wastewater generated. Thus, the current urban population growth trend will correlate to urban wastewater as an ever-growing resource for water as well as nutrients in it.

1.6.1 Water efficiency [9]

Conventional System (Open-loop)

Conventionally, in the developed world, urban wastewater moves through an extensive network of hidden infrastructure to large-scale, centralized wastewater treatment facilities that remove suspended and dissolved toxins and then discharge the treated water into oceans and freshwater bodies. Even where extensive, responsible wastewater infrastructure exists, in many developed countries it is showing its age. Water pollution, soil contamination and spread of waterborne diseases due to leakage and spillage are increasing, costing the local government and the residents in terms of both health and wealth. The prospect of reinstalling a new city-wide network for wastewater collection and treatment is tremendously daunting to local governments.

Figure 1-25 Conventional System of urban water treatment

Contemporary system (Closed-loop)

Localized, individual fixes in the next couple of decades will cost billions of dollars. Thus, regarded in the context of long-term viability, an ecological and economical approach that advocates decentralizing the process in order to treat water locally and naturally and allow it the opportunity to be reabsorbed back in the local ecosystem emerges as the best solution. This on-site wastewater treatment and reuse mimics the closed cycle of a natural ecosystem. As illustrated in below, this decentralized system will regenerate the urban ecosystem, manage urban wastewater and serve as a building block for a green economy by way of urban farms.

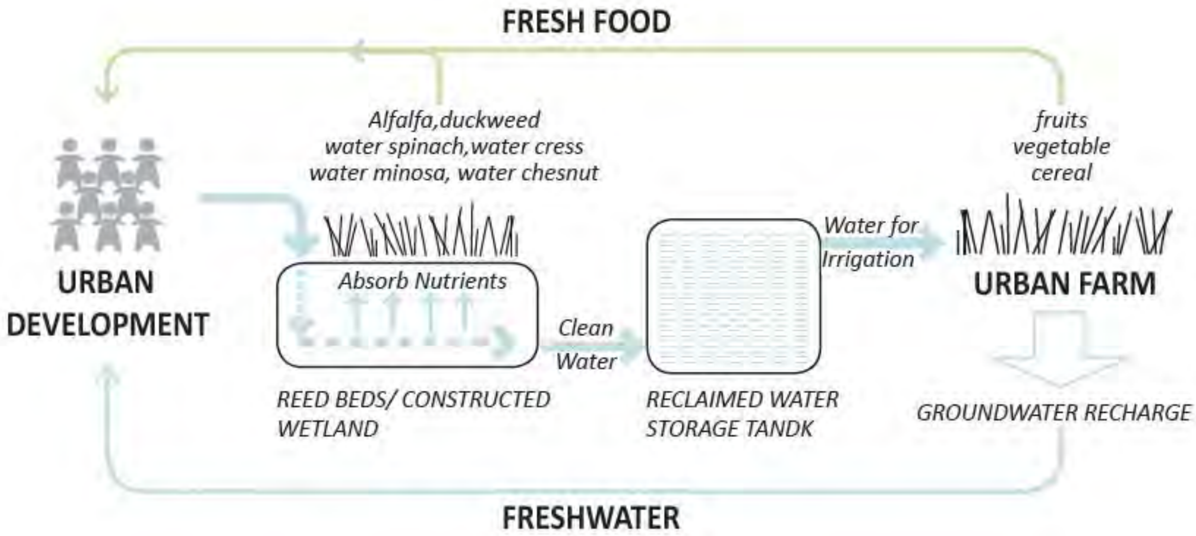


Figure 1-26 Closed-loop water system

1.6.2 Waste management [10]

The combination of urban organic wastes and urban agriculture creates particular issues in the modern urban setting. On the one hand, the interests of urban waste reduction mesh well with the promotion of urban agriculture, since urban and peri-urban farmers are in need of organic matter as soil conditioner/ fertilizer and animal feed, and cities and towns wish to conserve disposal space and reduce the costs of municipal solid waste management.

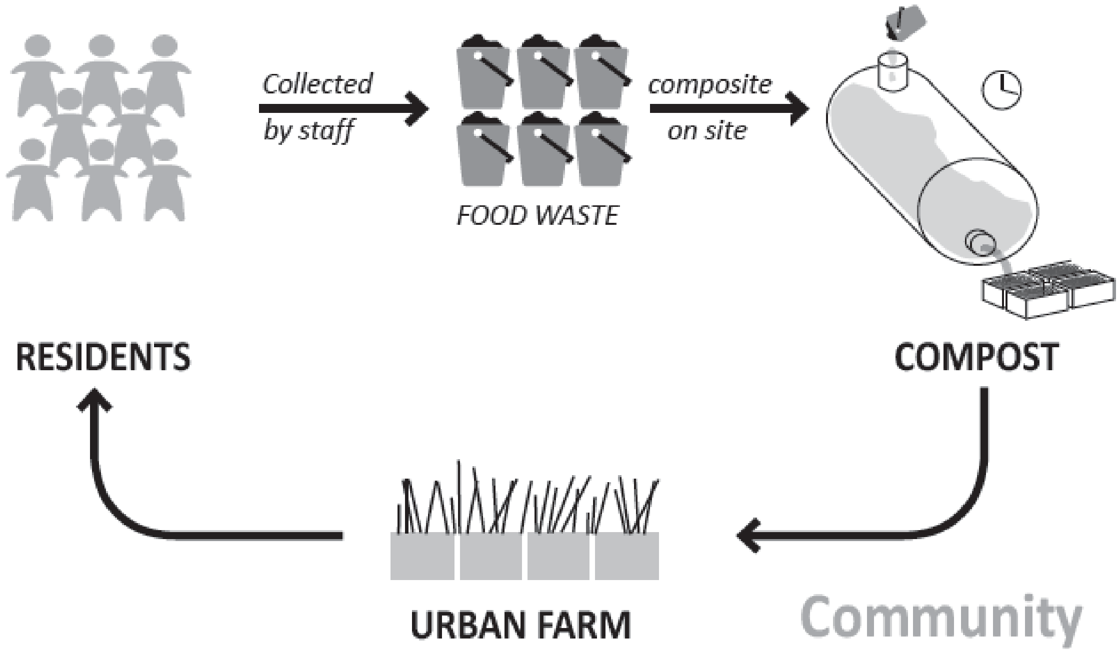


Figure 1-27 Waste reuse system

1.6.3 Other advantages [11]

Urban agriculture involves many different types of food-producing spaces, stakeholders, resources, and policies, and it contributes too many benefits.

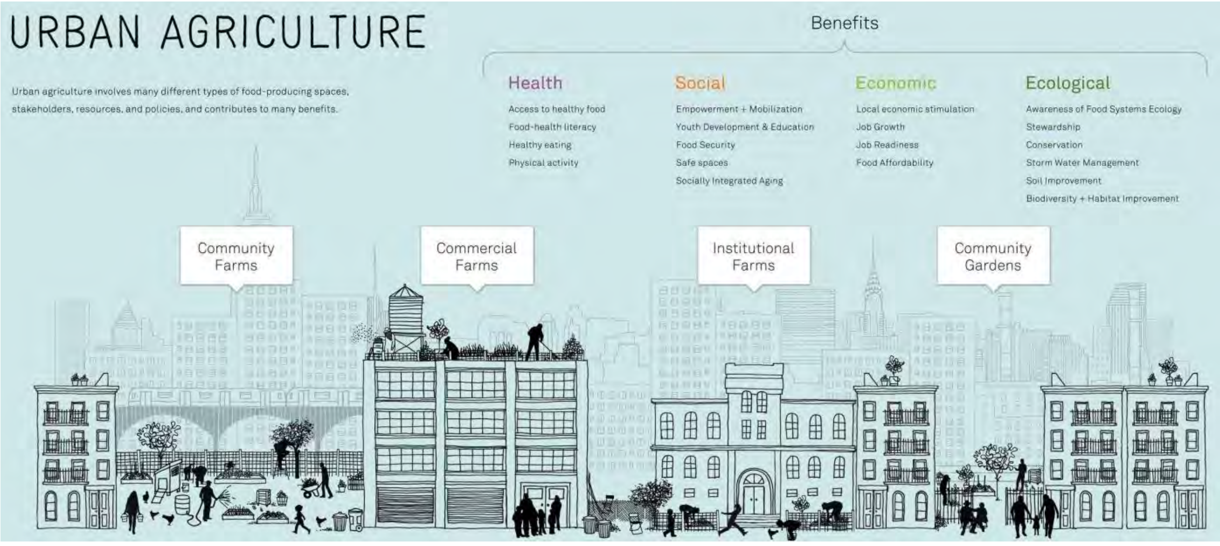


Figure 1-28 Urban Agricultural types and benefits

Health:
To improve the health of participants through providing access to fresh and safe food, involving people in farming as physical activity

Educational:
Motivating people to have healthy diet that to consume more vegetable and fruits, educating people the relationship between nutrition and food.

Social:
Transforming the vacant public space to urban farms to offer spaces for people to meet and working together. Residents in the neighborhood establish and join the Community based organizations and institutions in order to operation to farms.

Economical:
The farmers market helps getting income form selling what they grow. Some of the farms provide jobs of managing farm operations and participating in leadership programs, and this will atrract more tourists to consume here.

CHAPTER 2

URBAN DESIGN

2.1 General Objectives

To provide the Urban, Architectural, Structural, Technological and Energy Solutions that can satisfy the requirements established by the competition by taking into consideration the state of art in matter of technologies, techniques and strategies aiming to save energy and indirectly to exclude the use of fossil based fuels.

For Consideration of the area where the urban analysis has to be made, a regional scale investigation including relationships between public spaces, green, residential, industrial and infrastructural has been developed. We tried to elaborate the potential futuristic role that this area can play as a new urban-agriculture hub in order to be a good example and start point for this recent approach toward sustainable urbanism.

2.2 Local Scale Analysis

The competition site area, located in South Mirafiori of Turin, used to be a parking lot for the stock of the newly produced cars. It has been a barrier to the expansion and integration of the neighbourhood.

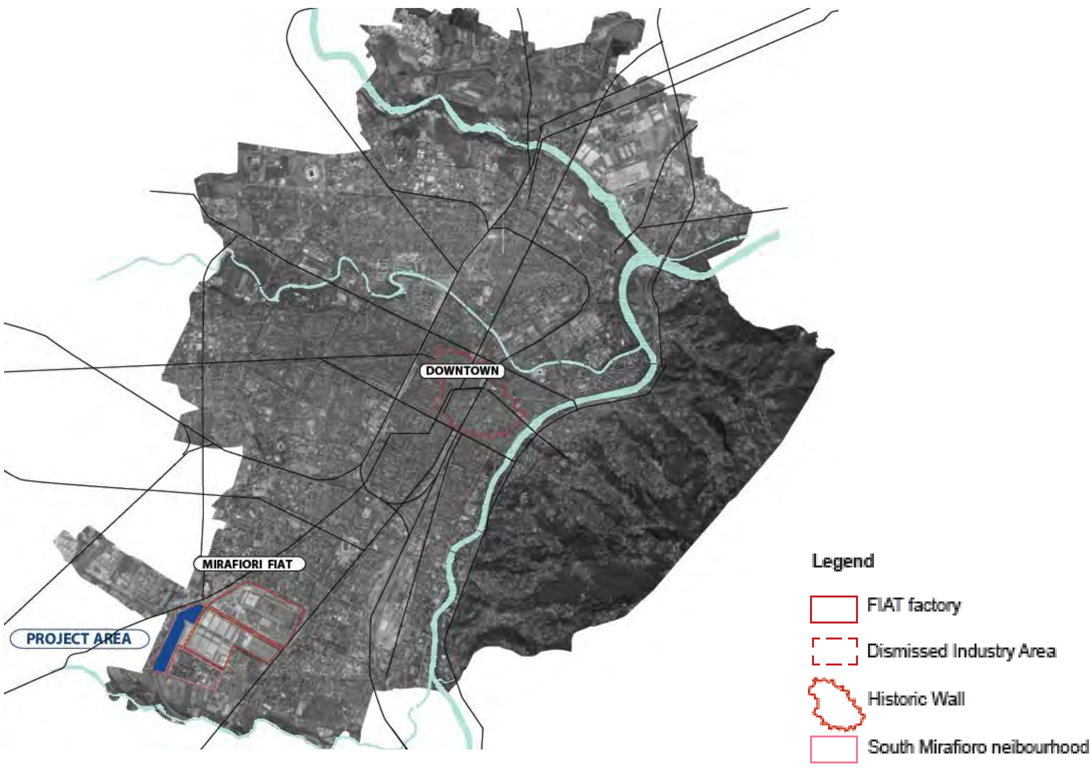


Figure 2-1 Site Location[12]

2.2.1 Rural areas around the site

Right to the area is the small village of Beinasco, which is now integrated with Turin, the site is the transition area between urban and rural.

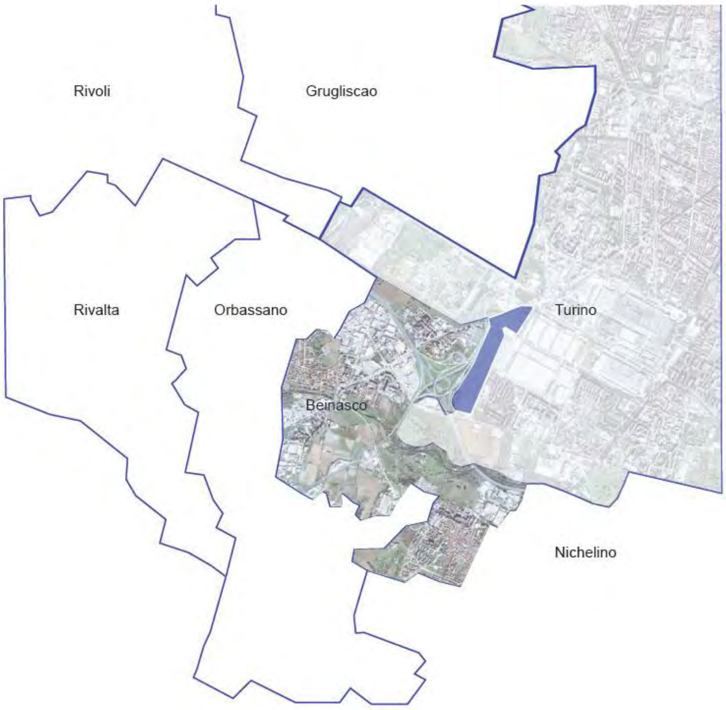


Figure 2-2 Administration boundary of Turin and the surrounding rural areas [12]

2.2.2 Industrial areas

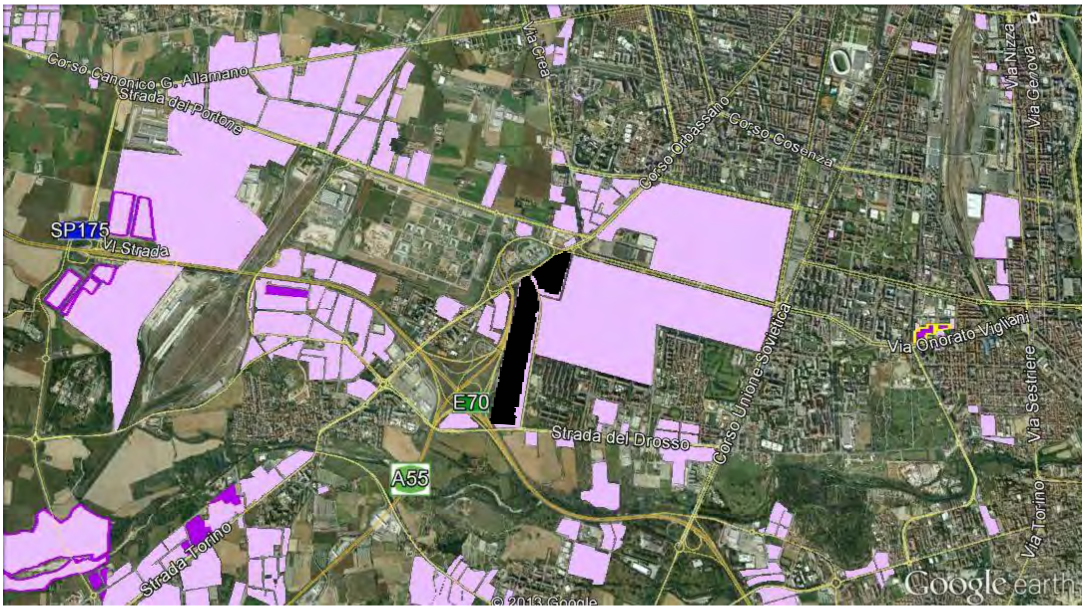


Figure 2-3 Industrial areas [3]

2.2.3 Residential areas and mixed use

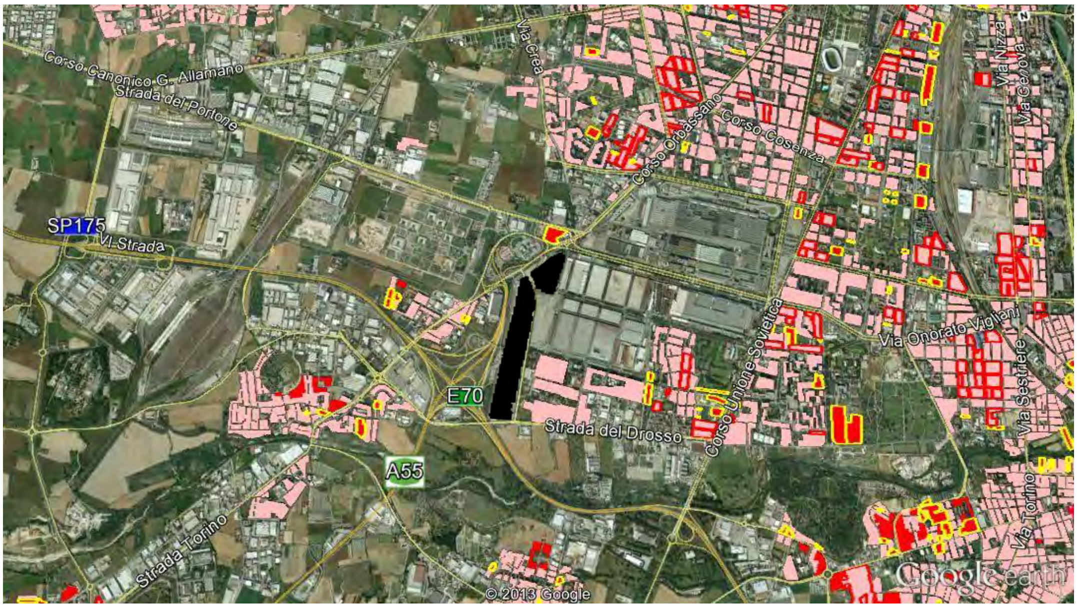


Figure 2-4 Residential and mixed use [3]

2.2.4 Existing and future infrastructure

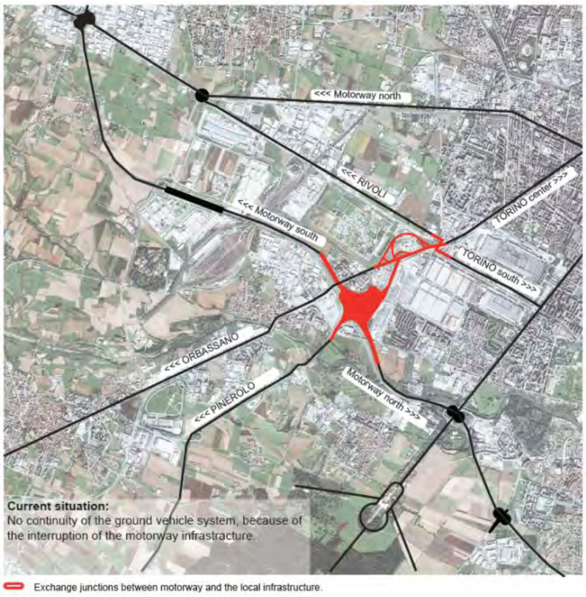


Figure 2-5 The existing situtaion of the infrastructure system [14]

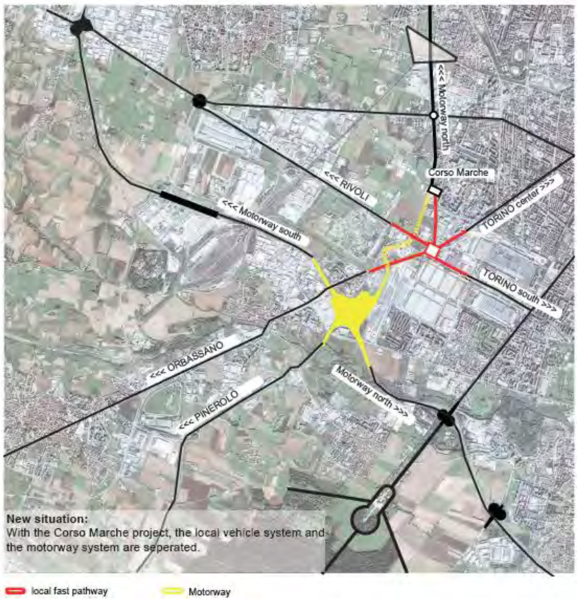


Figure 2-6 - The reorganized situation of the infrastructure system as in PUMS [14]

Current situation: No continuity of the ground vehicle system, because of the interruption of the motorway infrastructure.

New situation: With the Corso Marche project, the local vehicle system and the motorway system are separated. Further analysis on land usage can help us to understand better the contextual importance of the Fiat Mirafiori region in terms of diversity, functional content, accessibility and etc.

2.2.5 Green and Open spaces

Figure 2-7 Green and open space [14]

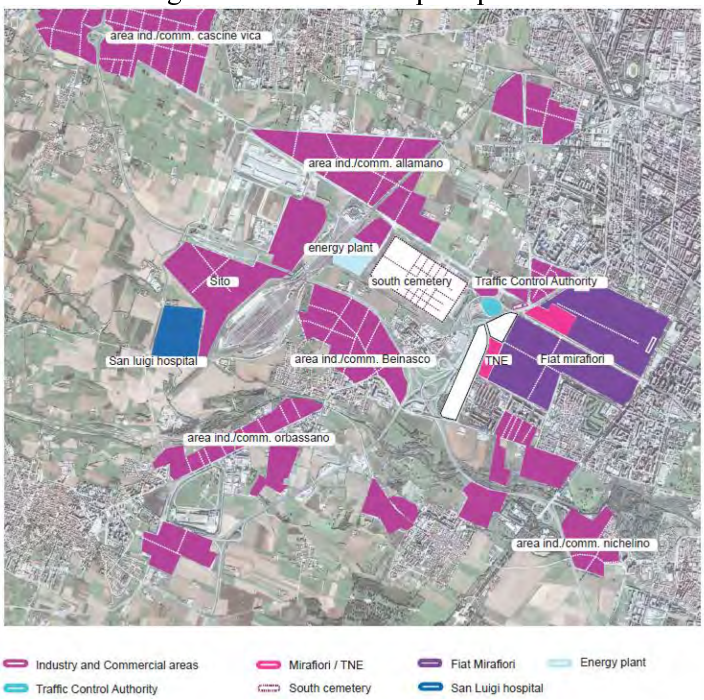


Figure 2-8 The Main features of around [14]

2.2.6 Conclusion

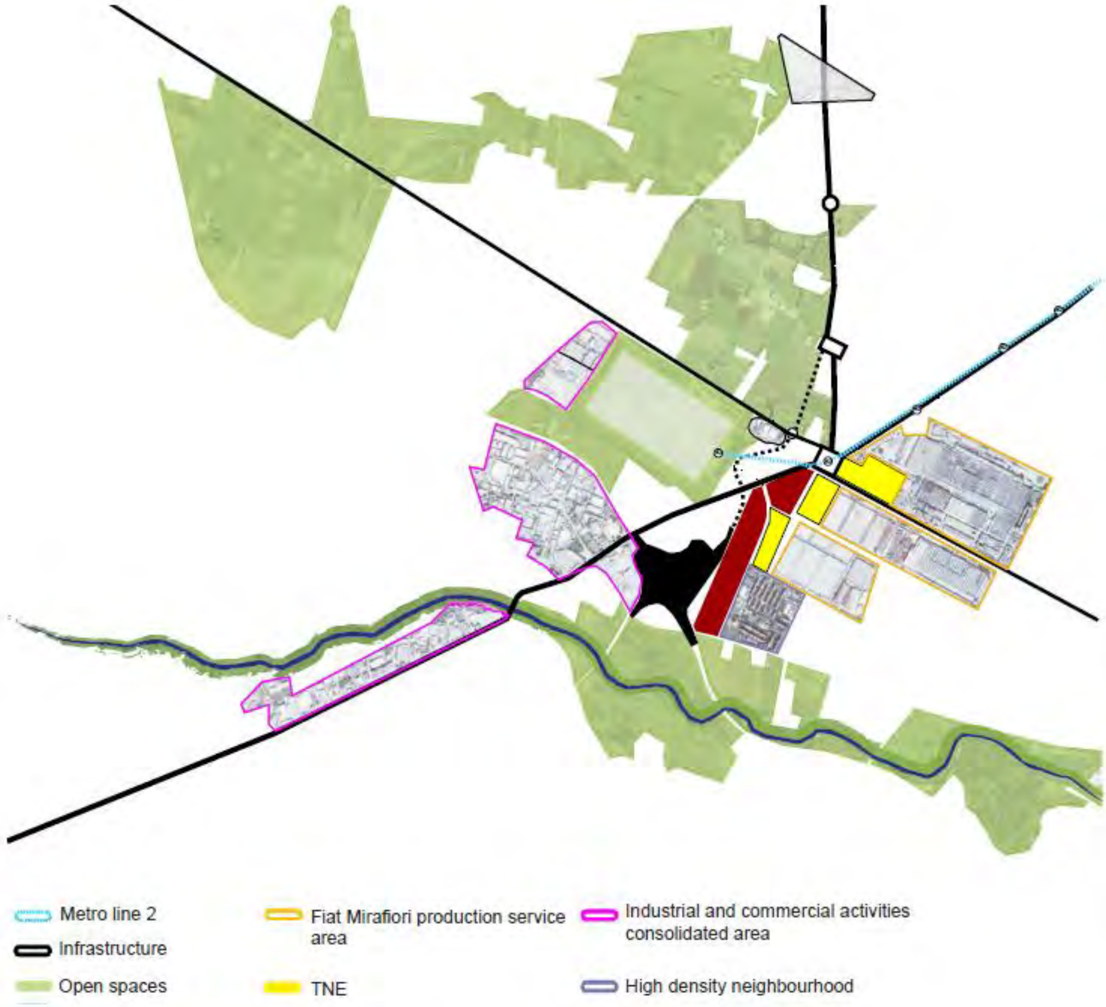


Figure 2-9 Selected important features of the site surrounding area

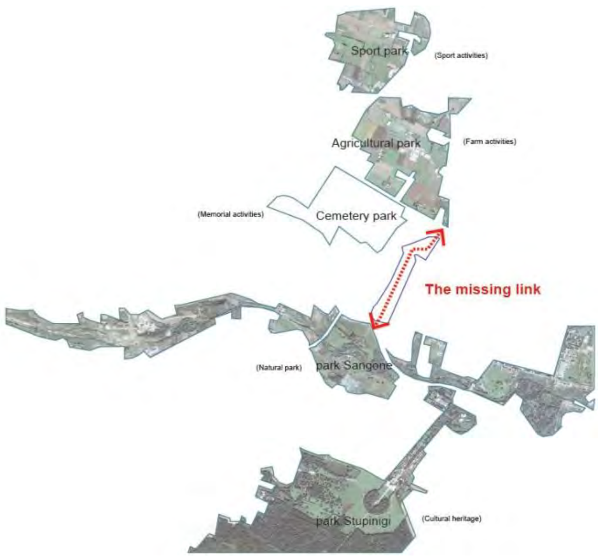


Figure 2-10 The recreational spaces

The open space of the community could be integrated to the city recreational structure, used by citizens for the recreational activities.As it can be seen the land use analysis shown a set of residential and agricultural lands with presence of dense industrial areas which are some abandoned and can be redeveloped or reused.

This can be perceived as a big opportunity as a added value to the city of Turin. On the other hand the site context has very low diversity and lack of mixed use functional contents which affect the mobility and socio economics.

The presence of relatively large amount of scattered green and agricultural areas gives the potentiality of the relevant transformation and creation of an ecological network, improving the resident's quality of life. The farmland border areas in large towns have always been considered as areas waiting to be built on. But recently inhabitants of these cities increasingly seek “country side”, free spaces and places where farming plays a renewed role in producing goods and food, near to the people, but also an educational and multifunctional role in a relationship between development and sustainability.

2.3 Site Scale Analysis

In accordance to previous analysis we continue our studies to the neighborhood scale. This can help us to figure out how this land which is used as a parking lot for FIAT factory has affected the surrounding and what can be achieved or solved by redeveloping of the area. Following are the most significant places around the site.

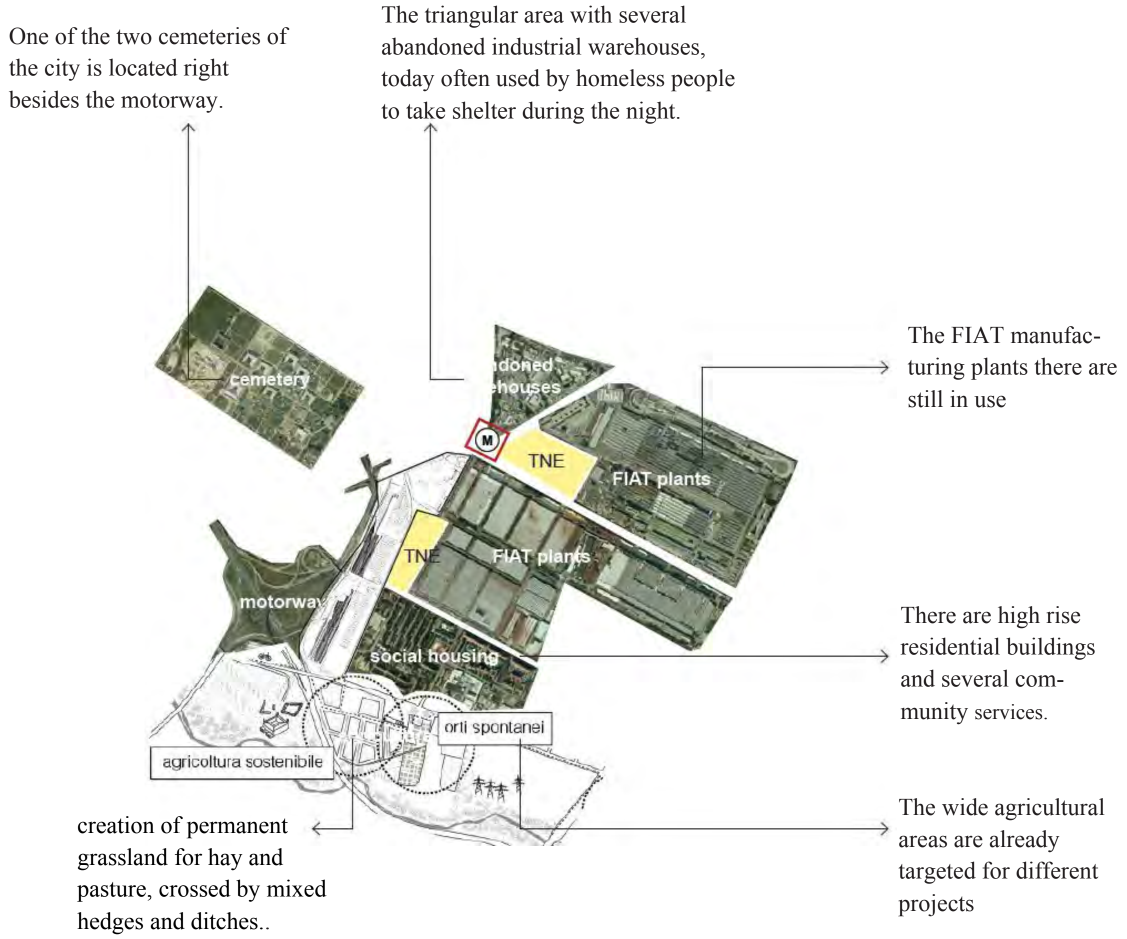


Figure 2-11 The important features of the site

2.3.1 Surrounding Relevant Functions [1]

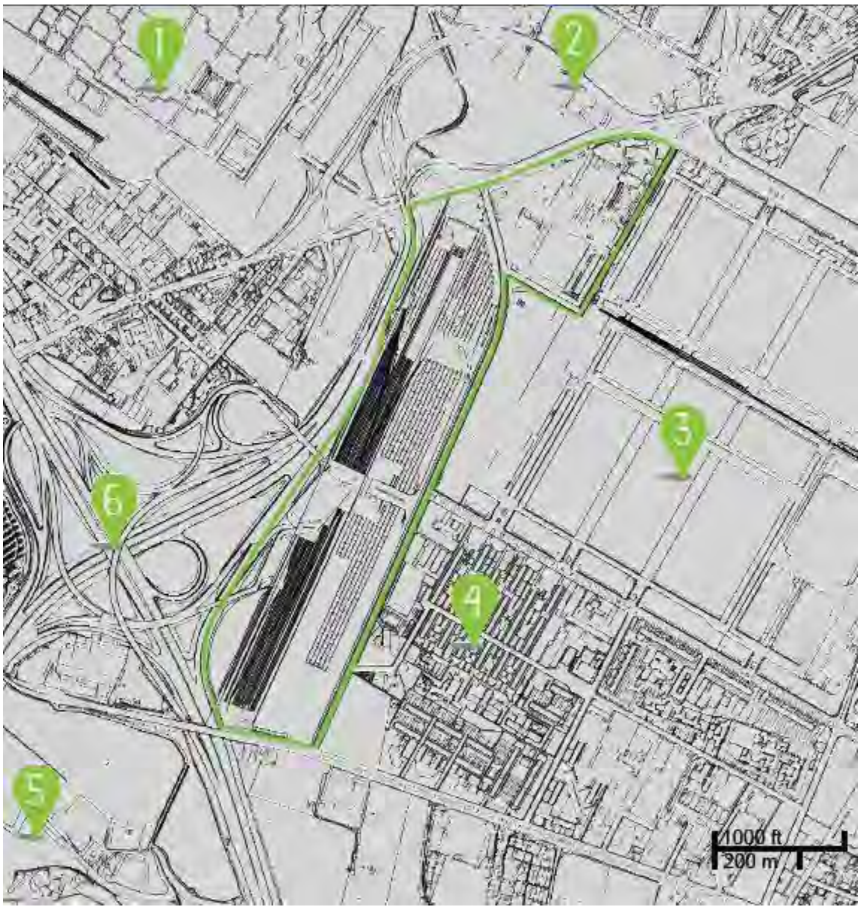


Figure 2-12 Site surroundings

2.3.2 Turin's cemetery park [1]

The Cemetery Park is the second biggest cemetery in Turin, inaugurated in 1972, after the exceptional growth of the population at the end of World War II, which induced the Civic Administration to foresee an increase of the cemetery structures.

Being impossible to make further amplifications of the already existing Monumental Cemetery of the city, it seemed essential to build a new complex, opportunely situated at the opposite city outskirts. in 2010 part of the cemetery has been reorganized by the local architect Massimo Ra-schiatore: the design reinterprets the naturalistic character, giving continuity to the traditional "Italian historical garden", where the idea of nature dominated by geometry finds solutions in the creation of artificial hillocks to hide the burial complexes.

Currently, besides the Evangelical field, there's also an area dedicated to the Islamic community.

*Turin's Cemetery Park is becoming a place of interest and a landmark in this area of the city; the compulsory buffer area around it [200m] helped to preserve the agricultural and green feature of the area.

Figure 2-13 Turin's cemetery park

2.3.3 Social Housing and Residential Buildings [1]

The residential buildings in the neighborhood tell the story of this part of the city. In the early '20s this has been one of the areas where people from the city were building their sub urban cottages, known as "villino". There are still owned by families whose origins are from Turin or from the North East of Italy.

From the beginning of the '60s Turin becomes the undisputed destination of the massive immigration following the growing cars production and the job availability. The population of South Mirafiori increased from around 3.000 up to 20.000. High rise prefabricated buildings were built to prevent - and partially to eliminate - the slum effect that was going to start. This has been the area with the highest quantity of social housing units built in Turin and in North Italy. A side of this, FIAT built its own complex, several blocks, with low rising buildings (4 floors), better quality and all the services such as sport facilities, a school, a church. The downside was that those were exclusive for FIAT employees with some "high ranking score" in the factory.

*Besides the “villini” very few private developments have been realized. Despite the lower quality of the buildings, the massive use of social housing has allowed higher standards in the design of public spaces, green areas and services: as a result Mirafiori is an interesting example of urban planning.

Figure 2-14 Residential Buildings

2.3.4 Drosso Castel [1]

It’s a medieval castle of historical-artistic value (chapel, park and rural complex): exceptional example of an ancient flatland structure, with a complex stratification of parts.

The Drosso castle and the pertinences were feud of the Monks of Staffarda, then owned by Turin’s bishop. In 1334 passed to the Gorzanis family, then to the Vagnones and, atthe end of the XVI century, it became property of the Gromes, the current owners.

The castle, inhabited since many years, unluckily has been heavily transformed in the XVIII and XIX centuries. Today the castle is abandoned but represents an important potentialfor its historical and environmental features. It has to be considered as an attractive focal pointin South Mirafiori, easily connected with the other projects.

Figure 2-15 Drosso Castel

2.3.5 Motorway junction [1]

The idea of building a motorway ramification from Turin to Pinerolo started in the '60s, after the increase of transit towards Pinerolo and its valleys (Chisone valley particularly).

The completion of the ramification has drastically reduced the journey duration between Turin and Pinerolo. Located right between Mirafiori and Beinasco, the motorway to Pinerolo is connected to the South ringroad; the complex geometry of the junction cover a huge green area, previously agricultural, and creates a physical barrier between Mirafiori neighborhood and Beinasco. The motorway junction connects Turin with all the smaller cities and villages in the south west axis; the downside is that divides the southern discrict in two bits, creating segregation and isolation.

Figure 2-16 Motorway junction

2.3.6 Facilities [1]

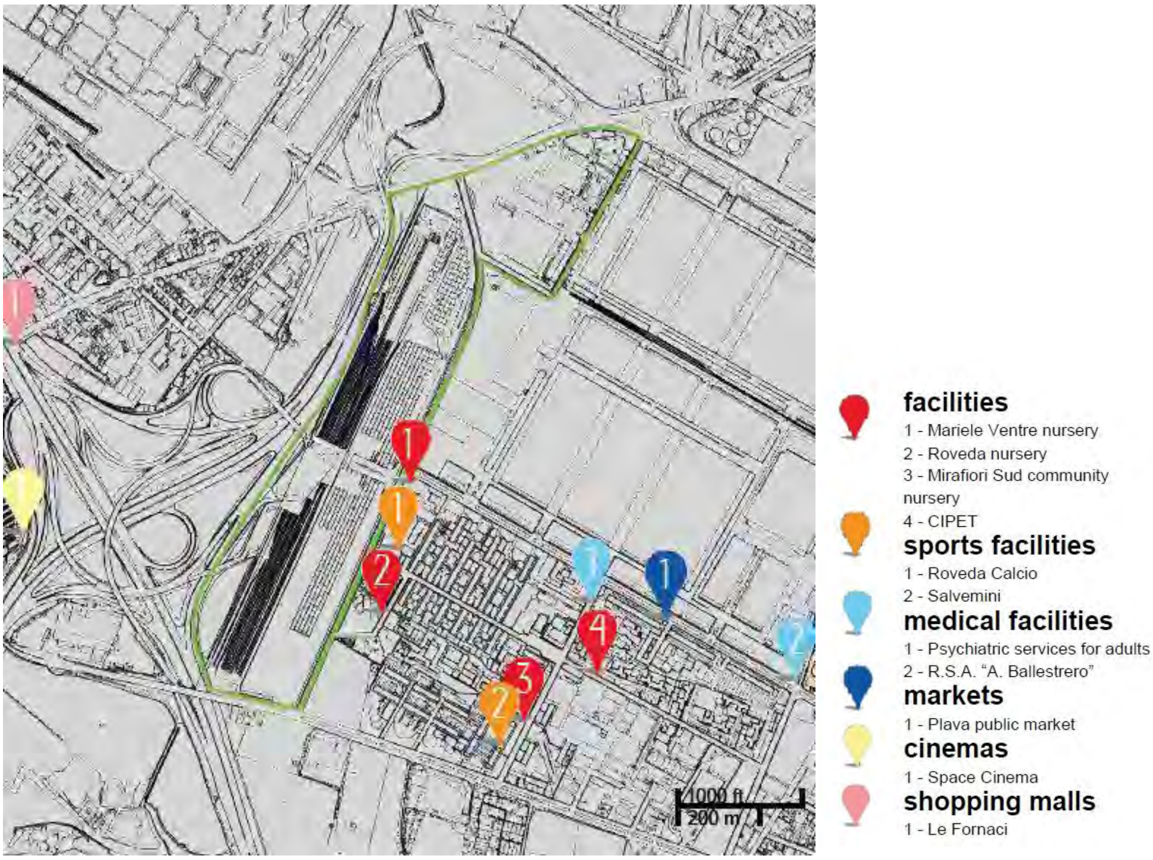


Figure 2-17 Facilities

In terms of facilities what we can see is a significant lack of public facilities due to very dense industrial zone as well as distance from the city center. This shows lack of public attraction spots which cause social integration and diversity. Existing sport facilities has to be renovated and still wouldn't be enough for further development of the area.

2.3.7 Site Photos [1]

For further studies a site visit has been made but unfortunately to enter the parking lot was not allowed. Following are the photos which were taken around the parking's wall.

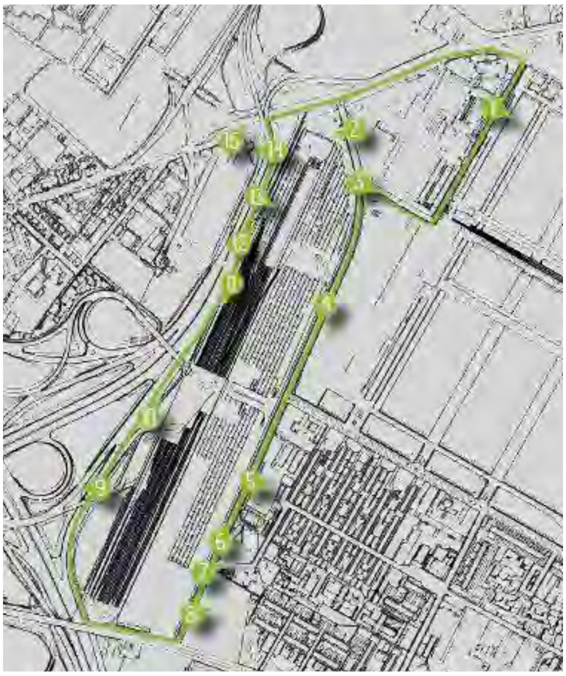


Figure 2-18
Immediate
surroundings

Figure 2-19 Site Photos

2.3.8 SWOT Analysis

Strengths

- The city already has an efficient mobility grid in place which is in conjunction with the national and European grid system.
- There is already a strong relationship between the two stations.
- The site has good accessibility and a richly woven public transportation system.
- There is a lot of green area present along the site.

Weaknesses

- No proper bicycle and pedestrian path exists.
- The relocation of FIAT has had negative impacts on the economy of Turin.
- There is no existing connection between the two parts.
- Lack of connection between the systems of green areas in the city.

Opportunities

- The central location of the station can be used to bring considerable order to the city.
- The presence of beautiful natural surroundings in connection with the mountainous areas could be a positive aspect.
- Our site being the final terminus for the underground line 2 will be an opportunity for us to create core central point in our system.
- Creating a mix of occupations and destinations in order to have an active life in the area.

Threats

- A lot of noise and air pollution is expected due to the rapid growth of the city.
- The recent economic initiatives have not proven to be successful and not much revenue has been realized in most of the investments made to the city during the recent years.
- High speed vehicular circulation can be a threat to the pedestrian and cycle movement.
- There is an obvious lack of architectural identity, and a lot of dead spaces can be found throughout the city.

2.3.9 Potential and Problems of the site

According to the previous analysis of all the information related to the site investigation, we evaluated the Potential and Problems of the site, which can be resulted, the following:

1. Existing geometry:
With a sunk space 6m below the ground level

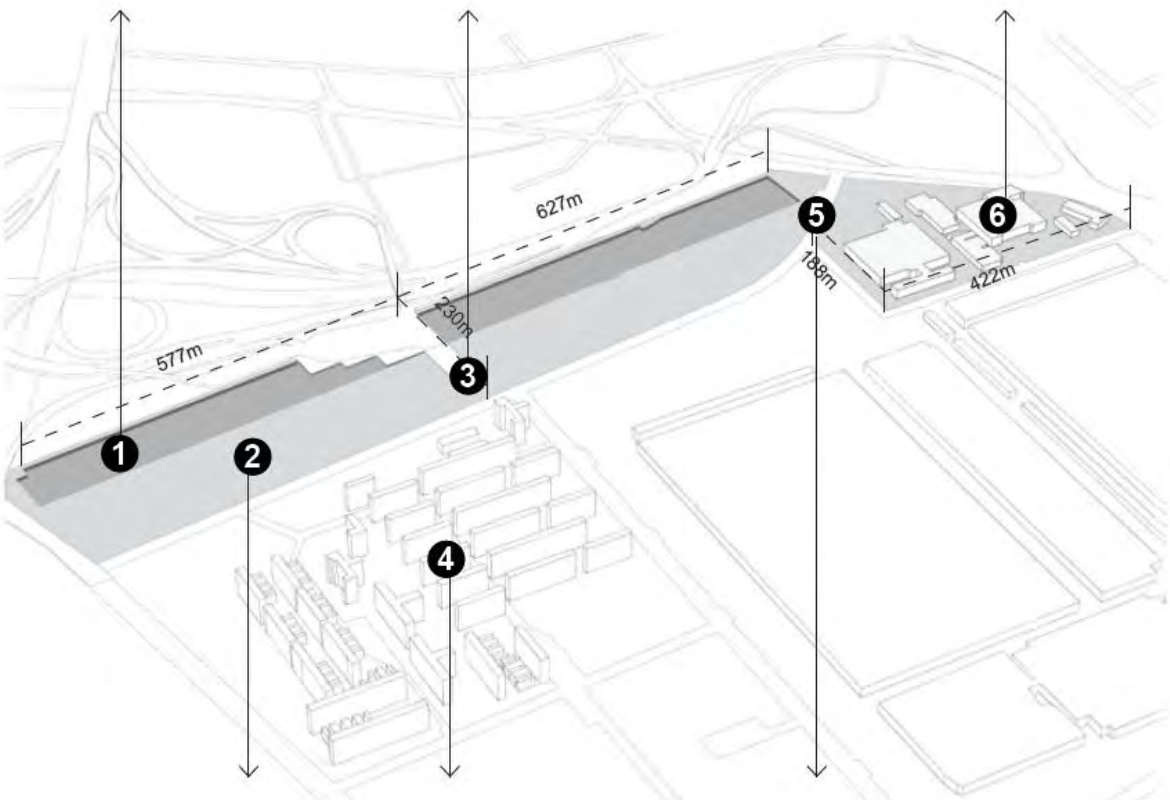
Respect the situation; make use of the different height

3. Existing underground path

The design will enlarge this under pass, and think about add other pass.

6. Existing buildings:
These are recent built buildings with poor conditions which are not sustainable in terms of reservation cost.

Demolish materials will be reused by the adjacent TNE project.



2. Parking lots
for the stock of newly produced cars

The space will be given new programs and increase the property values

4. High density community

The habitants here will be a certain flow for the site

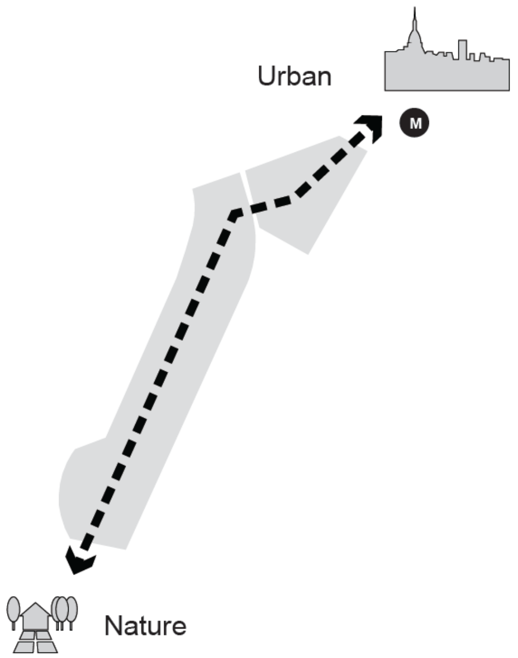
5. Exisiting underground path

The design will not keep this under pass. But create new pass to enhance this connection.

2.4 Toward the Design

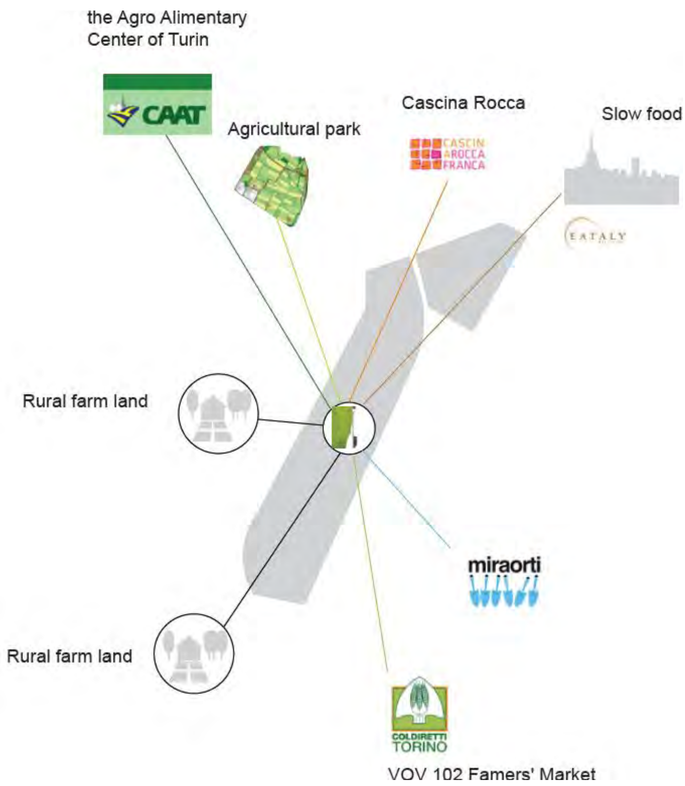
Figure 2-20 Existing urban scenario

2.4.1 Green Corridor:



- To make Green Corridor as a green bridge connecting green spaces around the south of Mirafiori.
- To propose and underline in detail the main ecological network of the city, as a buffer zone that should be protected from the environmental and sustainability point of view, and which will give a balance between the open green spaces and the urban areas to be

Figure 2-21 Flow from city to countryside cross the site



- To provide agricultural green spaces as a link between organizations like Miraorti and local schools to promote urban agriculture.
- To take advantage of the interesting heritage buildings like castle Drosso and others around and reconnect them to the city.
- To take advantage of the vast agricultural zones around as a possible future development of agro-tourism.

Figure 2-22 Agricultural Network

- To enhance the pedestrian activity of the intervention zone by means of rescaling the uses of roads to a human scale.
- To overlap and redefine pedestrian connections of residential area with those concerning the Green corridor.
- To provide transversal connection for non-inhabitants and inhabitants to eco-tourism activities, taking advantage of the TURINTOGREEN project proximity to the city, and its connectivity from the main gateways of the city.

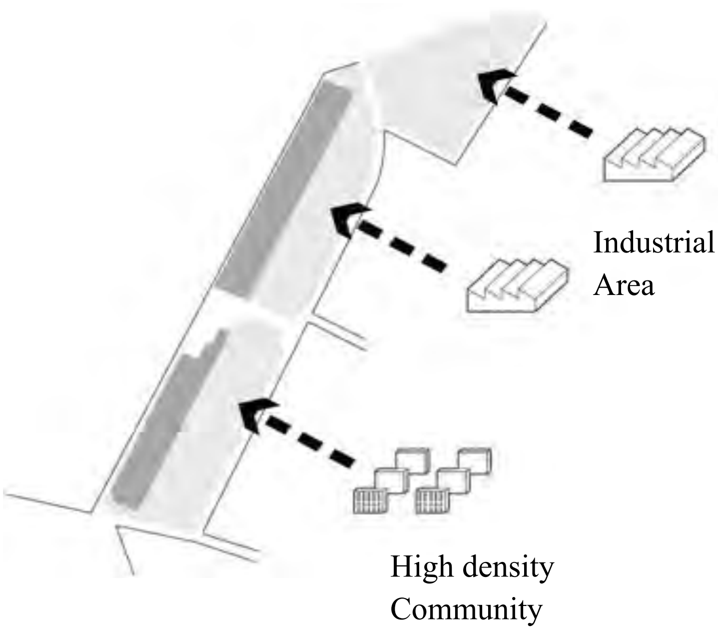


Figure 2-23 Connection to the neighborhood

2.4.2 Density of each area

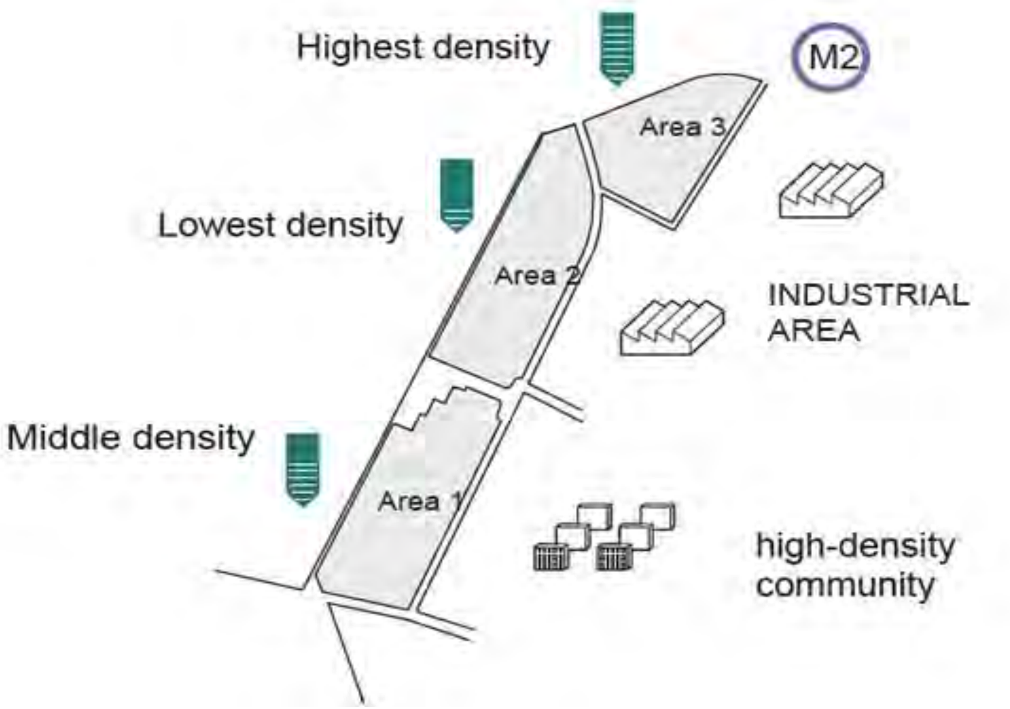


Figure 2-24 Density of area

- **Area 1** is next to the high-density community, In order to balance the density of the area, this area has less residential area, but provides more open spaces which area shared with the neighbourhood.

- **Area 2** has a lowest density, this area behave as an interaction point with different shared and open spaces and public buildings.

- **Area 3** adjacent with the new Mirafiori piazza and the Metro station of line 2, these give the area a good accessibility, therefore the area is more urban.

2.4.3 Define of public spaces:

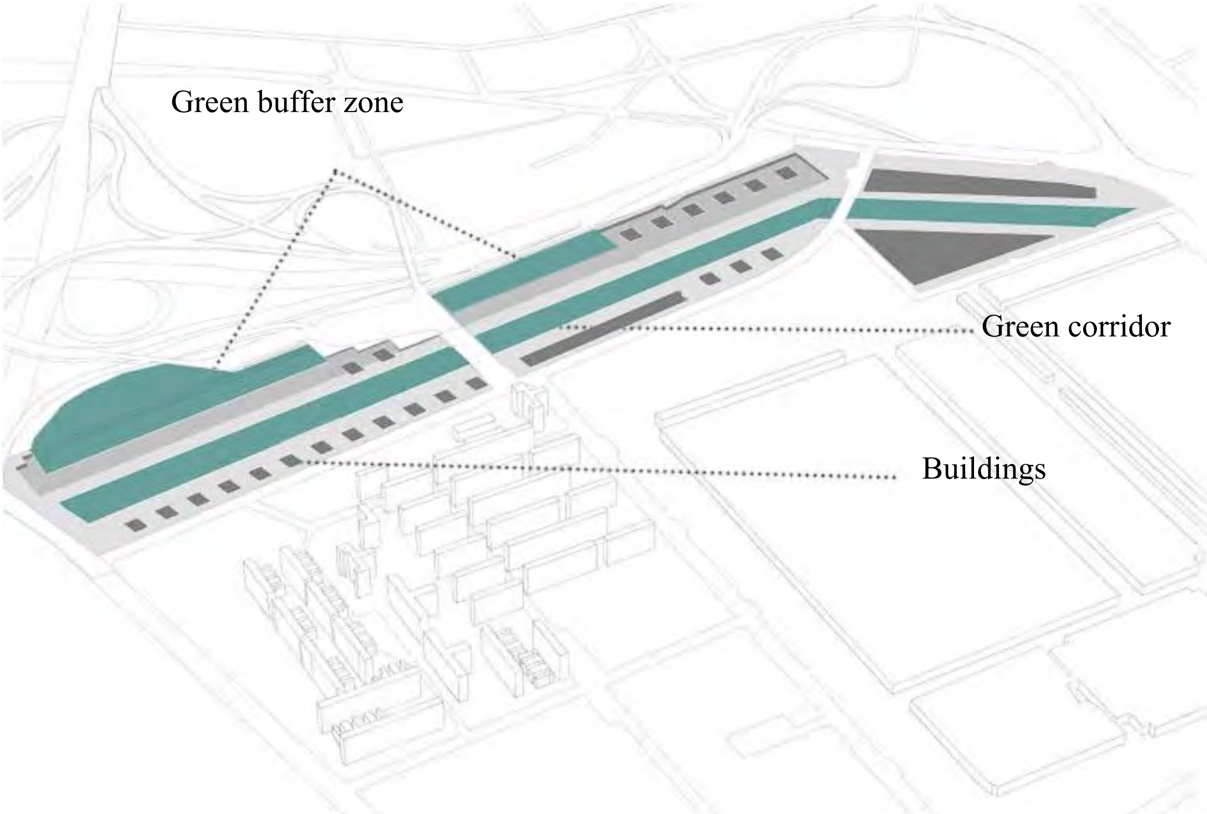


Figure 2-25 Connection to the neighborhood

With the analysis for the gateways and thresholds of the city we encountered a good connectivity of the City with the region in general. Access to the city can be made by means of train, car and bus. The train is a good connector with the northern and southern parts of the region. However a good connection between east and west is lacking.

We identified as important gateways and thresholds of the area the train station. However this threshold is not used to its higher potential because of the poor street configuration towards the train station itself from the city.

- To enhance and redesign the considered "not well used" public spaces which are localized in strategic positions throughout the Green Corridor and the nearby residential and commercial areas.
- To redefine the activities developed in the main public spaces which exist throughout the Green Corridor.
  - To redesign an existing area to become the new main cultural hub & entertainment center for the citizens of South-Torino/ Mirafiori region.

-Road interventions:

- To redefine the use of the provincial road considering the proposals given by the and the potentials and constrains of this node for the city.
- To solve the connectivity problem between different parts of the area in critical zones - such as some intersections in the provincial road/ highway and neighborhood roads.
- To provide a solution for the traffic problems presented in the area due to heavy-traffic and light traffic that does not belong to the zone.
- To plant more trees and make a dense green buffer as part of green corridor along the highway and site boundary with nature trails as active public spaces.

2.4.4 Urban Agriculture and Agro tourism

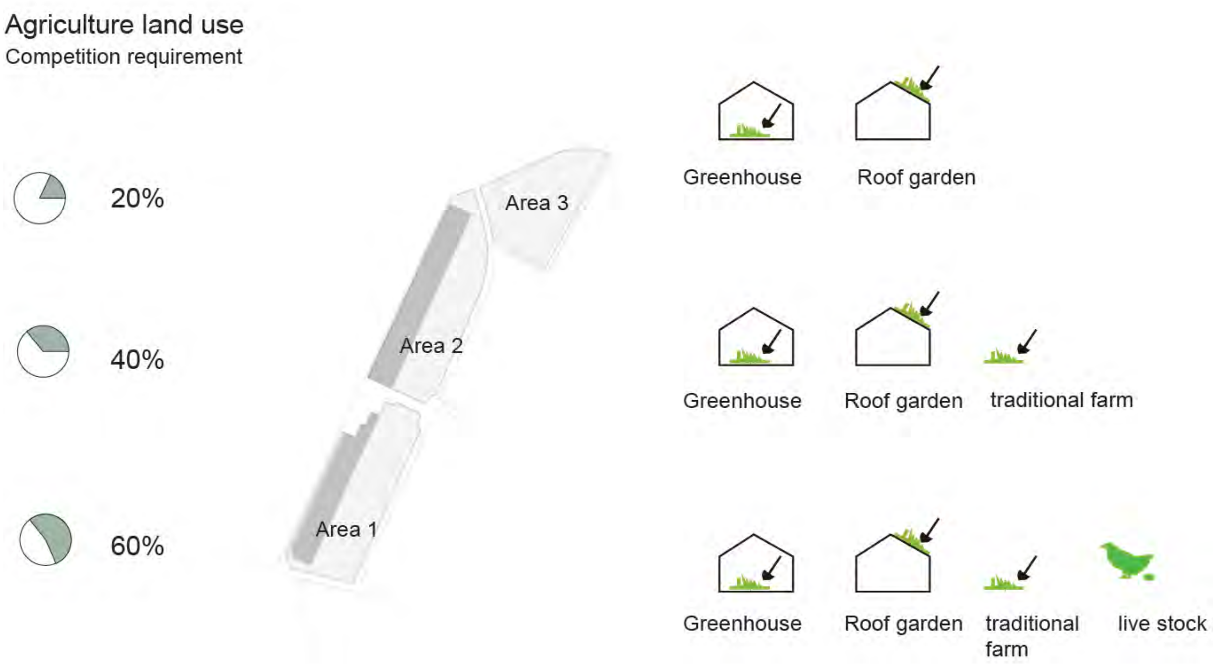


Figure 2-26 Different type of agriculture spaces

- As in the brief, the area will be developed as urban agriculture center promoting the area for increased public participation attracting all age groups to relive and discover the art of farming with a view to bridging the gap between the city and nature.
- It will also be promoted for Agro Tourism attracting people from other cities and regions to experience a green vacation.

The presence of many green protected areas is one of the main strongest characteristics of the area. Linked to this there is the proximity of the ecological networks proposed. Regarding the local Areas of Mirafiori, the green areas are divided into different kinds of protected areas according to the local territorial plan and which range from Environmental protected areas, Forrest areas, gardens and orchards, and even agricultural areas.

These green areas are an important asset for the city, not only because of the quality of space that they give to the community but also due to the direct relation these have with other natural environment elements. During the Analysis of the green Areas we found a Disconnection between the different green Areas, similar to the one seen overall in the urban analysis. There is a lack of development of them towards new uses and the exploitation of its full potential. Also, the misuse of these open green areas leads to the creation of high levels of pollution inside of them and in their surroundings. Considering all these factors and the importance of the green areas in the area, we took into consideration that state that Ecological Network projects aiming at the functional connection of the most interesting natural areas of the region is under way. All This Considering those areas that are most affected by the urban development.

2.4.5 Typology of each area

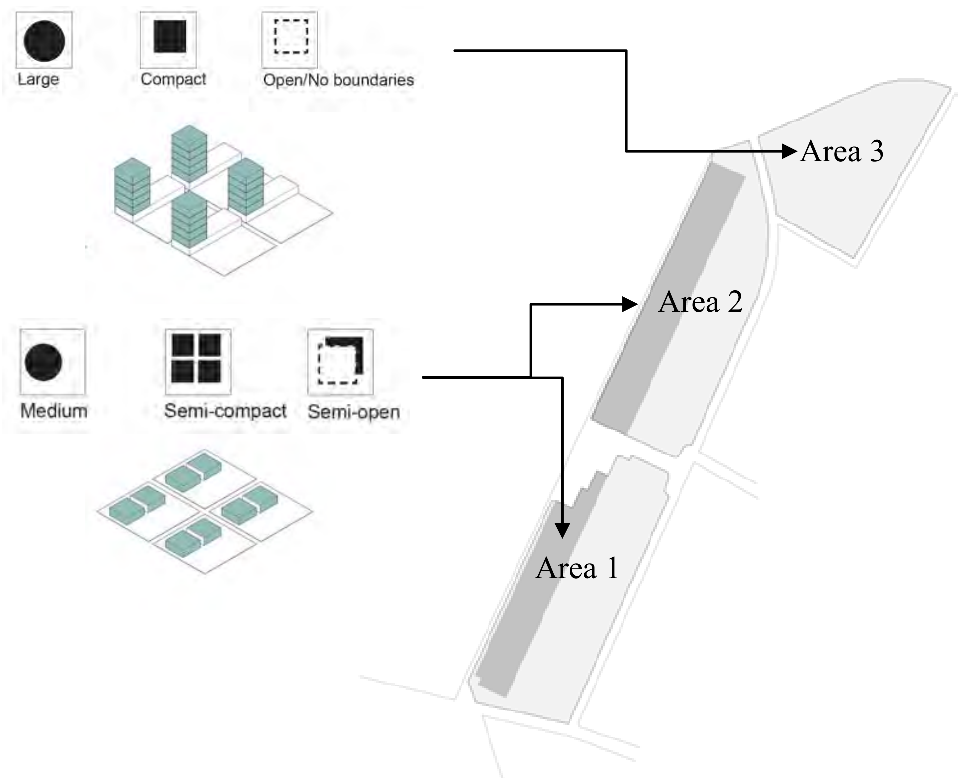
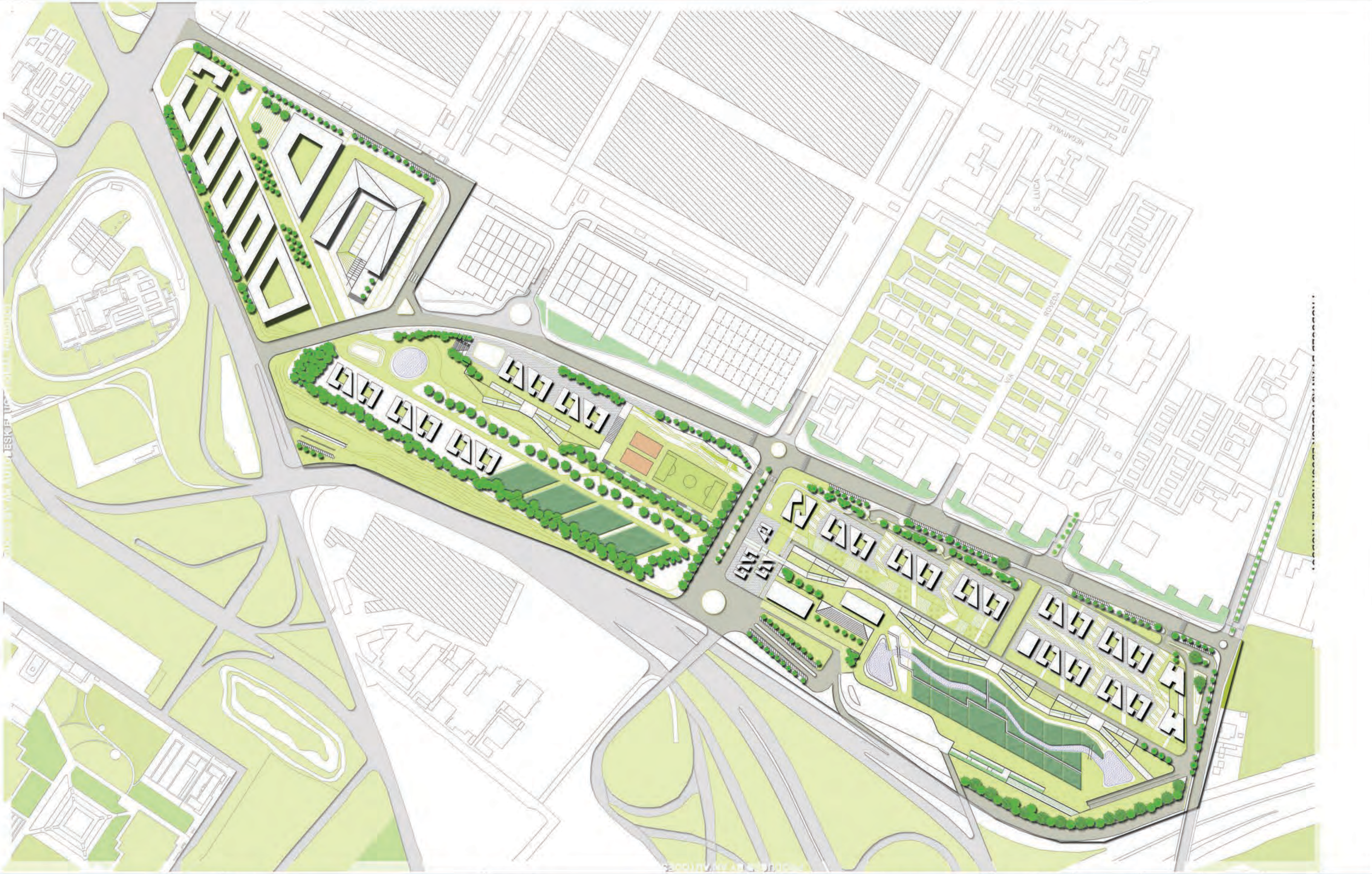


Figure 2-27 Arrangement of different typologies on the site

2.5 Urban Design Drawings:



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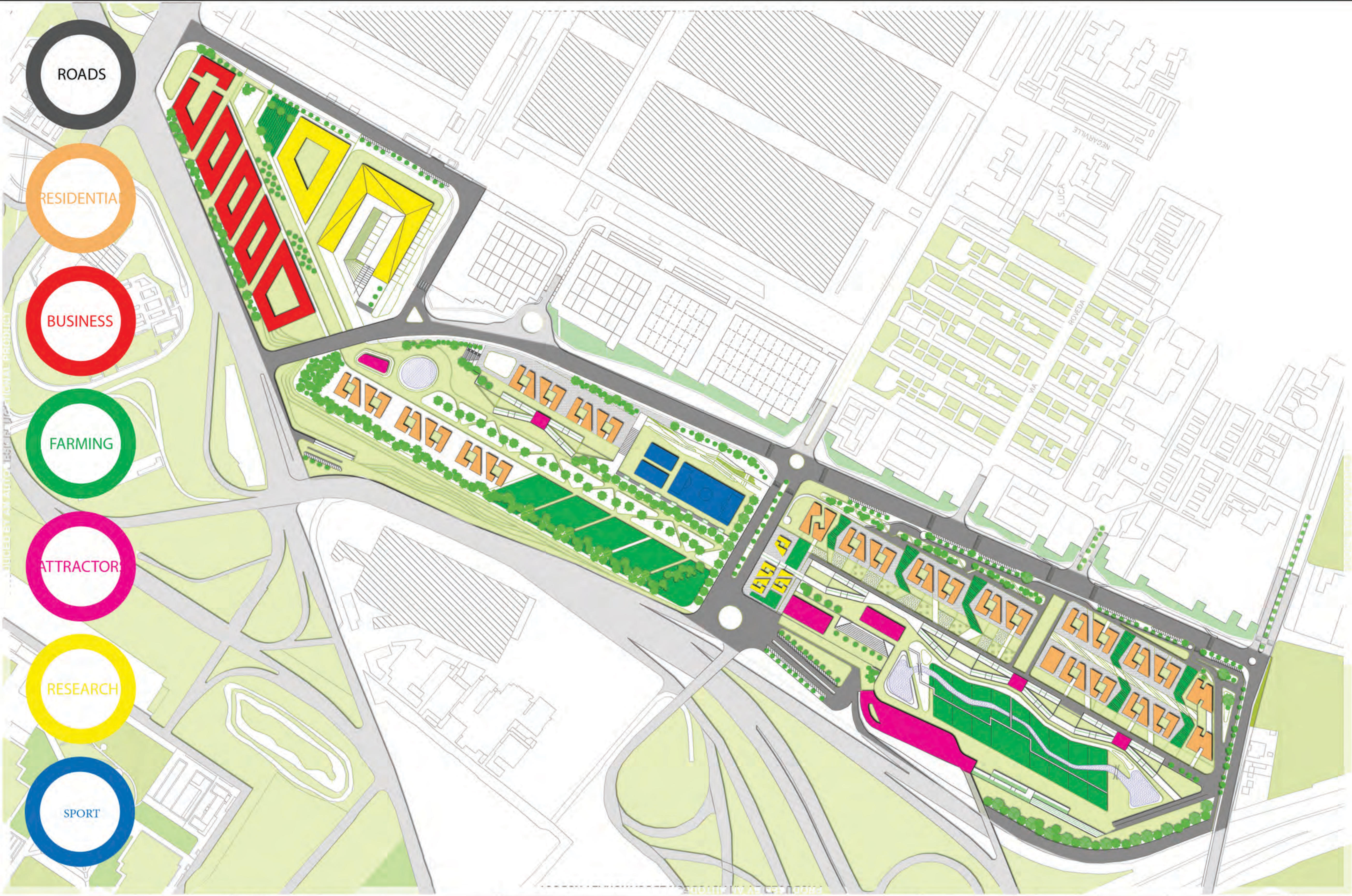
					DRAWING NO :	P-UR-02-02		REV :	001



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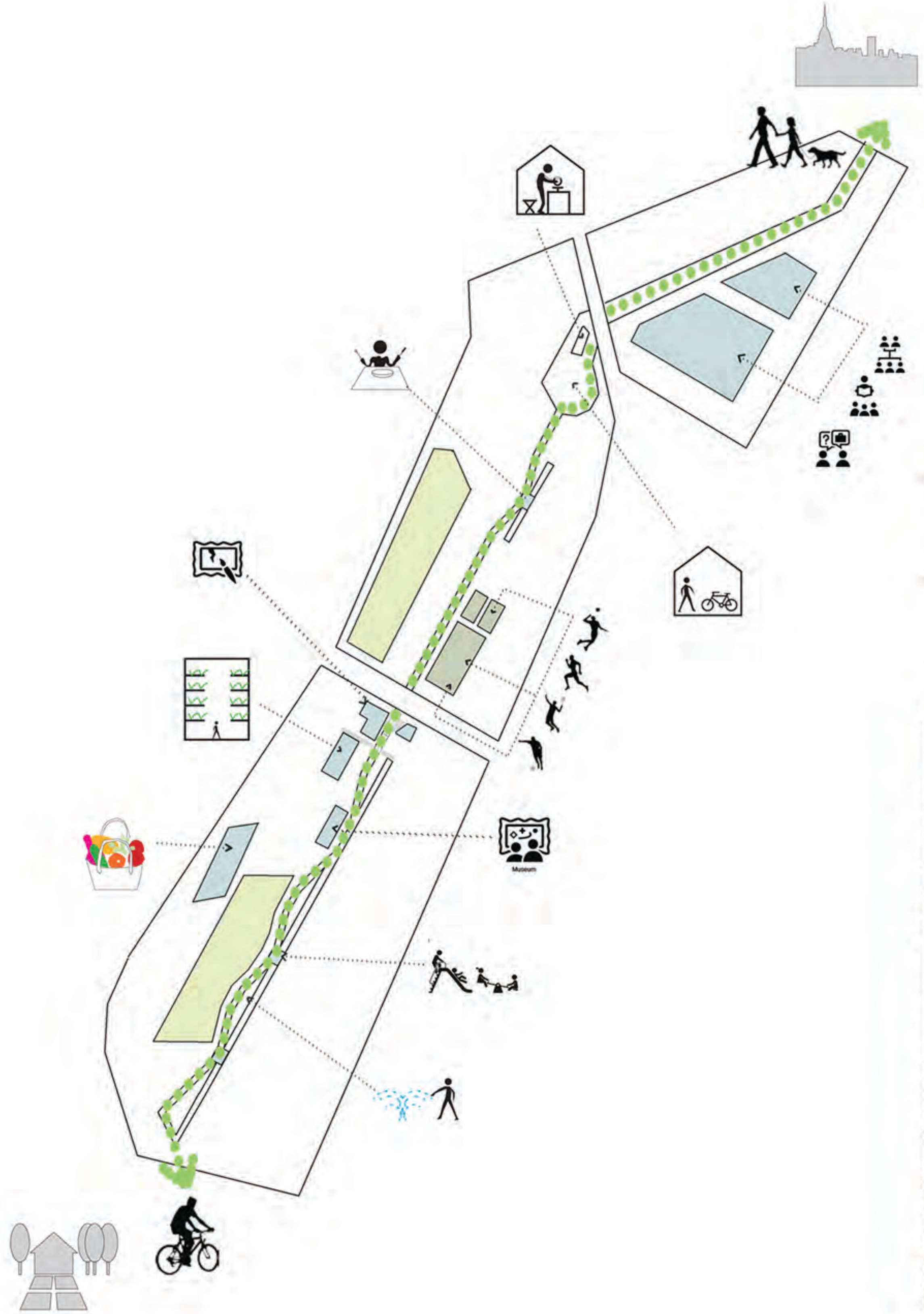
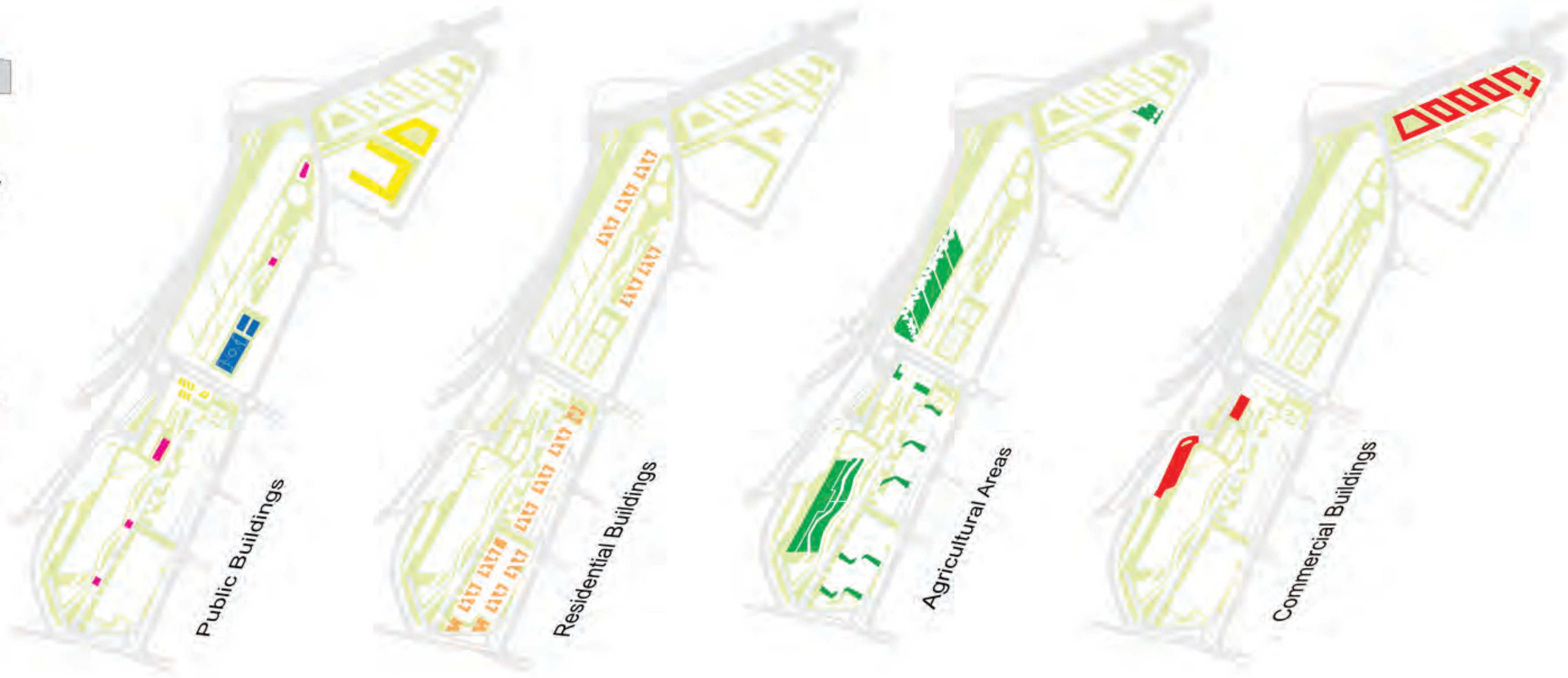
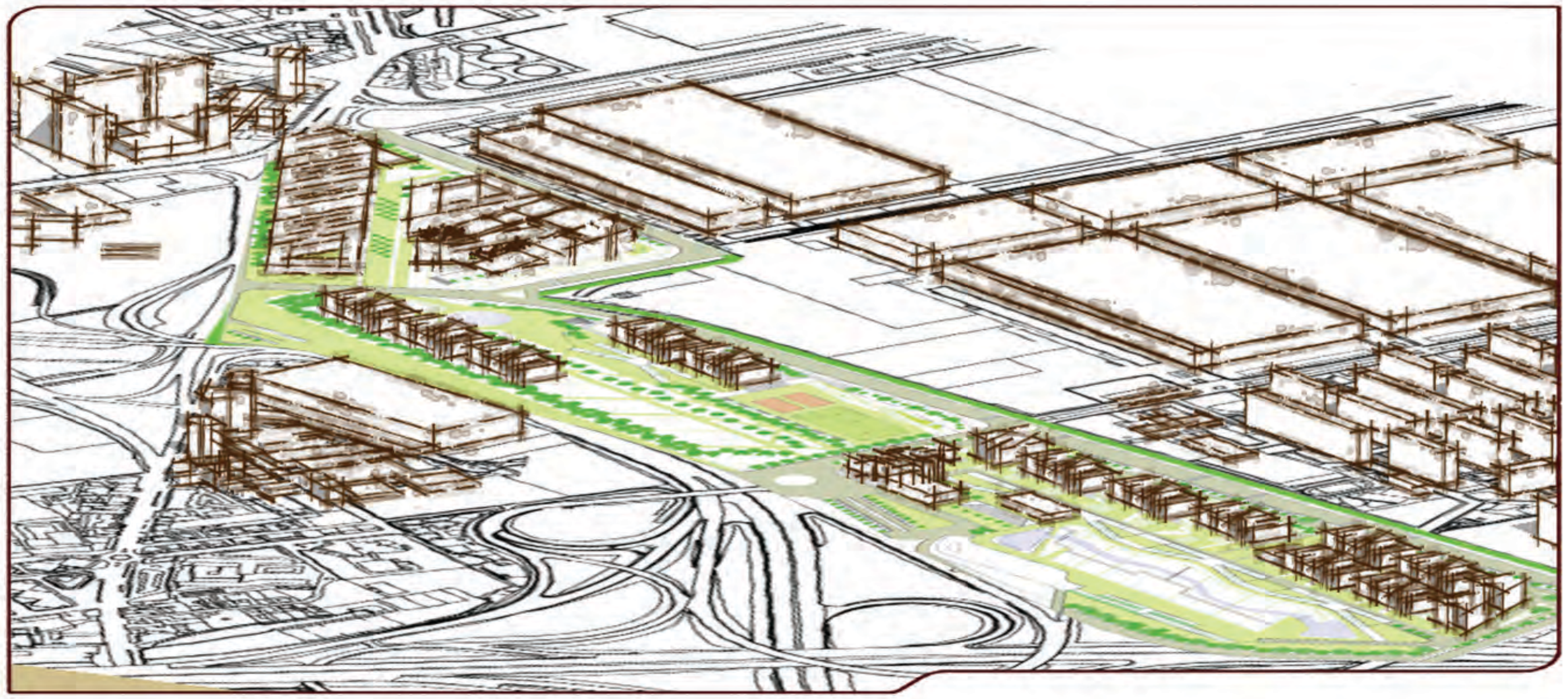






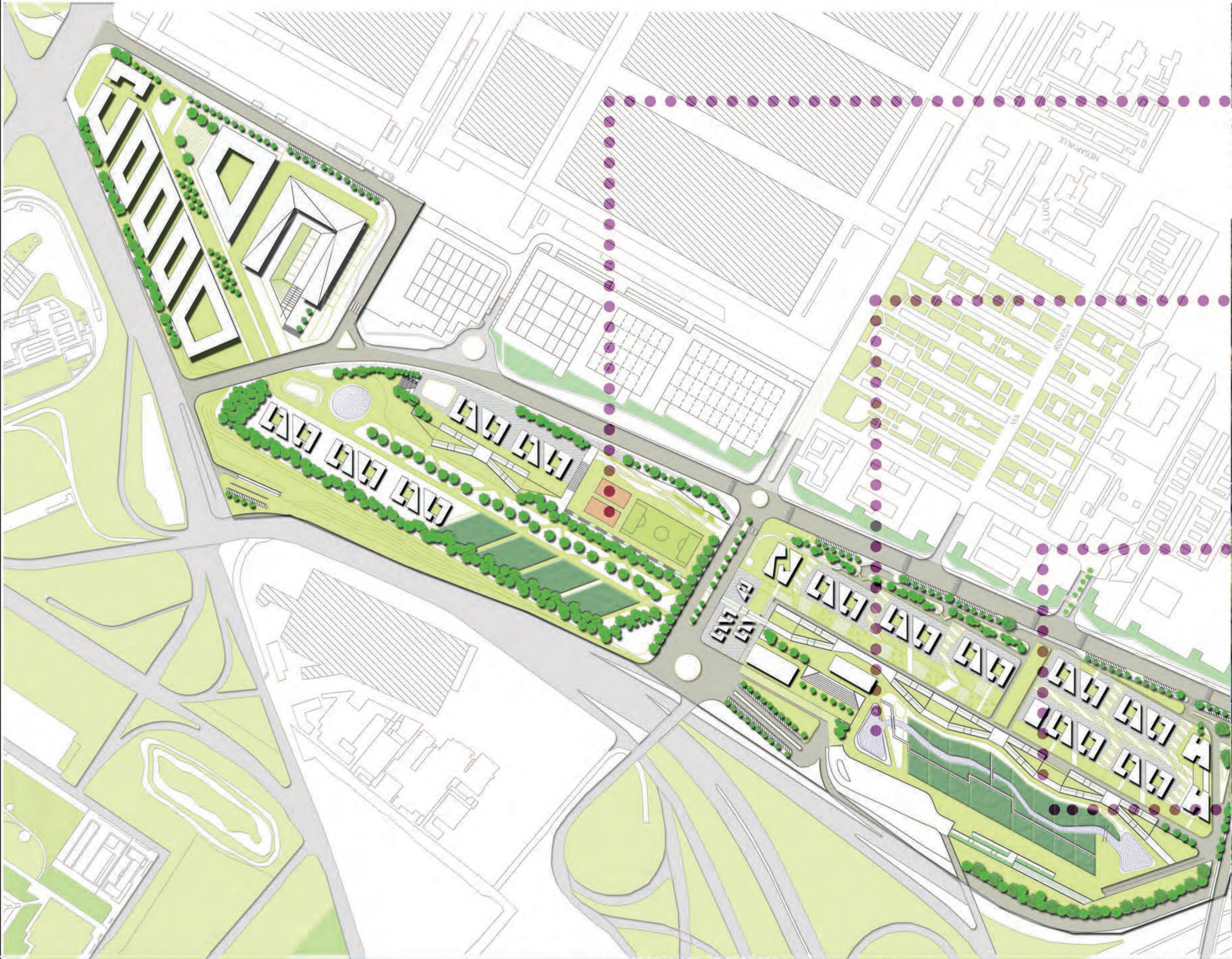
POLITECNICO DI MILANO
M. Sc. ARCHITECTURAL ENGINEERING

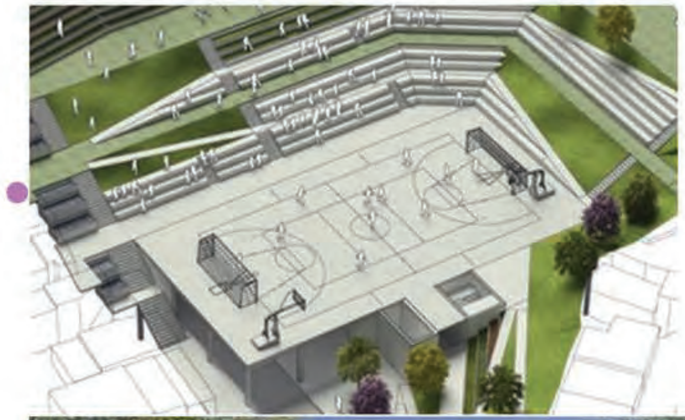
PROJECT TITLE :
Turin to Smart Green

DRAWING TITLE :
FUNCTIONAL LAYERING

AMENDMENTS	REV. DATE

DRAWN BY :	CHECKED BY :	APPROVED BY :	SCALE :	DATE :
AMIN	PROF. MASERA	PROF. MASERA	N.T.S	28/06/2014
DRAWING NO :	P-UR-02-03		REV :	001





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					AMIN	PROF. MASERA	PROF. MASERA	N.T.S	28/06/2014
					DRAWING NO :	P-UR-02-03		REV :	001

CHAPTER 3

ARCHITECTURAL DESIGN

3.1 Recreational and Educational Spaces and Activities

Through the community education program, kids know very well where the food they eat every day comes from, and are aware of saving the food. Agricultural fields will become the common grounds for citizens to meet and communicate. Furthermore, following the urban analysis a lack of cultural activities in this region was highlighted. In this regard a science park complex with focus more on specific fields of research and business is proposed at the northern part of the site with higher density in order to correlate with business sector.

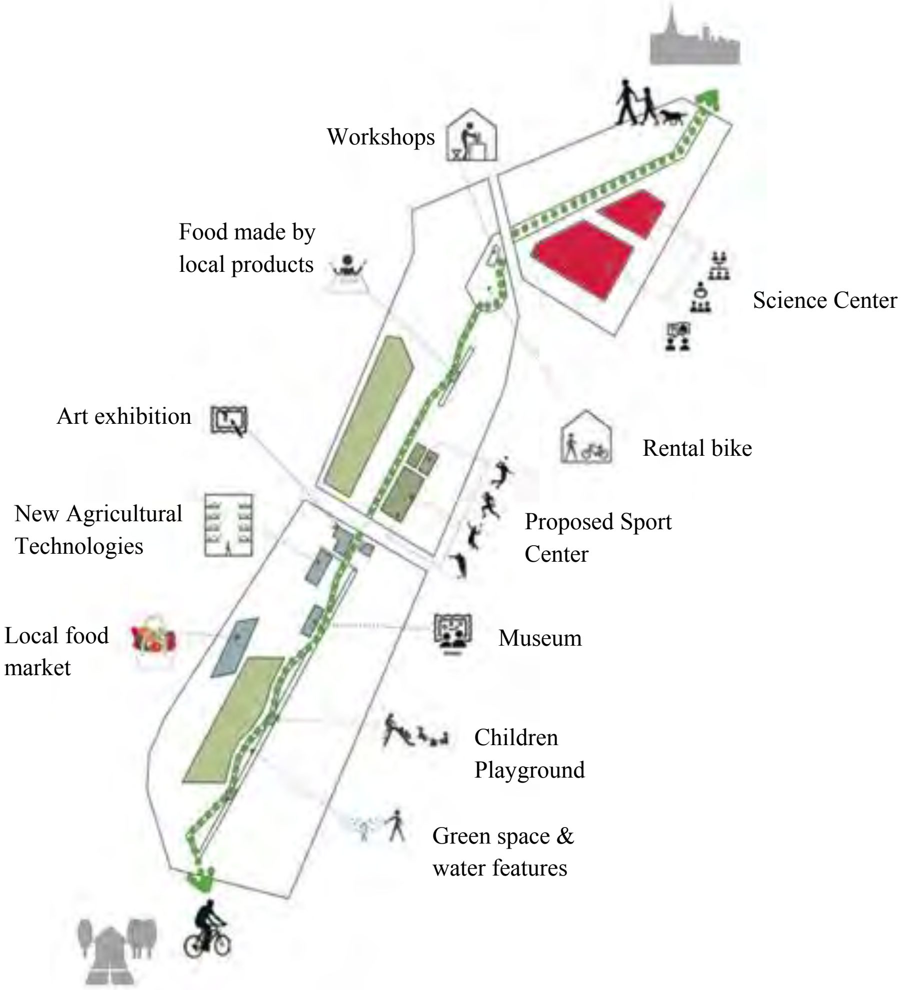


Figure 3-1 Activities map

3.2 Science Park

Science park is an area which innovation plays the main role. Universities, industries, governmental and non-governmental organization are collaborating in order to involve in Pioneering and Fundamental researches such as Nano Technology, ICT, Bio Technology can be placed. Here Entrepreneurs from Start-up Companies, researchers from research institutes and students from educational centers can take the advantage of the available knowledge on site and at the same time would be able to collaborate.

3.2.1 Scope and Vision

In view of the fact that dealing with such complex context is quite delicate, I was driven by the approach of creating a structure which blends seamlessly and appears to grow from the surrounding landscape. I started from the conclusion of the urban design, to let the smallest details of the context forms the mass, shape the boundaries of our intervention and define the proper solutions, taking the area opportunities and constrains into account.

3.2.2 Macro Zoning

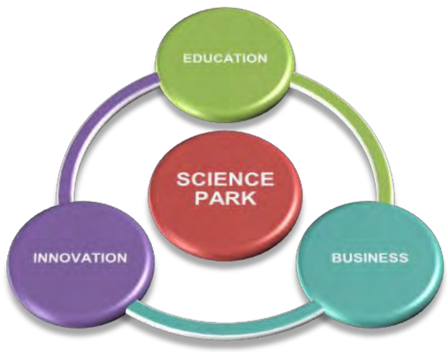


Figure 3-2 Science Park Scheme

Torino Science Park has to be designed as a network of meeting places. The buildings, landscape and public space to be interconnected and strongly intertwined and striking architecture often plays a prominent role. Torino Science Park has to become a vibrant melting pot where business, science and innovation meet. With the focus more on specific fields of research and business as follow;

- **Pioneering and Fundamental researches** like;
  - E-bio Lab
  - Nano Center
  - Ultra Modern glasshouse
  - ICT; Computing and Network Services (Super Computers, Virtual Reality, Complex Data and...)
- **Entrepreneurs**;
  - Facilities for Start-up Companies and research institutes like; work space and access to labratories and ICT facilities
- **Education Center**
  - Classrooms
  - Science exploring tour for students and so on
- **Catering and Conferences**
  - 2 or 3 conference area with different capacities between 200-400
  - Restaurant, Coffee shop and Bar with capacity of 150 for restaurant, 50-100 for Coffee shop and Bar.
- **Limit Accommodation** for researchers or entrepreneurs

These areas help many design companies realise their dreams, continues to work closely and maintains a creative working environment for grooming design talents.

3.2.3 Area Programme

As a result of the previously mentioned feasibility studies, in addition to the compatibility of the chosen functions for the science park building and the surrounding context, we went deeper into investigating the Education center, Library, enterprise one, innovation and convention center to guarantee adherence to the design approach, in terms of components, activities, space requirements and needed facilities, before going into the concept phase. As a result of these studies the total area required for the science park is around **13000 m^2,** which is programmed as below;

3.2.3.1 Library

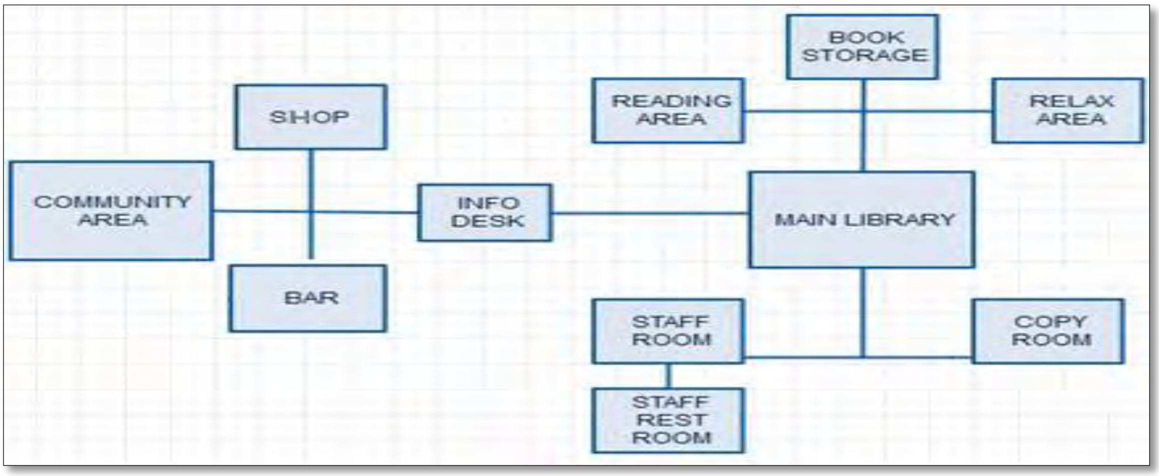


Figure 3-3 Library - Function Diagram

Figure 3-4-Entrance of Mediateca di Saint-Malo, France

The entrance area is the first place to which the user is compared must therefore contain all the services to guide them in the library. A common welcome counter for the lending services of books, registration, etc. Near the entrance there will be the shops that may possibly have books, stationeries and etc for selling.

Figure 3-5-Children area, Roseville library, United State

The cafeteria, will be linked to the community area, in connection will be a part of children space. This space is put here to allow relatives to relax watching the kids. Magazines and newspaper area considered so you can read the newspaper and having a coffee at the bar.

Figure 3-6 Reading area, Utrecht University Library, Netherland

Audio archive and an audio room has been planned in order to attract more people to use the ground floor which is more public zone.

Table 1- Library- Area Programme

Function	Area of Space (sq.m)	Total No. of Spaces	Total Area (sq.m)
	LIBRARY		
Shop	25	1	25
Reading area	100	4	400
Book storage	150	3	450
Community Area	100	1	100
Video room	50	1	50
Staff Room	50	1	50
Lobby	400	1	400
Children Areaa	200	1	200
Magazine & News	60	1	60
Audio archive	100	1	100
Info	25	2	50
Rest rooms	25	2	50
			2335

3.2.3.2 Education Center

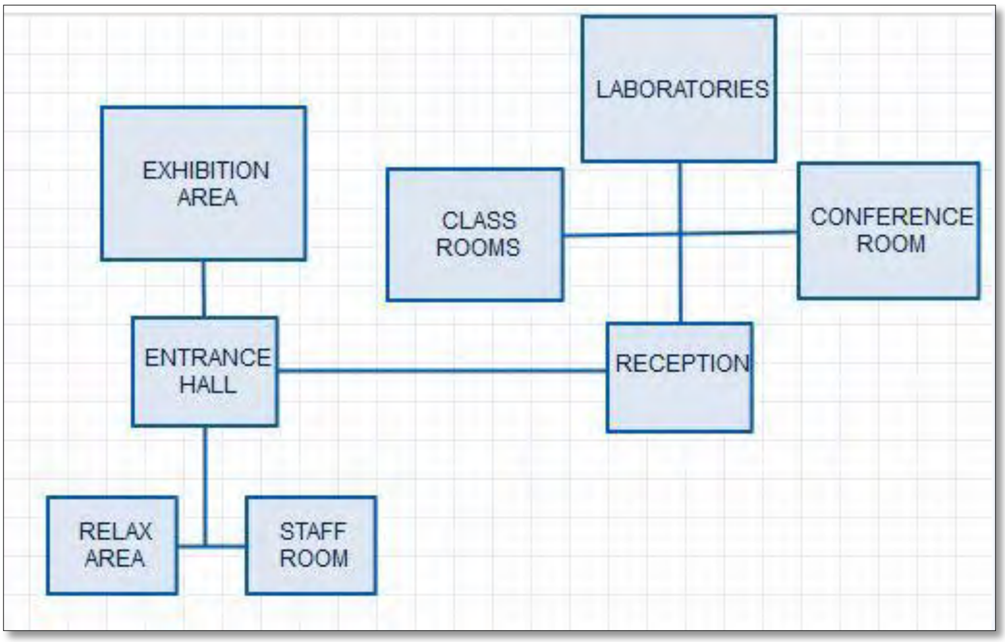


Figure 3-7 Education Center Function Diagram

Figure 3-8 Exhibition Area, CEA Grenoble, France

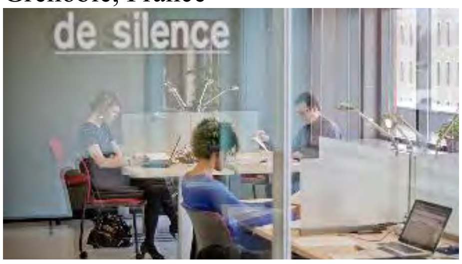


Figure 3-9 Silence Area, Montreal University, Canada

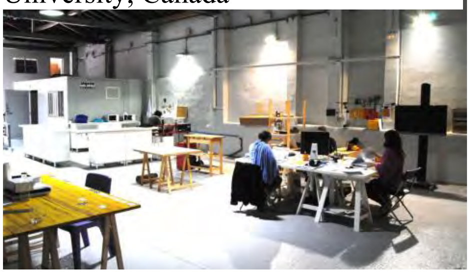


Figure 3-10 Living Lab in Bilbao - la Isla, Spain

Working as a link between the innovation center and business sector the students will be able to take advantage of the knowledge available on site and the special research that takes place there. Classrooms for teaching and meeting rooms to make training courses, etc and finally there will be working tables scattered on the shelves.

Open space for exhibitions has been provided which are designed as spaces where people can freely walk, but that could be closed in case of video projection. And spaces for group work in frame of workshop are been place on the southern part for the advantage of best daylight.

Table 2- Education Center-Area Programme

Function	Area of Space (sq.m)	Total No. of Spaces	Total Area (sq.m)
EDUCATION CENTER			
Classrooms	80	4	320
Exhibition	900	1	900
Staff area	80	1	80
Laboratory	80	2	160
Meeting area	100	1	100
Conference room	100	1	100
Flexible sitting area	350	1	350
Break area	120	1	120
Workshop	370	1	370
Rest rooms	50	2	100
			2600

3.2.3.3 Innovation Center

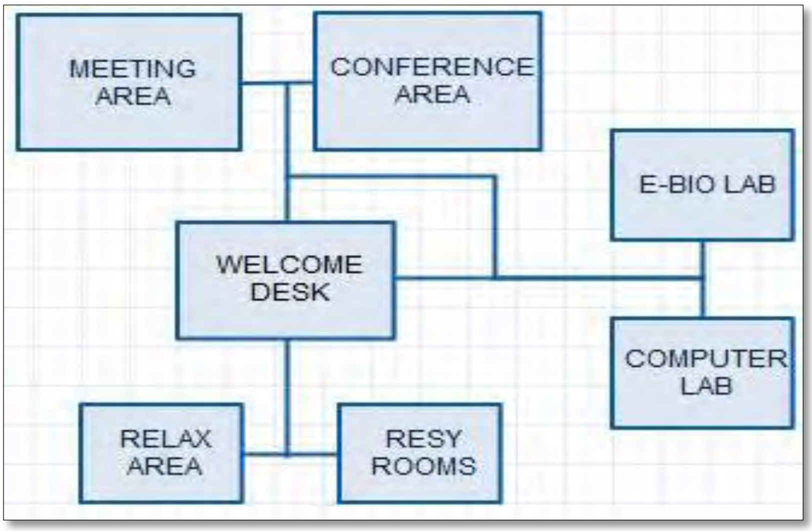


Figure 3-11 Innovation Center- Function Diagram

Figure 3-12 Fab Lab, Waag Society, Amsterdam

This has the goal to provide research area for young researchers which have access to various innovative facilities such as laboratories and high tech ICT access.

Figure 3-13 SAS Lab research center,Lleida, Spain

The Fab-lab is a place of manual activities; there are numerous opportunities for activities such as 3D printing. In addition E-bio labs which are directly connected to modern agriculture science will complete the cycle of urban-agro concept on the site. With an access to library, it will extend the availability of the researchers' resource data.

Table 3 Innovation Center- Area Programme

Function	Area of Space (sq.m)	Total No. of Spaces	Total Area (sq.m)
INNOVATION CENTER			
E-bio Lab	120	1	120
Conference Rooms	50	2	100
Computer Lab	100	1	100
Laboratory	50	2	100
Staff room	40	1	40
Meeting area	50	2	100
Relax area	40	1	40
Reception	25	1	25
Storage	60	1	60
Rest room	40	2	80
			765

3.2.3.4 Enterprise Zone

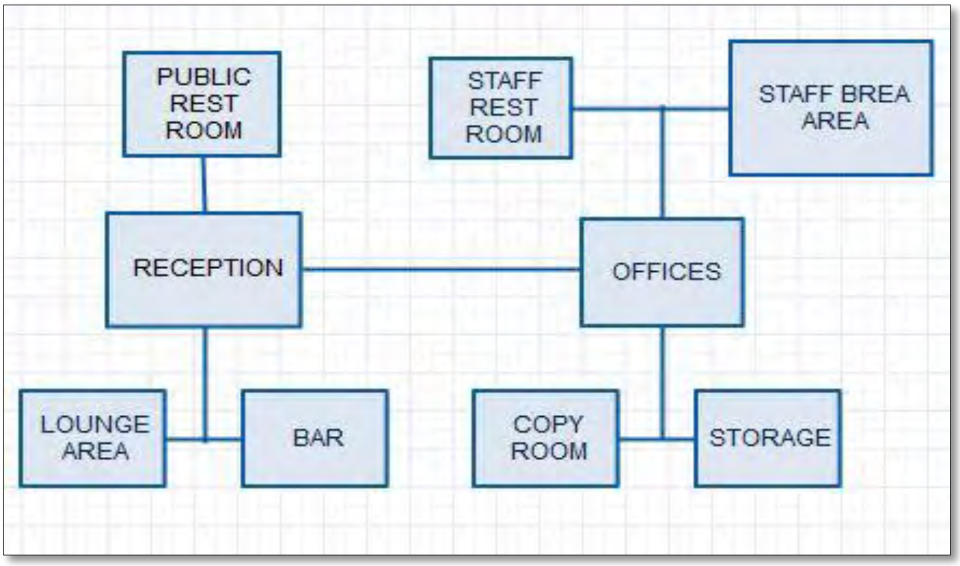


Figure 3-14 Enterprise Zone- Function Diagram


Figure 3-15 Relax Area, TNT Head Office, Netherlands


Figure 3-16 Open Offices, TNT Head Office, Netherlands


Figure 3-17 Catering Area, TNT Head Office, Netherlands

Science Park offers facilities for Start-up Companies and research institutes like; work space and access to laboratories and ICT facilities. Open office design were selected in order to provide a vibrant atmosphere which gives opportunity to young entrepreneurs having access an affordable high quality office area.

The open workplaces are combined with concentration workplaces, which also serve for small meetings. Between these closed meeting rooms an area has been created for open and informal consultation and meeting up. The general atmosphere is that of a lounge thanks to a large coffee corner with sofas, armchairs and ad hoc workplaces. This is where department presentations are given and birthdays are celebrated.

Workplaces also enjoy daylight from inside. This not only saves energy, it also enhances the quality of the workplaces. There are even more advantages to working in daylight. It boosts both the health and the performances of the building's users.

People feel better in daylight. The smart sun blinds mentioned earlier keep out the heat from the sun, therefore less cooling is required and the daylight is able to penetrate inside so that less artificial lighting is needed. Smart sun blinds thus contribute to people's well-being and to reducing energy consumption.

Table 4- Enterprise Zone- Area Programme

Function	Area of Space (sq.m)	Total No. of Spaces	Total Area (sq.m)
ENTERPRISE ZONE			
Shop	50	1	50
Lounge area	80	1	80
Bar & Café	80	1	80
Magazine & news	40	1	40
Lobby	200	2	400
Administration	70	2	140
Reception	30	2	60
Open office area	1400	2	2800
Conference Rooms	50	8	400
Storage	70	1	70
Staff break area	300	1	300
Copy area	2	30	60
			5460

3.2.3.5 Convention Center

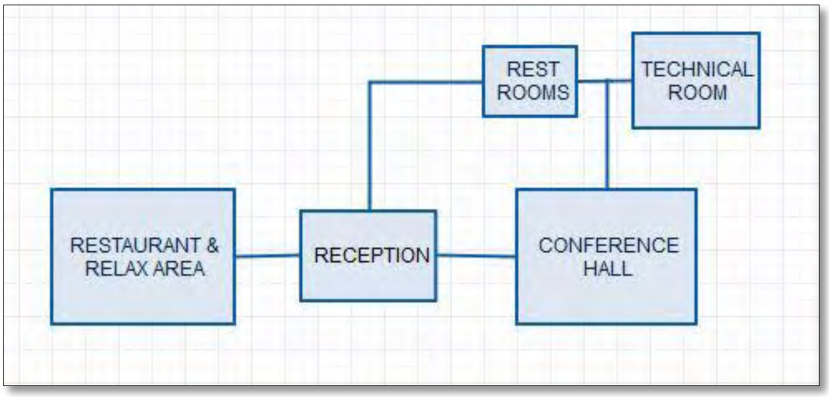


Figure 3-18 Convention Center - Function Diagram

Figure 3-19 Avel vor Cultural Center, Plougastel, France

As its name indicates, the multi-purpose hall can serve a number of things: concerts, theater, seminars; all types of events which require space for hundreds of people and sound equipment and light. the auditorium has a capacity of 250 people, it is the ideal configuration for a concert or a seminar in the auditorium.

Figure 3-20 - Pompidou Center, Metz, France

Table 5- Convention Center- Area Programme

Function	Area of Space (sq.m)	Total No. of Spaces	Total Area (sq.m)
CONVENTION CENTER			
Conference hall	500	1	550
Lobby	300	1	350
Rest room	70	1	70
Reception	30	1	30
			1000

3.2.3.1 Catering area

There should be various catering facilities at Science Park for staff, visitors and students.

- Restaurant;

Provides catering services for conferences and other meetings.

- Coffee shop;

Provides an ideal setting for business or social breakfasts or lunches.

- Bar;

Provides facility for informal lunch after-work drinks or private events.

Figure 3-22- Coffeshop, TNT Head Office, Netherlands

Figure 3-21- Bar, TNT Head Office, Netherland

Table 6- Catering - Area Programme

Function	Area of Space (sq.m)	Total No. of Spaces	Total Area (sq.m)
	CATERING		
Restaurant	250	2	500
Coffee Shop	50	2	100
Bar	50	1	50
			650

3.2.4 Conceptual Design Development

3.2.5 Fundamental Principles:

With respect to the design inputs addressed from the urban level, I started to consider the outputs resulted from a micro level guidelines and principles, in order to create a structure which works harmonically with the surrounding context, and grows out of the site accordingly by focusing on assessment of;

- Compactness
- Flexibility
- Daylight access
- Views
- Connectivity
- Performance
- Sustainability

3.2.5.1 General Objectives

a) To use the latest green technologies and sustainable building design in order to achieve a long term sustainable development

b) To consider cost effectiveness by using renewable energy in the Park

c) To promote sustainable construction and design practices in Turin by reducing CO_2 emissions and improving energy efficiency of the building.

d) Well designed building which shaped and oriented in order to be suited for the site existing built environment such as direction of wind and sun.

e) Maximizing the social interaction between members of the park by designing a well defined interior and exterior hierarchy schemes.

f) Maintaining the visual connectivity of the users towards the park while guaranteeing privacy, quietness and closeness.

g) Using well-integrated design with the most adoptable sustainable techniques to achieve the minimum energy requirement for the site.

In order to achieve the above mentioned goals, series of strategies and decisions has to be taken.

3.2.5.2 Building Orientation

As per the climatic analysis of north Europe, we maximized the façades area oriented towards south, to guarantee the highest amount of sun exposure. The direct speedy wind was completely avoided, but with a proper allowance for the fresh air to circulate the site using the well planted vegetation.

3.2.5.3 Urban Fabric Grid and Geometrical Alignment

By using the same language of lines, which belongs to existing context fabric grid, I achieved the creation of a structure which merges into the context. However the site constraints of having a dense industrial zone on neighborhood shaped the building in a way to retain the green characteristic of the site. So in the challenge is to making a building that blends with its landscape rather than dominate it.

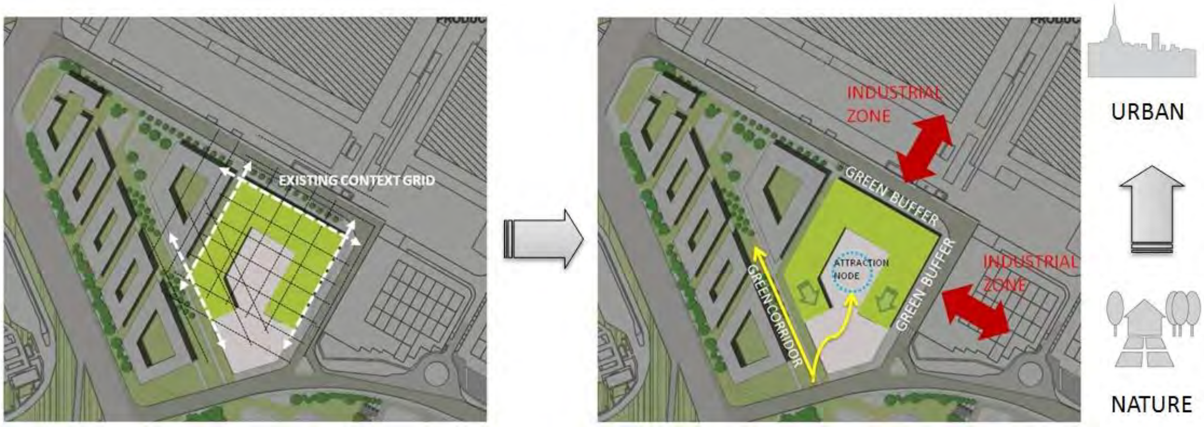


Figure 3-23 Urban Grid and Geometrical Alignment

3.2.5.4 Volumetric Study

The aim was to provide feeling of openness and connectivity in conjunction with introducing the green healing. Connectivity was the guiding principle for the ambitious project. In other words: people take priority. In practice this means an open and transparent building, comprising a U-shaped main volume surrounding a courtyard. This courtyard forms the central space in the building and functions as one, big meeting area.

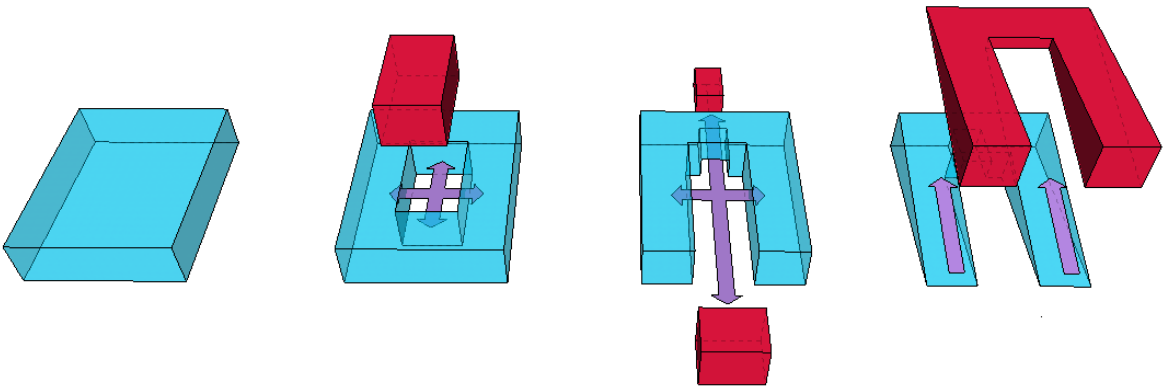


Figure 3-24 Volumetric Analysis

3.2.5.4.1 Visual and physical connectivity

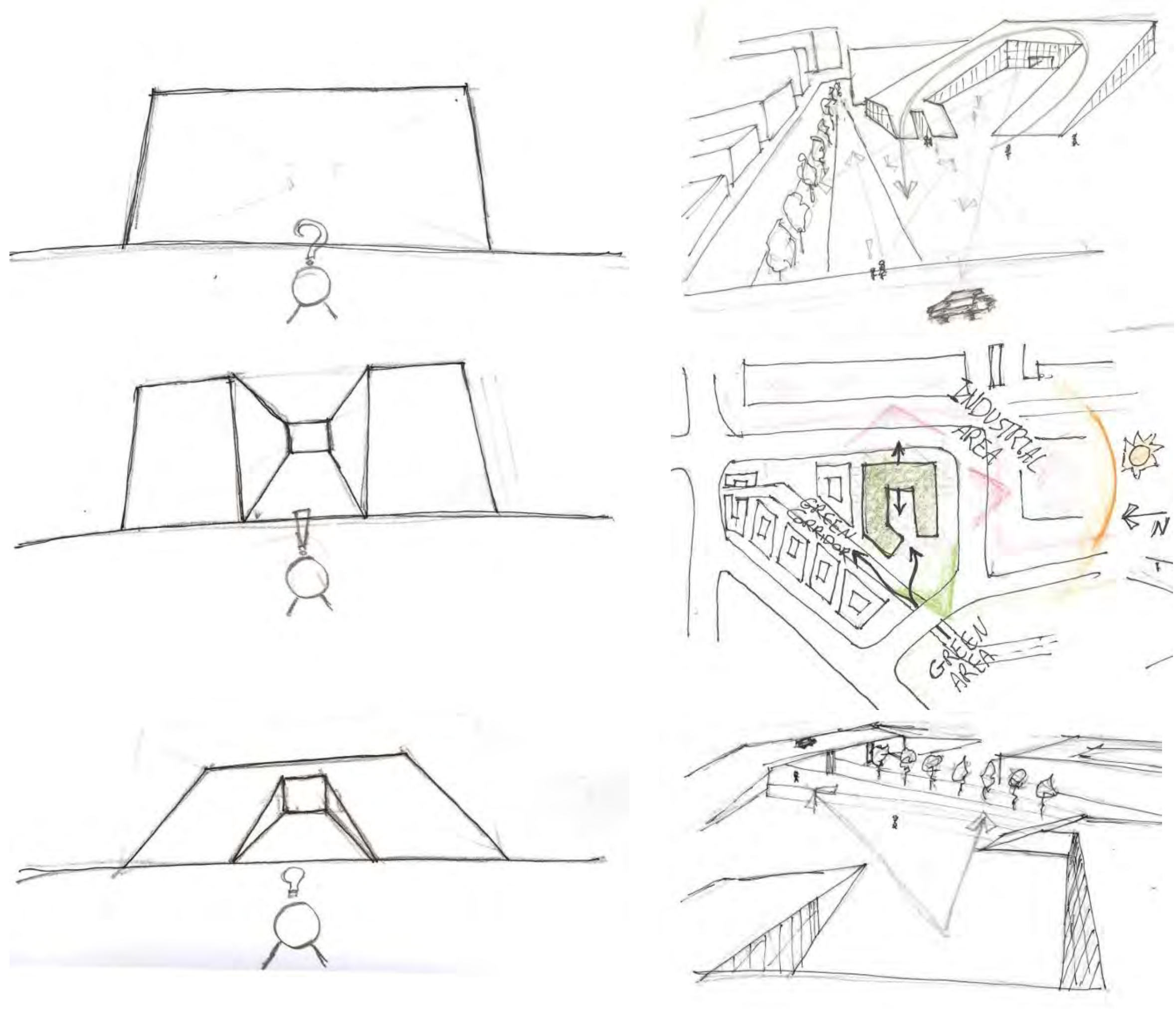


Figure 3-25 Study of Visual and Physical Connections

3.2.6 Micro Zoning

3.2.6.1 Bubble Diagram

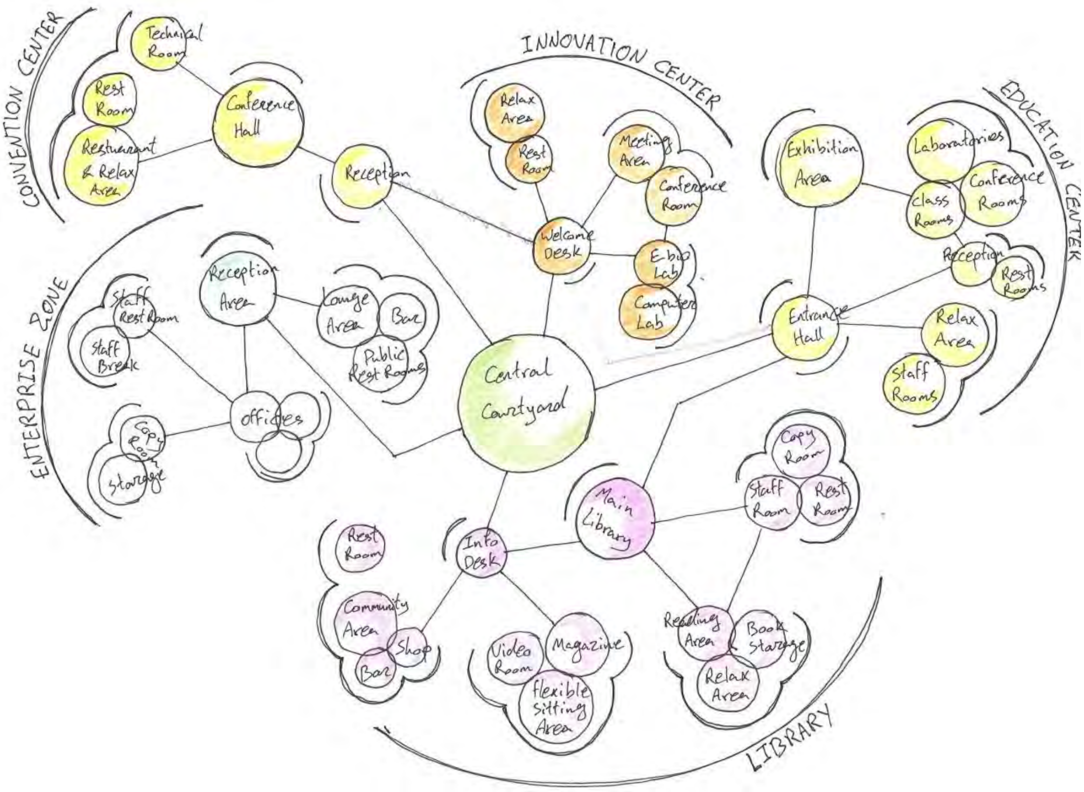
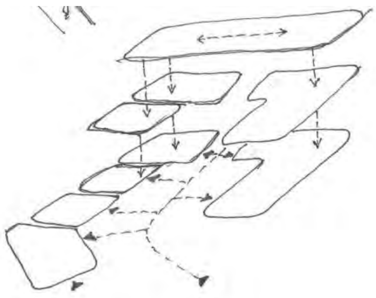


Figure 3-26 Bubble Diagram

This began by investigating what type of spaces I would need within the building so that I could get general idea of how the building would look and behave. For this I broke the programme up into five main zones; Education Center, Innovation Center, Convention Center, Library and Enterprise zone. I placed each zone within a lager border and used arrows to show spatial relations and interactions between them. I wanted the bottom floor to be very public spaces allowing residents to walk through and engage with diversity of functions exist on the site. As a result the courtyard plays an important role as a conjunction node to fulfil the well connectivity of the complex.

3.2.7 Hierarchy and Connections



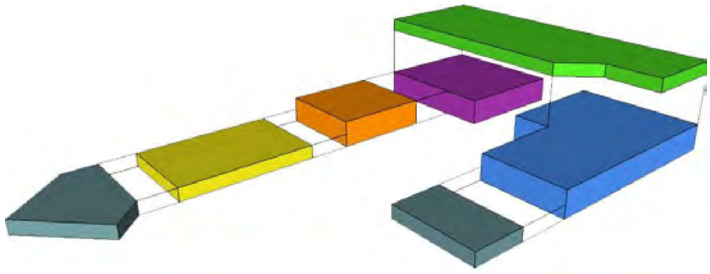


Figure 3-27 Function distribution

Besides sustainability, the communicative value of the building is very important. The Science park building is a transparent and inspirational building. The orientation and layout of the building are defined by the site, the urban and landscape structure. The building is fixed in the location, it 'knows where it is' and in this sense is connective. In the urban planning, logistics and social sense, connectivity is a key concept for sustainability. After all sustainability lies not only in the choice of materials, energy-efficient practices, $CO2$ reductions but also in flexibility of future use. The main meaning of sustainable is: do no harm to the (natural) environment or to the people around you. Harm is done whenever a building does not acknowledge the connection with its surroundings. At the same time a connective building affects social interaction; it connects people and promotes professional and social contact. This is embodied by the meeting places provided for users at the science park. The hierarchy of the functions as depicted below works through series of horizontal and vertical connection in order to have the most fluency of people movement in the complex.

3.2.8 Reference case studies

For the first part of the project location and the context around the building has been studied. As the next stage of design, hereafter I collect information about references to understand the principles of design and construction of similar type of buildings. This study allows a functional analysis on the main areas of the science park building and development that I have chosen for the thesis.

3.2.8.1 TNT Head Office [15]

Figure 3-28- External View - TNT Head Office, Netherland

Architect:	Paul de Ruiter
User:	TNT Express
Location:	Netherland
Gross Floor area:	17.250 m² (excluding car park)
Program:	Sustainable office with car park
Status	Completed Jan 2011

Daylight penetrates deeply through the building dueto the atrium and the glass facade, which faces the sun. The open workplaces are combined with concentration workplaces, which also serve for small meetings. Between these closed meeting rooms an area has been created for open and informal consultation and meeting up.

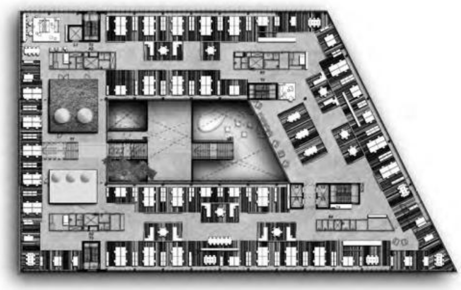


Figure 3-29- 2nd Floor Plan, TNT Head Office, Netherland

The changeover to flexible workplaces through the entire building reduces the floor area needed for the workplaces by 30%. This aspect also significantly contributes to the sustainability of the building.

The multifunctional use of the atrium makes this area the beating heart of the TNT Centre. Staff can meet each other here and receive clients. A coffee corner is situated here as well as various opportunities to sit and talk. From open to enclosed, formal to informal, from large to small areas. To sum up: a mix of meeting, working and mobility. Anyone can 'land up' here and work. Furthermore, between midday and 2 pm the area serves as a restaurant.

Figure 3-30-Centerl Courtyard, TNT Head Office, Netherland

3.2.8.2 Nanyang Technical University [16]

Architect:	CPG Consultants Pte Ltd
User:	Nanyang Technological University
Location:	Singapore
Gross Floor area:	10.000 m²
Program:	School of Art
Status	Completed June 2006

Figure 3-31 Green roof, Nanyang Technological University, Singapore

Housing more than two dozen studios and laboratories, two galleries, and as many lecture halls, alongside classrooms, a soundstage, a 450-seat auditorium, and motley other spaces spanning a library to prototyping rooms.

Figure 3-32 Access to the Green Roof, Nanyang Technical University, Singapore

Accessible by stairs along the edges, the curving, green roofs prevent a loss of open space meanwhile, this effect enhances the outdoor gathering space at a university that has made a mission of promoting creativity. The curving green roofs distinguish the building from among the other structures on campus but the line between landscape and building is blurred. The roofs serve as informal gathering spaces challenging linear ideas and stirring perception.

The roofs create open space, insulate the building, cool the surrounding air and harvest rainwater for landscaping irrigation. Planted grasses mix with native greenery to colonize the building and bond it to the setting.

Figure 3-33 Central Plaza, Nanyang Technical University, Singapore

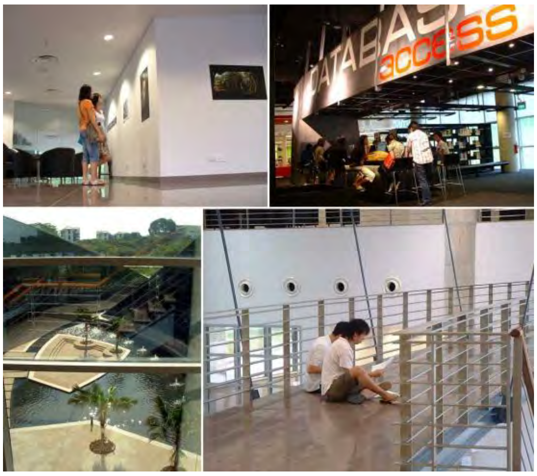


Figure 3-34 Interior Photos, Nanyang Technical University, Singapore

The glass façade provides a high performance building envelope that reduces solar gain and heat load while allowing the benefits of natural views and daylight into creative spaces. The glass walls provide a visual exchange between indoors and out allowing students and teachers to experience the building, the surrounding landscape and the interior plaza as fluid spaces. Diffused natural daylight is abundant throughout studios and classrooms, filtered through the surrounding foliage.

The unfolding arms of two blocks create an inviting entry court for the school. The double volume entrance leads into a large lobby with circulation elements, namely the elevators, open staircases and a link bridge. From this lobby space, students can quickly access to other parts of the building.

Figure 3-35 Ground Floor Plan, Nanyang Technical University, Singapore

3.2.8.3 Sendai Mediateque [17]

Figure 3-36 External View, Sendai Mediatheque, Japan

Architect:	Toyo Ito Architect
User:	Public
Location:	Sendai, Japan
Gross Floor area:	4.000 m²
Program:	Sendai Mediatheque
Status	Completed Aug 2000

For the Japanese culture media library was a new concept in 2000, space open until late in the evening, which gives access not only to books but also to the art gallery, places with free internet access and a service to loan dvd.The building takes its image from the concept of fluidity. In fact, its southern façade is created with a double skin of glass.

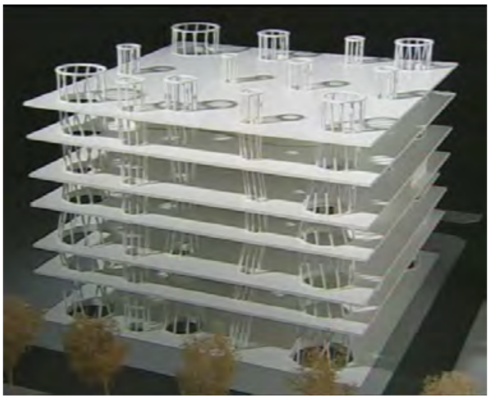


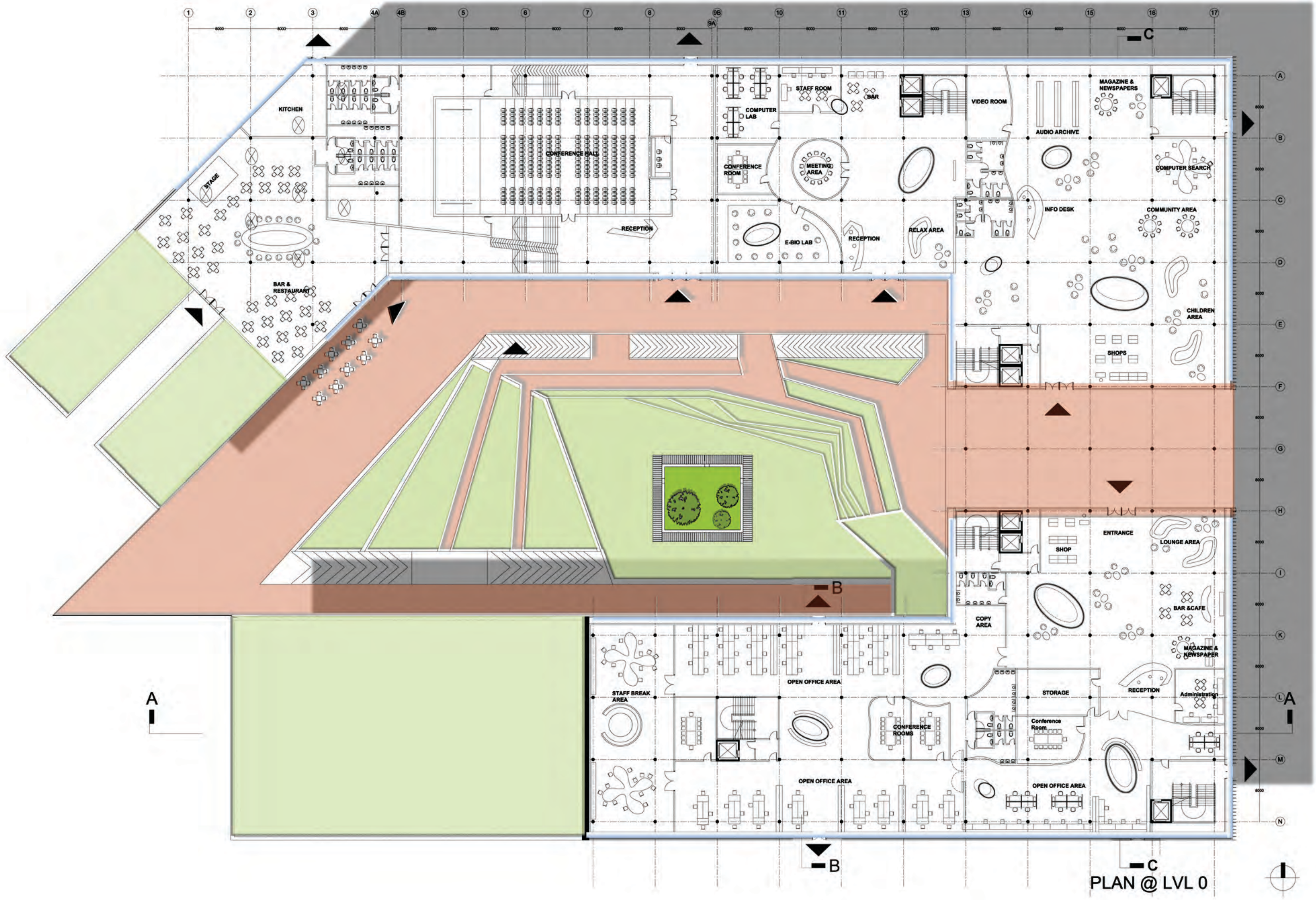
Figure 3-37- 3D Model, Sendai Mediatheque, Japan

Figure 3-39 Entrance Area, Sendai Mediatheque, Japan

Moreover multiple columns in tubular form are designed to give possibility for the exchange of air and light between the different levels. Most of these pillars are light shafts in the building of 50m x 50m. There are 13 pillars in the media library with the largest located in the four corners of the library. These large pillars are mostly works as a shaft for elevators and staircases. Another concept developed in the project is the separation of function that are placed at the same level, each function has its plan, this concept is marked by the east and west facades that all have a different material on each floor, only the entrance space is left in the glass to allow the entry visible on all the sides of the building and pick up the concept of fluidity and transparency of materials.

Figure 3-38 Double Skin Facade, Sendai Mediatheque, Japan

3.3 Architectural Design Drawings:



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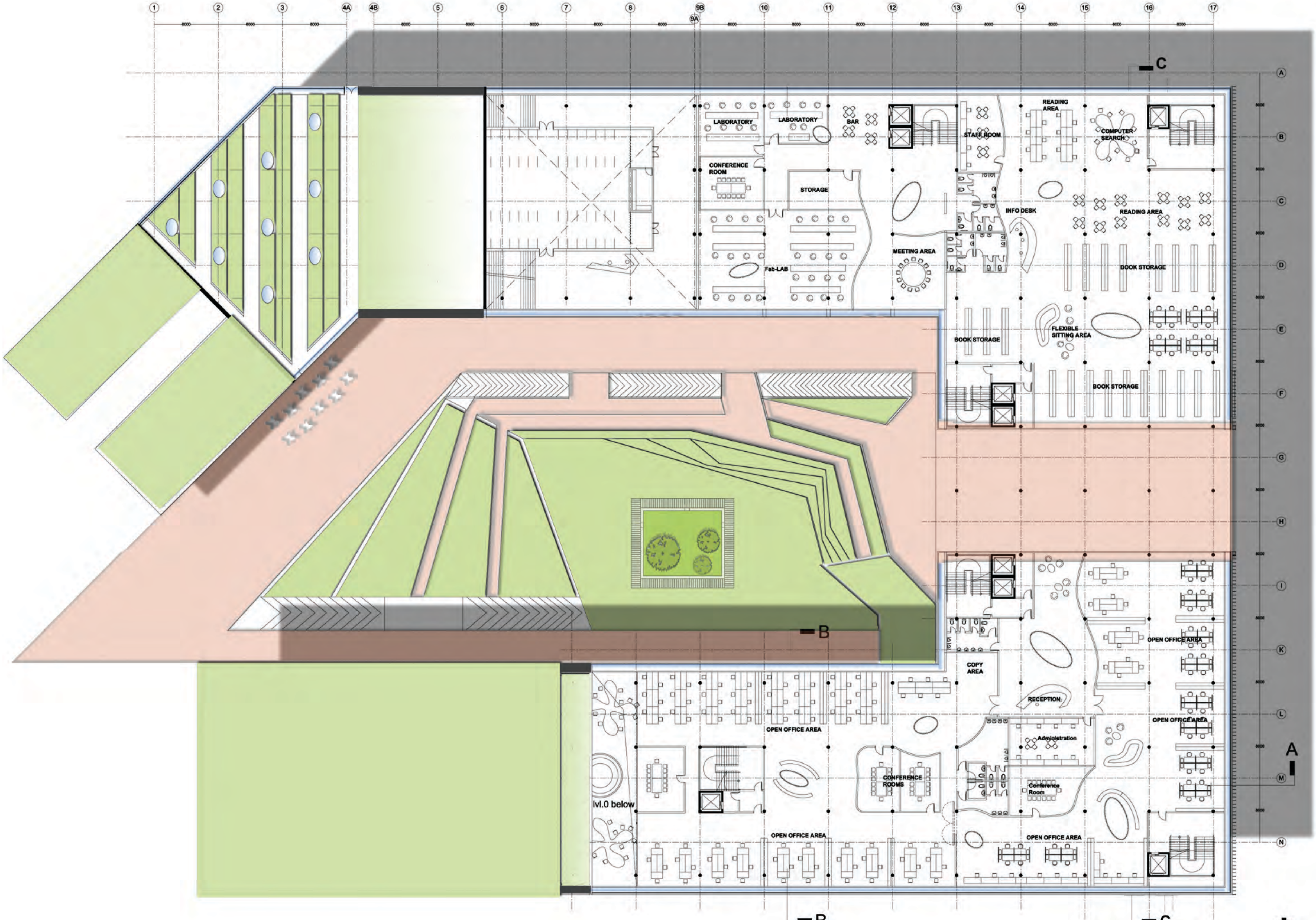
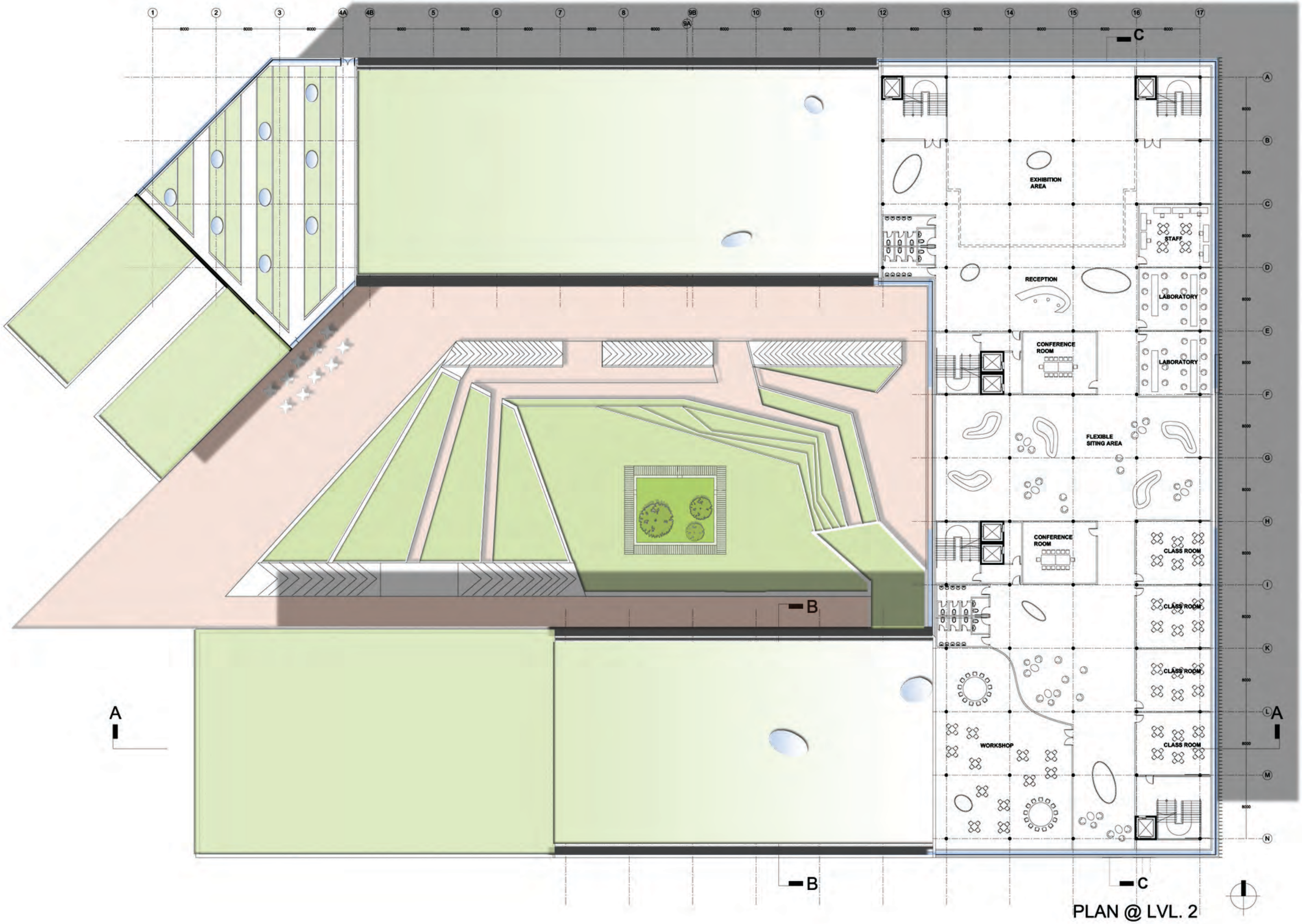


PLAN @ LVL 1

POLITECNICO DI MILANO
M. Sc. ARCHITECTURAL ENGINEERING

PROJECT TITLE :	DRAWING TITLE :	AMENDMENTS	REV. DATE	DRAWN BY :	CHECKED BY :	APPROVED BY :	SCALE :	DATE :
Turin to Smart Green	FIRST FLOOR			AMIN	PROF. MASERA	PROF. MASERA	1/500	27/06/2014
				DRAWING NO :	P-UR-01-02-01B		REV :	004



PLAN @ LVL. 2

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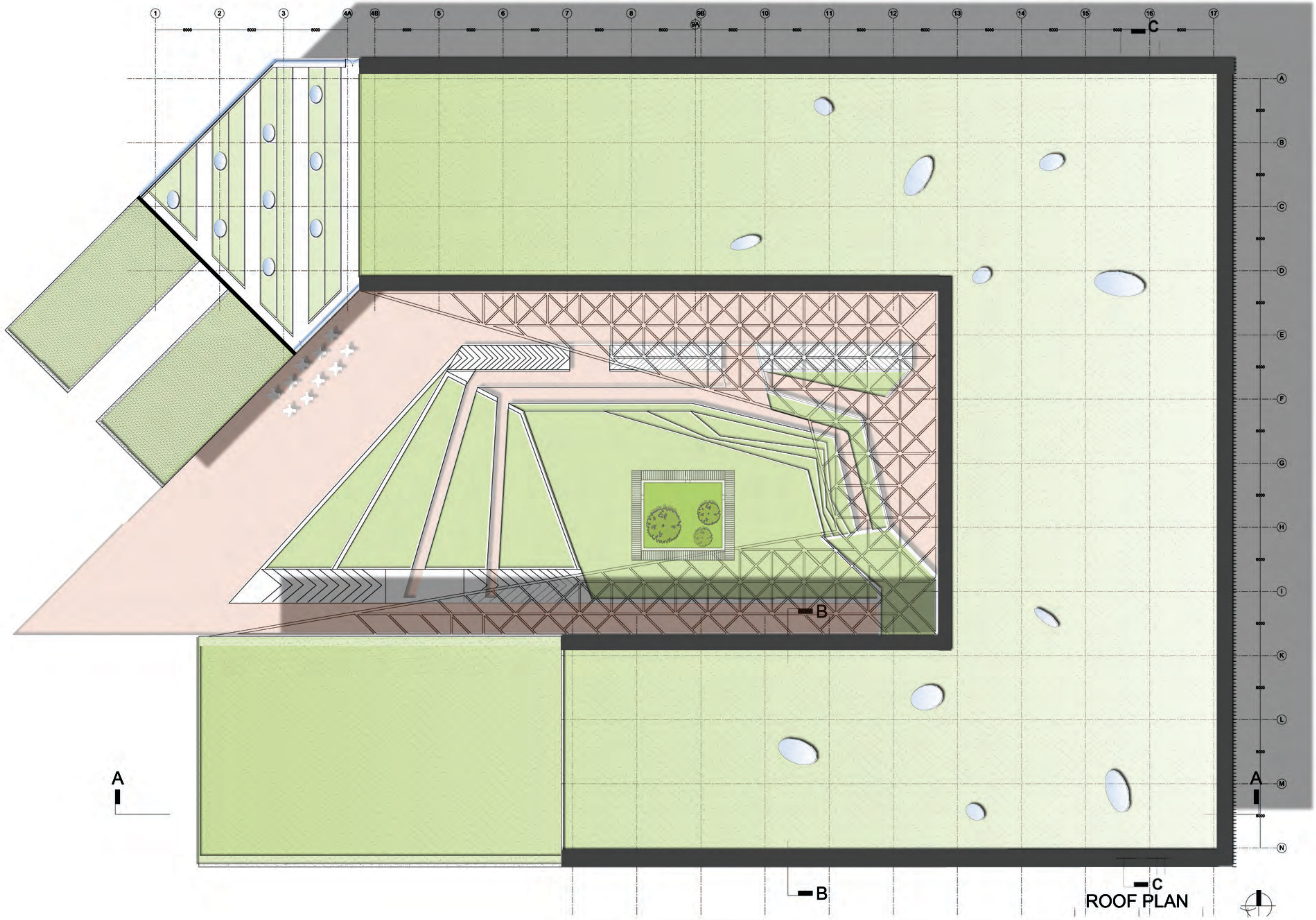

POLITECNICO DI MILANO M. Sc. ARCHITECTURAL ENGINEERING	PROJECT TITLE : Turin to Smart Green	DRAWING TITLE : ROOF TOP	AMENDMENTS	REV. DATE	DRAWN BY :	CHECKED BY :	APPROVED BY :	SCALE :	DATE :
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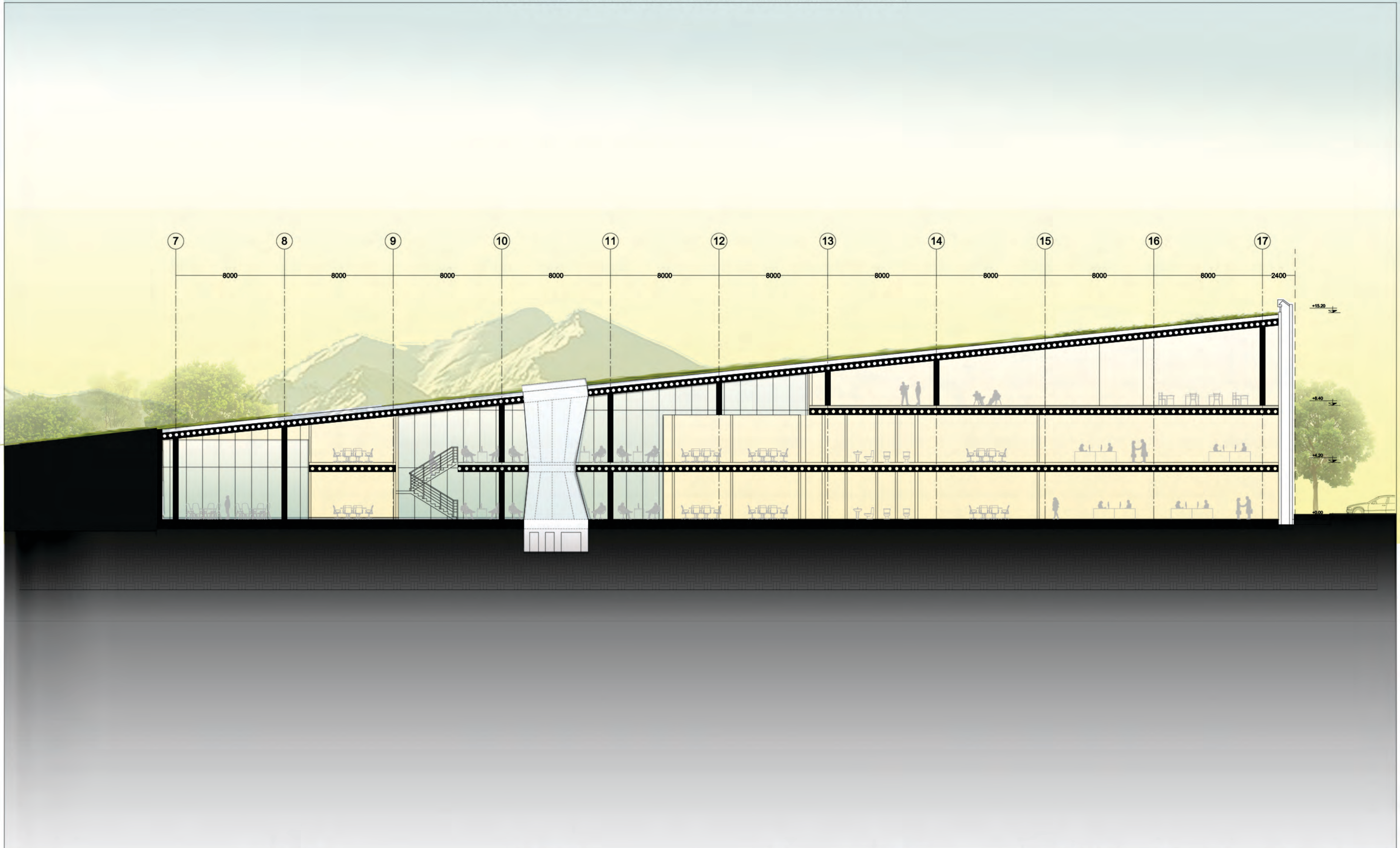


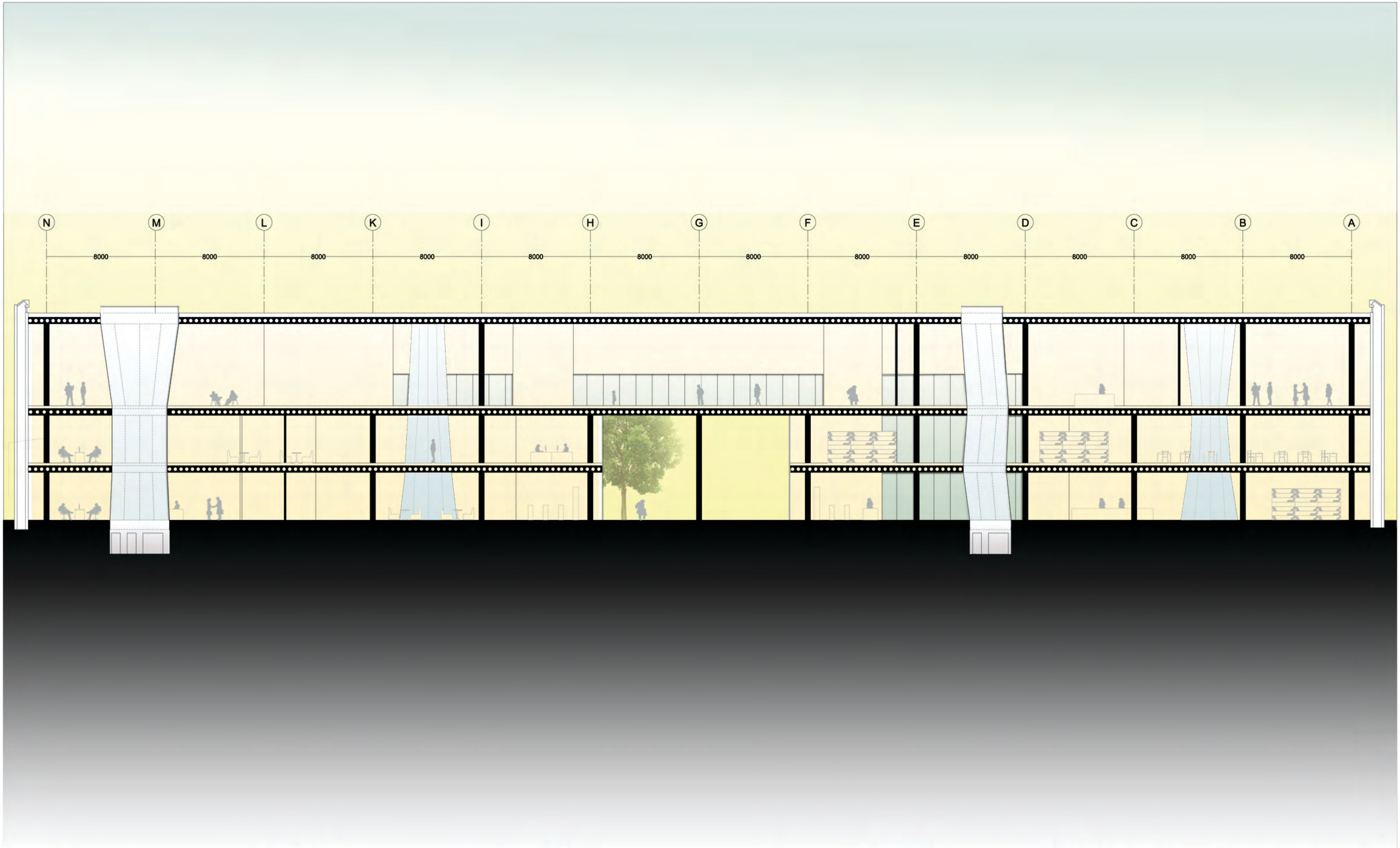
POLITECNICO DI MILANO
M. Sc. ARCHITECTURAL ENGINEERING

PROJECT TITLE : Turin to Smart Green

DRAWING TITLE : Section A-A

AMENDMENTS	REV. DATE

DRAWN BY :	CHECKED BY :	APPROVED BY :	SCALE :	DATE :
AMIN	PROF. MASERA	PROF. MASERA	1/250	27/06/2014
DRAWING NO :	100-P-UR-01-02A		REV :	004



POLITECNICO DI MILANO M. Sc. ARCHITECTURAL ENGINEERING	PROJECT TITLE : Turin to Smart Green	DRAWING TITLE : Section C-C	AMENDMENTS	REV. DATE	DRAWN BY :	CHECKED BY :	APPROVED BY :	SCALE :	DATE :
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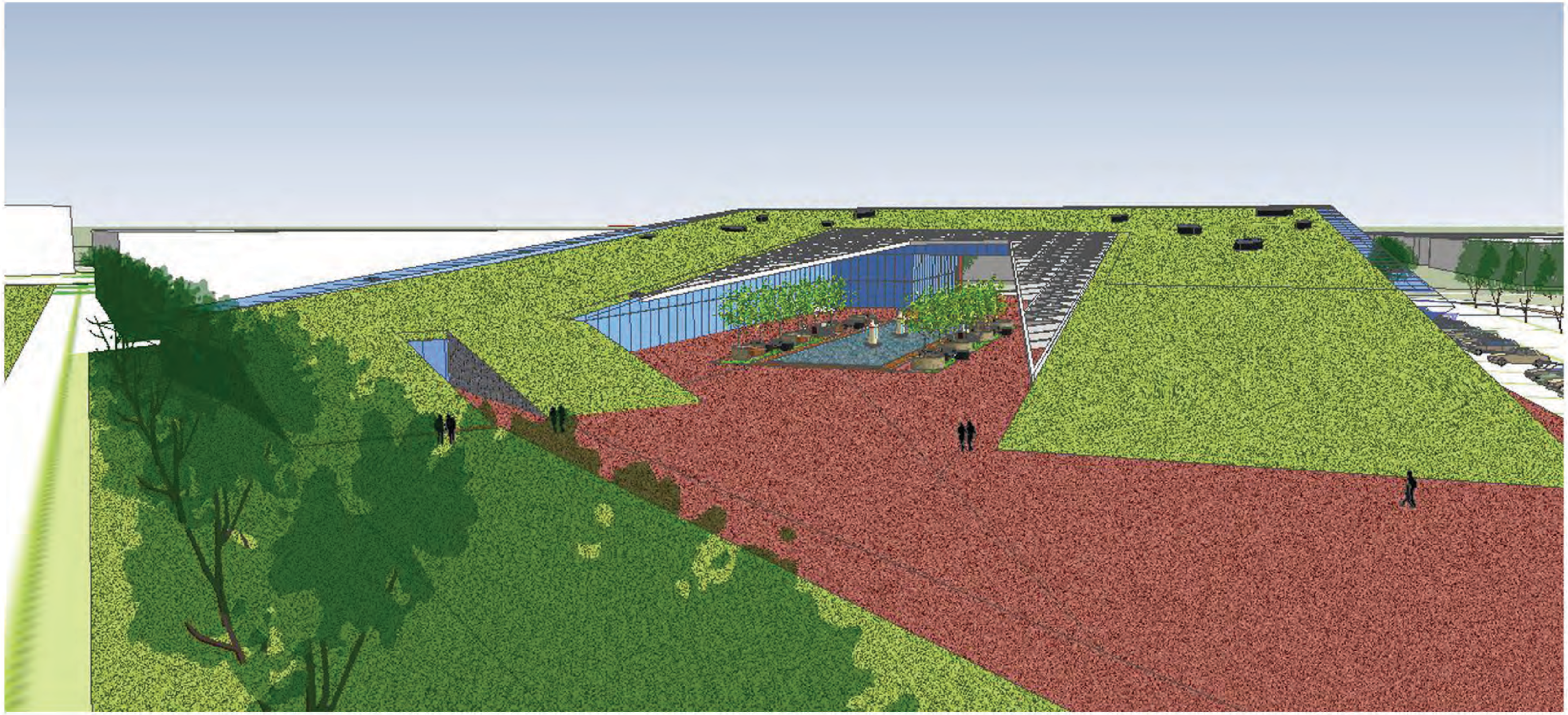
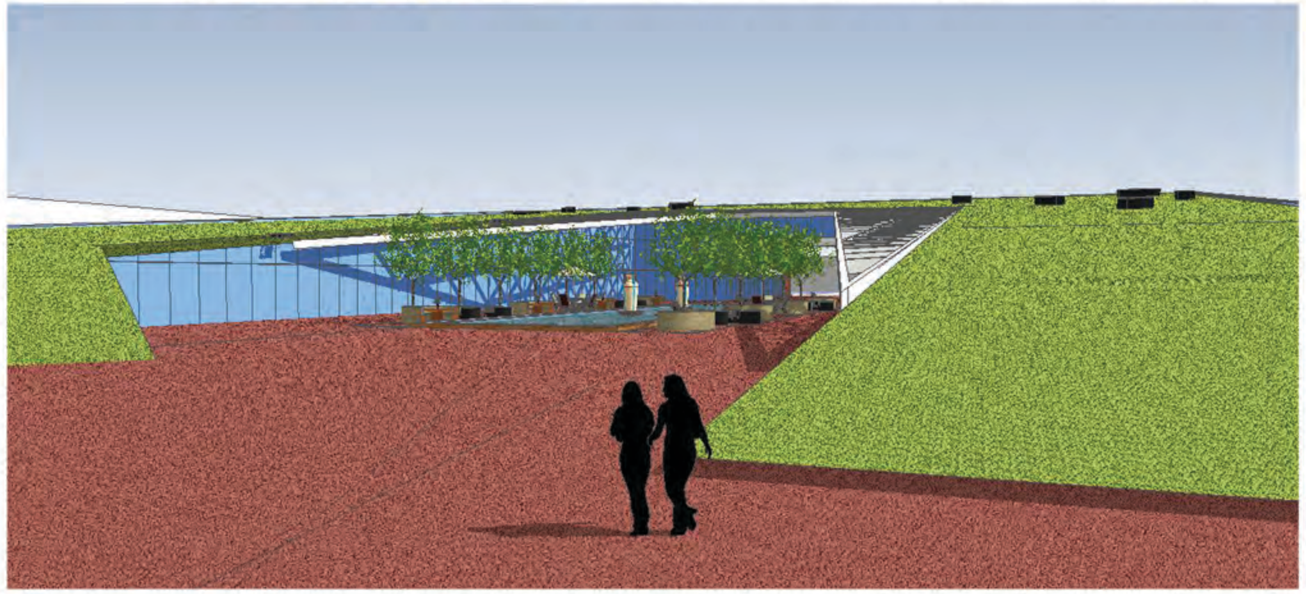




POLITECNICO DI MILANO
M. Sc. ARCHITECTURAL ENGINEERING

PROJECT TITLE :
Turin to Smart Green

DRAWING TITLE :
PERSPECTIVE VEIWS

AMENDMENTS	REV. DATE

DRAWN BY :	CHECKED BY :	APPROVED BY :	SCALE :	DATE :
AMIN	PROF. MASERA	PROF. MASERA	N.T.S	28/06/2014
DRAWING NO :	P-AD-02-03		REV :	001

CHAPTER 4

INTEGRATED SUSTAINABLE DESIGN

4.1 Climate Analysis [18]

As one of the first steps that has to be take toward design, in following is the climate analysis of Turin City and FIAT Mirafiori Sud. The results dictate which passive strategies are the most adaptable and applicable for project site. Designing climate responsive buildings requires a truly understanding of the local climate. Climate can categorize in different variable, here after we go through the most affective parameters in terms of sustainable and passive design. In this regard climate tool developed by UCLA energy design tool group has been used to analyze the project climate data. The premium data were applied to the software as follow:

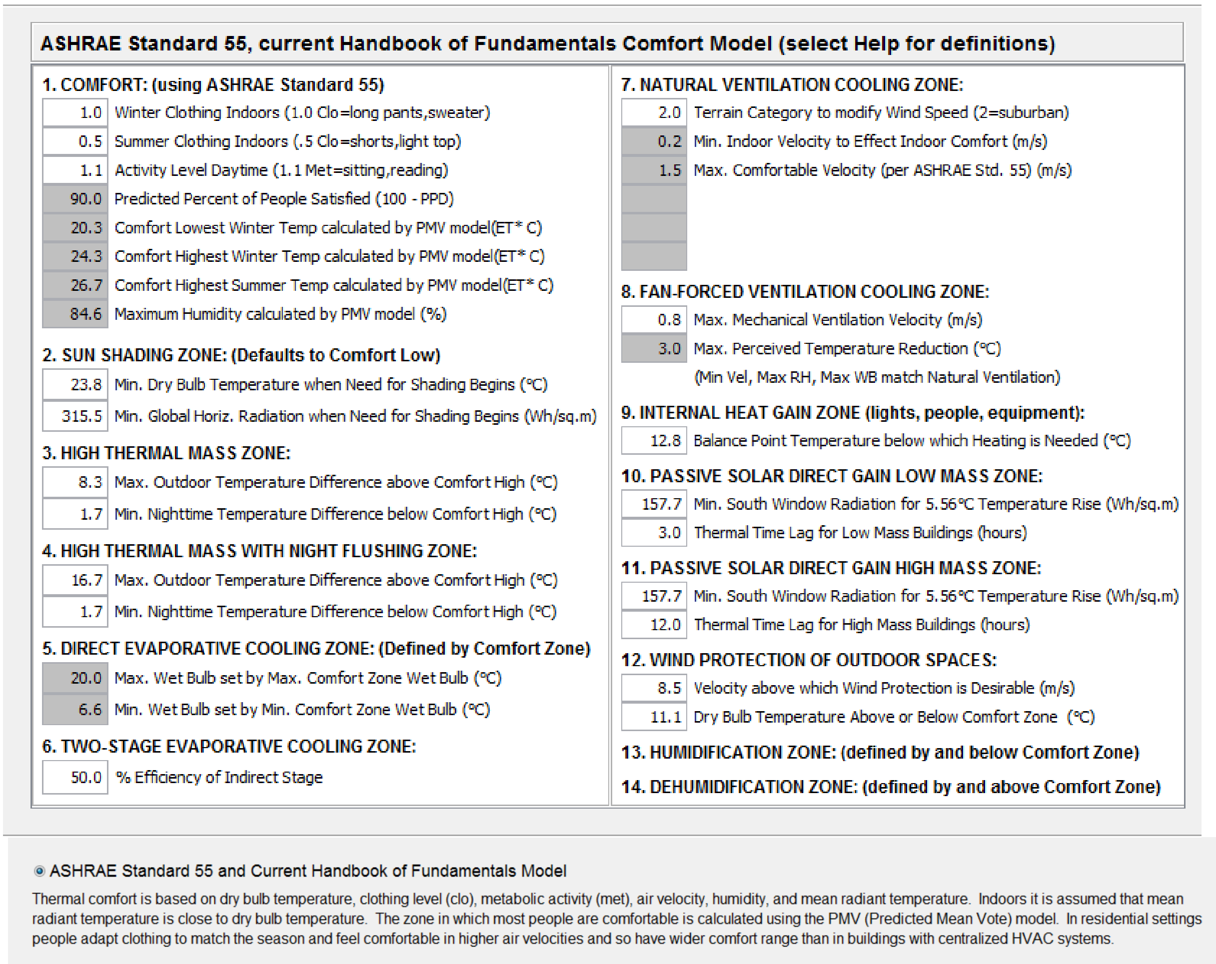


Figure 4-1 ASHRAE Standard 55 has been adopted

Thermal comfort is based on dry bulb temperature, clothing level (clo), metabolic activity (met), air velocity, humidity, and mean radiant temperature. Indoors it is assumed that mean radiant temperature is close to dry bulb temperature. The zone in which most people are comfortable is calculated using the PMV (Predicted Mean Vote) model. In residential settings people adapt clothing to match the season and feel comfortable in higher air velocities and so have wider comfort range than in buildings with centralized HVAC systems.

4.1.1 Historical Analysis

The weather data for last two decades of Turin city shows very well how the climate has been changing. It demonstrates the weather components such as temperature, wind, humidity, etc with their maximum and minimum values over a large time period for better understanding of the climate typology in the region of Turin city.

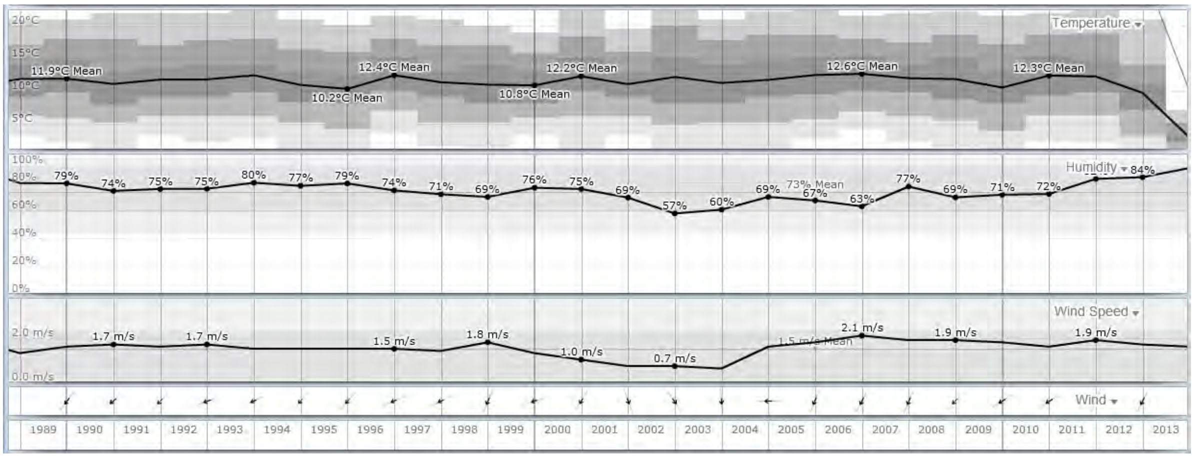


Figure 4-2Historical Climate Data [19]

4.1.2 Temperature

Temperature graph of the region shows the mean temperature values in Turin varies between -1° to 22°. And the lowest recorded is -10° and the highest recorded is 32°. It can also be interpreted that heating would be the critical load in this region for buildings.

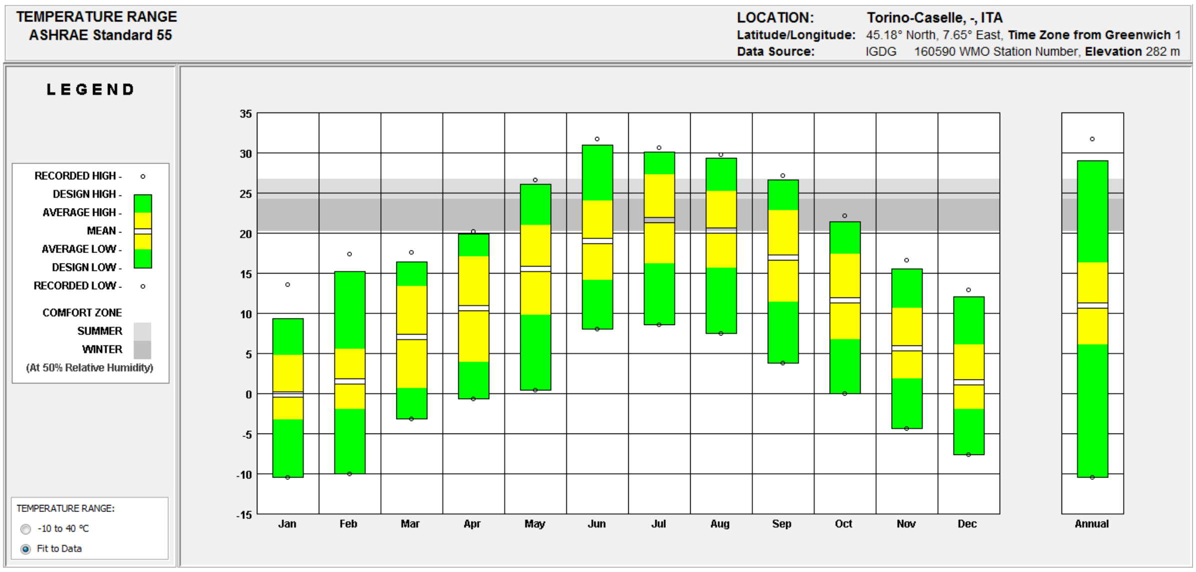


Figure 4-3 Daily high and low temperature [18]

This is the charts that shows the dry bulb temperature ranges enclosing the Recorded High and Low Temperature (round dots), the Design High and Low Temperatures (top and bottom of green bars), Average High and Low Temperatures (top and bottom of yellow bars), and Mean or Average Temperature (open slot). These values are calculated for each month and for the full year. The Annual Design Temperatures are used to calculate the Heat Loss and the Heat Gain of the building, which is used to size the heating and cooling equipment. Design Temperatures are also shown for each month using the same percentage of hours in that month.

4.1.3 Sun Exposure

From this chart as it can be observed, the highest amount of global radiation that can be obtain is 6500 Wh/m^2 per day in July and the lowest is 500Wh/m^2 per day in December and January. It also shows there is a high potentiality of radiation gains between April to August.

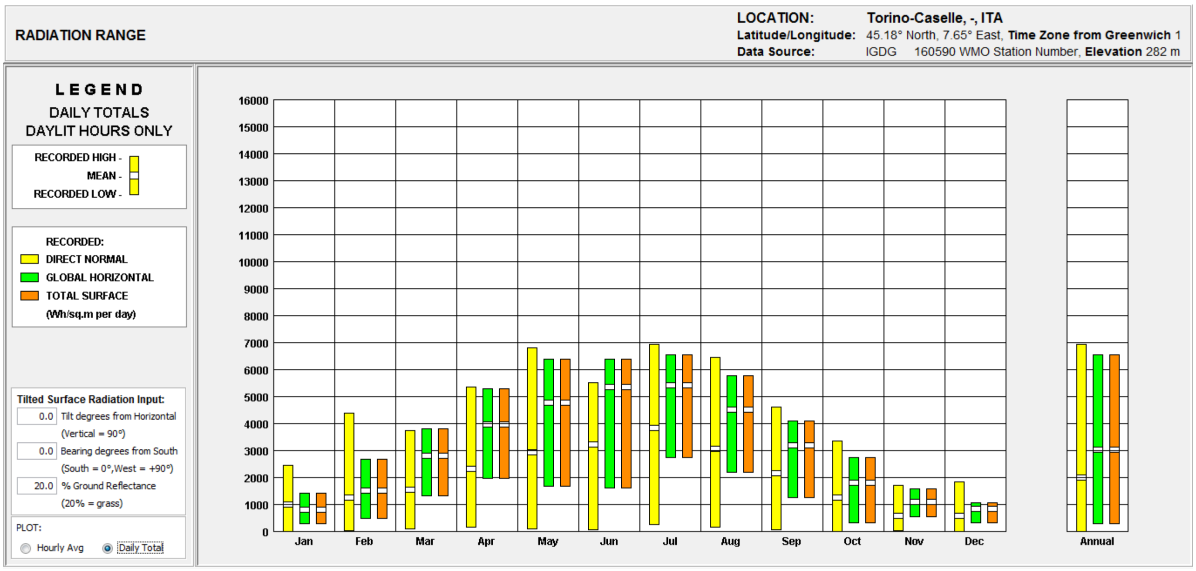


Figure 4-4 Daily total daylight hours [18]

*The Daily Total Radiation is the total Radiation for each day of the month showing the highest day of the month, the lowest day, and the mean or average day of the month. The units are in Btu/sq.ft or Wh/sq.m. The green bars show the amount of solar radiation that is recorded falling on a horizontal surface. In theory it is composed of all the diffuse radiation from the total sky vault plus the direct radiation from the sun times the cosine of the angle of incidence. Notice that the Global Horizontal Radiation peaks in summer because that is when the sun is highest in the sky and is thus more perpendicular to a horizontal surface. This is sometimes also called Total Horizontal Radiation.

4.1.4 Performance of PV

Observations: from the data in the above table, the two potentials for producing energy from the solar Photovoltaic panels are detailed for the whole year. As seen, the yearly potential is greater for summer (4750 Wh/m2.day) when the angle of opened louvers etc will be optimum. But in winter, when the angle is most probably zero owing to closing of louvers etc., but still a yearly potential of (3970 Wh/m2.day).

Monthly Solar Irradiation

PVGIS Estimates of long-term monthly averages

Location: 45°1'41" North, 7°36'27" East, Elevation: 256 m a.s.l.,

Solar radiation database used: PVGIS-CMSAF

Optimal inclination angle is: 38 degrees
Annual irradiation deficit due to shadowing (horizontal): 0.0 %

Month	H_h	H_{opt}	T_D	T_{24h}	N_{DD}
Jan	1510	2790	5.2	4.1	403
Feb	2550	4190	7.2	5.8	322
Mar	3850	5160	10.8	9.2	217
Apr	4880	5470	13.4	12.2	109
May	5770	5730	18.2	17.1	10
Jun	6450	6110	22.1	21.0	0
Jul	6790	6570	24.1	23.0	0
Aug	5720	6110	23.7	22.6	0
Sep	4320	5430	19.9	18.6	39
Oct	2660	3850	15.7	14.5	178
Nov	1610	2770	9.8	8.6	345
Dec	1500	2750	6.0	5.0	423
Year	3970	4750	14.7	13.5	2046

H_h: Irradiation on horizontal plane (Wh/m^2/day)

H_{opt}: Irradiation on optimally inclined plane (Wh/m^2/day)

T_D: Average daytime temperature (°C)

T_{24h}: 24 hour average of temperature (°C)

N_{DD}: Number of heating degree-days (-)

Figure 4-5 PVGIS estimates of solar electricity generation [18]

4.1.5 Precipitation Rate

The Average precipitation in Turin varies throughout the year. Precipitation in most happens in May, average value of 115 Millimiteres and Precipitation in least happens in December and January around 30 Millimeter. These data show there are high potentials to collect rain water during the year.

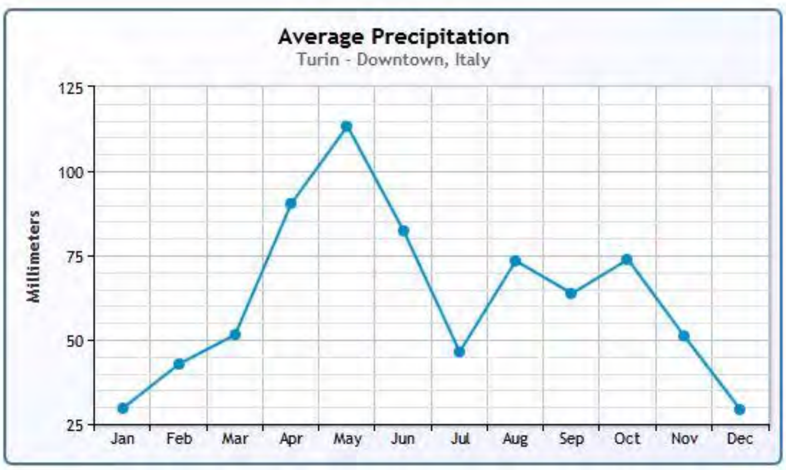


Figure 4-6 Average precipitation [20]

4.1.6 Relative Humidity

As per the following chart we can see the relative humidity in this region is quite high especially during cold period which is considerable in comfort design of the building.

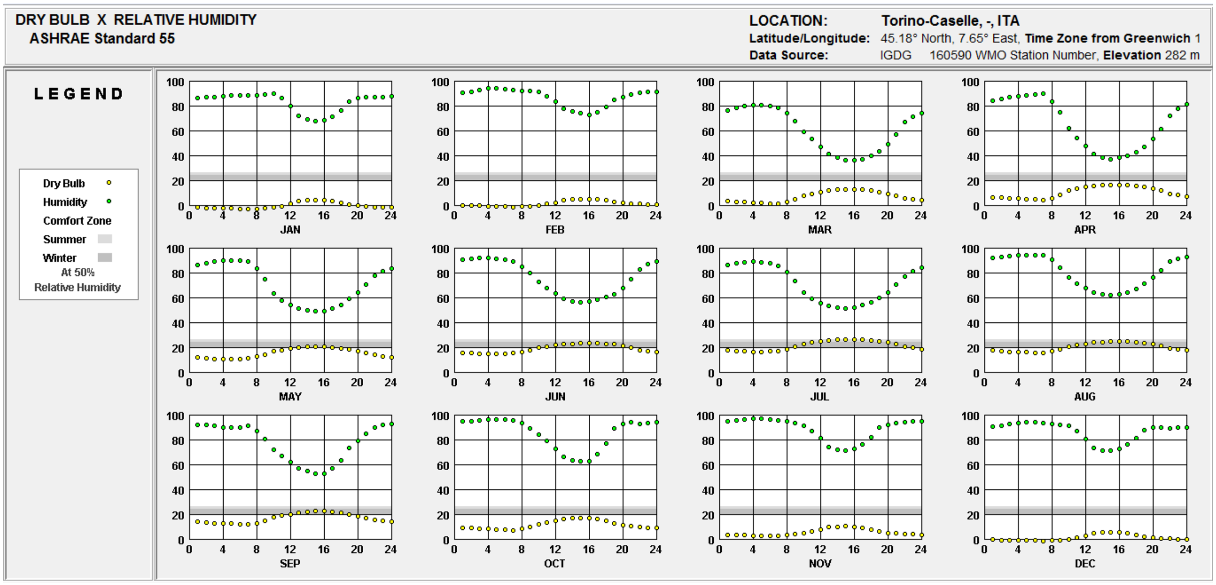


Figure 4-7 Relative Humidity [18]

These 12 charts are the average for each hour of each month of the Dry Bulb Temperature (yellow dot) and the concurrent Relative Humidity (green dot). Also shown on each monthly chart is a gray bar for the Comfort Zone as defined in (Fig 4-1). Notice that dry bulb temperature is almost exactly the inverse of relative humidity. Dry Bulb Temperature is the sensible temperature typically measured by a thermometer with a dry bulb. Relative Humidity is the ratio of the amount of moisture in the air compared to the total amount it could hold at the same dry bulb temperature. Relative Humidity is measured as a percent.

4.1.7 Dew Point

Dew point is often a better measure of how comfortable a person will find the weather than relative humidity because it more directly relates to whether perspiration will evaporate from the skin, thereby cooling the body. Lower dew points feel drier and higher dew points feel more humid.

The following chart shows during the hot season the dew points are close to comfortable zone.

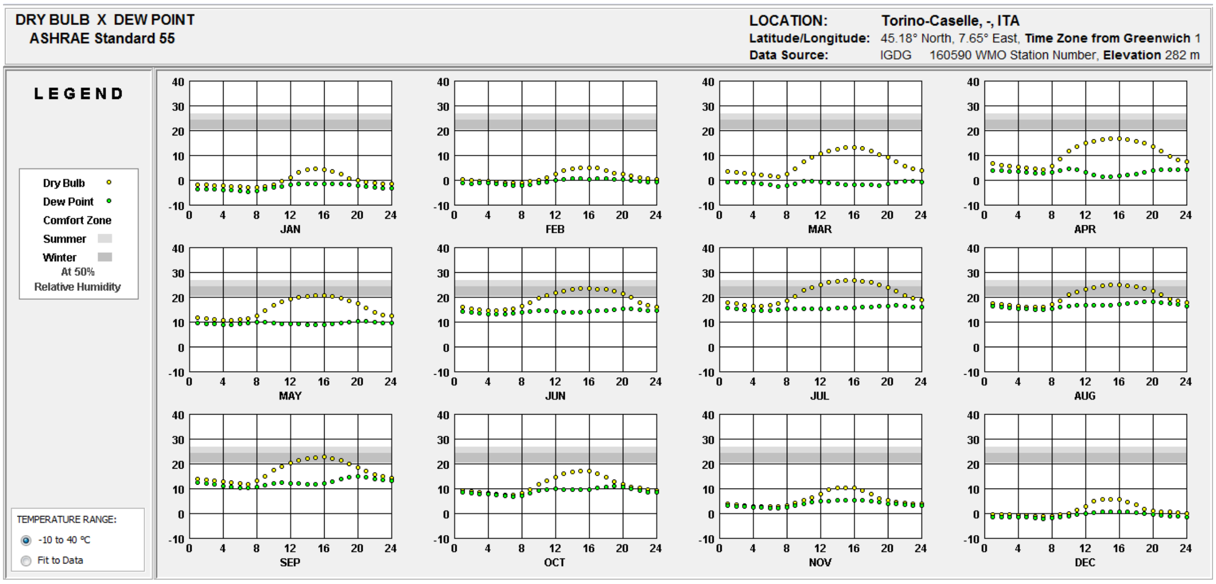


Figure 4-8 Dew Point [18]

4.1.8 Wind Characteristics

This chart shows for each month and for the full year, Wind Velocity in meters per second (m/s).

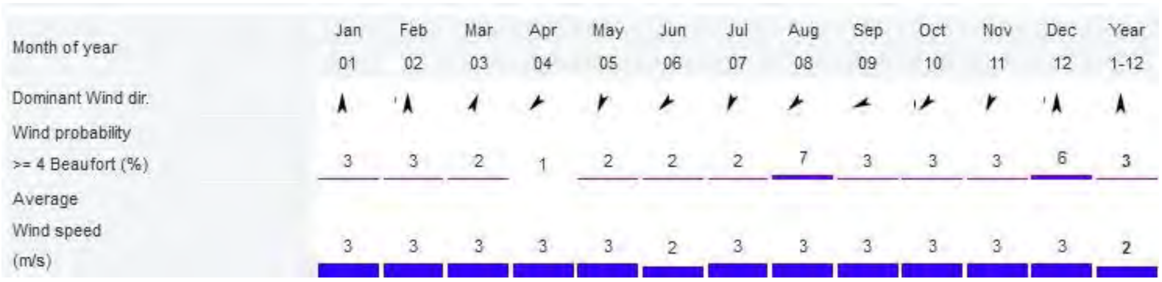


Figure 4-9 Wind characteristic in Turin [20]

Over the course of the year typical wind speeds vary from 0 m/s to 3 m/s (calm to gentle breeze), rarely exceeding 7 m/s (moderate breeze). the daily maximum is not more than 4 m/s, so it is not feasible to install a wind turbine for power production.

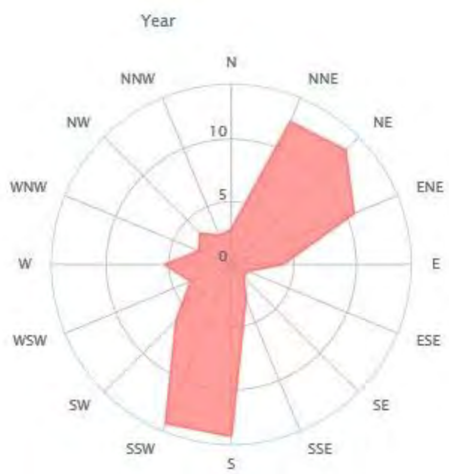


Figure 4-10 Prevailing Wind Direction [20]

4.2 Comfort Zones [18]

The comfort zone displayed in the chart has been derived from the Climate consultant software based on the parameters given in Fig 4-1.As we can see around 12% of the total hours from 7am to 8pm in one year is comfortable and 88% not comfortable.

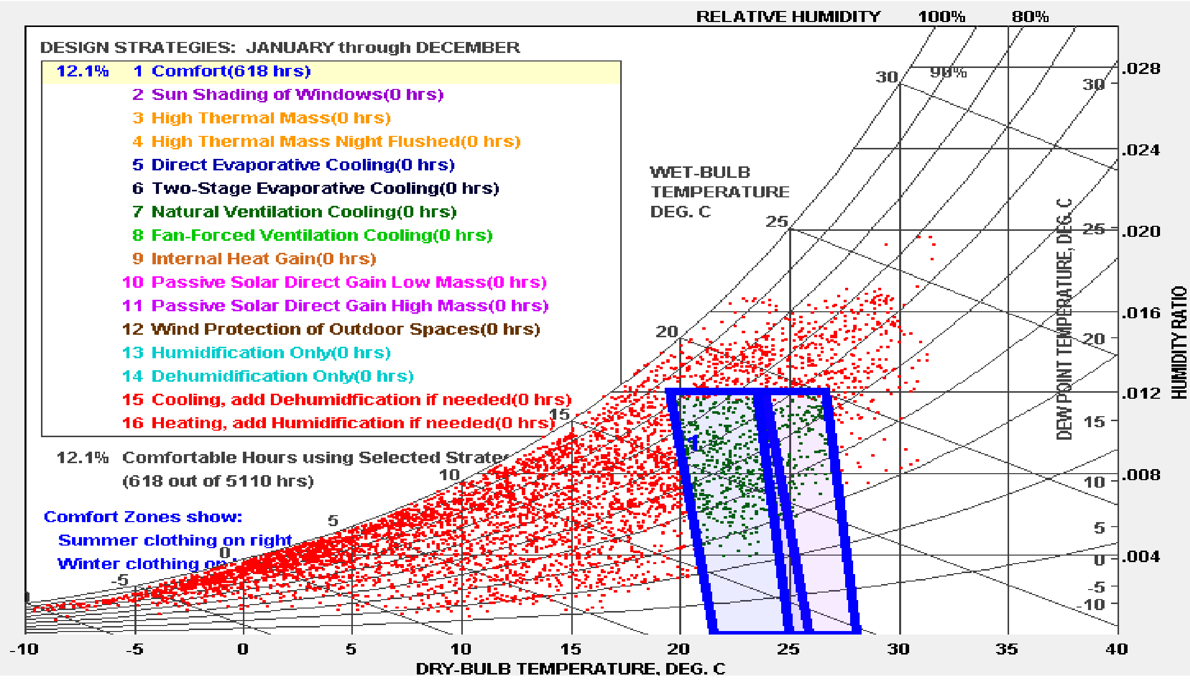


Figure 4-11 Comfort zone all year round frequency

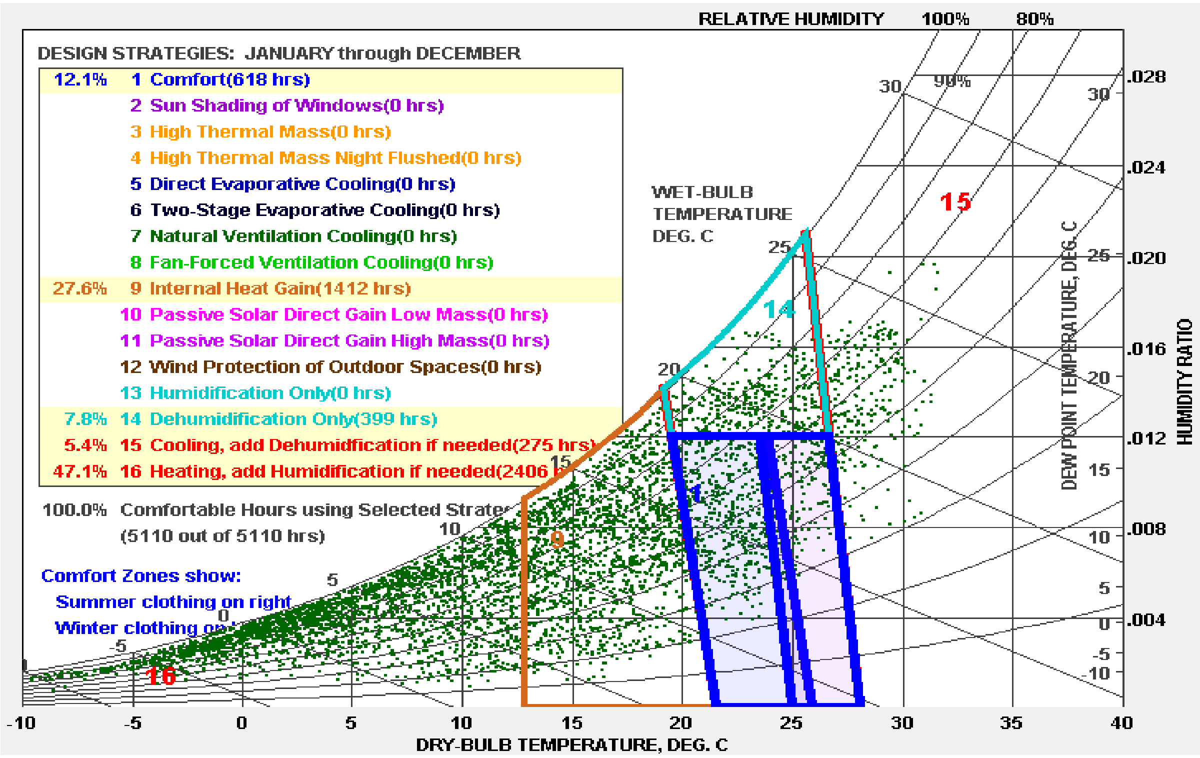


Figure 4-12 Design Strategies to reach 100% Comfort

The comfort zones representation for summer and winter seasons is represented in the following two diagrams. Depicting the requirement of summer cooling with dehumidification of air and heating of air with humidification in winter is necessary.

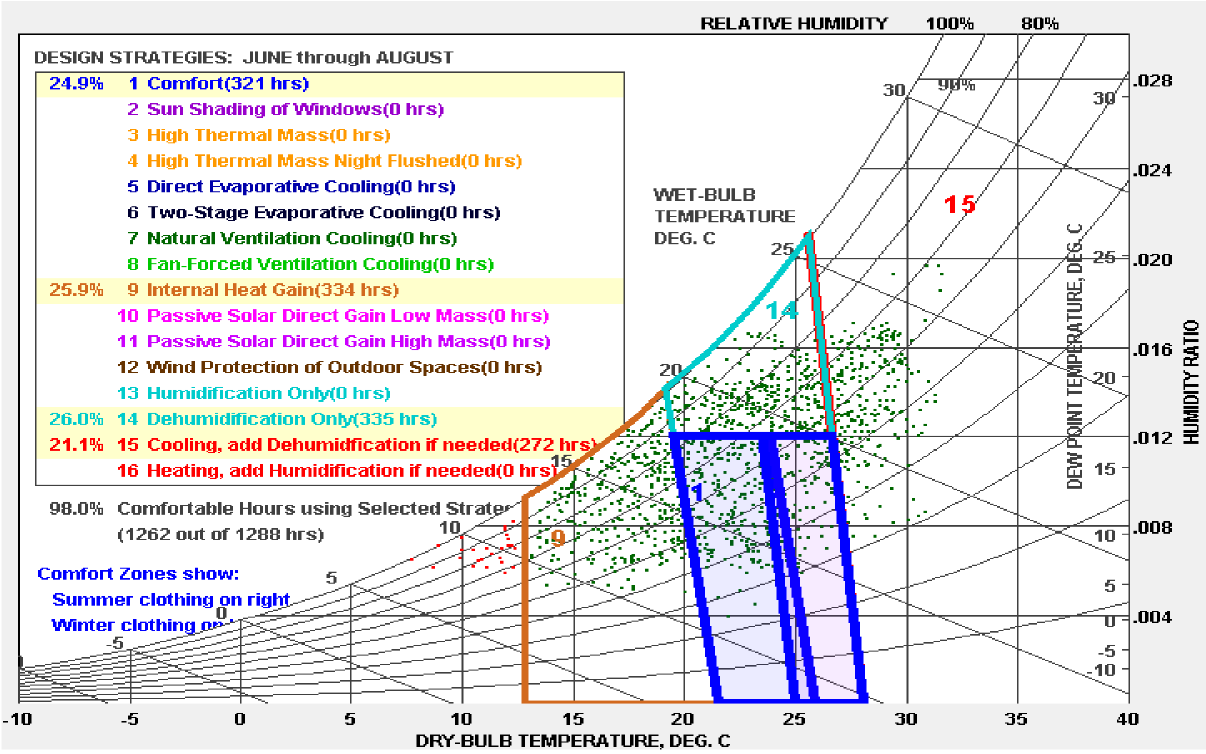


Figure 4-13 Summer comfort zone

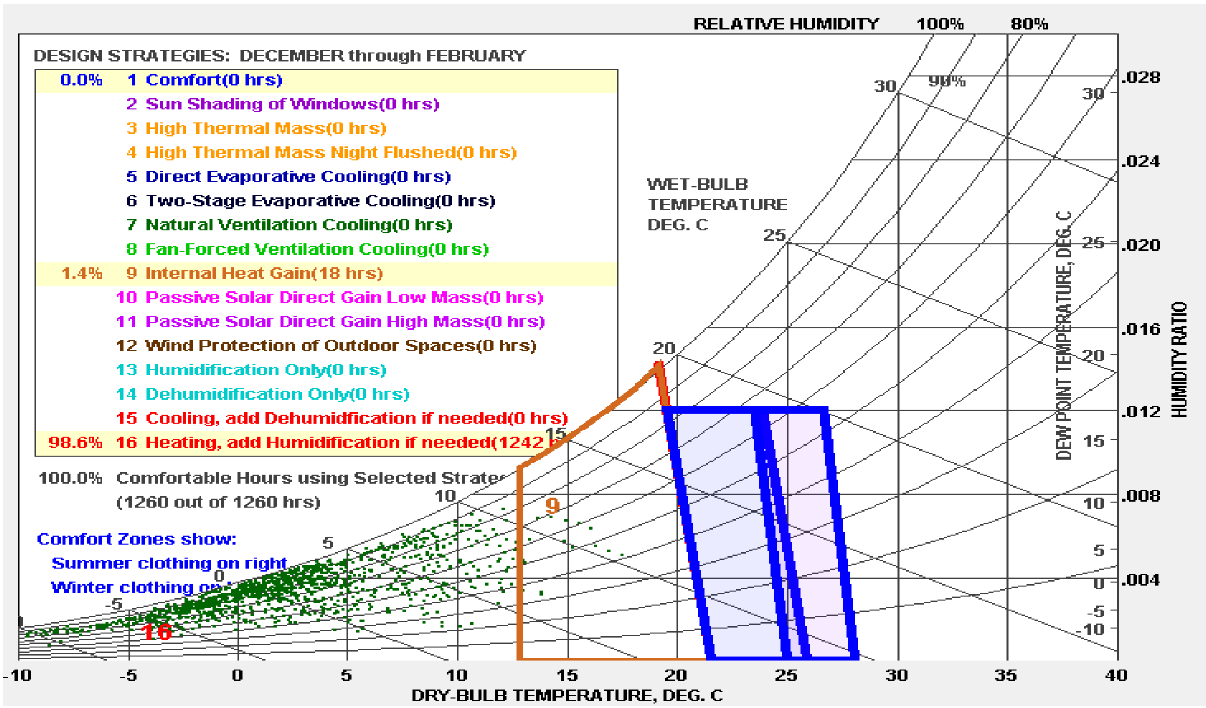
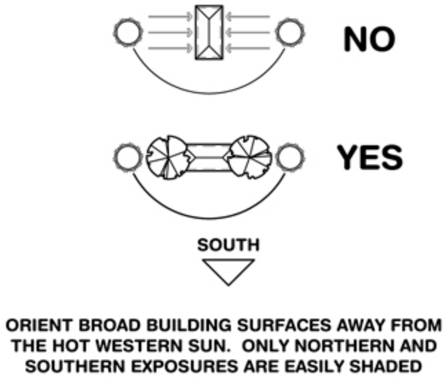


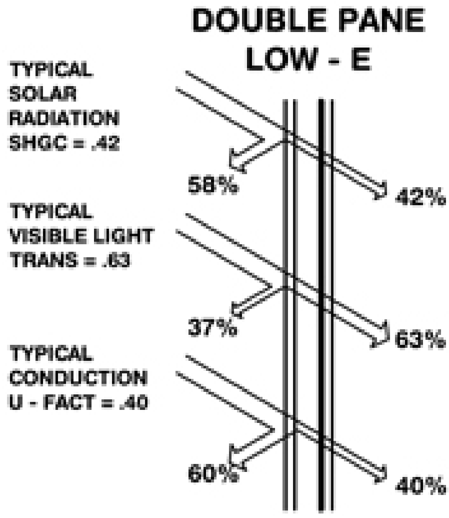
Figure 4-14 Winter comfort zone

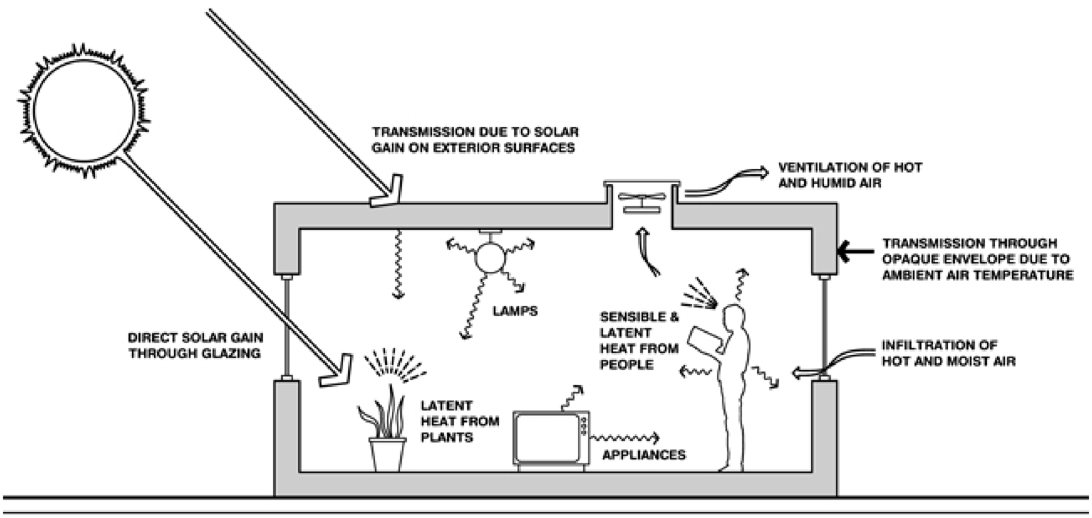
4.3 Conclusion: Proposed Strategies

In view of foregoing, we can conclude that all the passive design techniques will play their role in reducing the need to spend active means and energy to achieve comfort conditions. In the following, all the techniques are listed in combined manner.

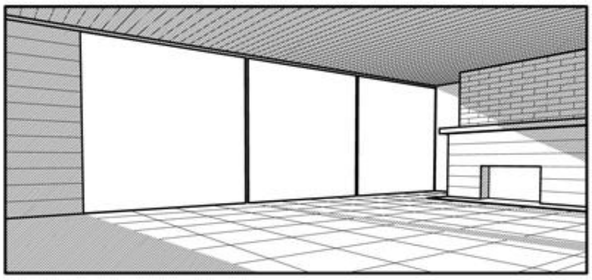


- For passive solar heating, face most of the glass area south to maximize winter sun exposure, but design overhangs to fully shade in summer
- Glazing should minimize conductive loss and gain (minimize U-factor) because undesired solar radiation gain has less impact in this climate
- Lower the indoor comfort temperature at night to reduce heating energy consumption (lower thermostat heating setback)
- Heat gain from lights, people, and equipment greatly reduces heating needs so keep home tight, well insulated (to lower Balance Point temperature)
- Keep the building small (right-sized) because excessive floor area wastes heating and cooling energy

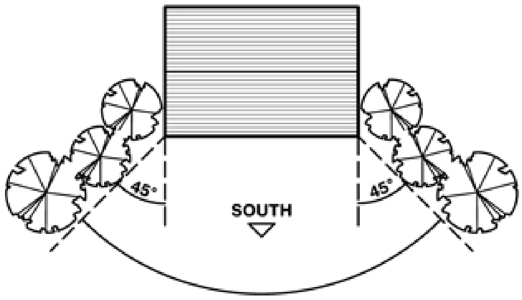




- Organize floor plan so winter sun penetrates into daytime use spaces with specific functions that coincide with solar orientation



- Trees (neither conifer or deciduous) should not be planted in front of passive solar windows, but are OK beyond 45 degrees from each corner



- Insulating blinds, heavy draperies, or operable window shutters will help reduce winter night time heat losses
- Carefully seal building to minimize infiltration and eliminate drafts, especially in windy sites (house wrap, weather stripping, tight windows)
- Super tight buildings need a fan powered HRV or ERV (Heat or Energy Recovery Ventilator) to insure indoor air quality while conserving energy
- Small well-insulated skylights (less than 3% of floor area in clear climates, 5% in overcast) reduce daytime lighting energy and cooling loads
- Use vestibule entries (air locks) to minimize infiltration and eliminate drafts, in cold windy sites

4.4 Building Energy Balance

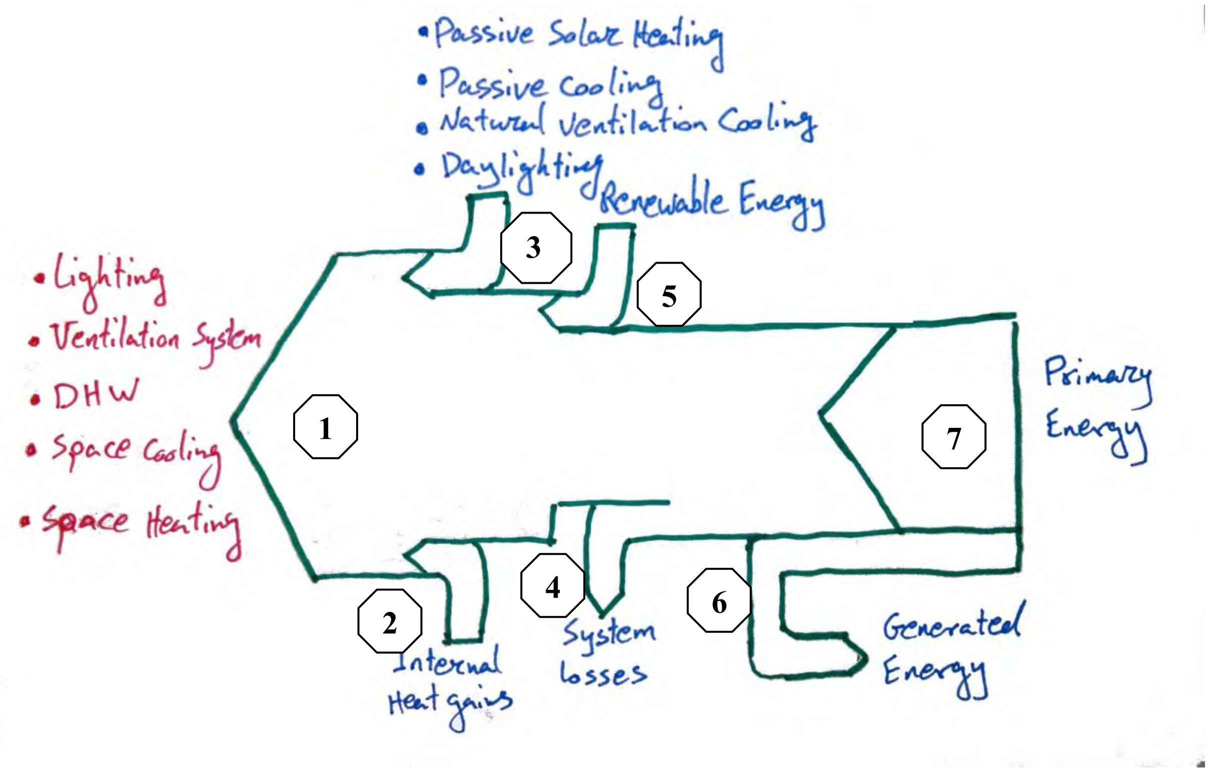


Figure 4-15 Schematic Illustration of energy balance in buildings

- [1] Represents the energy needed to fulfill the user's requirements for heating, cooling, lighting etc, according to levels that are specified for the purposes of the calculation.
- [2], [3] Represents the "natural" energy gains; passive solar heating, passive cooling, natural ventilation, daylighting together with internal gains (occupants, lighting, electrical equipment, etc).
- [3] Represent the energy losses due to ventilation and infiltration.
- [5] Represents renewable energy produced on the building premises.
- [6] Represents generated energy, produced on the premises and exported to the market; this can include part of [5].
- [7] Represents the primary energy usage or the CO2 emissions associated with the building.

Above diagram is derived and simplified from an umbrella document which Explain the general relationship between various European standards and the Energy Performance of Buildings Directive (EPBD). In this diagram we can see the energy balance of a building. In order to achieve and design low energy buildings means we have to minimize the difference between energy consumption and energy production of the building as a global system. Having this diagram in-hand in all steps in design process can help us to choose right decisions and strategies. Following are the sustainable approaches that have been adopted in order to reach to the best energy balance in our building.

4.5 Sustainable Approaches

Based on previous climate analysis and potential and strength of the site and the project service requirements the certain passive strategies were adopted in order to reach the minimum footprint construction.
Folowing will present the used techniques and tools to optimize the energy balance of the building and maximize the efficiency of the building systems.

4.5.1 Heating and Cooling

4.5.1.1 Ground Couple Passive Strategies [21]

Ground coupled passive air cooling, also sometimes referred to as earth or labyrinth cooling (two different passive cooling systems), involves using pipes/'earth tubes' buried in the ground or labyrinthine concrete passageways beneath a building to passively cool fresh air, which is then supplied to a building's interior (and potentially moved through the building using a passive stack system). Because the earth is at a constant temperature of around 10-12°C at greater than 5m depth, passing air underground provides free pre-warming of air in winter and pre-cooling during the summer, thereby reducing the need for active heating and cooling plant. In summer air can be cooled from 28°C down to around 17°C, while in winter air can be warmed from below zero to around 5°C.
Design considerations include ensuring pipework is designed to prevent bacterial growth and to enable thermal conductivity to the ground; and considering the quality of intake air and the possible need for air filters. Since the surrounding ground will be heated as summertime air passes through the system, the rate at which the cooling output of the system is reduced during continuous operation should also be considered. Excavation costs need to be taken into account, but these will be reduced where installation forms part of a new build project.

4.5.1.1.1 Earth Tubes [22]

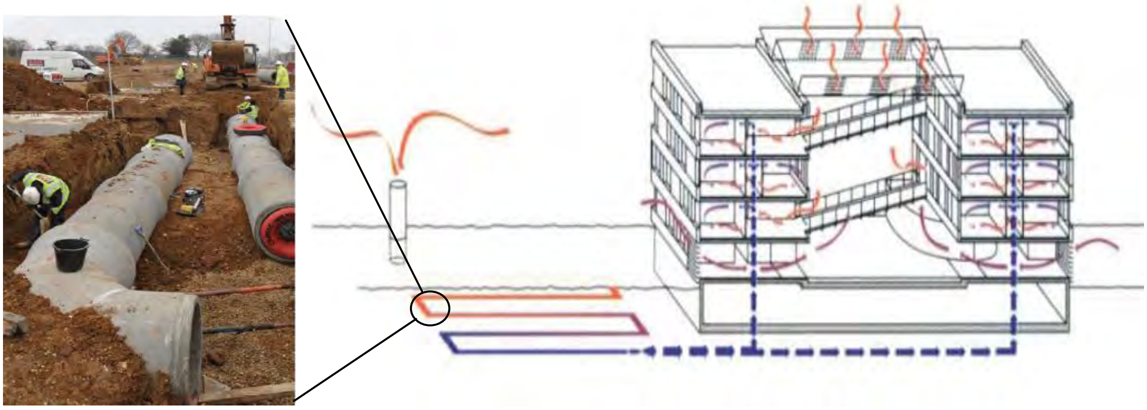


Figure 4-16 Earth-to-air heat exchangers

Earth-to-air heat exchangers are simple systems to save energy in buildings which are equipped with an active ventilation system: In addition to the conditioning and distributing of the air in the building, the fresh air is sucked through pipes buried in the ground. In this way the fresh air is pre-cooled in summer and pre-heated during the winter. The energy delivered by the system strongly depends on the different parameters of the earth-to-air heat exchanger like length beneath foundations, length beneath undeveloped ground, depth, diameter, material, number and distance of the pipes.

4.5.1.1.2 Ground Source Heat Pump System [23]

Ground-source or geothermal heat pumps are a highly efficient, renewable energy technology for space heating and cooling. This technology relies on the fact that, at depth, the Earth has a relatively constant temperature, warmer than the air in winter and cooler than the air in summer. A geothermal heat pump can transfer heat stored in the Earth into a building during the winter, and transfer heat out of the building during the summer. Special geologic conditions, such as hot springs, are not needed for successful application of geothermal heat pumps. Ground-source heat pumps (GSHPs) are receiving increasing interest because of their potential to reduce primary energy consumption and thus reduce emissions of greenhouse gases. A heat pump can save as much as 30%–40% of the electricity used for heating.

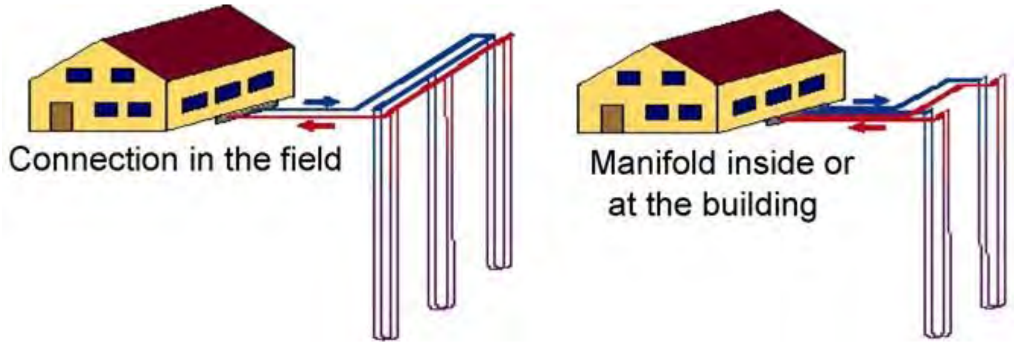


Figure 4-17 Vertical heat exchangers (double-U-pipe)

In a standard vertical heat exchanger, plastic pipes (polyethylene or polypropylene) are installed in boreholes, and the remaining room in the hole is iflled (grouted) with a pumpable material. Several types of borehole heat exchangers have been used or tested; the two possible basic concepts are:

- U-pipes, consisting of a pair of straight pipes, connected by a 1801 turn at the bottom. One, two or even three of such U-pipes are installed in one hole. The advantage of the U-pipe is low cost of the pipe material, resulting in double U pipes being the most frequently used borehole.
- Coaxial (concentric) pipes, either in a very simple way with two straight pipes of different diameter, or in complex conifgurations heat exchangers in Europe.

Wells are bored to depths that typically range from 20m-90m deep. The closed-loop pipes are inserted into the vertical well. Typical piping requirements range from (17.4 to 52.2 m/kW), depending on soil and temperature conditions.

Advantages: Requires less total pipe length than most closed-loop designs; requires the least pumping energy of closed-loop systems; requires least amount of surface ground area; ground temperature typically not subject to seasonal variation.

Disadvantages: Requires drilling equipment; drilling costs frequently higher than horizontal trenching costs; some potential for long-term heat build-up underground with inadequately spaced boreholes.

4.5.1.1.3 Surfaces with Capillary Tubes [24]

Modern office and business premises must be climate controlled nearly all year long because of their high thermal insulation and their internal loads from computers and office appliance.

At the heating period they have comparatively low heat consumption. The energetic cost saving solution is heating and cooling ceiling and walls. The heating and cooling mat with capillary tubes can be directly fixed to the raw ceiling and walls then plastered.

- **Plaster Wall and Ceiling with Heating and Cooling Mats**

In this system the heating and cooling mats are simply embedded into the ceiling plaster. Since the capillary tubes are positioned directly beneath the surface (the ceiling construction is thinner than 15mm). The surface will heat up or cool down fast. The time reaction of the ceiling is less than 15minutes.

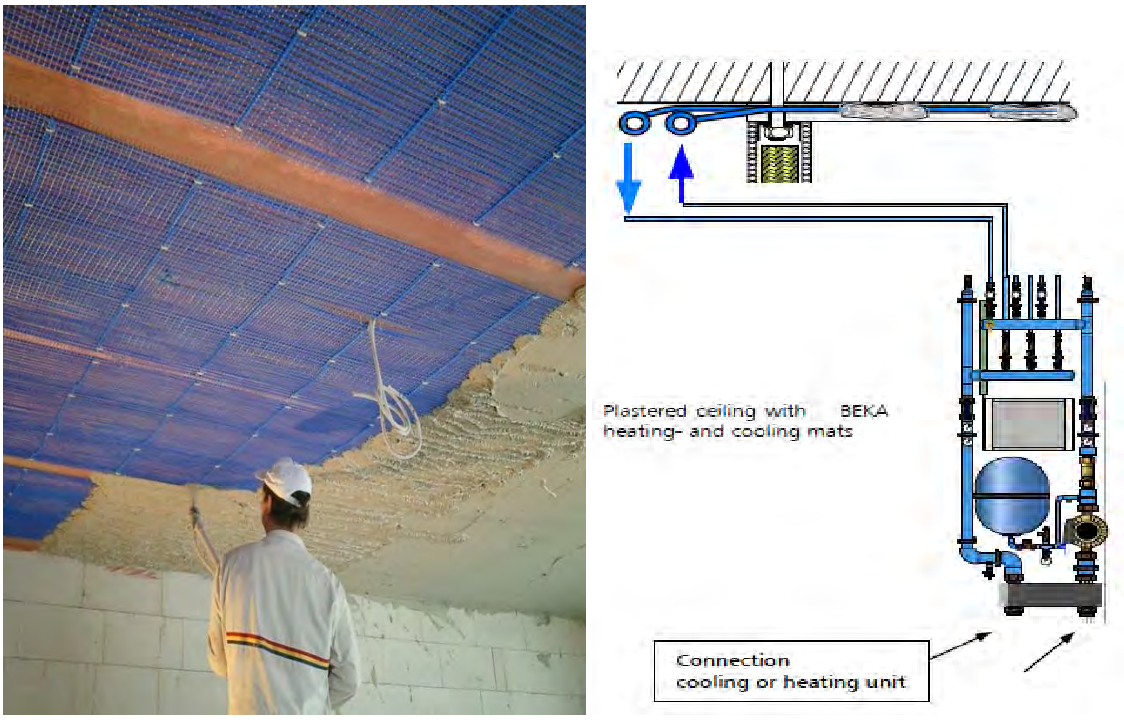


Figure 4-18 Ceiling Cooling Mats [24]

- **Plaster walls with Heating and Cooling Mats**

A low cost solution to save energy is the use of wall heating-cooling system. With the use of pre-fabricated units heating and cooling surfaces can be arranged simply and economically in the dry-build version. Through the combined function of the wall surface investments for the necessary building installations can be minimized. The system is fixed to support structure like any other standard dry-build board, according to the dry-build directions. The supply lines, pre fabricated to the required to measurements are laid into the wall cavities. The prefabricated units are connected to the supply lines with flexible hoses.

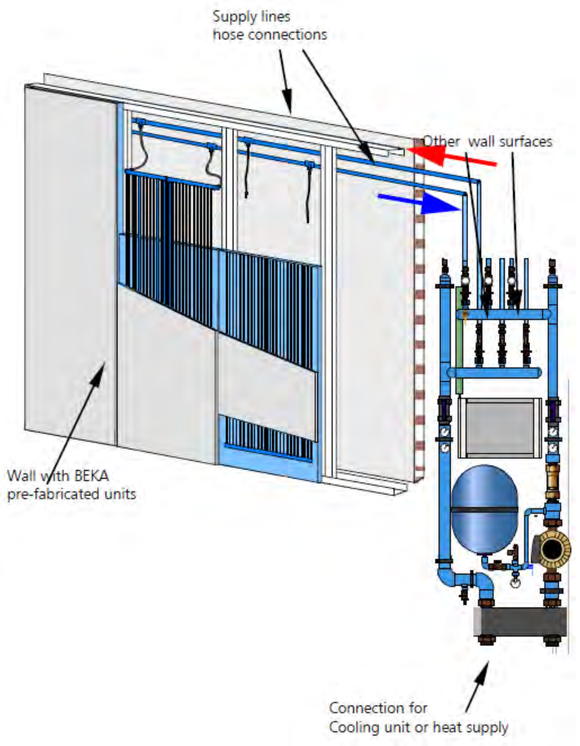


Figure 4-19 Wall System Cooling Mats [24]

4.5.1.1.4 Heat Recovery System

The heat recovery system is used as a technique to conserve heat energy by being extracted out of exhaust air. This fairly simple method is very proficient in saving energy and making the overall system more efficient. There are 3 types of heat exchangers for heat recovery: Liquid-to-liquid, Air-to-liquid and Air-to-air. Since the double skin façade is used to exhaust hot air in summer, this system can be integrated with air-to-air heat recovery system for winter season.

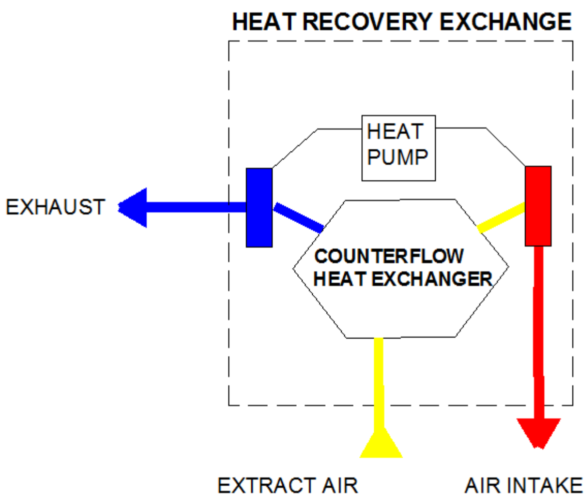


Figure 4-20 Wall System Cooling Mats

The (passively heated) exhaust air coming into the facade by the stack effect will be recovered in the system and send back to the light well air outlet.

4.5.1.1.5 Radiant Ventilated Raised Floor System [25]

Heating / cooling floor type Planium-Eurotherm, with tubing inserted inside the modules of a raised floor (size 600x600 mm), removable and replaceable in a punctual way, which can be finished with materials of choice. The system is suitable for offices and / or environments where a raised floor is necessary, that guarantees the possibility of inspection, either in the interspace below, or in the installation placed there (f.e. electrical cables or network cables), allowing flexibility in the organization of work stations. The system must be able to match any structures built by specialized companies. Mean while, the under floor radiant water heating is an efficient method of distributing heat into a building to provide comfortable space heating, the system is invisible and clutter-free and radiates heat gently from ground level to avoid the convection losses and draughts generated by wall-mounted radiators.

1. *Finishing*
2. *Galvanized steel cover*
3. *Expanded cellular cement filling*
4. *Galvanised steel structural core*
5. *MidiX tubing*
6. *Galvanized steel containment basin*

Figure 4-21 Radiant Floor System [25]

4.5.1.2 Natural Stack Ventilation [26]

Stack ventilated buildings were divided into four main types. The edge-in, centre-out approach (E-C), the edge-in, edge-out strategy (E-E), the centre-in, edge-out (C-E) and the center-in, center-out (C-C) strategy. For the building due to design and energy consideration two options were possible; The edge-in, centre-out approach (E-C) and the Center-in, Edge-out (C-E) system. The

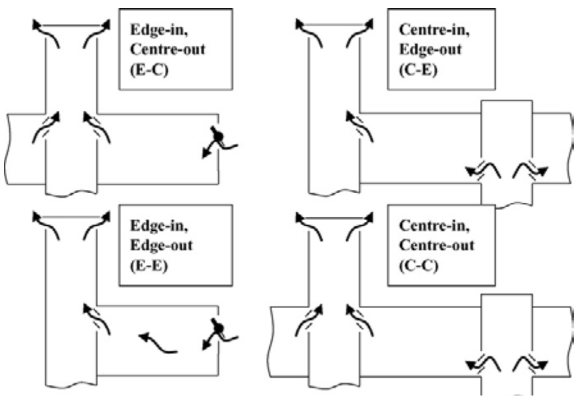


Figure 4-22 Schematic diagrams of the different forms of stack ventilation

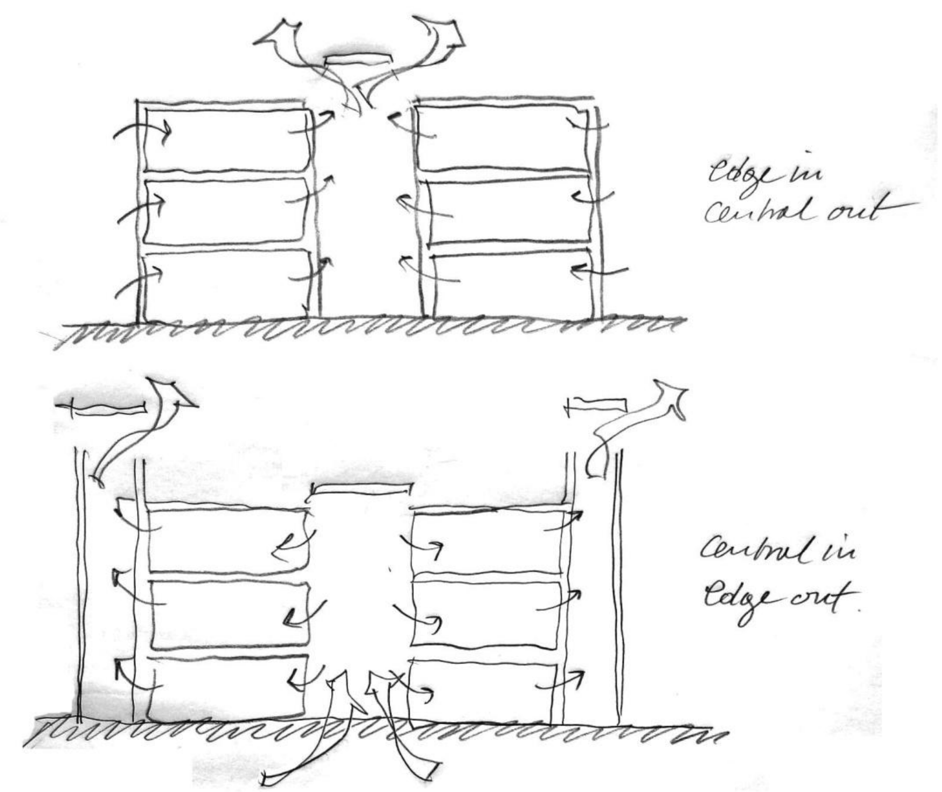


Figure 4-23 Schematic diagrams of the different solutions of stack ventilation

Final decision based on the study of both systems was taken considering the main advantages of each system which are generally as below;

- Night cooling of the building – when opening of inner windows is possible
- Improved burglary protection thanks to the double skins
- Better sound attenuation towards outside
- Efficient outer (intermediate) solar shading, as it can be used on windy days also
- Wind load on the façade can be reduced
- Airy, transparent and light buildings with a view to the inside and to the outside
- Building with increased access to daylight
- Openness and impression of the future
- Image creating

But in order to avoid noise pollution of the surrounding, and reduce the complexity of bringing direct air from outside to the façade (due to temperature and pressure fluctuation of outdoor climate), fully sealed façade were required that matches better with Center-in, Edge-out (C-E).

The leading innovation of the design process is the use of Natural Ventilation. The building will draw cool/warm air at the lower level through earth tubes, circulate this air throughout the facilities and eventually exhaust the air through double skin façade system. The combination of these elements creates a stack effect which both draws and exhausts naturally buoyant warm air.

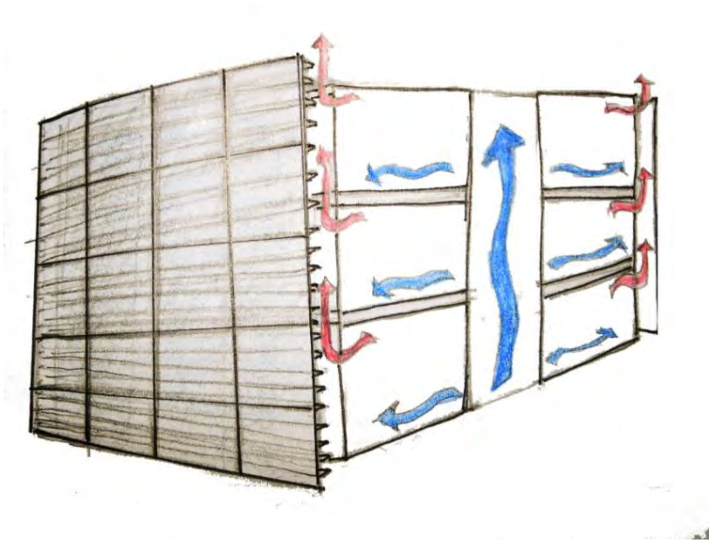


Figure 4-24-Schematic design of the C-E ventilation system used in the building

4.5.2 Lighting [27]

The first windows were conceived less for utilizing daylight than for ventilating rooms. The house itself was intended to provide protection against extreme weather condition and to offer safety. Historically buildings always have been planned in an integrated manner based on necessity: the characteristics and effects of daylight well-known because no other medium was able to provide adequate illumination. It was only after invention of electrical light and its widespread use that architects and planner began to lose their knowledge of daylight. Artificial light was seen as indisputable progress because it allowed light for the creation of windowless rooms and enormous room depth.

Today we have access to technological options, which can minimize many of the problems associated with glass façade in the past. Nevertheless, there is growing interest in daylighting, inspired, on the one hand, by lower costs for lighting and cooling and, on the other hand, by user comfort.

4.5.2.1 Natural Daylight [27]

Daylight differs qualitatively and quantitatively from artificial light in many different aspects, for example, in spectral composition and brightness as well as in fluctuation over the course of a day. This is why day light cannot replace by artificial light. Human beings need daylight because it satisfies two basic needs: illumination of the room and biological stimulation of psychological and physical sense of well-being. It is generally agreed that working in daylight cause less stress and discomfort than long-term working in artificial light.

4.5.2.2 Artificial Lighting [28]

LED light bulbs will eventually be what we use to replace incandescent bulbs – CFLs are a temporary solution to energy-efficient lighting. The reason LEDs have not yet displaced CFLs from the market are two: the first generation LED bulbs had a narrow and focused light beam, and the cost of the LED bulbs was too high.

Figure 4-25 Incandescent, CFL and LED lights

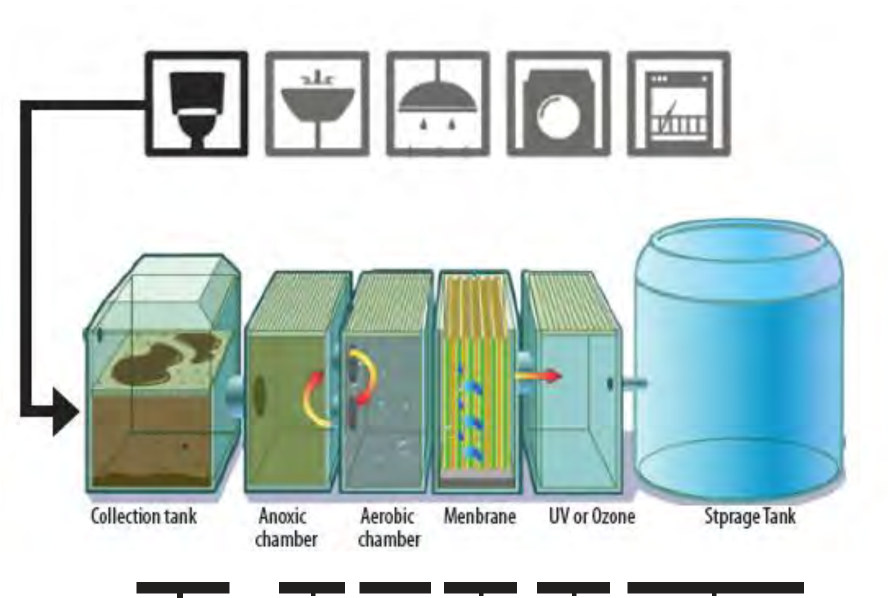
Recent developments in LED technology, however, have been addressing these issues. And advancements in manufacturing technology have driven the prices down to a level where LED bulbs are more cost-effective than CFLs or incandescent bulbs. The following comparison charts illustrate the value of the latest LED bulbs when compared with CFLs and incandescent for overall efficiency as well as cost-effectiveness.

Table 7

	LED	CFL	Incandescent
Light bulb projected lifespan	**50,000 hours**	**10,000 hours**	**1,200 hours**
Watts per bulb (equiv. 60 watts)	**10**	**14**	**60**
Cost per bulb	**$35.95**	**$3.95**	**$1.25**
KWh of electricity used over 50,000 hours	**500**	**700**	**3000**
Cost of electricity (@ 0.10per KWh)	**$50**	**$70**	**$300**
Bulbs needed for 50k hours of use	**1**	**5**	**42**
Equivalent 50k hours bulb expense	**$35.95**	**$19.75**	**$52.50**
Total cost for 50k hours	**$85.75**	**$89.75**	**$352.50**

4.5.3 Water Reuse

Water Reuse is the new term for what we used to know as water recycling or reclaimed water, and covers rainwater harvesting as well as greywater treatment. The purpose of these systems is to provide an alternative to mains drinking water that can be used for processes, or appliances that do not need such high quality water, this allows for non-wholesome water to be used for the first time, thereby trying to help reduce the reliance on public mains water. membrane system is a compact, odor-free, in-house system which can reuse all of the grey and blcak wastewater produced within a commercial or residential complex.



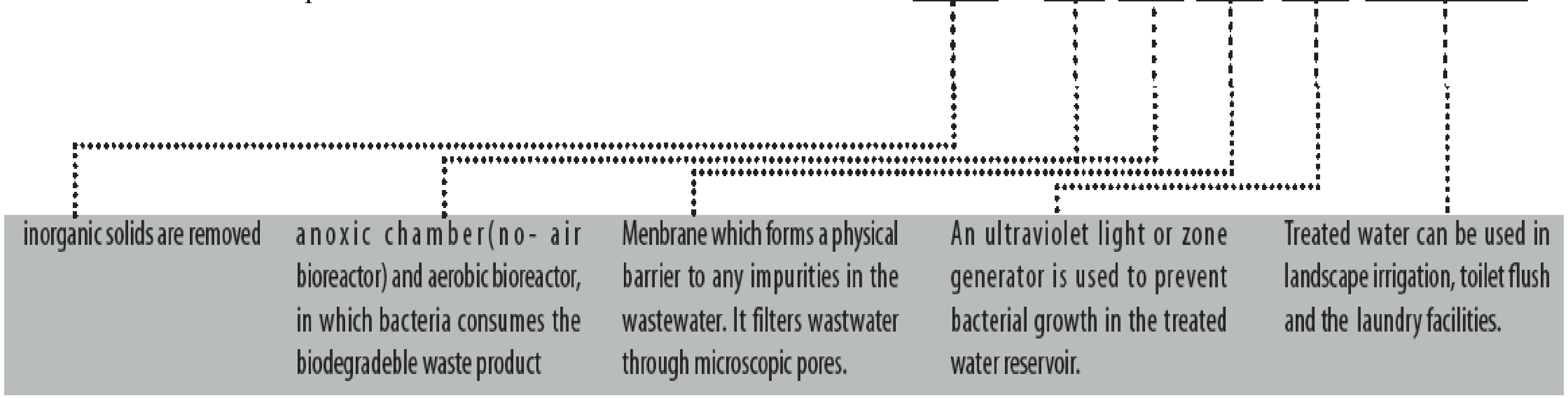
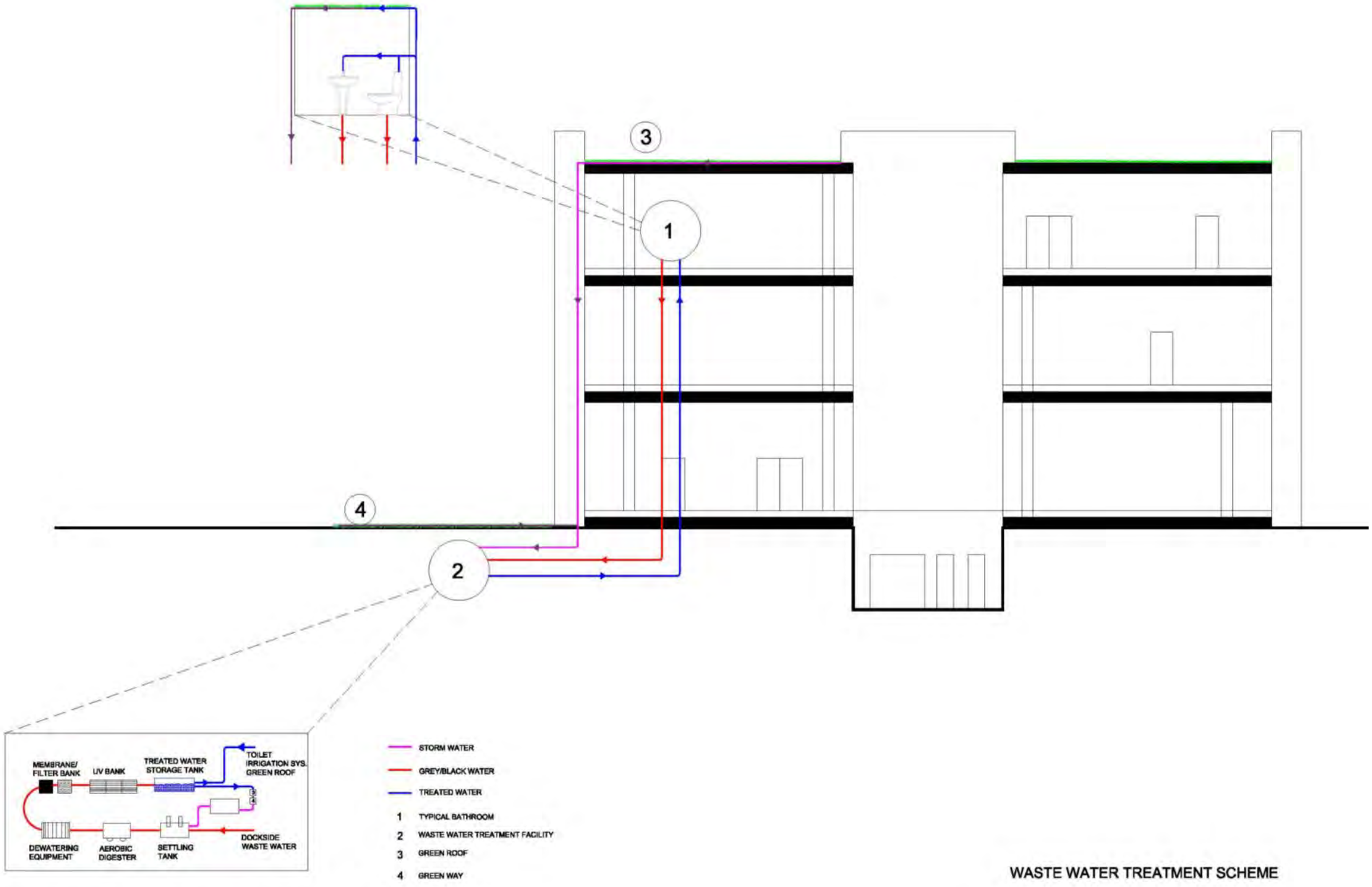


Figure 4-26 Wastewater treatment - Membrane Bioreactor Technology


3
1
4
2
MEMBRANE/ FILTER BANK
UV BANK
TREATED WATER STORAGE TANK
TOILET IRRIGATION SYS. GREEN ROOF
DEWATERING EQUIPMENT
AEROBIC DIGESTER
SETTLING TANK
DOCKSIDE WASTE WATER
STORM WATER
GREY/BLACK WATER
TREATED WATER
1 TYPICAL BATHROOM
2 WASTE WATER TREATMENT FACILITY
3 GREEN ROOF
4 GREEN WAY
WASTE WATER TREATMENT SCHEME

4.5.4 Building Automation System [29]

A Building Automation System is a computer-based control system installed in buildings that controls and monitors the building’s mechanical and electrical equipment such as ventilation, lighting, power systems, fire systems, and security systems. A BMS consists of software and hardware100. Systems linked to the system typically represent 70% of a building's energy usage, so it is a critical component to managing energy demand.

In addition to the controlling of the building’s internal environment, automation systems are sometimes linked to motorized vents, to control the natural ventilation and daylight coming into the building, which can be used to promote the stack effect and the fresh air circulation, noting that will be in correspondence to receiving an electrical signal from the CO2, daylight and occupancy sensors distributed within the building spaces. With its four basic functions of Controlling, Monitoring, Optimizing and Reporting, the system can maximize the users comfort and minimize the energy consumption, as it presents the switch on key of the mechanical active systems when facing a shortage with the typical passive means, in addition of being the optimum tool to cut the wastedenergy incase of the minor occupancy.

Figure 4-27 SIEMENS-Desigo building automation system

www.siemens.com/desigo

4.5.5 Envelope Composition

4.5.5.1 Green Roof [30]

A green roof is usually composed of a waterproof membrane, followed by a root barrier, a layer of insulation, a drainage layer, the growing medium or soil substrate, and the plant material. A shallow layer of gravel or pebbles are placed from 18 inches to three feet (50cm to 1m) within the outside perimeter of the roof, providing additional drainage, fire control, and access to the roof for maintenance.

The main issues to consider in all roofs are waterproofing and adequate drainage; in a green roof structural loading is also important.

Green roofs are recognised as important in the delay of rainwater run-off entering the storm water system, and the general retention of rainwater. Other recognized environmental advantages of green roofs include:

- Improved conservation and biodiversity.
- Provision of new wildlife habitat.
- Improved thermal insulation of buildings.
- Reduction of airborne particulates.
- Reduction in urban heat island effect.

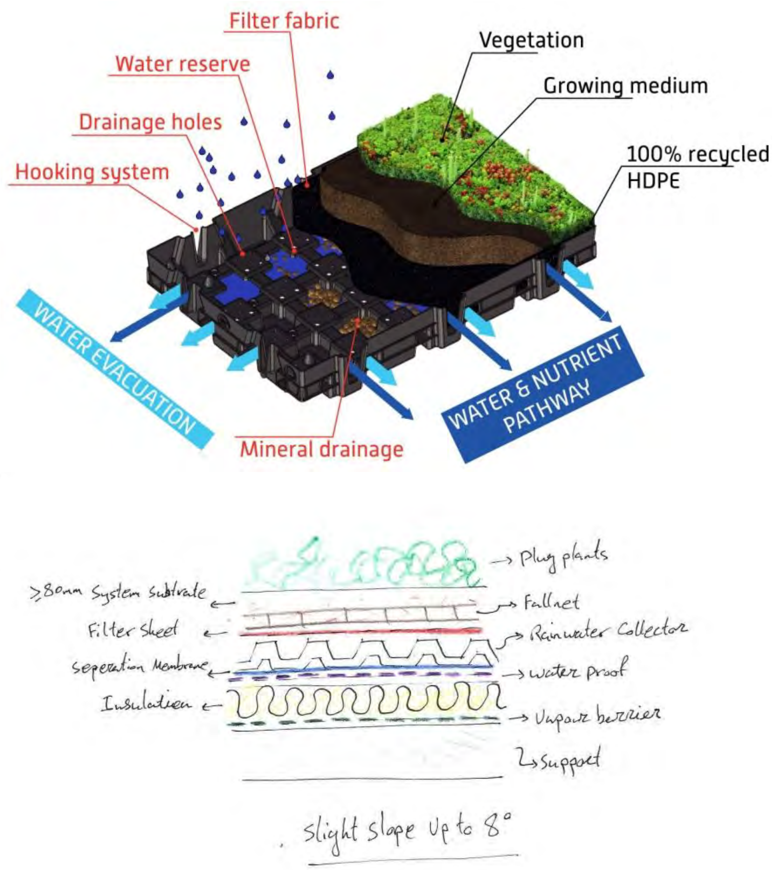


Figure 4-28 Hydropack®, the “all-in-one” module with a built-in water reserve

4.5.5.2 BubbleDeck System [31]

The BubbleDeck is a biaxial carrying hollow deck in which plastic balls serves the purpose of eliminating concrete that has no carrying effect. In other words, it removes the non working dead load, while maintaining biaxial strength. By adapting the geometry of the ball and the mesh, an optimised concrete construction is obtained, with simultaneous maximum utility of both moment and shear zones.

The reinforcement catches, disrtributes and locks the balls in exact position, while the balls shape the air volume, control the level of the reinforcement, and at the same time stabilise the spatial lattice. Incorporation of recycled plastic bubbles as void formers permits 50% longer spans between columns. Combination of this with a flat slab construction approach spanning in two directions (the slab is connected directly to concrete columns without any beams) produces a wide range of cost and construction benefits including:

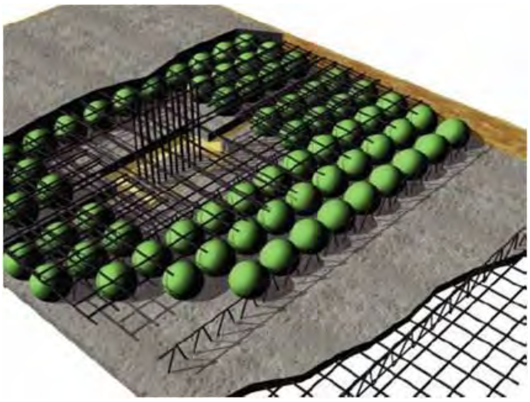


Figure 4-29 BubbleDeck® System

- Design Freedom – flexible layout easily adapts to irregular & curved plan layouts.
- Reduced Dead Weight - 35% removed allowing smaller foundation sizes.
- Longer spans between columns – up to 50% further than traditional structures.
- Downstand Beams eliminated – quicker & cheaper erection of walls and services.
- Load bearing walls eliminated – facilitating MMC with lightweight building envelopes.
- Reduced concrete usage – 1 Kg recycled plastic replaces 100 Kg of concrete.
- Environmentally Green and Sustainable – reduced energy & carbon emissions.

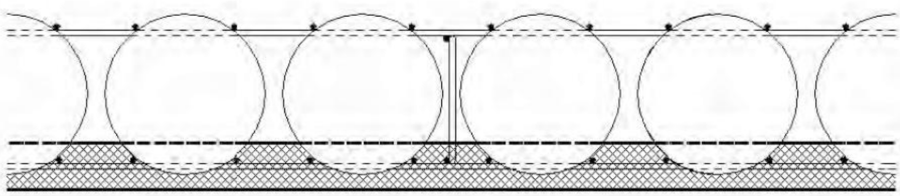


Figure 4-30-Filigree Elements where the bubbles are trapped between

4.5.5.3 Double Skin Façade [32]

The Double Skin Façade is a European architectural trend driven mostly by:

- The aesthetic desire for an all glass façade that leads to increased transparency
- The practical need for improved indoor environment
- The need for improving the acoustics in buildings located in noise polluted areas
- The reduction of energy use during the occupation stage of a building

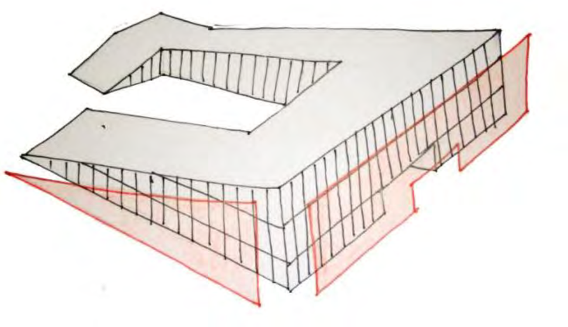


Figure 4-31- Architectural Approach of Double Skin Facade

Although that the concept of Double Skin Facades is not new, there is a growing tendency by architects and engineers to use them.

The Double Skin Façade is a system consisting of two glass skins placed in such a way that air flows in the intermediate cavity. The ventilation of the cavity can be natural, fan supported or mechanical. Apart from the type of the ventilation inside the cavity, the origin and destination of the air can differ depending mostly on climatic conditions, the use, the location, the occupational hours of the building and the HVAC strategy. The glass skins can be single or double glazing units with a distance from 20 cm up to 2 meters. Often, for protection and heat extraction reasons during the cooling period, solar shading devices are placed inside the cavity.

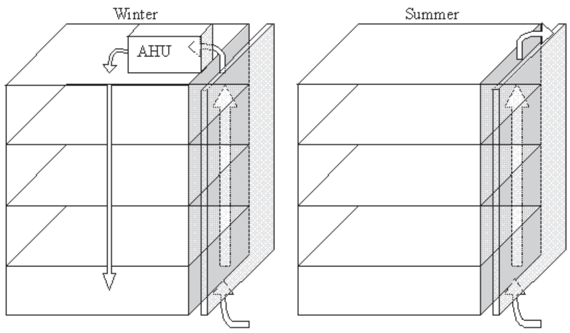


Figure 4-33- Double Skin Façade as an exhaust duct

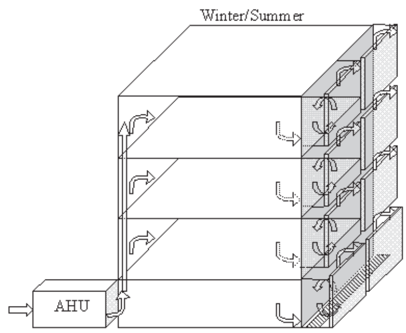


Figure 4-32-Double Skin Façade as an exhaust duct

4.5.5.4 Advantages [32]

Lower construction cost compared to solutions that can be provided by the use of electrochromic, thermochromic or photochromic panes (their properties change according to climatic or environmental conditions).

Acoustic insulation: In view of some authors the sound insulation can be one of the most important reasons to use a Double Skin Façade.

Thermal insulation: During the winter the external additional skin provides improved insulation.

Night time ventilation: During the hot summer days, the interior spaces can easily be overheated. In this case, it may be energy saving to pre-cool the offices during the night using natural ventilation.

Transparency – architectural design: In almost all the literature, the desire of the architects to use larger glazed facades is mentioned.

Natural ventilation: One of the main advantages of the Double Skin Façade systems is that they can allow natural (or fan supported) ventilation. Different types can be applied in different climates, orientations, locations and building types in order to provide fresh air before and during the working hours.

Fire escape: The glazed space of a Double Skin Façade may be used as a fire escape.

Low U-Value and g-value: Two advantages of the Double Skin Façades are the low thermal transmission (U-value) and the low solar heat gain coefficient (g-value).

4.5.5.5 Disadvantages [32]

Higher construction costs: compared to a conventional façade.

Fire protection: There is not yet very clear whether the Double Skin Facades can be positive or not, concerning the fire protection of a building.

Reduction of rentable office space: The width of the intermediate cavity of a Double Skin Façade can vary from 20 cm to two meters. This results in the loss of useful space.

Additional maintenance and operational costs: Comparing the Double Skin and the Single Skin type of façade, one can realize that the Double Skin type can have higher costs regarding construction, cleaning, operation, inspection, servicing, and maintenance.

Overheating problems: If the Double Skin Façade system is not properly designed it is possible that the temperature of the air in the cavity may increase the overheating of the interior space.

Increased construction weight: As it is expected the additional skin increases the weight of the construction which increases the cost.

Daylight: The Double Skin Facades are similar to other types of glazed facades (i.e. single skin façade). However, Oesterle et al., (2001) describe, that Double facades cause the reduction of the quantity of light entering the rooms as a result of the additional external skin.

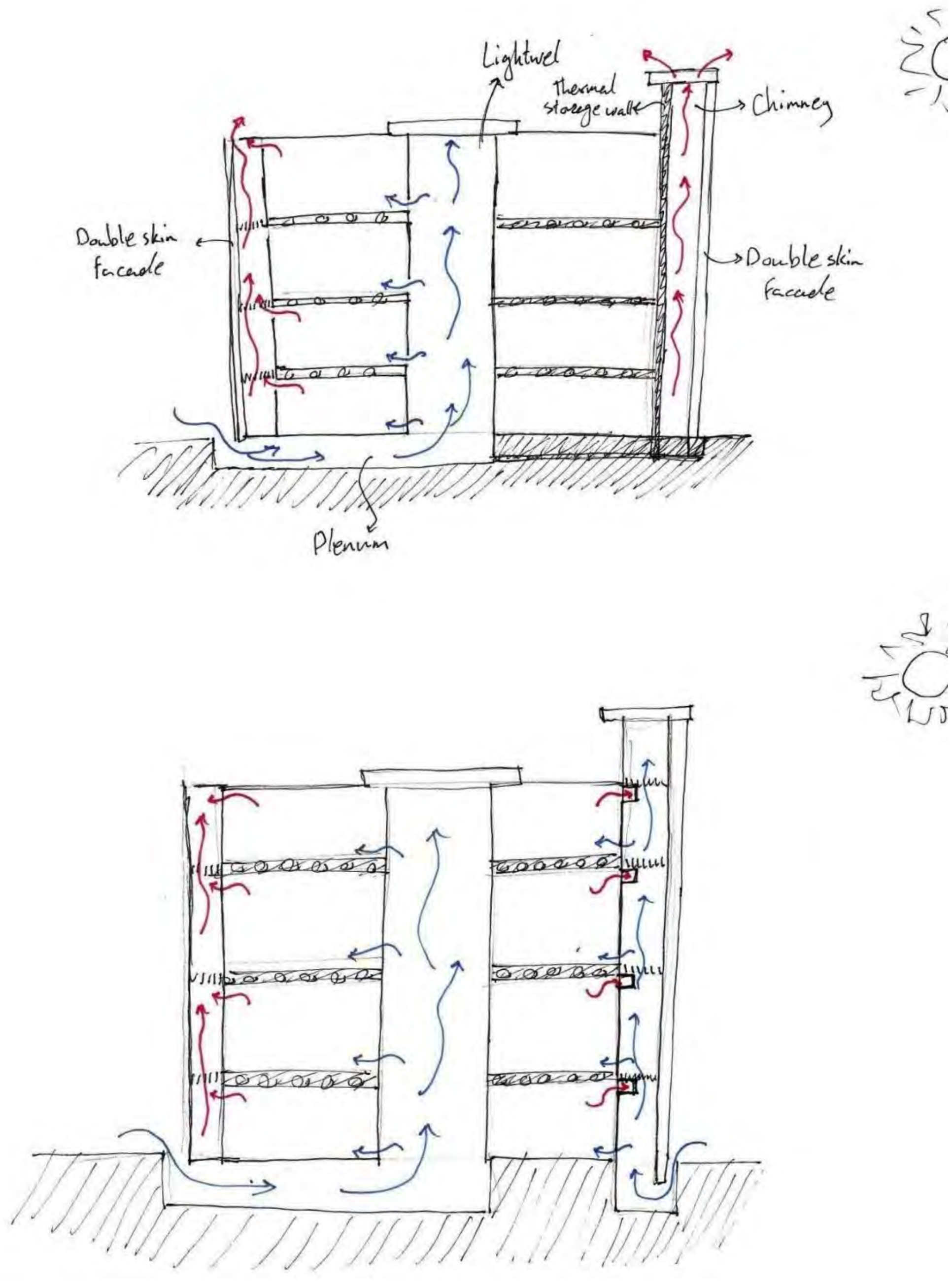
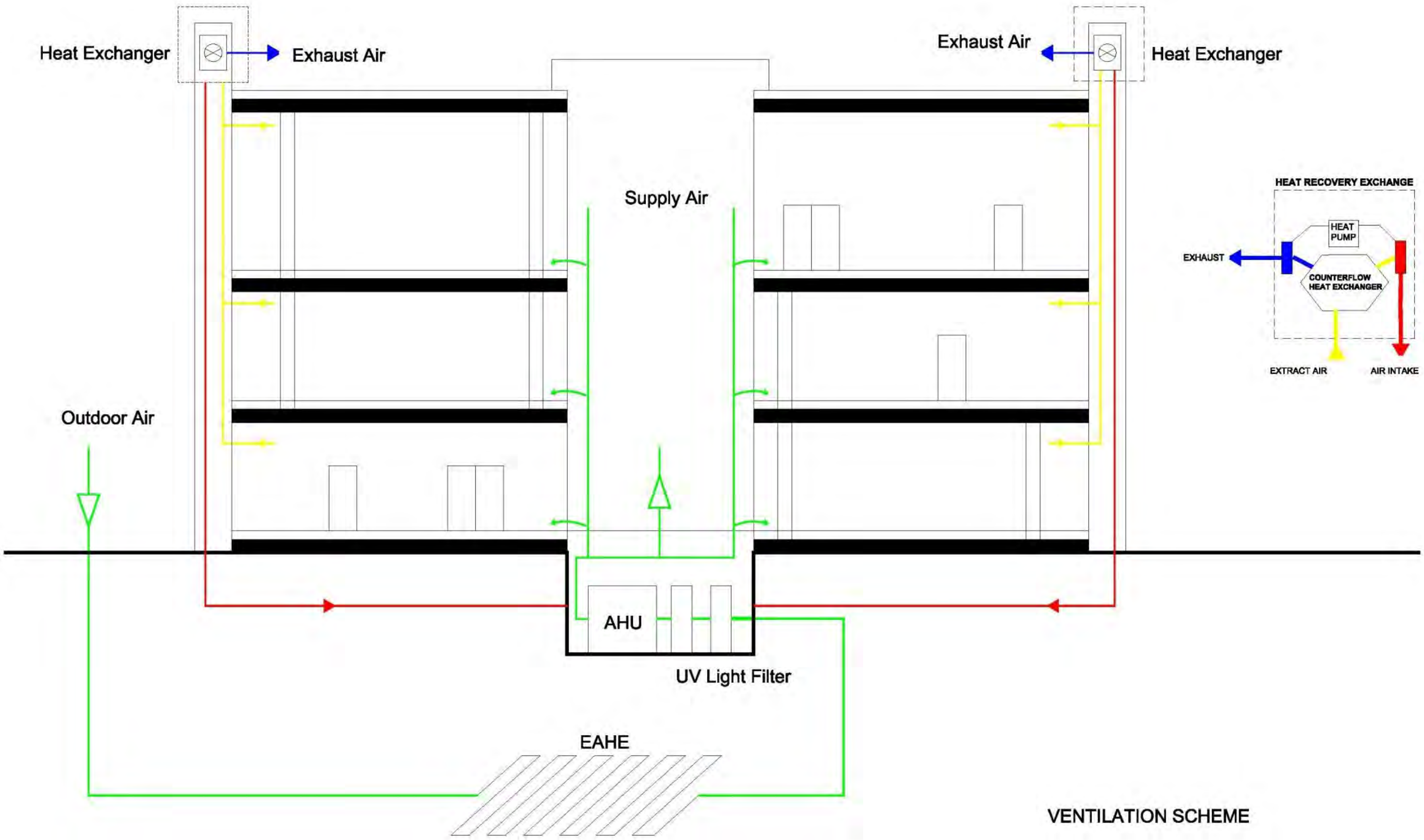


Figure 4-34 Study of C-E system for winter and summer


Heat Exchanger
Exhaust Air
Exhaust Air
Heat Exchanger
Supply Air
HEAT RECOVERY EXCHANGE
HEAT PUMP
EXHAUST
COUNTERFLOW HEAT EXCHANGER
EXTRACT AIR
AIR INTAKE
Outdoor Air
AHU
UV Light Filter
EAHE
VENTILATION SCHEME

4.6 ECOTECT Analysis and results [19]

The below schemes will present the results generated from the software, as the final composition layers arrangement and thicknesses were determined accordingly, with respect to the building heating/cooling loads influence.

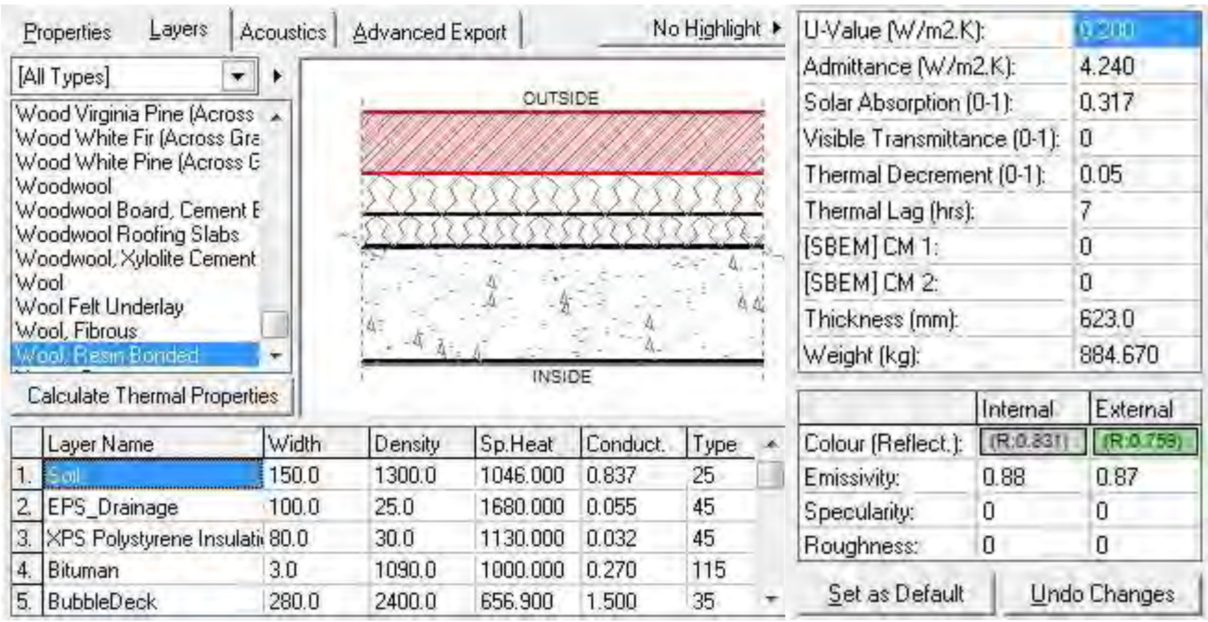


Figure 4-35 Green roof material properties

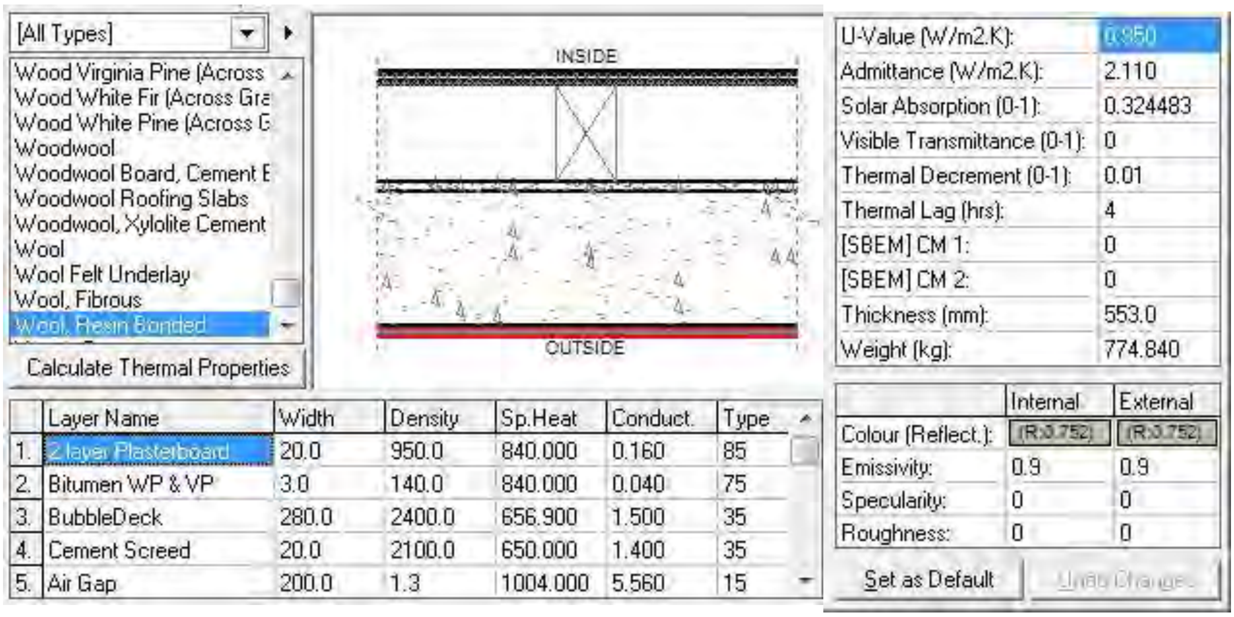


Figure 4-36 Bubbledeck slabs material properties

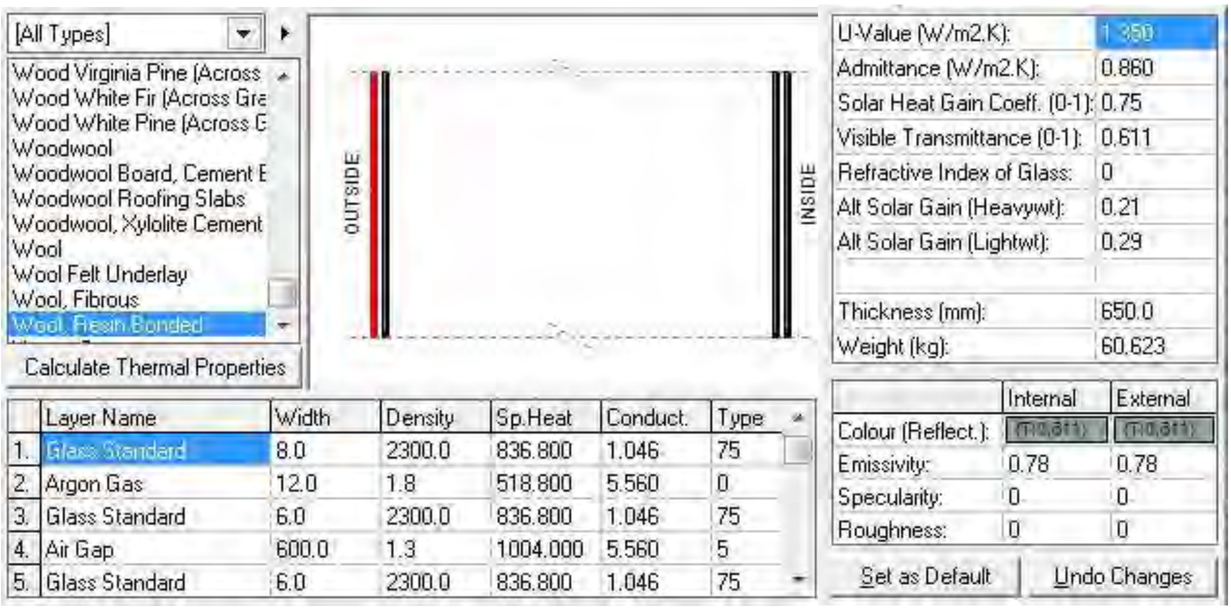


Figure 4-37 Double skin façade material properties

4.6.1 Condensation Risk [33]

Condensation is by far the most common cause of dampness in buildings, probably accounting or most dampness problems reported. It affects both old and new properties, but it appears to be a significant problem where the building has been modernized.

Condensation is directly associated with mould growth, and it is this that the occupier first sees and gives an idea as to the potential scale of the problem. The mould is usually found on decorative surfaces, especially wallpapers, where it can cause severe and permanent spoiling.

The obvious places or condensation to occur are on cold walls and floors, but sometimes it occurs in roof spaces and in subfloor areas where there is a suspended floor. Timbers in these areas will become damp and susceptible to damage by dry rot or wet rot.

It is a fact that warm air can hold more water as vapour than cool air. So, quite simply, condensation is caused when moisture-laden air comes into contact with a cold surface –the air is cooled to a point where it can no longer hold its burden of water vapour. At this point, (DEWPOINT), water begins to drop out of the air, and it is seen as condensation on surfaces.

The avoidance of condensation can be through adopting the single layer construction system, or using a multi-layered construction system with the usage of Vapor barrier where the condensation more likely expected to occur, which simply lowers the partial pressure Pv. This can be obtained by inserting in the wall – towards the warm environment - a layer with high resistance to vapor flow (vapor barrier - polyethylene or aluminum sheet.

In order to determine whether the condensation will occur or not, a numerical scheme will be needed based on the envelop compositions; relevant scheme is the (Glaser Diagram).

4.6.1.1 Glaser Diagram

Basically, it is a diagram represents and compares Pv and Ps to assess the risk of condensation. Simply where the Pv (partial pressure) curve is higher than Ps (saturation pressure), the condensation can be expected.

Climatic Analysis	External	Internal
Temperature [°C]	-5	20
Relative humidity (%)	80	50

Figure 4-38 Climatic inputs values

Keeping in mind if the distribution of temperatures through the wall is known, saturation pressure can be determined using a Psychometric chart, so the first step is to determine T and Ps at every intersection between parallel layers for a flux of thermal energy resulted from the difference in temperature between the two Medias.

4.6.1.1.1 Temperature and saturation pressure at each interface calculations

$$T_i = (T_i - 1) - (\Delta T * U / K_i)$$

T_{int} = Internal temperature, 20°C

T_{ext} = external Temperature -5°C

ΔT = Difference in Temperature between the two sides of the composition

K_i = λ/s is the thermal Conductivity of the interface layer

U = Thermal conductivity of whole composition [W/m²K]

$$\Phi = U.S.\Delta.T$$

Φ= Heat flux [W]

U= Thermal conductivity of whole section [W/m²K]

S= Total thickness of Section [m]

$Tpi = Ti - (\Phi/S)*(1/h_i)$

Tpi = Internal Surface Temperature [C°] **T**i = Internal ambient temperature [C°] **S** = Total thickness of Section [m]
Hi = Internal Convective co-efficient [m²K/W]

From that, the Saturation pressure curve at each interface can be calculated and drawn using the equation below:

$Ps = \exp(26,23-[5416/(T+273,15)])$

4.6.1.1.2 Partial Vapor pressure at each interface calculations:

$P_i = P_i\text{-}1 - (\Delta P/\rho_{tot})\ \rho_i$

ρ_{tot} is the resistance (diffusivity) to vapor diffusion of the whole wall and is calculated as:

$\rho_{tot} = \Sigma\rho_j$

ΔP = Difference in vapor pressure between the two sides of the section (Pint - Pext);

P_{int} = Internal Pressure at 20°C Temp & 50% Rh

P_{ext} = external Pressure at -5 °C Temp & 80% Rh

$\rho_i = s_j/\delta_{jis}$ the resistance to vapor diffusion of the i-th layer

δ_j is vapour permeability of the i-th layer (Useing UNI 10351 or DIN 4108)

4.6.1.2 Results

Sample of the calculations are presented below. Noting that the numerical scheme will focus on some of the compositions exposed to the outer air during the winter with respect to the dramatic difference in temperatures between the 2 Media, which does not exist on the layers adjacent to the soil.
As the lowest average temperature of soil in the area can be around 10C°, so the thermal flux value is very minor compared to the compositions with an interaction with the outdoor environment. Further clarification will be provided in the thermal load calculations, regarding the expected thermal flux through the basement walls.

								Flux (W/m2)	Vapour Flux (kg/m2 h)		
								4.74	826.3		
Material	Thickness (m)	λ (W/mK)	ρ (kg/m3)	μ	Rj (m2 K/W)	Rdj(Pa*m2*h/kg)		Tj (°C)	Sp (m)	P sat (hPa)	P vap (hPa)
					0.17		T int	20.00	-0.100	23.597	11.798
Plaster Board	0.0125	0.21	900	23	0.06	0.0005		19.19	0.000	22.427	11.798
BubbleDeck Slab	0.28	1.5	70	2.5	0.16	0.1120		18.91	0.013	22.029	11.794
Vapour barrier	0.003	0.27	0	0.01	0.16	0.3000		18.15	0.293	20.992	10.868
XPS Polystyrene insulation	0.08	0.032	1000	6.3	2.50	0.0127		17.40	0.296	19.999	8.389
Protection mat	0.05	0.27	30	0.1	0.19	0.5000		5.55	0.376	9.063	8.285
EPS_Drainage	0.1	0.055	500	6	1.82	0.0167		4.67	0.426	8.920	4.153
Polypropylene Filter Sheet	0.0006	0.137		3.9	0.004	0.0002		-3.94	0.526	4.393	4.015
Soil	0.15	0.837	1300	200	0.18	0.0008		-3.96	0.526	4.385	4.014
					0.04			-4.79	0.676	4.087	4.008
			R TOT		5.28		T ext	-5.00	0.776	4.014	4.014
			U TOT		0.19						
			Rd TOT		0.94						

Figure 4-39 inner temperatures and partial pressure values

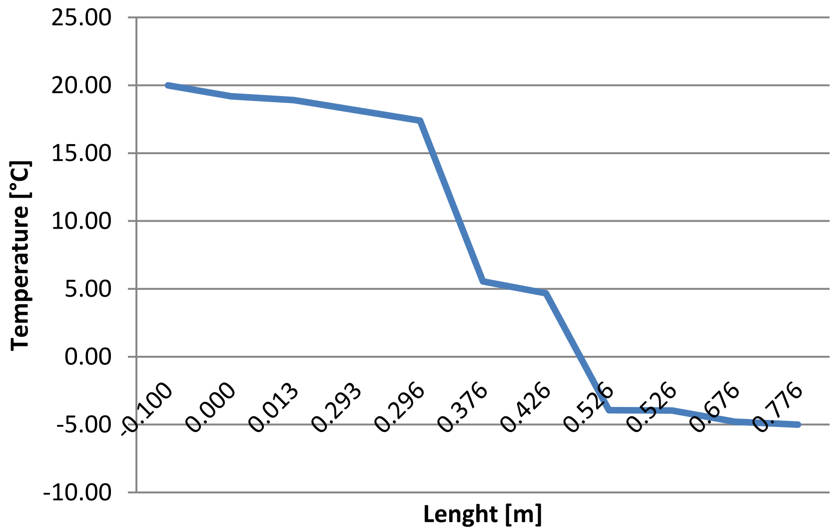


Figure 4-40 inner layers temperature profile

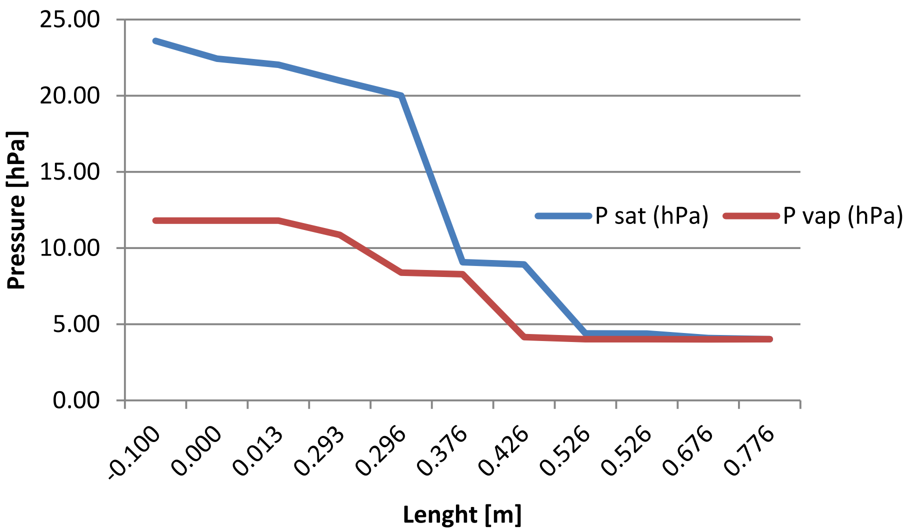


Figure 4-41 Inner layers Partial and Saturation pressures profiles

As a conclusion from the above shown outcomes, Ps curve is always above the Pv, which states that presence of the Vapor barrier makes the Condensation risk completely negligible, which guarantees the creation of healthy inner environment, maximizing the tightness of the envelope and increasing the building life span.

4.6.2 Thermal Analysis [19]

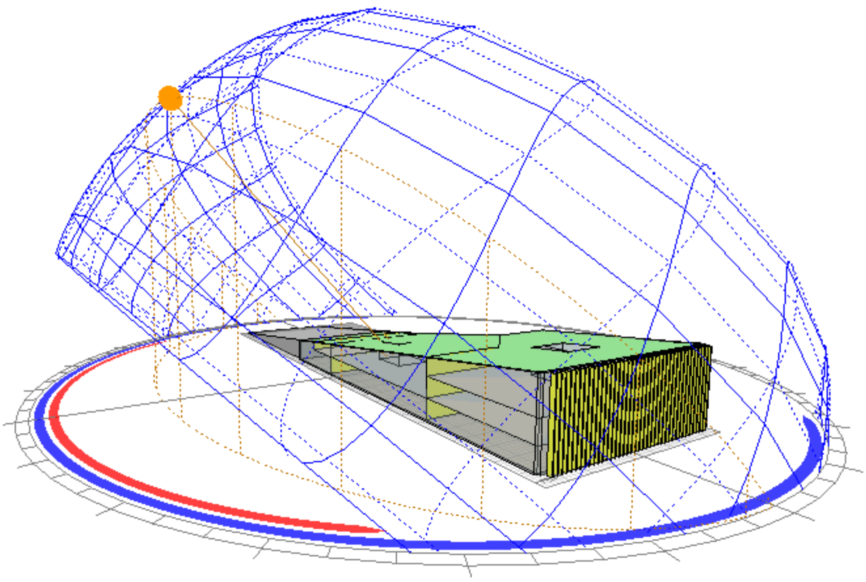


Figure 4-42 Model on ECOTECT

The scope of the thermal analysis is limited to the office area on the south side of the building. This is to better understand the performance of the new technologies and materials implemented therein. The thermal analysis is the integral part of the design for achieving the energy efficiency and reducing the cost incurring for managing the indoor environment of the building.

In the calculation of the heating and cooling loads for the building, many factors were taken into account including the double skin façade as a buffer zone, low conductivity materials, green roofing, solar gain, using earth tubes for pre-heating/cooling the air before treating, etc. All of these passive tools are used in order to control the indoor environment and provide the users with the desired level of comfort.

The observation elaborates the significance of double skin facade and the usage of earth tubes in reducing the conditioning loads of the building. All the thermal analysis is done using the energy simulation software ECOTECT 2010.

4.6.2.1 Methodology

For the purpose of calculating the conditioning loads for building, we have to work on some suggestions. The comfort zones are already explained in the form of psychrometric charts in previous sections. Also, for defining the indoor comfort criteria for different functional areas of the building, we defined the specific hours of the building operations i.e., 07:00 hrs to 21:00 hrs. The last but not the least, the comfort temperature range was defined depending on the internal environmental requirements of the spaces.

The building was divided into thermal zones basically according to the functions assigned. The internal gains coming from the occupants would also be considered while analyzing by the software. The following diagram shows the different zones, in various colours for differentiation.

4.6.2.2 Heating and Cooling Loads

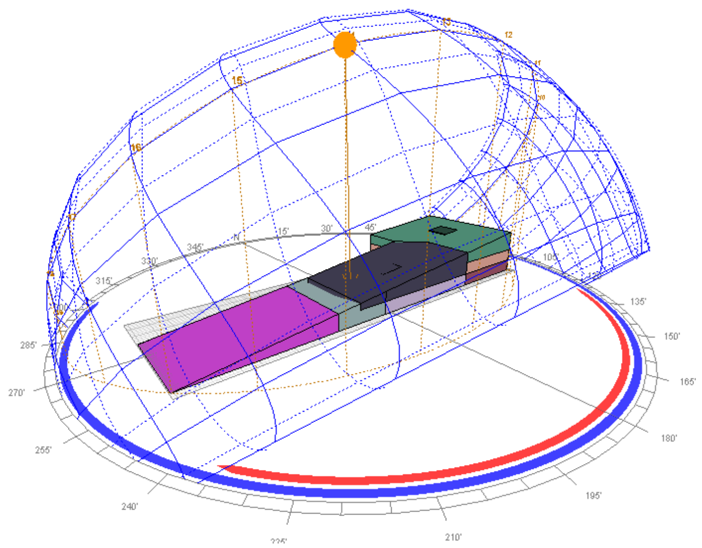


Figure 4-43 Zoning of the building

The heating loads are calculated for the whole year considering the improvisations explained above and putting the U-values and ach in ECOTECT to have the following load calculations:

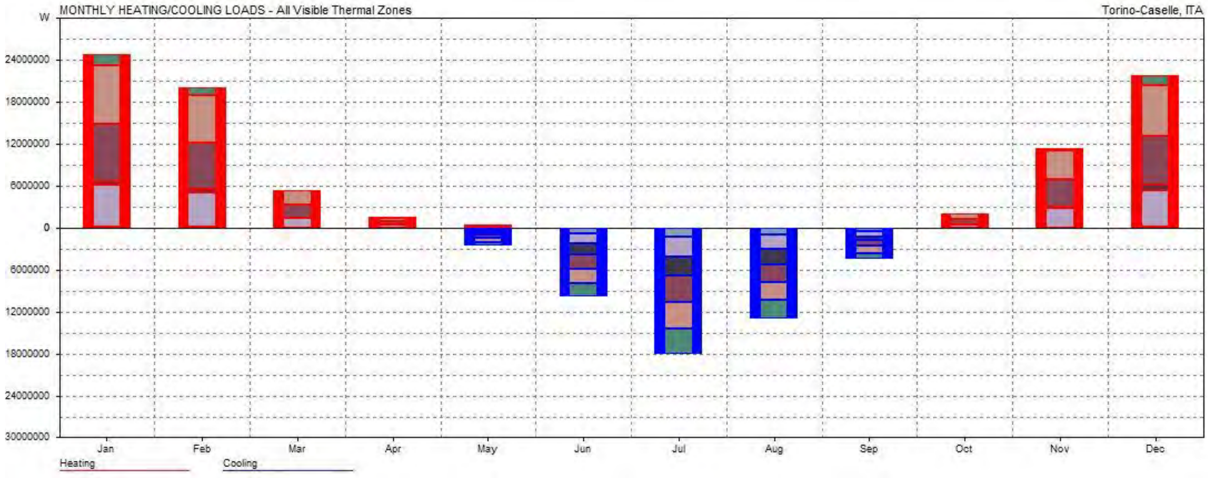


Figure 4-44 Heating and Cooling loads

All Visible Thermal Zones

Max Heating: 214124 W at 15:00 on 16th December
Max Cooling: 148167 W at 13:00 on 25th June

MONTH	HEATING (Wh)	COOLING (Wh)	TOTAL (Wh)
Jan	24872192	0	24872192
Feb	20109396	0	20109396
Mar	5444212	0	5444212
Apr	1509399	0	1509399
May	458398	2544095	3002493
Jun	0	9890238	9890238
Jul	0	18014258	18014258
Aug	0	13008501	13008501
Sep	1105	4400052	4401157
Oct	2089937	0	2089937
Nov	11474765	0	11474765
Dec	21891792	0	21891792
TOTAL	87851192	47857144	135708336
PER M^2	13656	7439	21095
Floor Area:	6433.16 m2		

Figure 4-45 Monthly heating and cooling loads

Heating load kW/m^2	Cooling load kW/m^2	Total load kW/m^2
13.656	7.439	21.095

Figure 4-46 Total Loads

4.6.2.2.1 Advanced Naturally Ventilated Buildings [34]

4.6.2.2.2 Preliminary sizing of advanced natural ventilation system components

Table 8 Estimated structural inlet and outlet areas for use at the preliminary design stage of advanced natural ventilation systems

Total heat gain (W/m^2)	Airflow rates		Target structural areas as percentage of area of floors served (%)		
	(l/s)^a	(l/s)^b	Lightwell outlets^c	Lightwell, plenum outlet and stacks^d	Plenum inlet^e
20	2.4	2.5	1.6	0.5	1.0
30	3.6	3.7	2.4	0.7	1.4
40	4.8	4.8	3.2	1.0	2.0
50	6.0	6.0	4.0	1.2	2.4
60	7.1	7.4	4.8	1.4	2.8

Values in bold are target area for preliminary design purposes.

[a] Air flow rate required for ventilation cooling per m^2 of floor area.

[b] Assumes 3.5 m floor to ceiling height.

[c] Eq. (8) assumes gross structural area is twice the free area and the air speed is limited to 0.3 m/s.

[d] Eqs. (3), (4), (9) and (10) presume no obstruction by grills, dampers, meshes, louvers, etc. and an air speed of 0.5 m/s.

[e] Eq. (7) assumes gross structural area is twice the free area and the air speed is limited to 0.5 m/s.

a. Stack Ventilation Design for the C-E system

The sizing equations are based on considerations of a simple stack-driven displacement ventilation regimen; that is, a low level inlet supplying the space to be cooled and a high level outlet into a stack. The volume flow of air, m (m3/s), required to provide ventilation cooling for different internal heat gains is given by:

1-1) Volume flow of air (m)

$$m = \frac{QA_t}{C_C \Delta T} \quad (m^3/s)$$

Q: Heat gain (w/m^2)
A_t: Floor area (m^2)
ΔT: Allowable temperature rise (k)
C_c: Volumetric heat capacity of air (1200 j/m^{3}K)

1-2) Free area of ventilation opening (A_v)

$$A_v = \frac{m}{v} \quad (m^2)$$

v: Assumed air speed

m: Volume flow of air (m^3/s)

For the preliminary design calculation of the inlet which directly effect the size of the lightwell has been developed as follow. Indeed furthere detailed design can involve more accurate manual calculations, such as the application of stack effect equations and, later in the design process, the use of sophisticated computer-based methods such as thermal simulation and computational fluid dynamics (CFD) analysis.

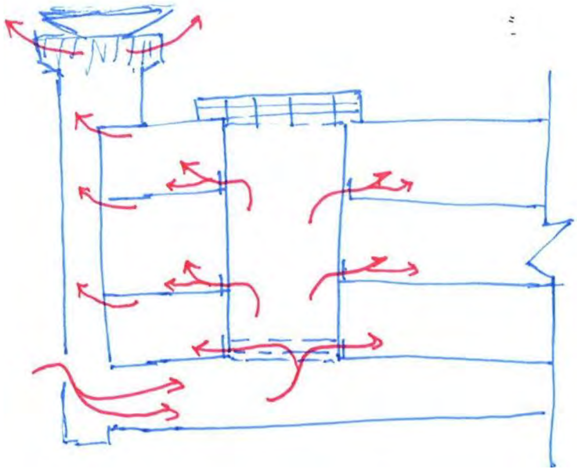
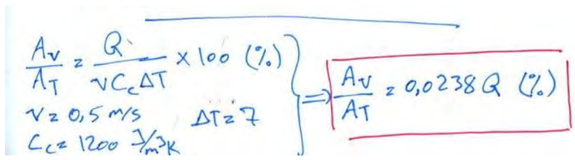
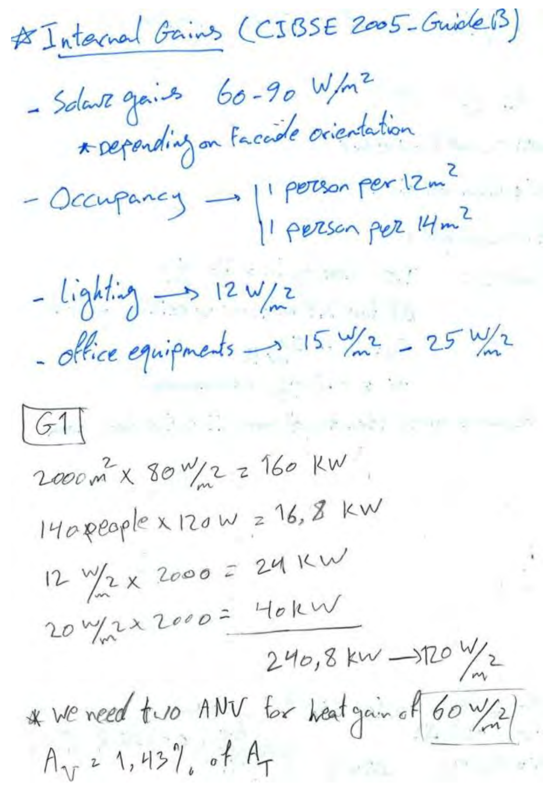
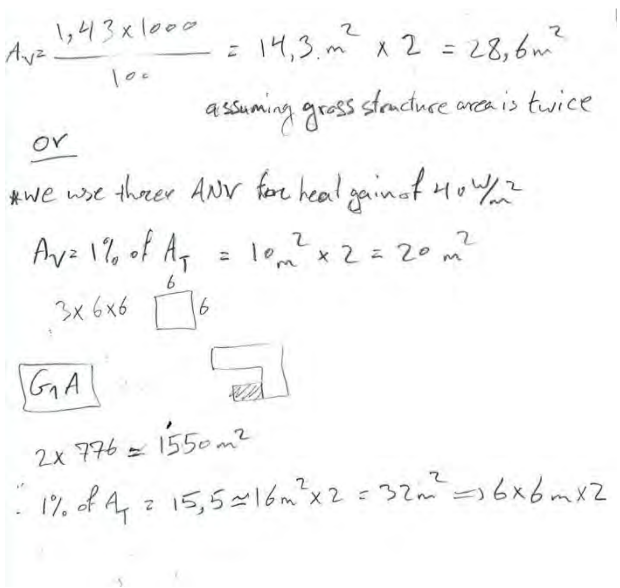


Figure 4-47-Center-in Edge-out natural ventilation system



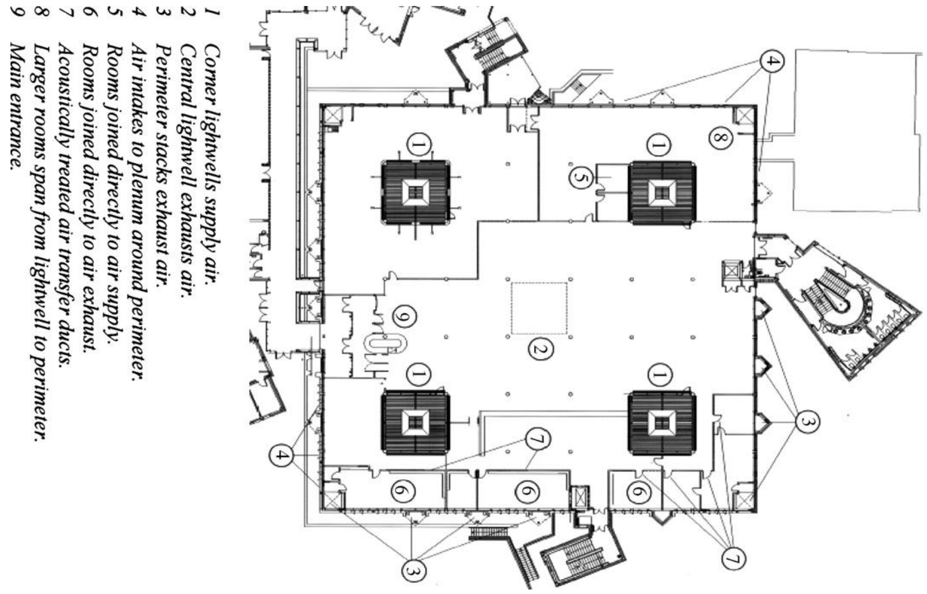


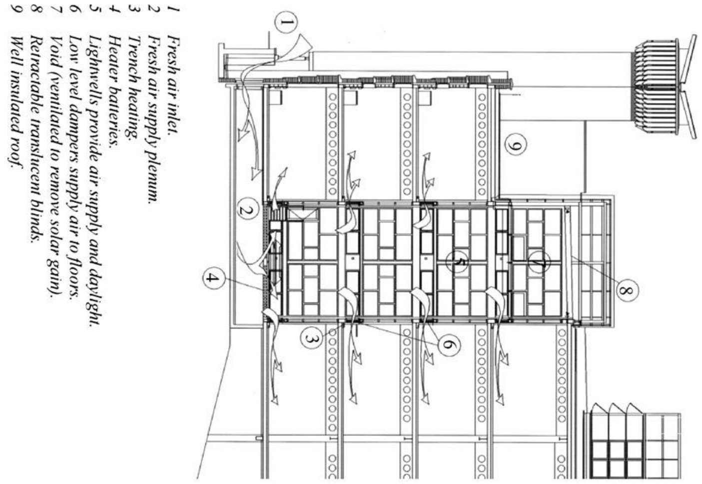


*As we can see a 2 lightwell with the dimension of 6m X 6m is required for the open office floor area. In the architectural consideration it can be divided to different shapes with total area equal to 32 m^2

4.6.2.2.3 Examples of Naturally Ventilated Buildings [34]

Figure 4-48 Frederick Lanchester Library showing air supply strategy (left) and air exhaust strategy





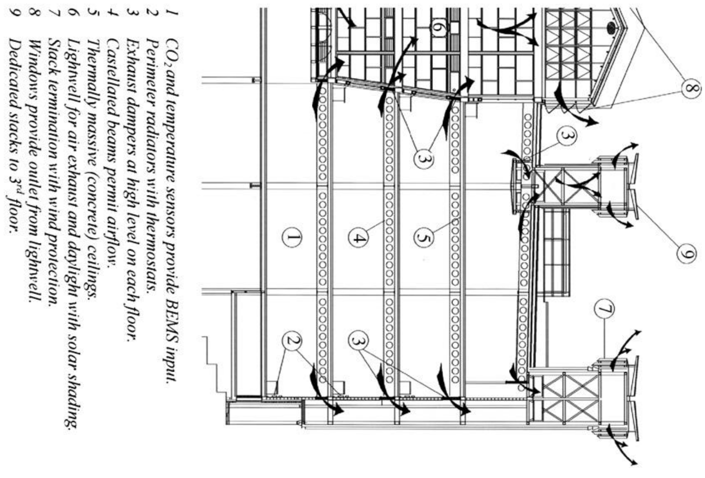
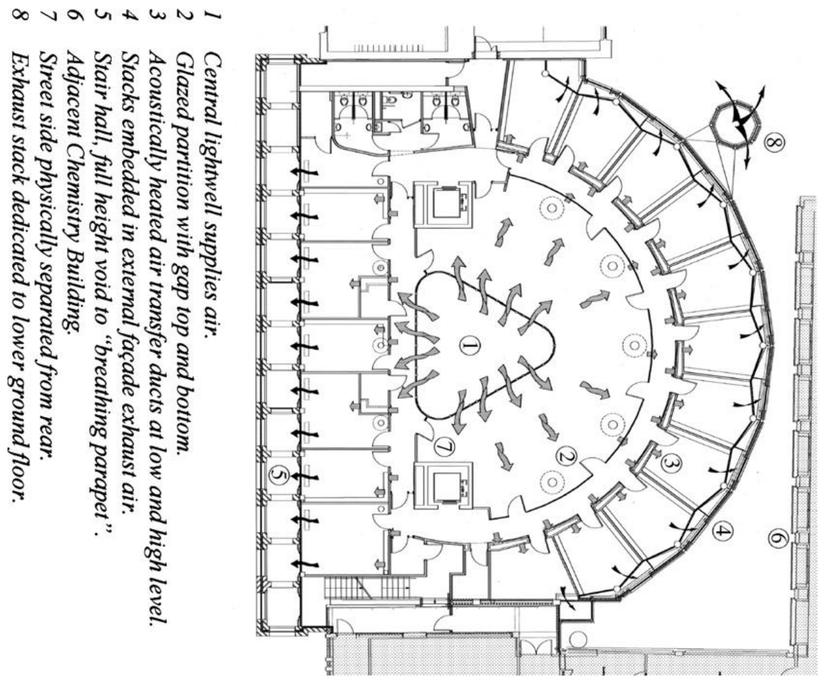


Figure 4-49 School of Slavonic and East European studies building showing the natural ventilation cooling strategy



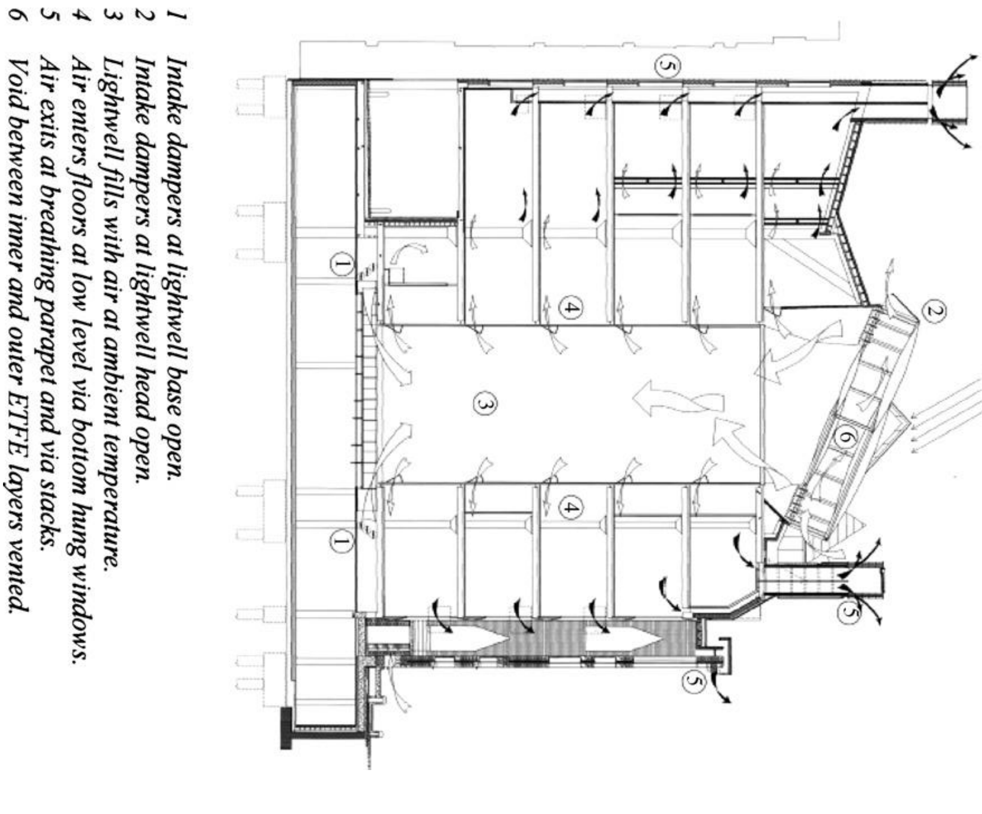
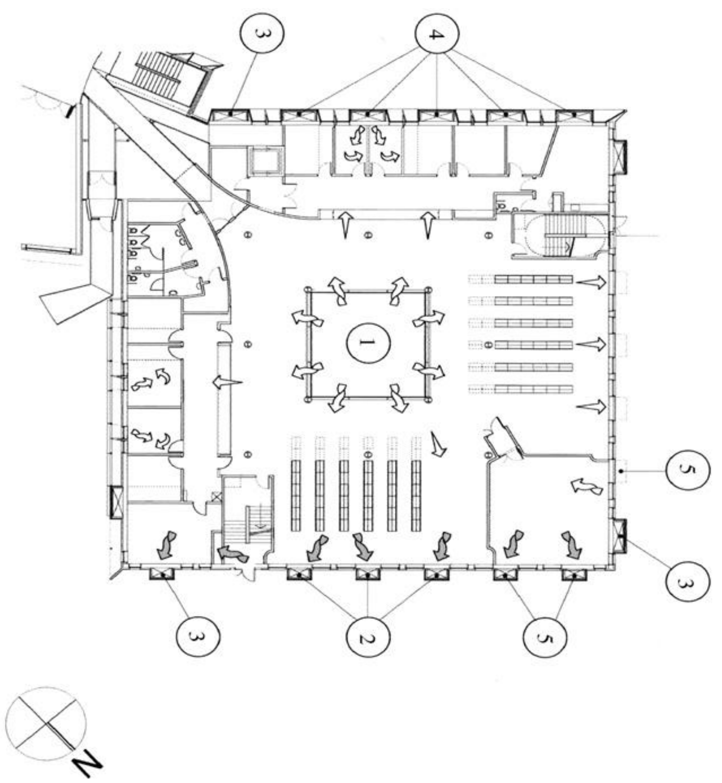
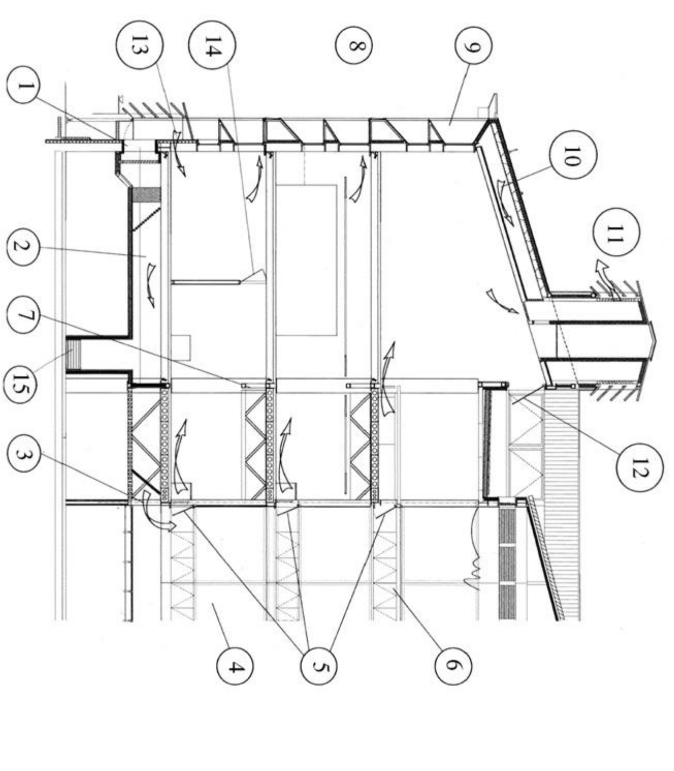


Figure 4-50 Harm AWebber Library showing the natural ventilation strategy



1 Central lightwell supplies air.
2 Exhaust air ducts embedded in façade.
3 Return air duct from roof plenum to HVAC plant.
4 Riser ducts supply air to perimeter rooms.
5 Exhaust stacks from corner classroom.



1 Fresh air inlet to plenum.
2 Fresh air supply plenum.
3 Plenum outlet into lightwell.
4 Lightwell supplies fresh air.
5 Low-level, top hung windows provide air to floors.
6 Horizontal glass lens seals lightwell.
7 Open truss permits airflow.
8 Air outlets at high level with dampers.
9 Insulated steel exhaust duct in deep façade.
10 Plenum connects ducts to terminations.
11 Air exhausts via louvered terminations with damper.
12 Clerestory windows provide additional top floor ventilation.
13 Dedicated supply from plenum to perimeter offices.
14 Operable windows for office occupants.
15 Downfeeds from plenum to basement area.

4.6.3 Comparative Analysis

The passive gains breakdown graph maps gains and losses that occur via the various heat transfer mechanisms that occur within a zone. These mechanisms include *conduction*, *sol-air*, *direct solar*, *ventilation*, *internal* and *inter-zonal* gains and losses, indicated by the colours shown in the legend below the graph. The passive gains breakdown graph consists of the six heat transfer mechanisms that can occur in a zone.

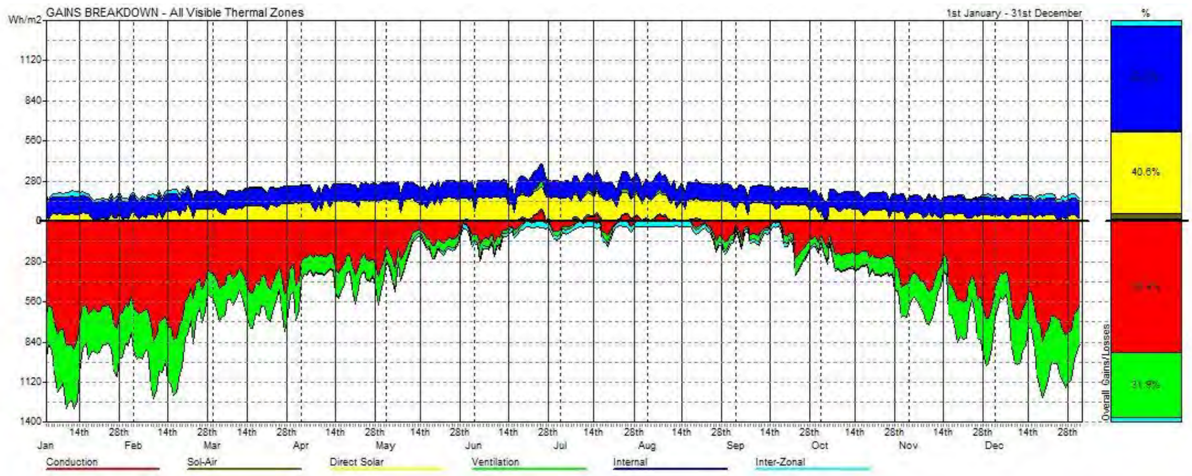


Figure 4-51 Gains break down graph – Traditional System [19]

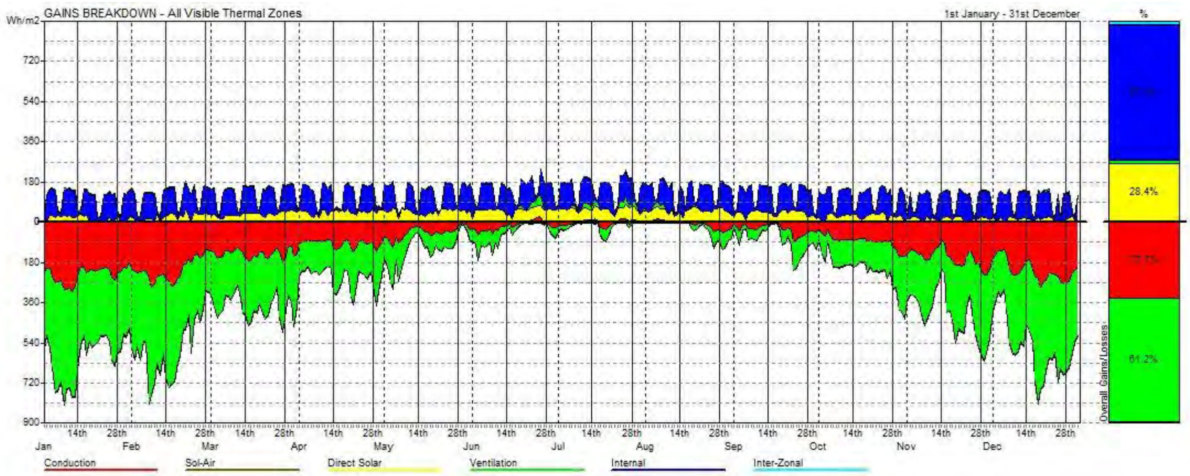


Figure 4-52 Gains Breakdown – Green roof System and DBS Façade system applied [19]

Values above the horizontal 0 axis indicate heat gain; values below this axis indicate heat loss. The passive gains breakdown is presented in two ways - the graph itself shows the individual breakdowns, measured in Watts per hour per square metre.

To the right of the graph, the gains are presented as percentage values. Note that these percentage values are relative to the total amount of heat gains and losses - this is important to be aware of when comparing results between different gains breakdown graphs.

- The passive gains breakdown graph shown above indicates that the majority of heat gains occur via *internal heat gain*, or direct solar gain. This suggests that changing the properties of glazing should reduce the direct solar gains.
    - Change the glazing system to with double facade, and then recalculate the passive gains breakdown graph shows how heat gains via *direct solar* have reduced from around 40% to around 28%.
- The passive gains breakdown graph shown above indicates that the majority of heat losses occur via *Conduction* heat transfer, or through the building fabric. This suggests that changing the envelope to use materials with low U-Values should reduce these gains.
    - Change the skin to use *double facade*, and the roof to be *green roof*. Then recalculate the passive gains breakdown graph - conduction heat losses are reduced from around 65% to around 38%. While the percentage change may not seem significant, note that the peak measured heat loss values have almost reduced by half.

4.6.4 Lighting Analysis

In the following section, I have analysed the effect and availability of solar radiations as a mean of providing both solar energy, free of cost, and natural daylight throughout the year. These considerations were kept in mind while designing the components of the building like, windows, blinds, skylights, etc. serving the purpose of daylight and shading, as required.

4.6.5 Sun Protection System

The design of transparent building component and windows is, on the one hand, defined by primary function of lighting penetration and visual transparency. On the other hand, these elements fulfill an important control function for aspects of lighting and heating/cooling. The primary function is fulfilled in the arrangement and orientation of the building, the sizing and placement of windows, and the selection of most transparent glazing for the least favorable

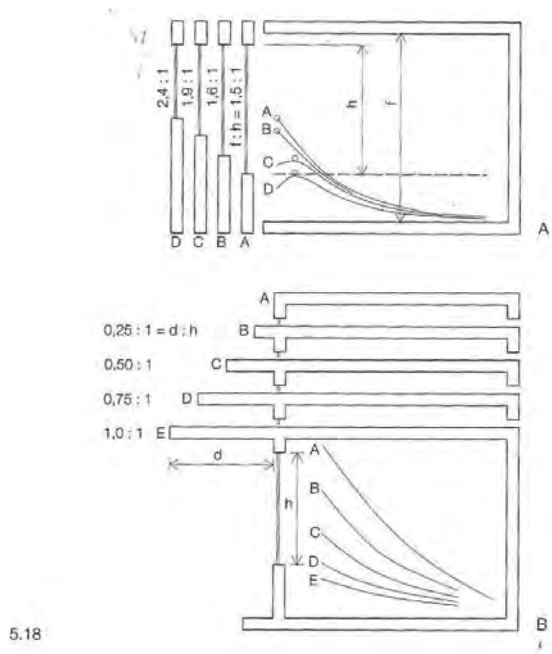


Figure 4-53 Daylight availability under overcast sky: for side-li room with varying window-sill heights (A), for side-lit room with different roof overhangs (B) [27]

conditions. An effective approach is to redirect direct sun radiation, especially in combination with shading measures, for example, rigid horizontal louvers in the upper half of the window, frequently referred as light shelves. There is a risk of glare when the sun is low I the sky, unless a moveable shading system is provided.

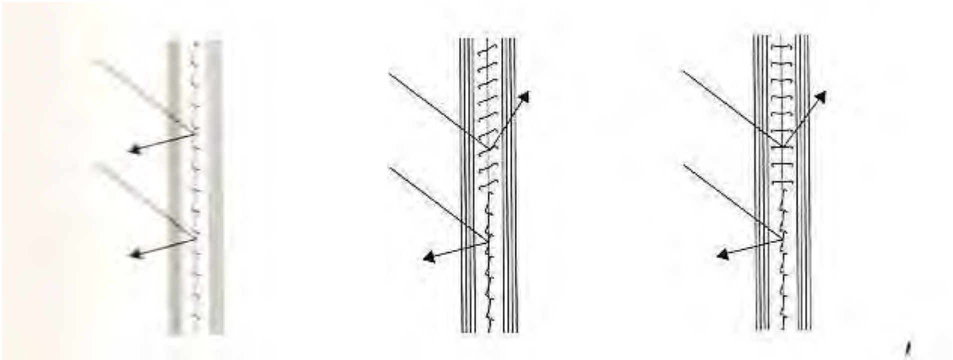


Figure 3-54 Flexible shading system in the form of louver blinds: the louver can be utilized in part for redirecting sunlight.

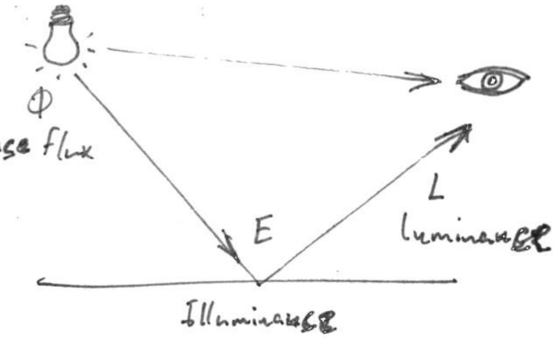


Figure 4-55 The photometric units; Luminous flux(φ), Illuminance (E) and Luminance (L)

The light sensitivity of the eye dependent on the wave length is the reference for photometric units, which are employed to measure and calculate lighting design:

- Luminance flux (φ): total light output of a luminous source; unit: lumen (lm)
- Luminance intensity (l): luminous flux in solid angle of 1 steradian (lm/sr); unit: candela (cd)
- Illuminance (E): luminous flux/area (lm/m^2); unit: (lux)
- Luminance (L): impression of brightness emanating from a light source or illuminated surface, given as luminous intensity per area (cd/m^2)

Very high luminance present, for example when direct sunlight falls onto reflecting surface also result in uncomfortable glare effects, which must be avoided at workstations.

4.6.5.1 Winter Solstice

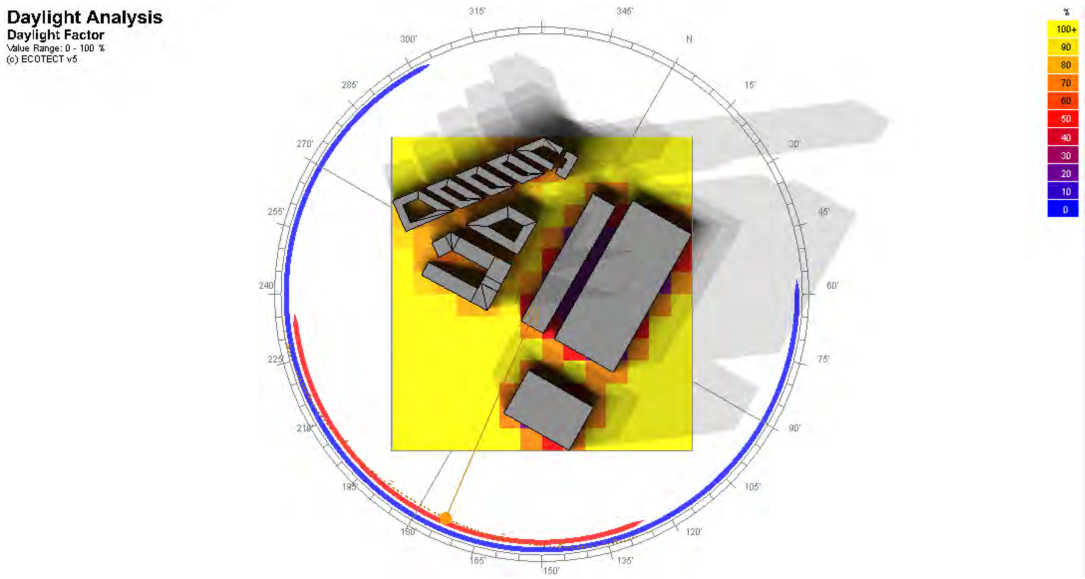


Figure 4-56 Winter solstice

By analyzing the weather data of Turin in ECOTECT, I came up with the following diagram, showing the availability of sunlight falling on the building.

Table 9 Solar data fro winter solstice

Latitude 45.2 ° Sunrise 08:10 Date: 21st December

Longitude 7.7 ° Sunset 16:43 Local Correction: -27.1 mins

Local Time (hrs)	Solar Time (hrs)	Azimuth angle (degree)	Altitude angle (degree)
8:30	08:02	127.9	2.7
9:00	08:32	133.5	6.7
9:30	09:02	139.4	10.4
10:00	09:32	145.6	13.6
10:30	10:02	152.1	16.3
11:00	10:32	159.0	18.5
11:30	11:02	166.1	20.1
12:00	11:32	173.3	21.0
12:30	12:02	-179.3	21.3
13:00	12:32	-171.9	20.9
13:30	13:02	-164.7	19.8
14:00	13:32	-157.6	18.1
14:30	14:02	-150.8	15.8
15:00	14:32	-144.4	13.0
15:30	15:02	-138.2	9.7
16.00	15.32	-132.4	6.0
16:30	16:02	-126.8	1.9

In winter, I have considered winter solstice date i.e., December 21st, for which the sun is rather available for a small period of time on the whole. The highest solar altitude angle is equal to 21.3° at 12:30 in the afternoon.

4.6.5.2 Summer Solstice

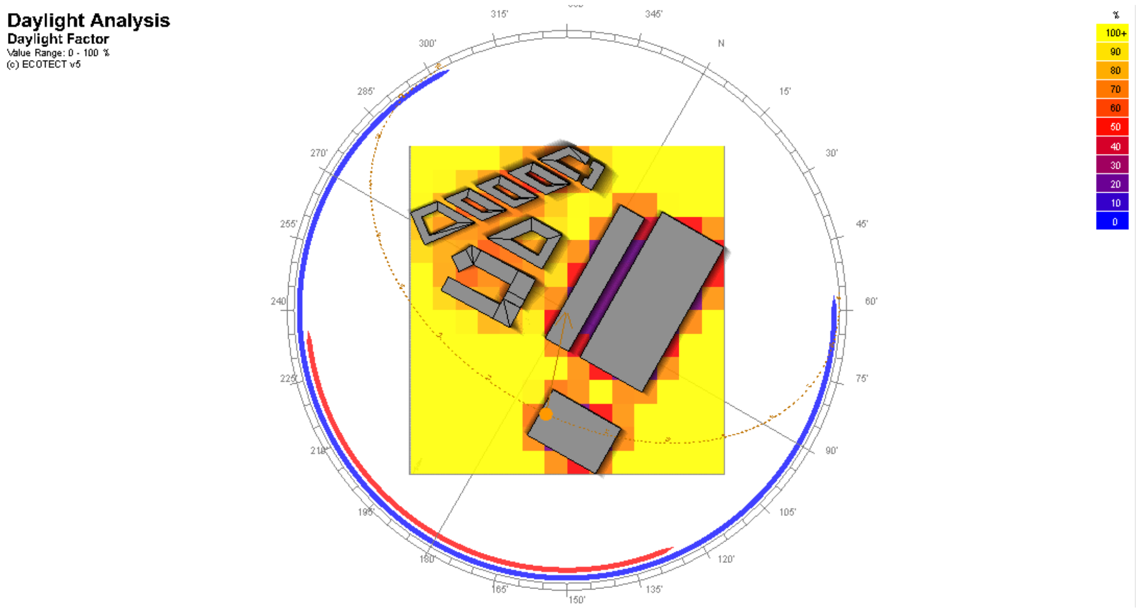


Figure 4-57 Summer solstice

By analyzing the weather data of Turin in ECOTECT, I came up with the following diagram, showing the availability of sunlight on the building.

Table 10 Solar data fro summer solstice

Latitude 45.2 Sunrise 08:06 Date 21st December

Longitude 7.7 Sunset 16:34 Local Correction -20.7 mins

Local Time (hrs)	Solar Time (hrs)	Azimuth angle (degree)	Altitude angle (degree)
5:00	04:29	57.9	1.9
5:30	04:59	63.0	6.5
6:00	05:29	68.0	11.3
6:30	05:59	72.9	16.3
7:00	06.59	77.8	21.4
7:30	06:59	82.7	26.6
8:00	07:29	87.8	31.8
8:30	07:59	93.1	37.1
9:00	08:29	98.9	42.4
9:30	08:59	105.3	47.5
10:00	09:29	112.7	52.5
10:30	09:59	121.7	57.2
11:00	10:29	132.1	61.5
11:30	10:59	145.4	65
12:00	11:29	161.4	67.4
12:30	11:59	179.5	68.2
13:00	12:29	-162.3	67.4
13:30	12:59	-146.1	65.1
14:00	13:29	-132.8	61.7
14:30	13:59	-122.0	57.5
15:00	14:29	-113.1	52.8
15:30	14:59	-105.7	47.8
16.00	15:29	-99.2	42.6
16:30	15:59	-93.4	37.4
17:00	16:29	-88.0	32.1
17:30	16:59	-82.9	26.8
18:00	17:29	-78.0	21.6
18:30	17:59	-73.1	16.5
19:00	18:29	-68.3	11.5
19:30	18:59	-63.3	6.7
20:00	19:29	-58.1	2.1

In summer, I have considered summer solstice i.e., on June 21st, for which the sun is available almost for the longest time in the whole year. The solar altitude angle is also the highest equal to 68.2° at 12:30 in the afternoon.

4.6.5.3 Solar Radiation Exposure

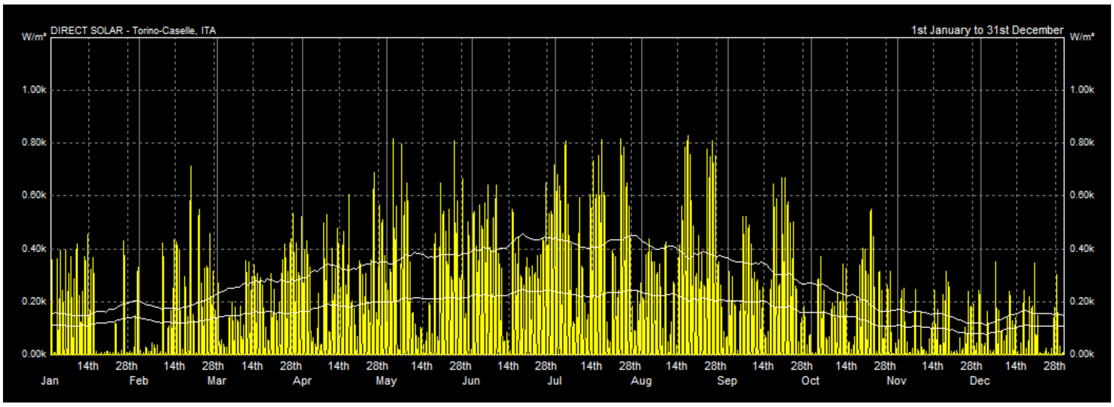


Figure 4-58 Direct solar radiation

Solar radiations, as already explained above, have the benefits like no other natural energy, as it is available for almost the whole year without spending any energy to extract it unlike other forms of natural energies available. The depicted graph generated from ECOTECT reflects the direct solar radiations incident on the whole building area, and the energy associated with it.

The areas on the building envelope, directly exposed to the sunlight have the potential to convert incident solar radiations into useful energy. The site characteristics may be utilized and electric power be produced using solar photovoltaic panels and other passive means to better condition the building interior space and lessen the electric load.

4.6.5.4 Total Monthly Solar Exposure

The following tabular data depicts the true potential of solar radiations incident on the site. The available energy is the one coming directly from sun without any losses.

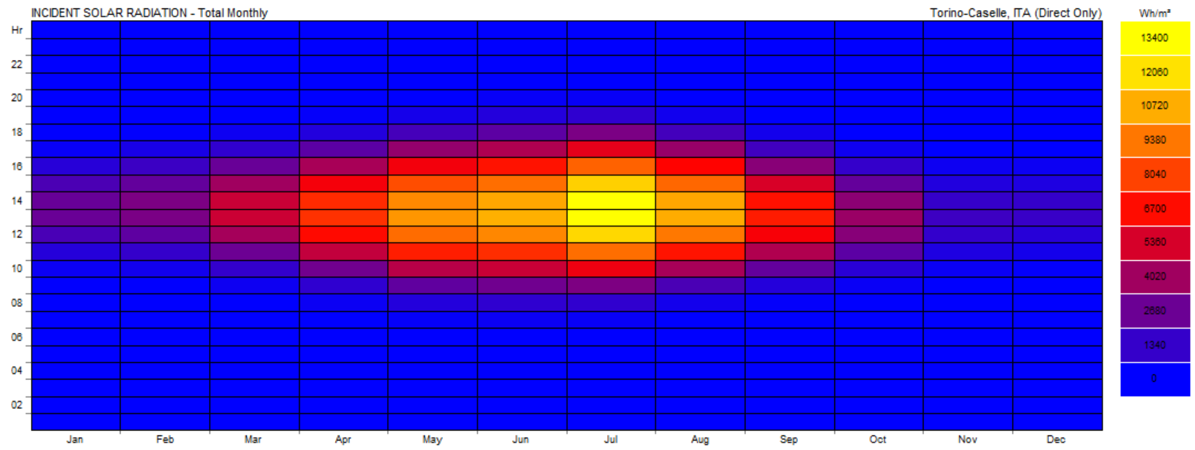


Figure 4-59 Incident solar radiation

Table 11Solar energy available

MONTH	AVAILABLE ENERGY Wh/m^2	INCIDENT ENERGY Wh/m^2
Jan	33778	11748
Feb	35284	15677
Mar	47554	27071
Apr	69855	45987
May	90384	64990
Jun	96772	72068
Jul	118254	86656
Aug	94672	64485
Sep	64138	38729
Oct	38823	18473
Nov	17534	6451
Dec	17372	5351
TOTALS	**724420**	**457686**

The incident energy is the part of the energy falling on the building envelope, since some may be interrupted through various means. This will be captured specifically by the photovoltaic panels installed, for instance, on the roof top. Therefore, contributing in bringing the building, one step closer to being a sustainable one.

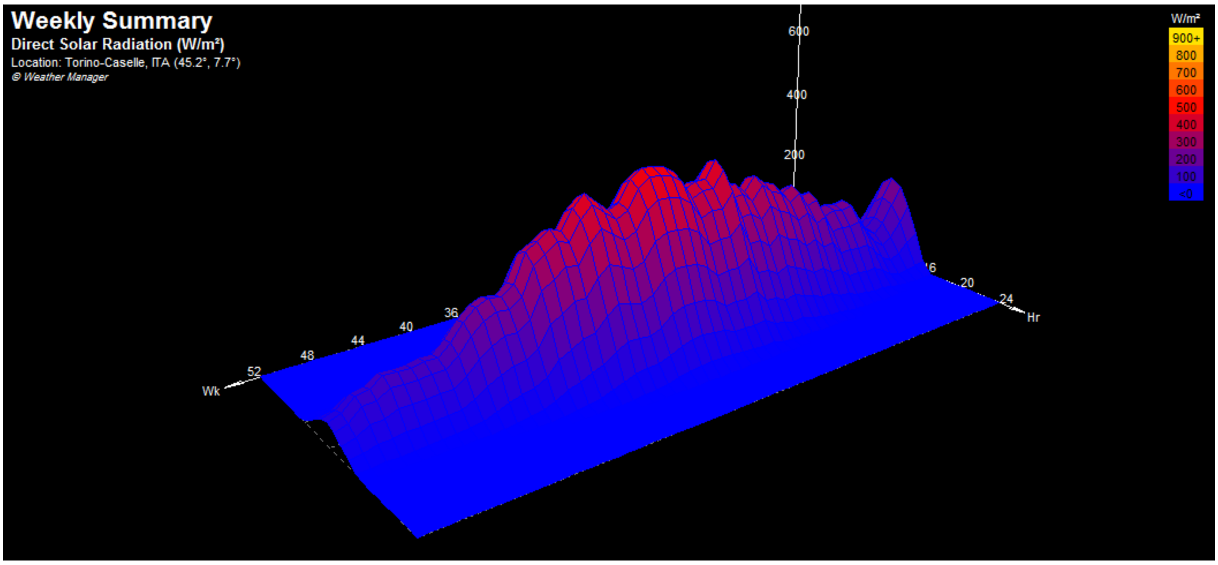


Figure 4-60 Weekly direct solar radiation

In view of the foregoing solar radiation analysis represented in tabular and graphical forms, we designed elements on the surfaces directly exposed to the sun, to catch the sunlight and convert it into electric energy. The technological innovations are necessary to take advantage of this free energy and convert it into electricity and absorb it as heat.

The project particularly comprises of technologies inserted for the purpose of exploiting the solar radiation available. Solar photovoltaic (PV) panels installed on the top of green roof and Double skin facade.

The study of solar radiations at different times of the year proves that the elements will work properly throughout the day for almost the year round.

Figure 4-61 Onyx Photovoltaic Panels
www.onyxsolar.com/

4.6.6 Daylight Analysis

Daylight is an important factor influencing human behavior, health, and productivity. Windows admitting daylight provide occupants with a view and a temporal connection with the outdoors. Daylight renders the environment in a vivid range of experiences and delight. It is important for basic visual requirements to view tasks and to perceive space.

Orientation: From a daylighting standpoint, orientation is important aspect because direct solar radiation received by the south façade is easier to control to prevent excess solar gain, is relatively uniform, and is necessary for passive solar heating strategies.

For my project, I have analysed the office spaces for the purpose of daylight levels. The Open offices areas are oriented towards south and north with the double skin façade as a buffer area directly facing the south for better working.

Components of daylight: Understanding the components of daylight is important to the design of apertures and the selection of materials. Daylight in a building consists of three components;

i. Sky component (SC)
ii. Externally reflected component (ERC)
iii. Internally reflected components (IRC1 + IRC2)

DF is the sum of these three components, each calculated individually for each location being considered. DF is a ratio, but the value of a given DF is based upon contributions from these components:

DF = SC + ERC + IRC

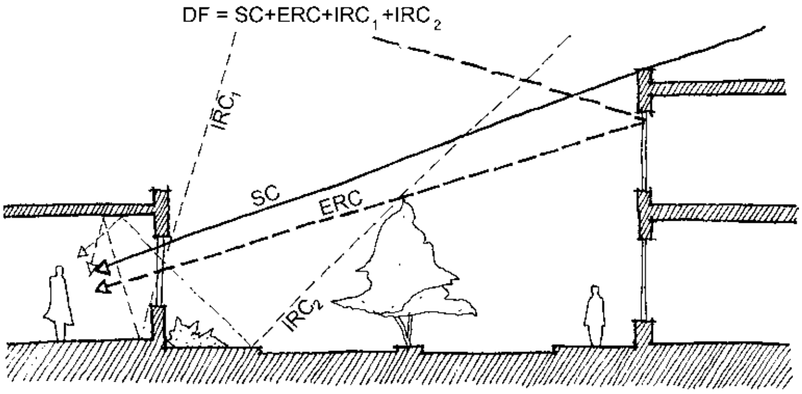


Figure 4-62 Component of Daylight

4.6.6.1 Criteria Adopted [27]

The general used values range for daylight factor and daylight levels in an activity area like office the range being as below:

Daylight level = 500-1000 lux

4.6.6.2 Office Area

Daylight analysis was performed using ECOTECT for open offices area on ground floor to exploit the daylight and the following results were obtained. The following graphs reflect the daylight level.

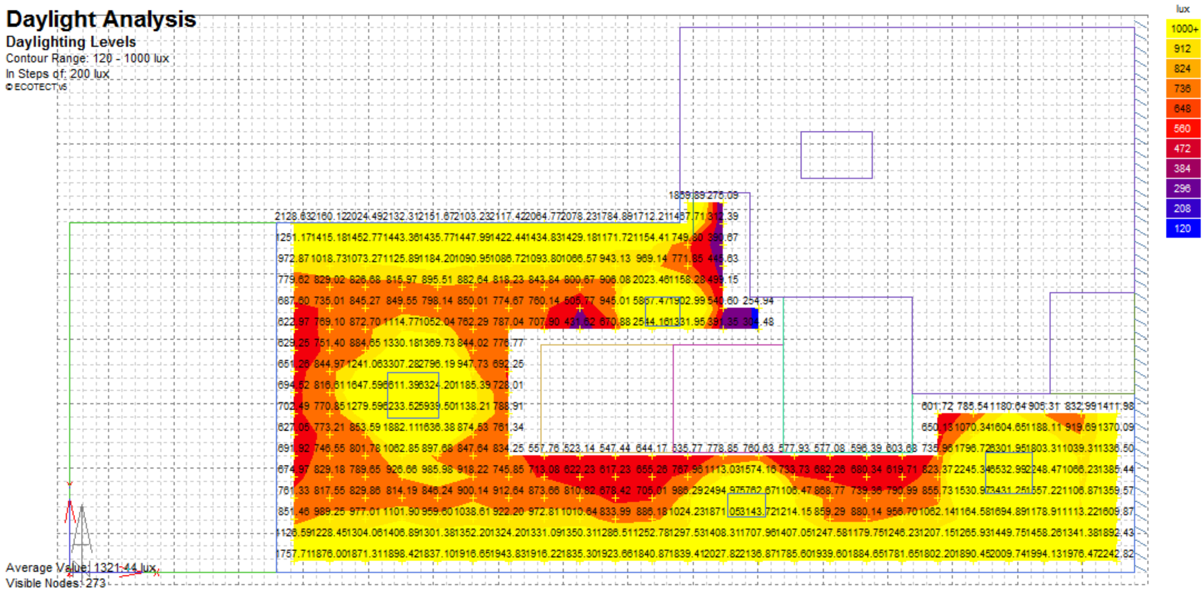


Figure 4-63 Daylight Level without DSF

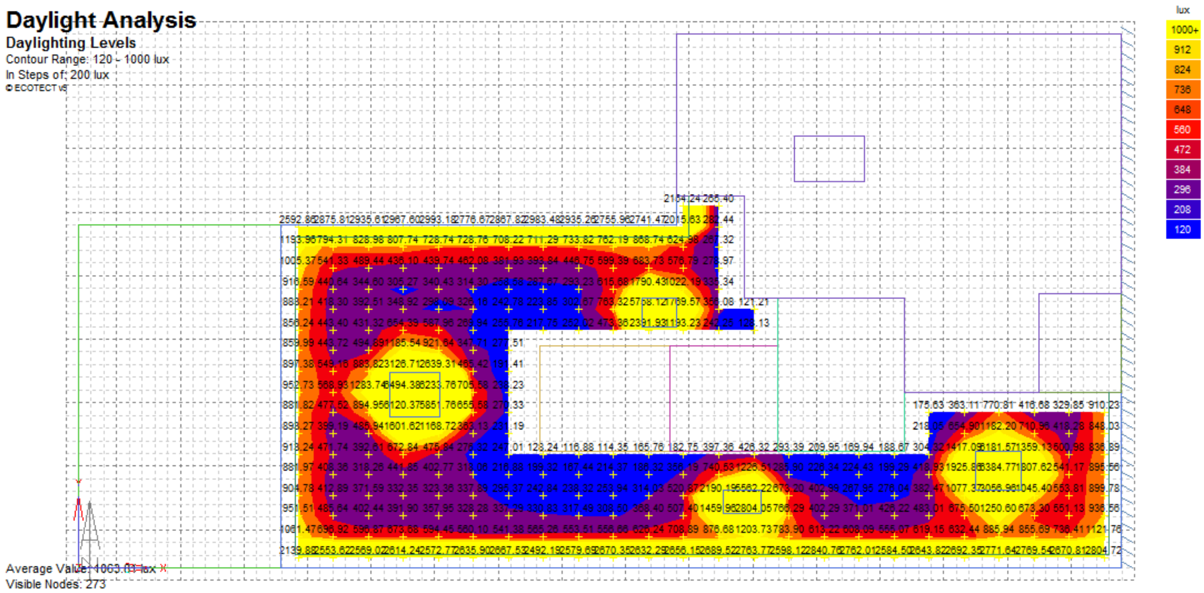


Figure 4-64 Daylight level with DSF

From the above graphical representation it is evident that by adding the double façade and blind shading system to the model values for daylight level falls in the range recommended. Thus satisfying the criteria and fulfilling the purpose of daylight comfort.

4.6.6.3 Courtyard [35]

It is scorching hot in the central courtyard under the strong sunshine of the summer. This poor environment can be greatly improved by fractal sunshades. The sunshade consists of many units of Sierpinski's tetrahedron which has the almost same fractal dimension as trees. Following analysis shows results of comparative measurements of radiant environment in visual, near-infrared and thermal infrared bands under the fractal sunshade and a parasol. The results showed that the MRT under the sunshade was lower by 17 degree than that under the parasol. Furthermore, some sensory tests and long term measurements showed some results favourable to the sunshade.

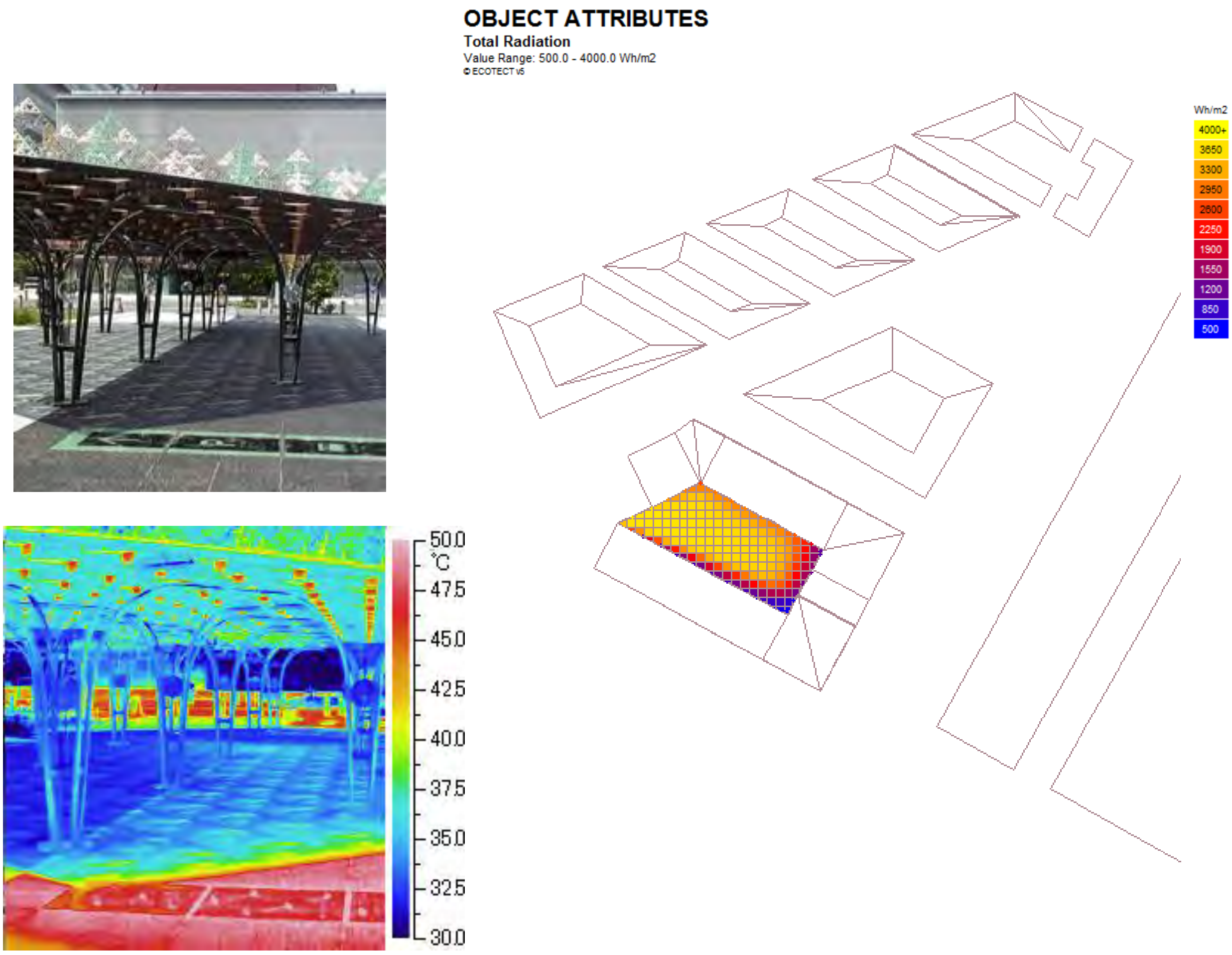


Figure 4-65 Central Courtyard total radiation and the effect of Fractal sunshade

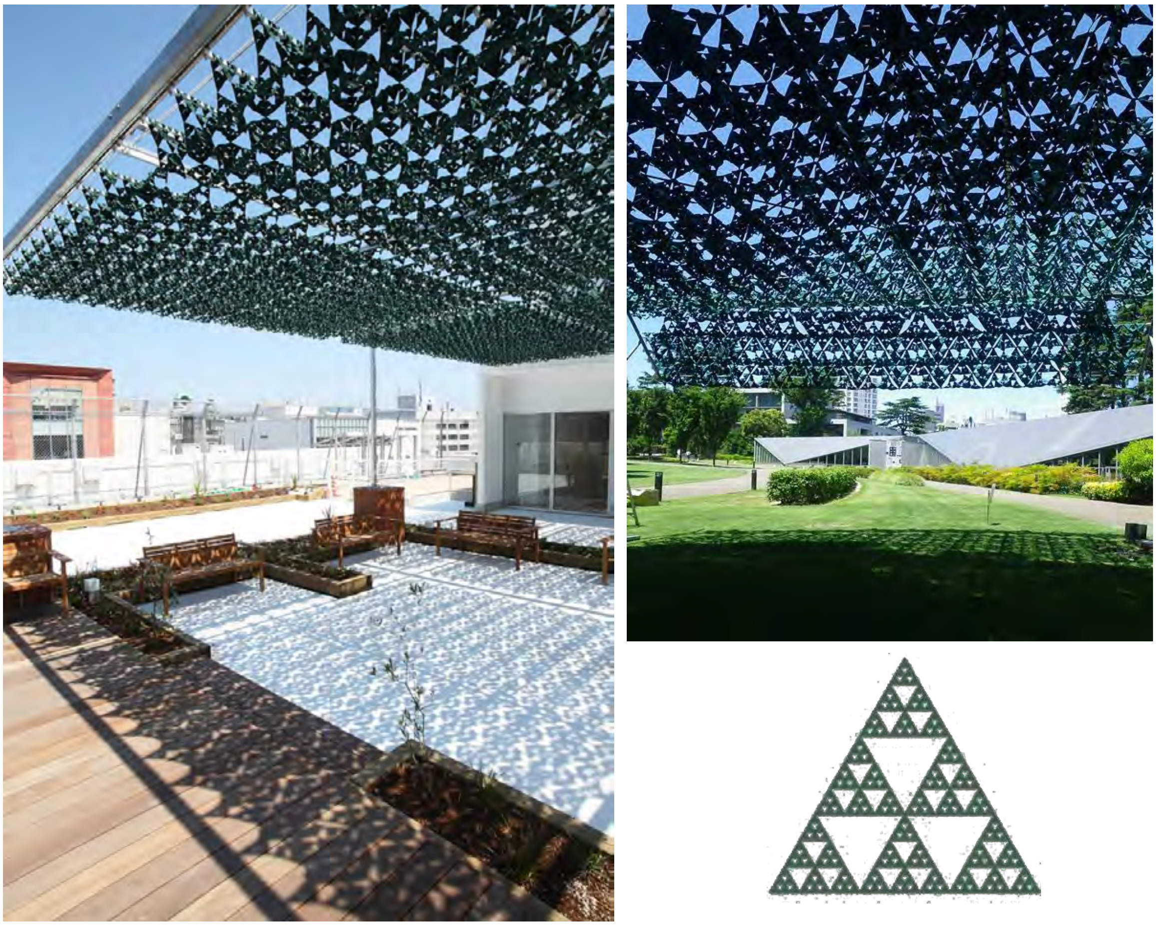
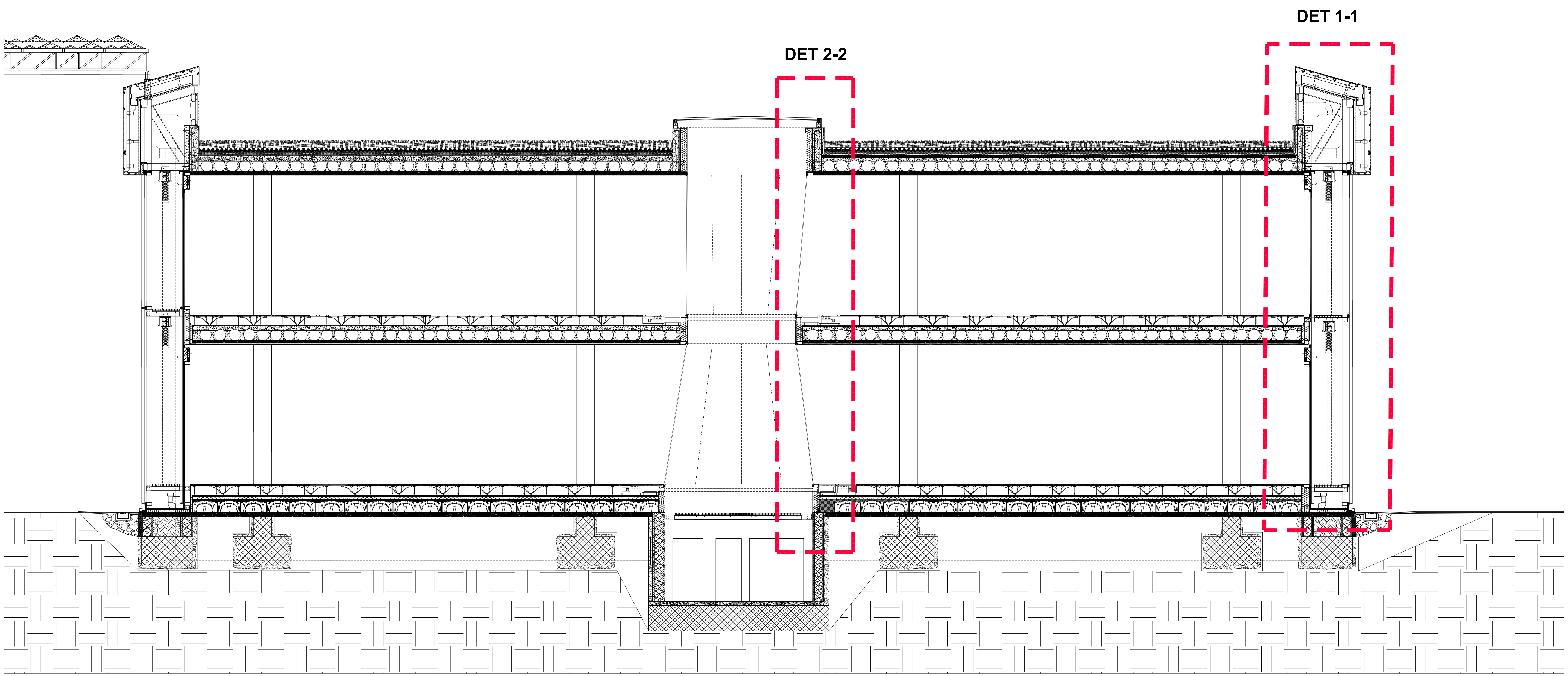


Figure 4-66 Fractal sunshade system

http://www.losfee.jp/

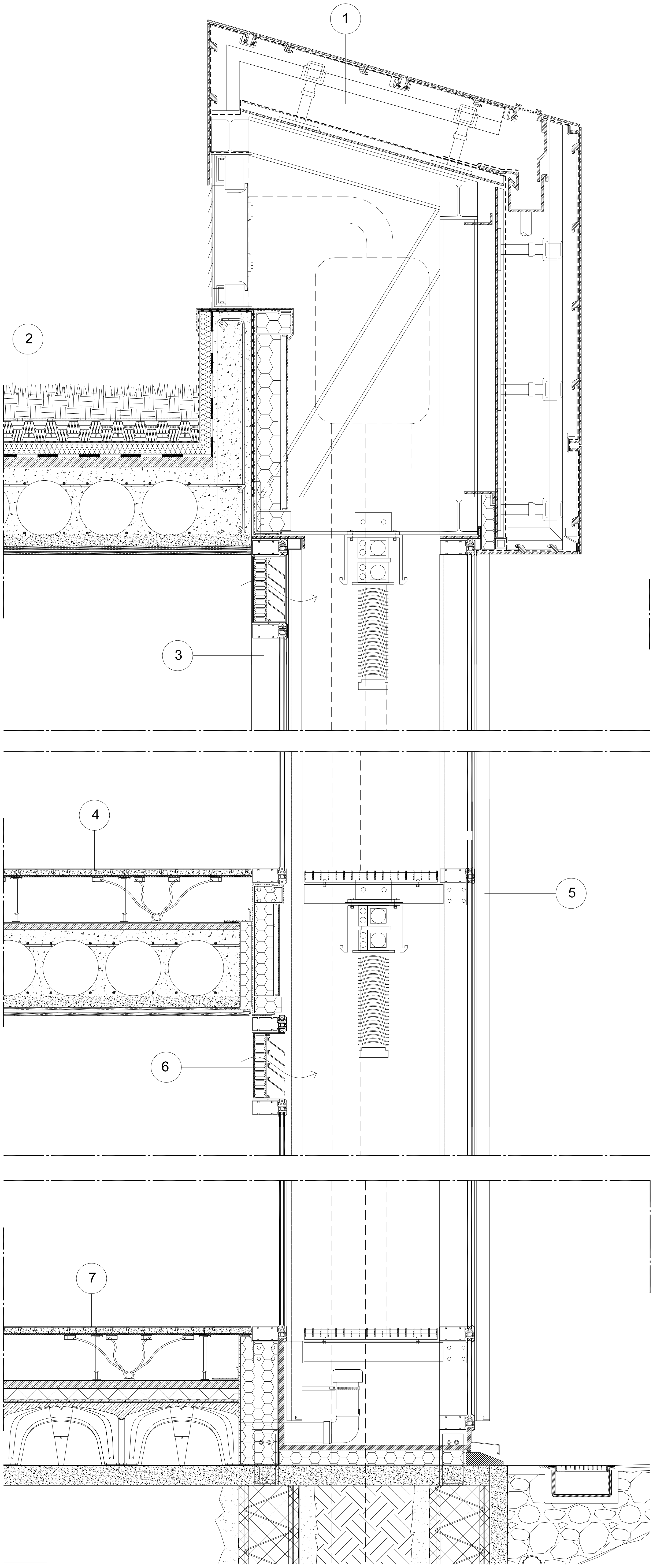
4.7 Technological Design Drawings



POLITECNICO DI MILANO
M. Sc. ARCHITECTURAL ENGINEERING

PROJECT TITLE :	DRAWING TITLE :	AMENDMENTS	REV. DATE
Turin to Smart Green	SECTION B-B		

DRAWN BY :	CHECKED BY :	APPROVED BY :	SCALE :	DATE :
AMIN	PROF. MASERA	PROF. MASERA	1/100	28/06/2014
DRAWING NO :	P-TD-01-01A		REV :	004



.1Chimney:
- 1995x745x10 mm aluminium sheets with joint with lateral ribs
- 60x60 mm U-shaped aluminium profile grooved in the direction of the inclination and connected with metal screws;
- 60x60 mm U-shaped aluminium profile perpendicular to the inclination
- 80x80 mm connecting squared steel profile with variable height steel jacks
- mechanically fixed EPDM waterproofing coat
- vapour barrier
- 40 mm undulated sheet steel
- upper batten: HEB 180 reticular beam
- heat recovery system
- exhaust fan

.2Green Roof:
- Plug plants
- > 80mm System Subtrate
- Fallnet
- Rainwater collector
- Insulation
- BubbleDeck (280mm Slab)
- 40mm Plaster with capillary tubes

.3Iner glazing skin:
- 6 mm toughened glass
- 16 mm cavity with inert-glass filling
- 6 mm float glass with low-E coating

.4Floor system
- Tiles factory applied
- Heating pipe 12 mm
- Calcium solphate panel
- insulation layer with aluminium barrier
- Metal PEDESTAL
- Distibution flexible hose
- Main water Pipe
-- Protective cement screed 20 mm
- W.P and V.B polymer bitoumin 3 mm
- Polyethylene Acoustice insulation
- 280 mm bubbledeck slab
- 60 mm concrete screed

.5Outer glazing skin:
- 8 mm toughened glass
- 22 mm cavity with inert-glass filling
- 6 mm float glass with low-E coating
- Mullion 200 mm x 120 mm x 12 mm
- Transom 150 mm x 100 mm x 10 mm

.5Exhaust Vent
- Flow damper 600mm X 1200mm
- Vent attenuator
- Internal Louvre

.7Ground floor:
- Tiles factory applied
- Heating pipe 12 mm
- Calcium solphate panel
- insulation layer with aluminium barrier
- Distribution flexible hose
- Main hot water pipe
- Sand cement screed 40 mm
- Water proof & vapore barrier polymer bituman 4mm
- Light weight concrete
- Cuploex form 400mm
-Foundation

POLITECNICO DI MILANO
M. Sc. ARCHITECTURAL ENGINEERING

PROJECT TITLE: Turin to Smart Green

DRAWING TITLE: DETAIL 1-1

AMENDMENTS

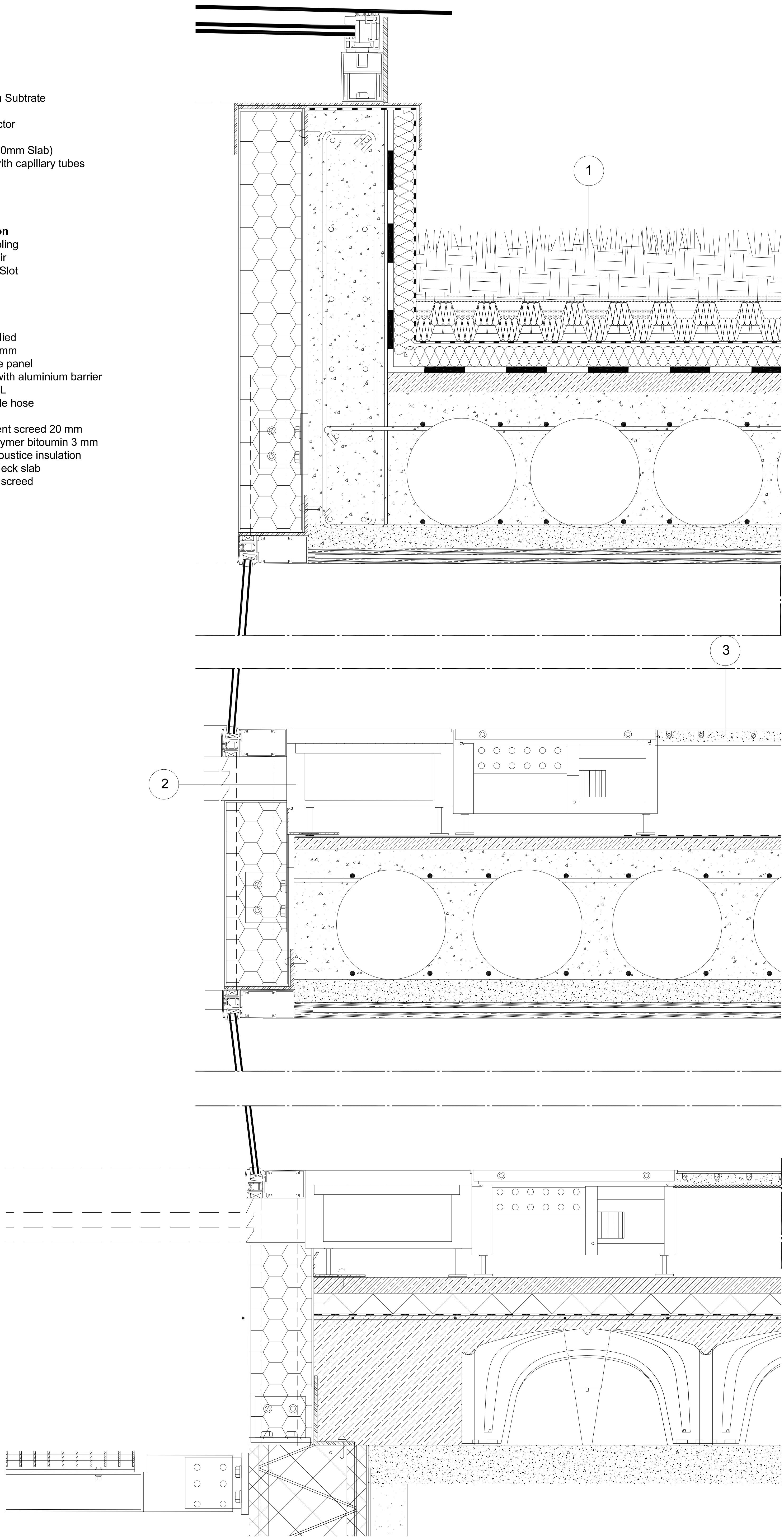
REV. DATE

DRAWN BY:	CHECKED BY:	APPROVED BY:	SCALE:	DATE:
AMIN	PROF. MASERA	PROF. MASERA	1/20	28/06/2014
DRAWING NO.:	P-TD-01-01E		REV.:	004

1.Green Roof:
- Plug plants
- > 80mm System Subtrate
- Fallnet
- Rainwater collector
- Insulation
- BubbleDeck (280mm Slab)
- 40mm Plaster with capillary tubes

2.Floor Ventilation
- Heating and Cooling
- Supply/Extract Air
- Integrated Filter Slot
- Heat Recovery

3.Floor system
- Tiles factory applied
- Heating pipe 12 mm
- Calcium solphate panel
- insulation layer with aluminium barrier
- Metal PEDESTAL
- Distibution flexible hose
- Main water Pipe
-- Protective cement screed 20 mm
- W.P and V.B polymer bitoumin 3 mm
- Polyethylene Acoustice insulation
- 280 mm bubbledeck slab
- 60 mm concrete screed



POLITECNICO DI MILANO
M. Sc. ARCHITECTURAL ENGINEERING

PROJECT TITLE: Turin to Smart Green

DRAWING TITLE: DETAIL 2-2

AMENDMENTS

REV. DATE

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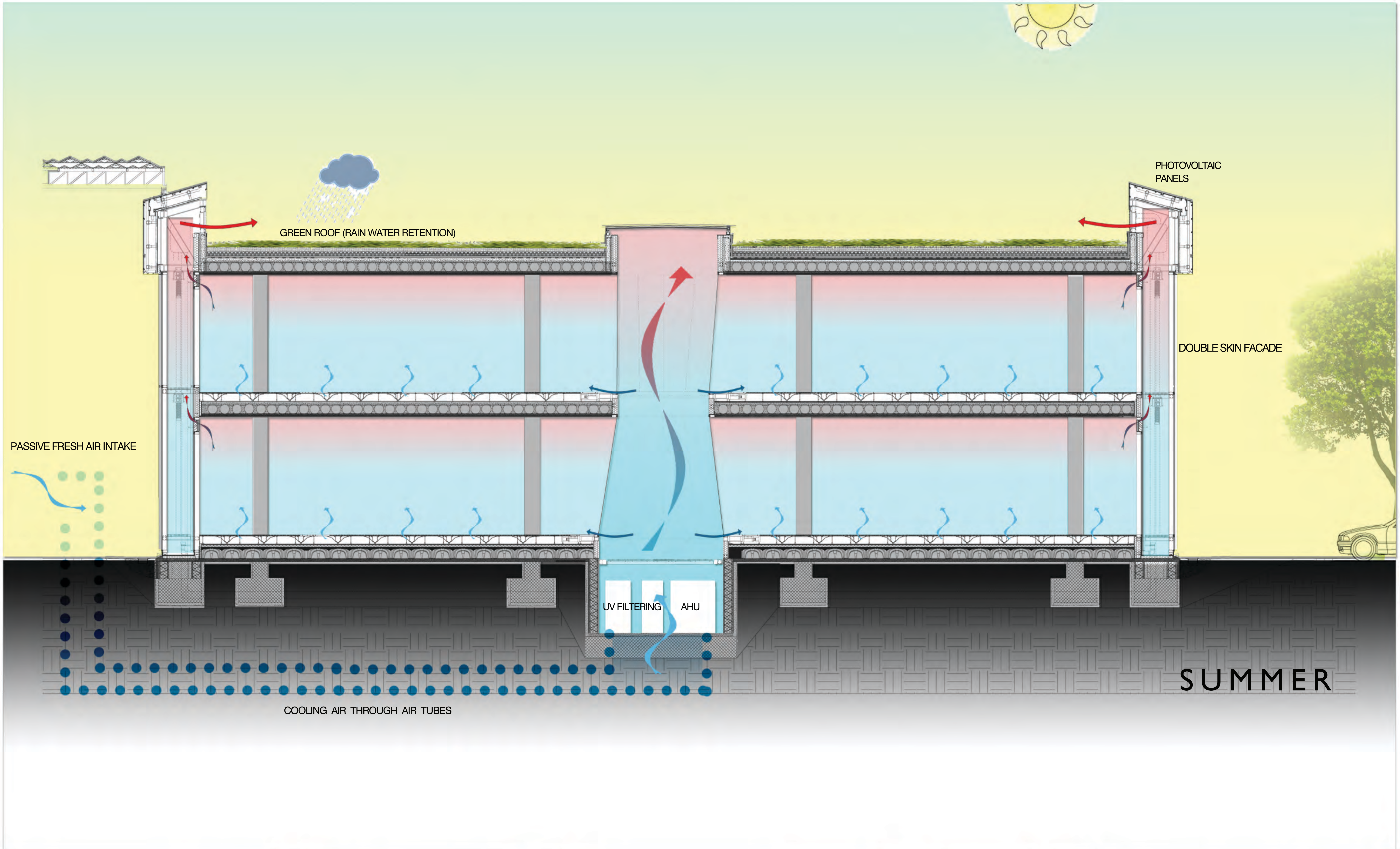
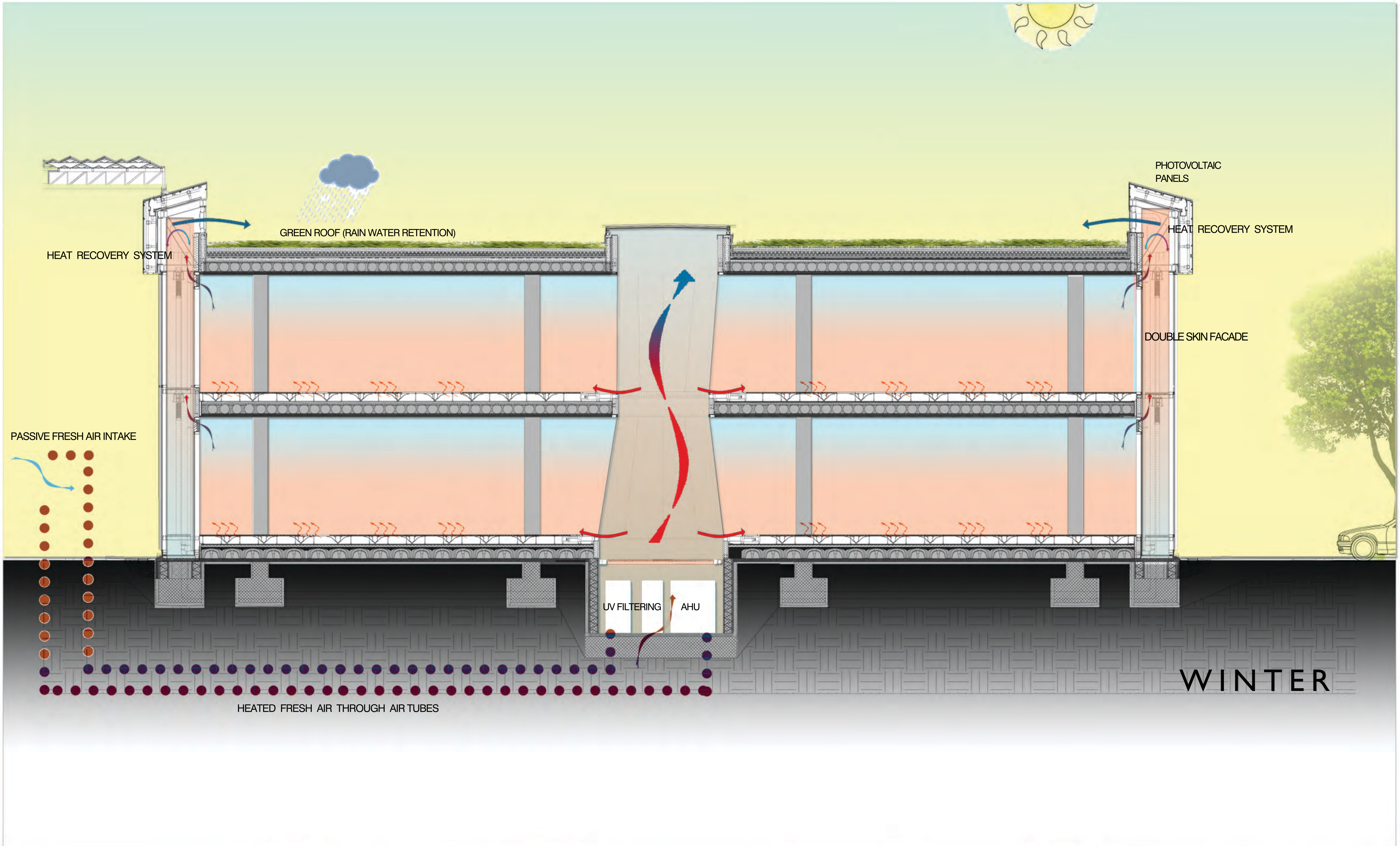
AMIN	PROF. MASERA	PROF. MASERA	1/50	28/06/2014
DRAWING NO.:	P-TD-01-01D		REV.:	004



POLITECNICO DI MILANO M. Sc. ARCHITECTURAL ENGINEERING	PROJECT TITLE : Turin to Smart Green	DRAWING TITLE : SECTION B-B	AMENDMENTS	REV. DATE	DRAWN BY :	CHECKED BY :	APPROVED BY :	SCALE :	DATE :
					AMIN	-	-	1/100	28/03/2014
					DRAWING NO :	P-TD-01-01A		REV :	001



POLITECNICO DI MILANO M. Sc. ARCHITECTURAL ENGINEERING	PROJECT TITLE : Turin to Smart Green	DRAWING TITLE : SECTION B-B	AMENDMENTS	REV. DATE	DRAWN BY :	CHECKED BY :	APPROVED BY :	SCALE :	DATE :
					AMIN	-	-	1/100	28/03/2014
					DRAWING NO :	P-TD-01-01A		REV :	001

CHAPTER 5

STRUCTURAL DESIGN

5.1 Introduction

The simplest way to define the function of a building structure is to say that it is part of the building which is resist the imposed loads applied on it. The envelope surfaces are exposed to the outdoor loads such as wind, snow and rain; floors are subjected to the gravitational loads of the occupants and their effects; also have to carry their own weight as live loads and dead loads. Therefore more accurately the structure has the role of conducting that is applied on it from the points they arise to the ground where they can eventually be resisted.

The project is located in Turin, Italy. The design of building is mainly in concrete, to achieve the desired results for the applications of structure design.

The analysis is made by both handmade calculations and computer based. For this very purpose I have used ETABS structure analysis software which gives sufficient descriptive and graphical representations of the stresses and forces, including bending moments, shear forces and axial forces etc. The applied load is used in different combinations in the software to cover exceptional and extreme load cases applied on different structural elements. The calculations are presented for different typical elements.

As a design code I followed the Eurocode approach for loading, actions, materials etc. The corresponding checks for different elements were verified as were mentioned in the corresponding documents of Eurocode standards.

5.2 Structural expansion joint

The complexity of the building concerning its linear dimensions resulted in the scale that it is better to design the structure into two parts, also following these reasons:

1- Preferably, every building should be separated after about 35 meters running length.
2- The irregular structural behavior of the building fulfilling seismic requirements.

For the matter of safety, if the building is of such a size, to prevent damage to only a part of it rather than the whole complex.

5.2.1 Sustainable Approach

5.2.2 Material selection [43]

Using concrete can facilitate the process of obtaining LEED® Green Building certification.

Five Ways Concrete Helps Build Green

1. Concrete creates sustainable sites.
2. Concrete enhances energy performance.
3. Concrete contains recycled materials.
4. Concrete is manufactured locally.
5. Concrete builds durable structures.

Table 12

Flexible space and large open expanses within the building, in addition to concrete's excellent thermal mass, help increase HVAC efficiency and lower energy costs. That same flexibility makes the building more attractive to potential long-term tenants, contributing to the overall sustainability of the project.

5.2.3 Silica Fume [42]

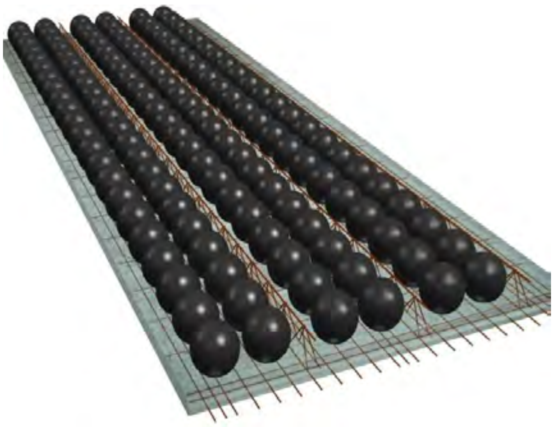
The appropriate use of silica fume improves both the mechanical characteristics and the durability of concrete, in particular its compressive strength, bond strength, and abrasion resistance. These improvements stem from both the mechanical improvements resulting from addition of a very fine powder to the cement paste mix as well as from the pozzolanic reactions between the silica fume and free calcium hydroxide in the paste.
Addition of silica fume also reduces the permeability of concrete to chloride ions, which protects the reinforcing steel of concrete from corrosion, especially in chloride-rich environments such as coastal regions and those of humid continental roadways and runways (because of the use of deicing salts) and saltwater bridges.

5.3 System selection

5.3.1 Bubbledeck Slab [31]

Bubledeck system is a method used to reduce dramatically the dead weight by eliminating concrete from the middle of a floor slab which doesn't have any structural function. This cause 35% reduction of a slab weight with Integration of recycled plastic bubbles as void formers which gives the ability of increasing span length by 50%. Combining this with a two way force distribution flat slab construction which connects directly to the columns without any beams, allows a wide range of cost and construction benefits such as;

- Design Freedom – flexible layout easily adapts to irregular & curved plan layouts.
- Reduced Dead Weight - 35% removed allowing smaller foundation sizes.
- Longer spans between columns – up to 50% further than traditional structures.
- Downstand Beams eliminated – quicker & cheaper erection of walls and services.
- Load bearing walls eliminated – facilitating MMC with lightweight building envelopes.
- Reduced concrete usage – 1 Kg recycled plastic replaces 100 Kg of concrete.
- Environmentally Green and Sustainable – reduced energy & carbon emissions.



	Solid deck	BubbleDeck® same thickness	BubbleDeck® same capacity
Carrying capacity			
Dead load			
Relative values in % of solid deck			
Carrying capacity	25	50	25
Dead load	75	50	40
Dead load / Carrying capacity	3:1	1:1	1.5:1
Absolute values in % of solid deck			
Carrying capacity	100	200	100
Dead load	100	65	50
Utility value of concrete increased		300	200

A BubbleDeck® has twice the capacity with 65% concrete and the same capacity with 50% concrete compared with a solid deck.

Figure 5-1 Bubbledeck slab[31]

5.4 Load estimation and design

5.4.1 Assumptions / limitations

The analysis of the building structure is done in accordance with the Eurocodes applicable thereto and some basic assumptions regarding the design of elements are also mentioned hereunder:

Eurocode 0 (EN 1990): Basis of structural design Eurocode 1 (EN 1991): General actions on structures Eurocode 2 (EN 1992-1-1): Design of concrete structures

i. The Persistent & Transient design situation for materials (EC2 Table 2.1N) is considered.
ii. The load actions are based on Eurocode 1.
iii. The concrete strength is taken as specified in the design code (EC2 3.1.2(3)).
iv. The cover distances input will satisfy the minimum cover requirements (EC2 4.4.1.2).
v. The design value of the modulus of elasticity of steel reinforcement, Es, is assumed to be 200 GPa (EC2 3.2.7(4)).

5.4.2 Material Properties

Basic data of structure, materials and loading

Intended use:	Office block		
Fire resistance:	1 hour for all elements		
Loading (excluding self-weight of structure):			
Flat slab:	- imposed:	$Q_k = 3kN/m2$	
	- finished:	$Gk_{,2} = 1.25kN/m2$	
Category B			
	- partitions:	$G_{k,3} = 1.25kN/m2$	
Combination factors:			
Frequent actions:		$z_1 = 0.5$	
Quasi-permanent actions:		$z_2 = 0.3$	
Exposure classes:			
Flat slab:			
Internal columns:	Class 1 (indoors)		
Faoade elements:	Class 2b (humid environment with frost)		
Block foundation:	Class 5a (slightly aggressive chemical		
environment) Subsoil conditions:			
Sand, gravel	Allowable pressure 300 kN/m^2		
Materials:			
Concrete:	-Columns:	$\gamma_c = 2400\ kg/m3$	$E_c = 37000\ N/mm2$
v= 0.2		$F_{cd} = 33.3\ N/mm2$	$F_{ck} = 50\ N/mm2$
	- Slabs:	$\gamma_c = 2400\ kg/m3$	$E_c = 33500\ N/mm2$
		$F_{cd} = 23.3\ N/mm2$	$F_{ck} = 35\ N/mm2$
Steel:		$\gamma_s = 7850\ kg/m3$	$E_s = 2*10^5\ N/mm2$
		$F_{yd} = 435\ N/mm2$	$F_{yk} = 500\ N/mm2$

5.4.2.1 Load stimation

A. Dead loads

Typical Floor dead load = 5.88 kN/m2

Bubble deck Self weight = 5.17 kN/m2

Exterior walls = 2 x 0.7 + 0.2*0.7 = 1.54 kN/m2

Internal partitions = 1.47 kN/m2

Green roof (avg) = 1 kN/m2

B. Live loads

Live loads are a result of the occupancy of a structure. From EN 1991- 1-1: 6.3; we inferred C2 category. As the building consists of multifunctional areas like spa, pool, offices etc, we used 4KN/m2 as the live load, according to the EN 1991-1-1 Table 6.1.

i. Snow load calculation [44]

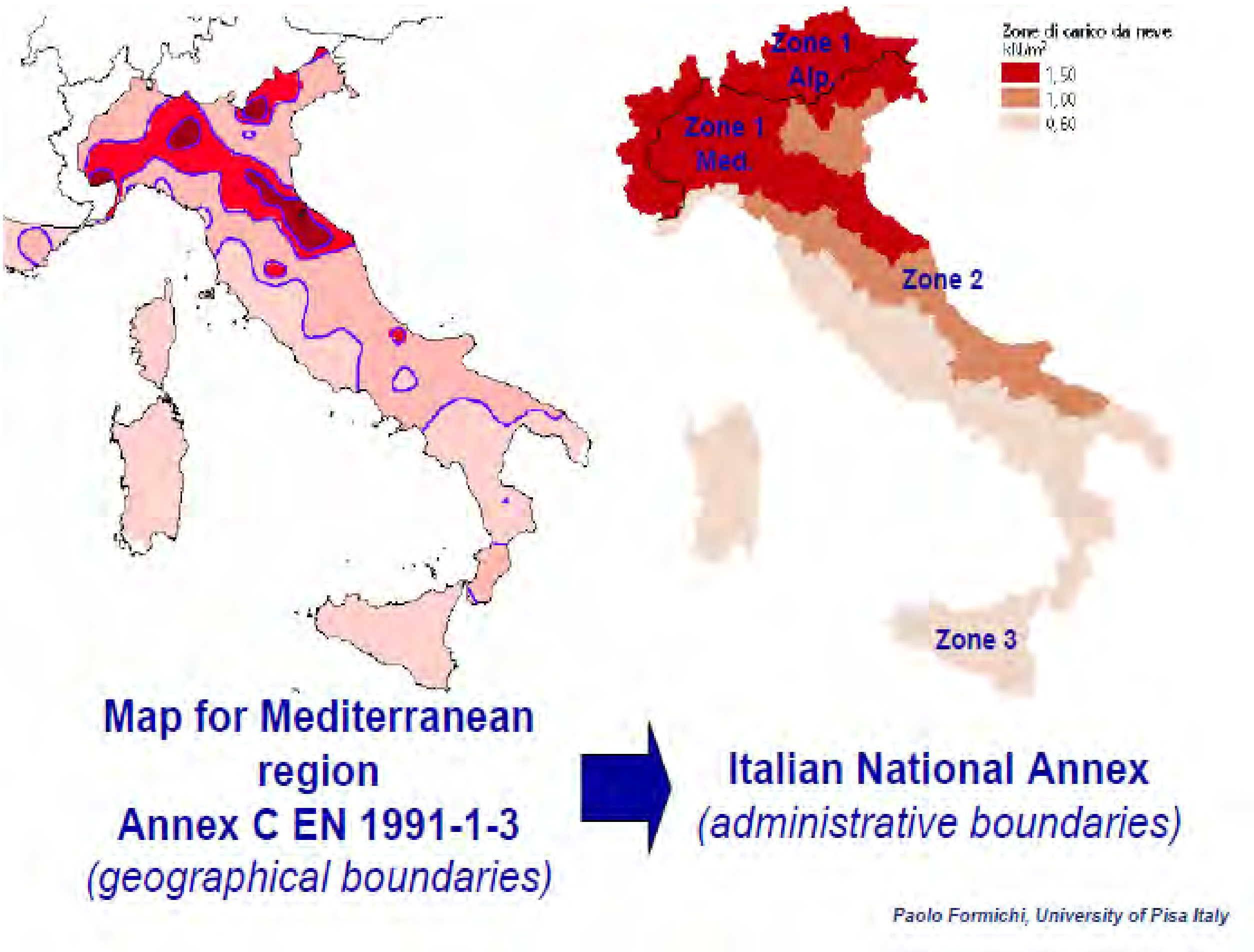


Figure 5-2 Snow load for Italy

The snow load is calculated in accordance with Eurocode criteria using equation:

$S = \mu_i \cdot C_e \cdot C_t \cdot s_k$

Climatic Region	*Expression*
Alpine Region	$s_k = (0{,}642Z + 0{,}009)\left[1 + \left(\frac{A}{728}\right)^2\right]$
Central East	$s_k = (0{,}264Z - 0{,}002)\left[1 + \left(\frac{A}{256}\right)^2\right]$
Greece	$s_k = (0{,}420Z - 0{,}030)\left[1 + \left(\frac{A}{917}\right)^2\right]$
Iberian Peninsula	$s_k = (0{,}190Z - 0{,}095)\left[1 + \left(\frac{A}{524}\right)^2\right]$
Mediterranean Region	$s_k = (0{,}498Z - 0{,}209)\left[1 + \left(\frac{A}{452}\right)^2\right]$
Central West	$s_k = 0{,}164Z - 0{,}082 + \frac{A}{966}$
Sweden, Finland	$s_k = 0{,}790Z + 0{,}375 + \frac{A}{336}$
UK, Republic of Ireland	$s_k = 0{,}140Z - 0{,}1 + \frac{A}{501}$

Figure 5-3 Eurocode: Snow Load [44]

Where,

μ_i is the snow load shape coefficient

s_k is the characteristic value of snow load on the ground

C_e is the exposure coefficient (taken as 1.0 unless otherwise specified for different topographies)

C_t is the thermal coefficient

The altitude of the site is 258m and the zone number can be obtained from the Figure 4-3 above, which is 2. Therefore the characteristic value of snow load on the ground at the relevant site is taken as,

$$S_k = 0.642Z + 0.009\ [1 + (A/728)^2]$$

Where,

Z= zone number on the map = 2

A = Altitude above sea level (m) = 258m for Turin, sud mirafiori

S_k = 1.29 kN/m2

The snow load shape coefficient: μ_i = 0.8 (alpha < 30degree)

Exposure coefficient: C_e = 1

Thermal coefficient: C_t = 1

$S = \mu i \, .C_e \, . \, C_t. \, S_k$

$S = 0.8 \times 1 \times 1 \times 1.29 \approx$ **1.0 KN/m2**

5.4.3 Load combinations

The combination of loads is to represent the maximum state of stresses that in term represent the most unfavorable conditions for the structure, taking the probability of occurrence of these loads simultaneously and in the specified combination. According to the methodology selected, partial factors Υ_f will be applied for safety reasons to the characteristic actions followed by the combination of the actions that will include a factor (Ψ) that takes into account the probability of happening of these mixed actions.

Action	ψ_0	ψ_1	ψ_2
Imposed loads in buildings, category (see EN 1991-1-1)			
Category A : domestic, residential areas	0,7	0,5	0,3
Category B : office areas	0,7	0,5	0,3
Category C : congregation areas	0,7	0,7	0,6
Category D : shopping areas	0,7	0,7	0,6
Category E : storage areas	1,0	0,9	0,8
Category F : traffic area, vehicle weight ≤ 30kN	0,7	0,7	0,6
Category G : traffic area, 30kN < vehicle weight ≤ 160kN	0,7	0,5	0,3
Category H : roofs	0	0	0
Snow loads on buildings (see EN 1991-1-3)*			
Finland, Iceland, Norway, Sweden	0,70	0,50	0,20
Remainder of CEN Member States, for sites located at altitude H > 1000 m a.s.l.	0,70	0,50	0,20
Remainder of CEN Member States, for sites located at altitude H ≤ 1000 m a.s.l.	0,50	0,20	0
Wind loads on buildings (see EN 1991-1-4)	0,6	0,2	0
Temperature (non-fire) in buildings (see EN 1991-1-5)	0,6	0,5	0
NOTE The ψ values may be set by the National annex. * For countries not mentioned below, see relevant local conditions.			

Figure 5-4 Probability factor for mixed actions [37]

Persistent and transient design situations	Permanent actions		Leading variable action (*)	Accompanying variable actions	
	Unfavourable	Favourable		Main (if any)	Others
(Eq. 6.10)	$\gamma_{Gj,sup}G_{kj,sup}$	$\gamma_{Gj,inf}G_{kj,inf}$	$\gamma_{Q,1}\ Q_{k,1}$		$\gamma_{Q,i}\psi_{0,i}Q_{k,i}$

(*) Variable actions are those considered in Table A1.1

NOTE 1 The γ values may be set by the National annex. The recommended set of values for γ are :

$\gamma_{Gj,sup} = 1,10$

$\gamma_{Gj,inf} = 0,90$

$\gamma_{Q,1} = 1,50$ where unfavourable (0 where favourable)

$\gamma_{Q,i} = 1,50$ where unfavourable (0 where favourable)

NOTE 2 In cases where the verification of static equilibrium also involves the resistance of structural members, as an alternative to two separate verifications based on Tables A1.2(A) and A1.2(B), a combined verification, based on Table A1.2(A), may be adopted, if allowed by the National annex, with the following set of recommended values. The recommended values may be altered by the National annex.

$\gamma_{Gj,sup} = 1,35$

$\gamma_{Gj,inf} = 1,15$

$\gamma_{Q,1} = 1,50$ where unfavourable (0 where favourable)

$\gamma_{Q,i} = 1,50$ where unfavourable (0 where favourable)

provided that applying $\gamma_{Gj,inf} = 1,00$ both to the favourable part and to the unfavourable part of permanent actions does not give a more unfavourable effect.

Figure 5-5 Partial factor for load actions [37]

Load combinations	
Comb C1	1.35 DEAD
Comb C2	1.35 DEAD + 1.5 LIVE
Comb C3	1 DEAD + 0.45 LIVE + 1 EQY
Comb C4	1 DEAD + 0.45 LIVE - 1 EQY
Comb C5	1 DEAD + 0.45 LIVE + 1 EQX
Comb C6	1 DEAD + 0.45 LIVE - 1 EQX
Comb C7	1 DEAD + 1 EQY
Comb C8	1 DEAD - 1 EQY
Comb C9	1 DEAD + 1 EQX
Comb C10	1 DEAD - 1 EQX

Table 13 Load combinations

5.4.4 Conceptual manual calculation for elements under load:

For better understanding of the structure, I went through the process of structure design in two stages. Firstly, the hand calculations were made for the desired structure and verified through different checks. Then, the results from the same were utilized as an input to the software to have computer based analysis.

For the purpose of this project, the flexibility method for manual calculations was chosen to analyze the elements and thus considering the bending moments and shear forces, obtained there from to complete the design. After calculation of the required forces and designing the elements the necessary checks were performed to have confirmation that the element will be able to sustain the loads applied upon and remain stable.

It was not possible to design all the elements of the structure, so typical horizontal and vertical elements were chosen to cover most of the structure and the rest of the elements would be designed on the same lines in accordance with the Eurocode requirements. The effect of earthquake was not covered under the manual calculations but only in the computer software ETABS.

5.4.5 Column Design

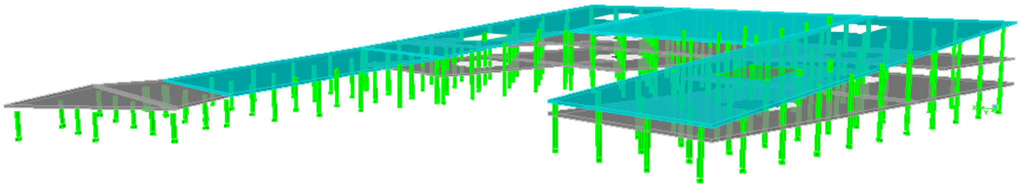


Figure 5-6 Structural Axonometric

5.4.5.1 Second Order Effect and Slenderness [38]

According to EC2 – 5.8.3.3 the evaluation whether global second order effects may be ignored is performed. The total vertical load on the column needs to be calculated first. Here typical columns will be checked for the second order effect using the Eurocode 2 approach.

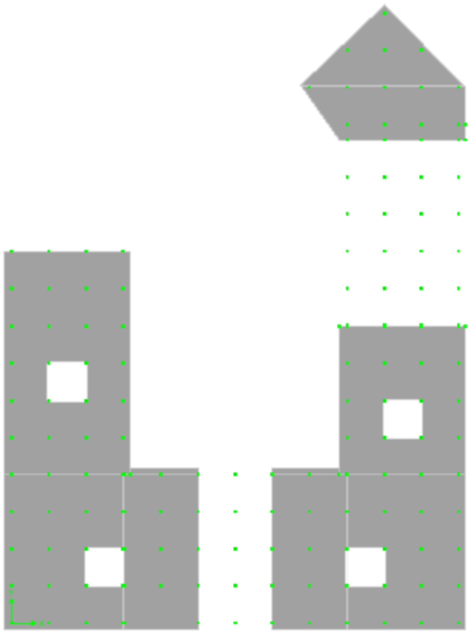


Figure 5-7 Column distribution (Ground Floor)

As an alternative to 5.8.2 (6), second order effects may be ignored if the slenderness A- (as defined in 5.8.3.2) is below a certain value λ_{lim}•

Note: The recommended value for λ_{lim} follows from:

$\lambda_{lim} = 20 \cdot A \cdot B \cdot C/\sqrt{n}$ = **46.9**

where:

A = $1/(1+0.2\varphi_{ef})$ (if φef is not known, A= 0.7 may be used)

B = $\sqrt{(1+2\omega)}$ (if ω is not known, B = 1.1 may be used)

C = $1.7 - r_m$ (if rm is not known, C = 0.7 may be used)

φ_{ef} effective creep ratio

ω = $A_s f_{yd} / (A_c f_{cd})$; mechanical reinforcement ratio;

As is the total area of longitudinal reinforcement

n = $N_{Ed} / (A_c f_{cd})$; relative normal force

rm = M_{01} / M_{02} ; moment ratio

M_{01}, M_{02} are the first order end moments, $|M_{02}| \geq |M_{01}|$

If the end moments M_{01} and M_{02} give tension on the same side, r_m should be taken positive (i.e. C < 1.7), otherwise negative (i.e. C > 1.7).

In the following cases, r_m should be taken as 1.0 (i.e. C = 0.7):

a. for braced members in which the first order moments arise only from or predominantly due to imperfections or transverse loading
b. for unbraced members in general

For instance at column M-16 in the structural plan:

Permanent Loads = 5.17 + 1.03 + 5.88 = 12.08 kN/m2

Approximate influence area = 16 m2

Applicable loads = 16 x 12.08 = G_k = 193.28 kN

Weight factor γ_G = 1.35

Permanent loads = γ_G x G_k = 1.35 x 193.28 kN = 260.9 kN Variable Loads = 4 kN/m2

Approximate influence area = 16 m2

Applicable loads = 16 x 4 = Q_k = 64 kN

Weight factor γ_G = 1.5

Variable loads = γ_G x Q_k = 1.5 x 64 kN = 96 kN

$F_{v,Ed} = (\gamma_G \text{ x } G_k) + (\gamma_G \text{ x } Q_k)$

$F_{v,Ed}$ = 260.9 kN + 96 kN = **356.9 kN**

Therefore value of λ_{lim} is calculated as follow:

$\lambda_{lim} = 20•A•B•C/\sqrt{n}$

$\lambda_{lim} = 20*0.7*1.1*0.7/ \sqrt{(356.9*103/4002*33.3)}$

λ_{lim} = 42.2

The slenderness of a column or wall is given by:

$\lambda = l_0 / l_i$

Where:

l_i is the radius of gyration of the uncracked concrete section

l_0 is the effective length of the member which can be assumed to be:

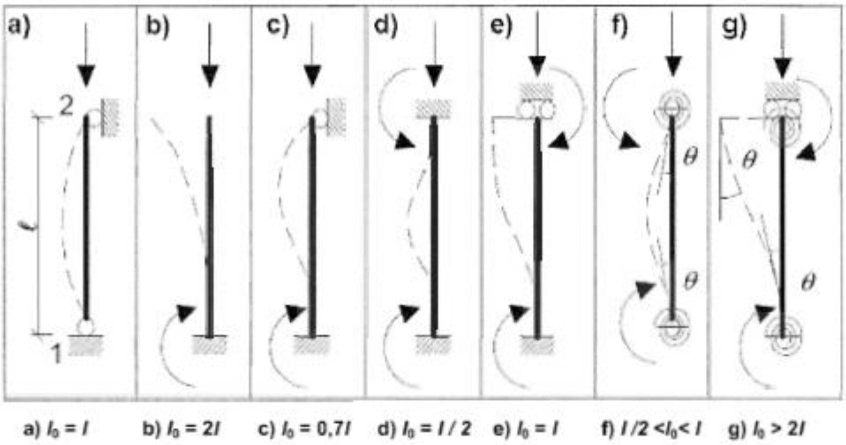


Figure 5-8 Examples of different buckling modes and corresponding effective lengths for isolated members

For column under observation:

$l_0 = 1 * 3.5 = 3.5$ m

$l_i = \sqrt{(I / A)} = \sqrt{(0.4*0.43/12)/0.42} = 0.115$

$\lambda = l0 / li = 3.5/0.115 = 30.43$

λ = 30.43 < 42.2

Therefore the Global Second Order effect can be ignored.

5.4.5.2 Pre-dimensioning for the central axial loading:

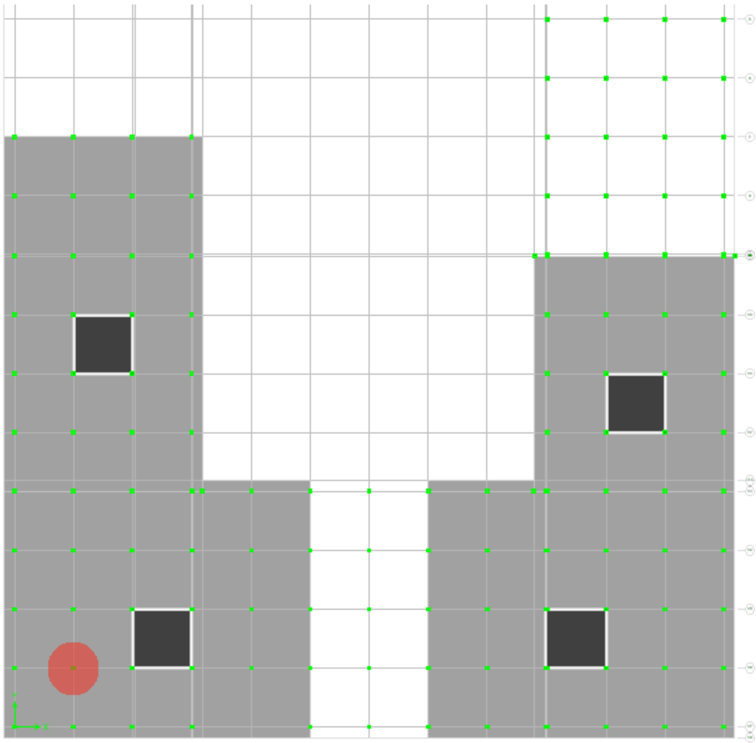


Figure 5-9 Column C44 (Ground Floor)

A column at grid line M-16 represented in ground floor is analyzed as a typical case. The "influence areas" method will be used in order to determine the axial load to be taken into account during the pre-dimensioning of reinforcement. The influence area we can calculate the desired load in the following way:

Influence area = 8 x 8 = 64 m^2

Modified influence area taking redundancy into account = 64 x 1.4 = 89.6 m^2

Slab weight = 5.17 x 89.6 = 463.23 kN

Finishes = (5.88 + 1.54 + 1.37) x 89.6 = 787.58 kN

Variable loads = 4 x 89.6 = 358.4 kN

Loads	Typical Floor
Permanent loads G_k (kN)	1250.81
Variable loads Q_k (kN)	358.4
F_k	1609.21 kN

Table 14 Total load

5.4.5.3 For ULS combination of Actions: [37]

A single multiplicative factor will be referred to, as a simplification: J_F is obtained as weighted mean of the coefficients $J_G = 1.35$ and $J_Q = 1.5$, respectively concerning permanent actions and variable actions.

$$J_f = \frac{J_G \cdot G_K + J_Q \cdot Q_K}{G_K + Q_K} = \frac{1.35 * 1250\ kN + 1.5 * 358.4\ kN}{1250.81\ kN + 358\ kN} = 1.38$$

In the Table 15 pre-dimensioning of the geometry of column is shown:

Table 15 Column M-16 pre-dimensioning for centred axial load

Column	F_k (kN)	N (kN) $N = \sum F_{kj}$	$N_{Ed} = J_F * N$ (kN)	$A_{C0} = \frac{N_{Ed}}{f_{cd}}$ (mm^2)	b x h (mm)	A_c (mm^2)
Second	1609.21	1609.21	2220.7	66687.7	300 x 300	90000
First	1609.21	3218.42	4441.42	133376	400 x 400	160000
Ground	1609.21	4827.63	6662.13	200063.9	450 x 450	202500

5.4.5.4 Column self weight influence:

Second floor column = 0.3 x 0.3 x 3.5 x 25 = 7.9 kN

First floor column = 0.4 x 0.4 x 3.5 x 25 = 14 kN

Ground floor column = 0.45 x 0.45 x 3.5 x 25 = 17.7 kN

Table 16 Column M-16 Self-weight influence

Column	F_k (kN)	N (kN) $N = \sum F_{kj}$	$N_{Ed} = J_F * N$ (kN)	$A_{c0} = \frac{N_{Ed}}{F_{cd}}$ (mm^2)	b x h (mm)	A_c (mm^2)
Second	1617.11	1617.11	2231.6	67015.4	300 x 300	90000
First	1617.11	3232.42	4460.74	133956.1	400 x 400	160000
Ground	1617.11	4845.33	6686.56	200797.5	450 x 450	202500

5.4.5.5 Longitudinal reinforcement

Each bar at corner of the column should not be ≤ 12mm

Geometric limit $A_s \geq 0.003\ A_c$

Static limit $A_s \geq 0.10\ N_{Ed}/F_{yd}$

Table 17 Column M-16 Pre-dimensioning of longitudinal reinforcement

Column	**A_c (mm^2)**	**$A_{s\ min}$ (mm^2) $\rho_s = 0.3\%$**	**$A_{s\ min}$ (mm^2) $= 0.10\ N_{Ed}/f_{yd}$**	**n° x φ**	**A_s (mm^2)**
round	202500	607.5	1537.1	8 φ 16	1608.5
First	160000	480	1025.5	8 φ 16	1608.5
Second	90000	270	513	8 φ 12	904.8

5.4.5.6 SLS verification:

The translational equilibrium of the cross-section for SLS is

$$N = \sigma_c A_c + \sigma_s A_s$$

Under the hypothesis of plane sections (Euler-Bernoulli), same strain in steel and surrounding concrete ($\varepsilon_c = \varepsilon_s$) and elastic materials, it is $\sigma_s = \alpha_e \sigma_c$, where the ratio between the modulus of elasticity α_e is assumed equal to 15 in order to take into account the time-dependent behaviour of concrete.

$N = \sigma_c (A_c + \alpha_e A_s) = \sigma_c A_{ie}$

$\sigma_c = \frac{N}{A_{ie}} \leq \sigma_{c,adm} = 0.6\ f_{ck} = 30$ N/mm2

Column	**A_c (mm^2)**	**A_s (mm^2)**	**A_{ie} (mm^2)**	**N (kN)**	**σ_c (N/mm^2)**	**$<\sigma_{c,adm}$?**
Ground	202500	1608.5	226627.5	4845.4	21.3	Yes
First	160000	1608.5	184127.5	3232.4	17.5	Yes
Second	90000	904.8	103572	1617.1	15.6	Yes

Table 18 Column M-16 SLS verification

5.4.5.7 ULS verification:

The translational equilibrium for ULS is

$$N_{Rd} = A_c\ f_{cd} + A_s\ f_{yd}$$

Column	A_c (mm^2)	A_s (mm^2)	N_{Ed} (kN)	N_{Rd} (kN)	N_{Rd} / N_{Ed}
Ground	202500	1608.5	6686.5	7442.9	1.11
First	160000	1608.5	4460.74	6027.7	1.35
Second	90000	904.8	2231.6	3390.6	1.52

Table 19 Column M-16 ULS verification

5.4.5.8 Transversal reinforcement

In Eurocode 2, some prescriptions on transversal reinforcement are outlined.
The minimum diameter of transversal bars needs to be not less than ¼ of the longitudinal diameter and not less than 6 mm.
The spacing of the transverse reinforcement along the column needs not to exceed the following limits:

- 20 times the longitudinal bar size (20 • 12 = 240 mm; 20 • 14 = 280 mm)
- The smaller dimension of the column (at most, 300 mm)
- 400 mm

In those sections within a distance equal to the larger dimension of the column cross-section above and below beams and slabs the previous limits are reduced by a factor 0,6 i.e., (0,6 • 240 = 144 mm).
Stirrups φ8/200 will be provided along all the columns, whereas at the bottom and the top of the columns for a distance equal to 500 mm stirrups φ8/125 will be provided.

5.4.6 Bubble Deck Slab [40]

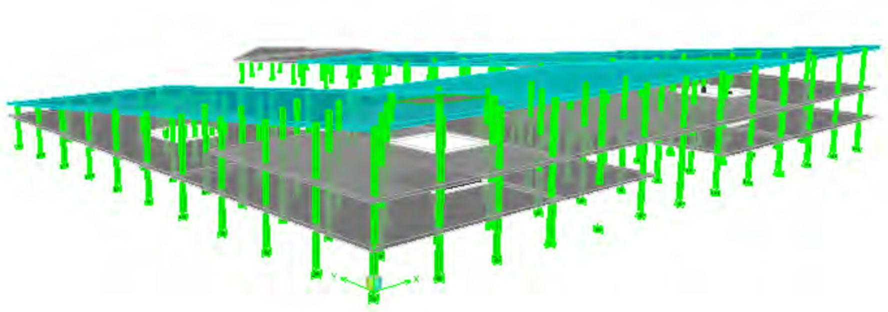


Figure 5-10 Structural 3D Model with Column and Slab System

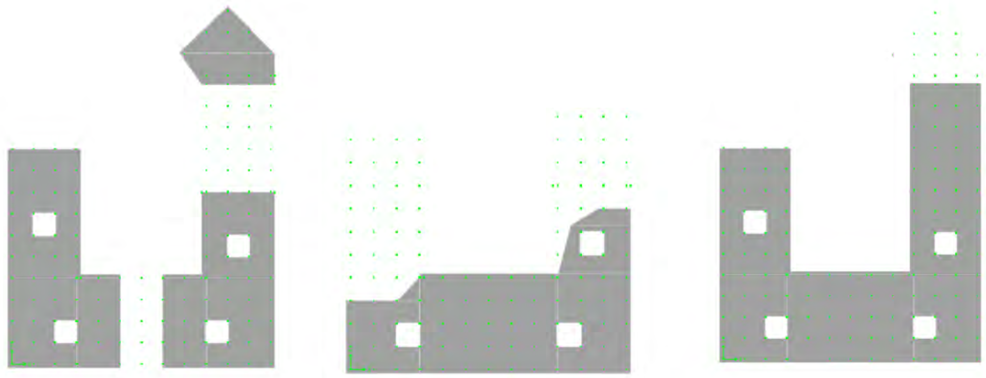


Figure 5-11 Left to right: 1st Floor, 2nd Floor, and Roof Slab

5.4.6.1 Slab size:

The sizing of the slabs is given according to the estimated span width. The table of the manufacturer is utilized as a guide to get a preliminary design as follows:

Version	Slab Thickness	Bubbles	Span (Multiple bays)	Cantilever Maximum Length	Span (Single bays)	Completed Slab Mass	Site Concrete Quantity
	mm	mm	metres	metres	metres	kN/m²	m³/m²
BD230	230	Ø 180	5 – 8.3	≤ 2.8	5 – 6.5	4.34	0.109
BD280	280	Ø 225	7 – 10.1	≤ 3.3	6 – 7.8	5.17	0.142
BD340	340	Ø 270	9 – 12.5	≤ 4.0	7 – 9.5	6.25	0.186
BD390	390	Ø 315	11 – 14.4	≤ 4.7	9 – 10.9	6.93	0.213
BD450	450	Ø 360	13 – 16.4	≤ 5.4	10 – 12.5	7.94	0.245
BD510 *	510	Ø 410	15 – 18.8	≤ 6.1	11 – 13.9	9.06	0.291
BD600 *	600	Ø 500	16 – 21.0	≤ 7.2	12 – 15.0	10.22	0.338

Figure 5-12 Manufacturer proposed dimensions for slabs[40]

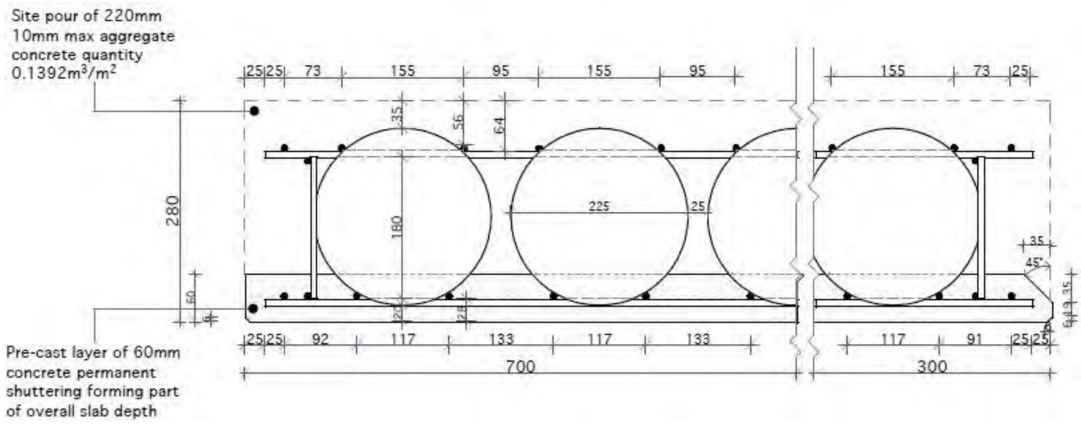


Figure 5-13 Typical slab dimensioning[41]

5.4.6.2 Design requirements:

The hollow slab can be designed with conventional structural analysis of a full section, if the following limits are observed:

DIN 1045-1: $\mu_{sds} = m_{sd} \cdot D_{BD} \cdot 1.96 / (d_B^3 \cdot f_{ck}) \leq 0.2$

where:
- μ_{sds} = relative bending moment in the ball zone [-]
- m_{sd} = max. bending moment [MNm/m]
- D_{BD} = ball diameter [m]
- d_B = static height of the BubbleDeck® [m]
- f_{ck} = characteristic strength according to DIN 1045-1 [MN/m²]

DIN 1045: $m_s = m \cdot D_{BD} \cdot 1.17 / (d_B^3 \cdot ß_R) \leq 0.2$

where:
- m_s = relative bending moment in the ball zone [-]
- m = max. bending moment under occupancy load [MNm/m]
- D_{BD} = ball diameter [m]
- d_B = static height of the BubbleDeck® [m]
- $ß_R$ = calculated strength according to DIN 1045 [MN/m²]

Figure 5-14 Flexion requirements[41]

5.4.6.3 Handmade design calculations:

The design of the slab is made considering a 1 m wide strip.

Applied loads are:

- Permanent actions:
  - self-weight + finishes: G_k = 5.17 + 5.88 = 11.08 kN/m
- Variable actions
  - live load: Q_k = 4 kN/m

Slab thickness = 280 mm

Column size = 450 mm

5.4.7 Handmade Structural analysis[36]

The structural analysis will be carried out using linear analysis based on the theory of elasticity, considering the combination of actions for Ultimate Limit States [EC2 – 5.1.3(1)P] that is;

$$\sum_{j\geq 1} \gamma_{Gj}.G_{kj} + \gamma_{Q1}.Q_{k1} + + \sum_{i>1} \gamma_{Qi}\Psi_{0i}.Q_{ki}$$

The most unfavourable condition results in considering the live load Q1 as the leading variable action and the load due to inside partitions with its combination value Ψ_{02} Q2 = Q2 (Ψ_{02} = 1.0 according to National Annex).

5.4.7.1 Load Combination [36]

Permanent loads: J_G (G_k) = 1.35 (G_k)

Variable loads: J_Q (Q_k) = 1.5 (Q_k)

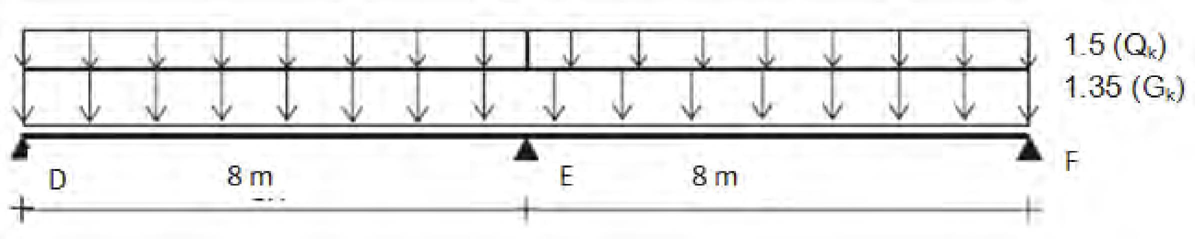


Figure 5-15 Panel centred on Grid line

The structure is solved using the Flexibility Method

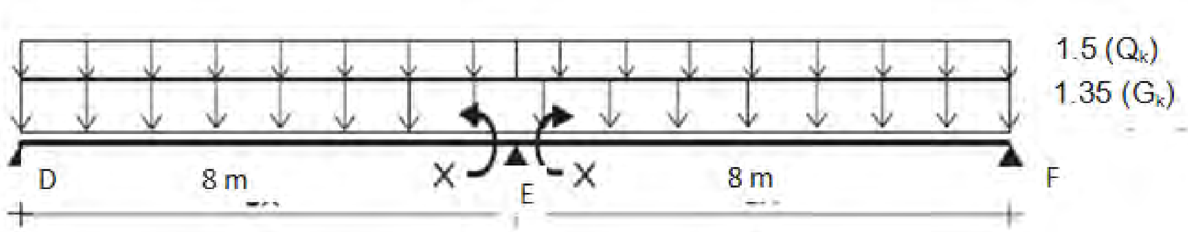


Figure 5-16 Flexibility method: load combination

The panel is center on Grid line 4.

The ultimate load is given by = 1.35 (Gk) + 1.5 (Qk) = 20.92 kN/m

5.4.7.2 Cover[36]

$C_{nom} = C_{min} + \Delta C_{dev}$

here C_{min} = max of [$C_{min,b}$; $C_{min,dur}$; 10 mm]

where;

$C_{min,b}$ = 20 mm, assuming 20 mm diameter reinforcement; and $C_{min,dur}$ = 10 mm

ΔC_{dev} = 10 mm

For Fire resistence:

For 1 hours fire resistance, a_{min} = 35 mm, so is not critical.

ΔC_{nom} = 20 + 10 = 30 mm

5.4.7.3 Analysis

Consider grid line.
Effective spans:

8 – 2(0.45/2) = 7.55 m

For two spans, using increased coefficients for central support moments and shear.

Design moments in bay:

M_{Ed} = 297.89 kNm

At Support:

M_{Ed} = 1191.56 kNm

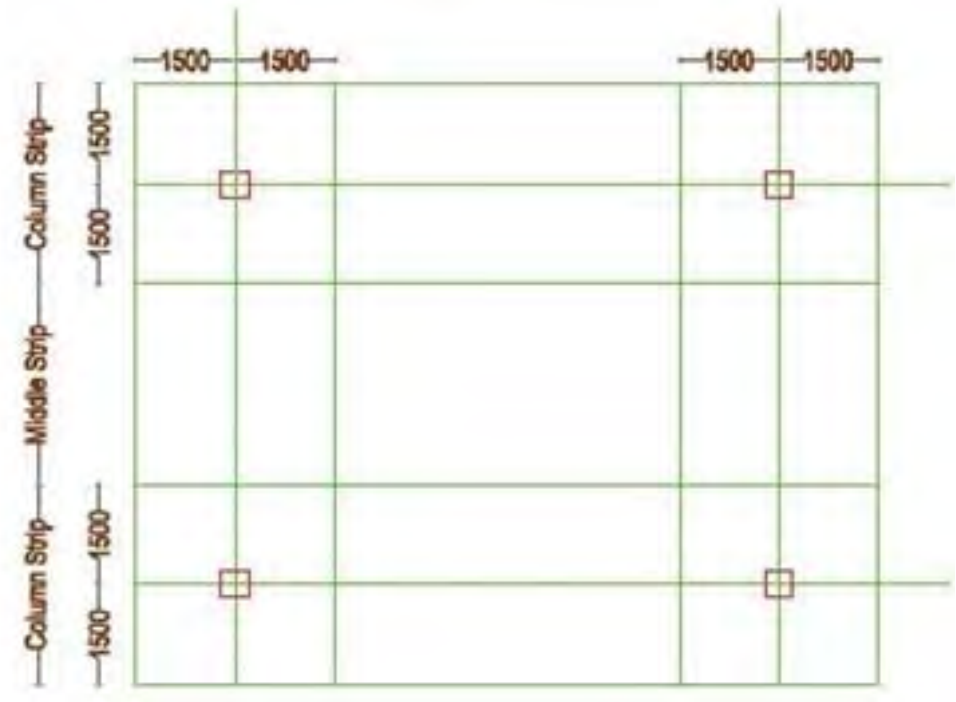


Figure 5-17 Column and middle strips allocation

From specifications:[36]

Apportionment of moments between column and middle strips

	Column strip portion (%)	Middle strip portion (%)
-ve (hogging)	Long span = 70% Short span = 30%	Long span = 30% Short span = 25%
+ve (sagging)	50%	50%

The column and middle strips are 3 m each.

Long span moments:

M_{Ed}	Column strip	Middle strip
-ve (hogging)	0.7 (1191.56)/3 = 278.03 kNm/m	0.3 (1191.56)/3 = 119.16 kNm/m
+ve (sagging)	0.5 (297.89)/3 = 49.65 kNm/m	0.5 (297.89)/3 = 49.65 kNm/m

Table 20 Long span moments

5.4.7.4 Punching Shear: [37]

$V_{Rd,c} = C_{Rd,}\, k\, (100\rho_1 f_{ck})^{1/3} + 0.10\, \rho_{cp} \geq (V_{min} + 0.10\, \rho_{cp})$

Where,

f_{ck} is in MPa

$k = 1+ \sqrt{200/d} \leq 2.0$ d in mm

$\rho_1 = \sqrt{\rho_{1y.}\, \rho_{1z}} \leq 0.02$

For column at grid line M-16, f_{ck} = 35 Mpa

$k = 1.84 < 2.0$ Ok!

$\rho_1 = 0.02$

$C_{Rdc} = 0.18/\gamma_c$

$V_{min} = 0.035\, k^{3/2}\, f_{ck}^{\ 1/2}$

$V_{Rd,c}$ = **3817.9 kN** ; and

V_{Ed} = 223.15 x 8 = **1785.2 kN**

Since $\boldsymbol{V_{Ed} < V_{Rd,c}}$, therefore we conclude that shear reinforcement is not required.

5.4.7.5 Designing the elements:

At Gridline B

Effective depth = 280 - 10 – 20/2 = 260mm

5.4.7.5.1 Flexure: column and middle strip, sagging

The design moment is M_{Ed} = 49.65 kNm/m

z/d = 0.94

z = 244.4 mm

$A_s = M_{Ed}/ f_{yd}z$ = 467.01 mm2/m

5.4.7.5.2 Deflection: column and middle strip

Checking span (l) to effective depth (d) ratio:

Allowable l / d = N x K x F_1 x F_2 x F_3

Where,

N = 23.68 (ρ = 0.51%, f_{ck} = 35 MPa)

K = 1.2 (for flat slab)

F_1 = 1.0 (b_{eff} / bw)

F_2 = 1 (because there are no brittle partitions)

$F_3 = 310/\sigma_s \leq 1.5$

Therefore, l / d = 31.82

Actual l / d is calculated as

l / d_a = 8000 / 260 = 30.77

l / d_a < l / d Satisfied!

5.4.7.5.3 Flexure : column strip, hogging

M_{Ed} = 278.03 kNm/m z/d = 0.89

z = 231.4 mm

$A_s = M_{Ed}/ f_{yd}z$ = 2762.1 mm^2/m

5.4.7.5.4 Flexure : middle strip, hogging

M_{Ed} = 119.16 kNm/m

z/d = 0.95

z = 247 mm

$A_s = M_{Ed}/ f_{yd}z$ = 1109.03 mm^2/m

5.4.7.6 Requirements

5.4.7.6.1 In column strip, inside middle 1500mm

There is a requirement to place 50 % of A_t within a width equal to 0.125 times the panel width on either side of the column.

Area required = (3 x 2762.1) + (3 x 1109.03) / 2 = 11613.39mm2

Over width = 2 x 0.125 x 6 = 1500mm

i.e., required 11613.39/1.5 = 7742.26mm2/m for 750mm on either side the column centerline.

5.4.7.6.2 In column strip, outside middle 1500mm

Area required = (3 x 2762.1) - (16 x 314) = 3262.3 mm2

Over width = 3000 – 2 x 750 = 1500 mm

5.4.7.6.3 Minimum area of reinforcement check

$A_{s,min} = 0.26 (f_{ctm}/f_{yk}) b_t d \geq 0.0013 b_t d$

$0.26 \times 3.2/500 b_t d \geq 0.0013 b_t d$

$0.00166 b_t d \geq 0.0013 b_t d$ OK!

5.4.7.6.4 Deflection check

Span / 250 = 8 / 250 = 0.032 m

Max deflection = 0.00761 m

0.00761 m < 0.032 m satisfied!

5.5 Software Analysis [39]

Pursuing the handmade design process for structural elements, an estimate of the sizes and amount of reinforcement for the elements was obtained. Using the range and size of the cross sections for the elements and the corresponding loads upon them, the results were added as input to the software for computer based analysis. These achievements are beneficial in several ways like verifying the sections from software.

The software ETABS was used for modeling the complex buildings and all its analysis and design. The Eurocode 2 -1992-2004 was chosen as the criteria in the software. In line with the requirement of the structure to split into two separate units, it was necessary to make two separate models in ETABS for this purpose. The software's calculations are based on the force method. The gap provided between the buildings is usually taken as 2 percent of the height of the buildings. For the height of 15 meters in this project a gap of 30 centimeters is provided between two parts of the buildings.

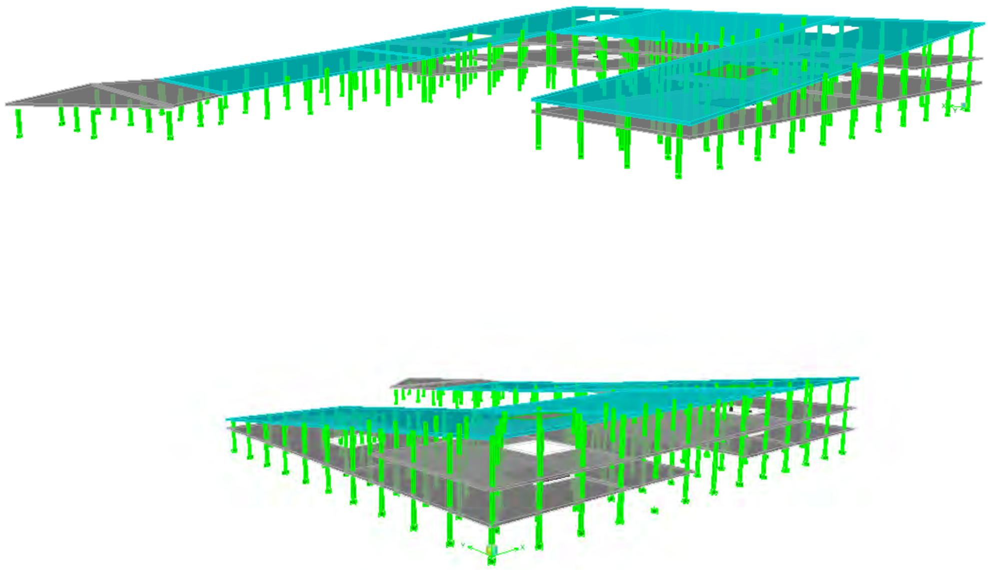


Figure 5-18 the structure model in ETABS

5.5.1 Column design:

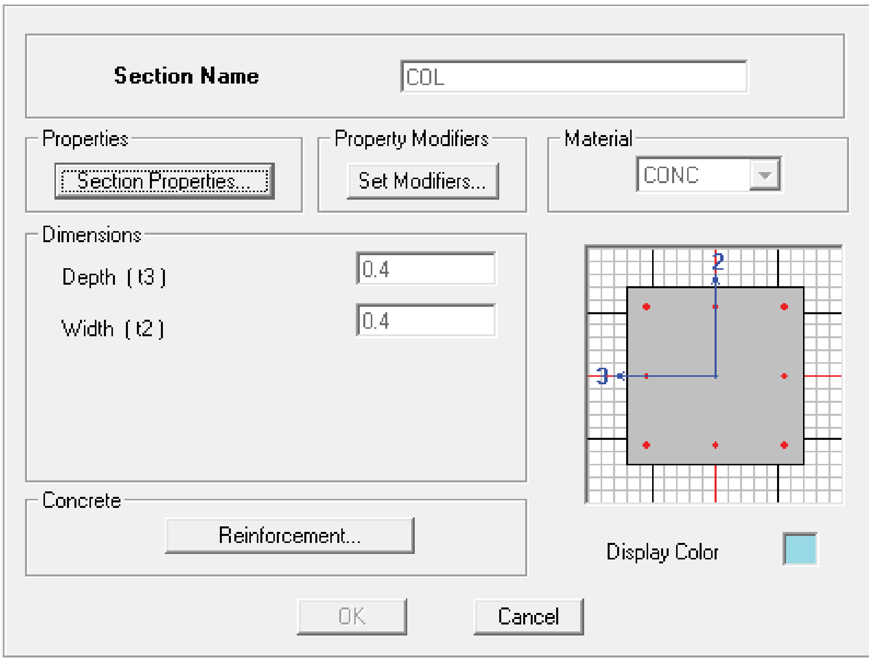


Figure 5-19 Column M-16 Dimensions

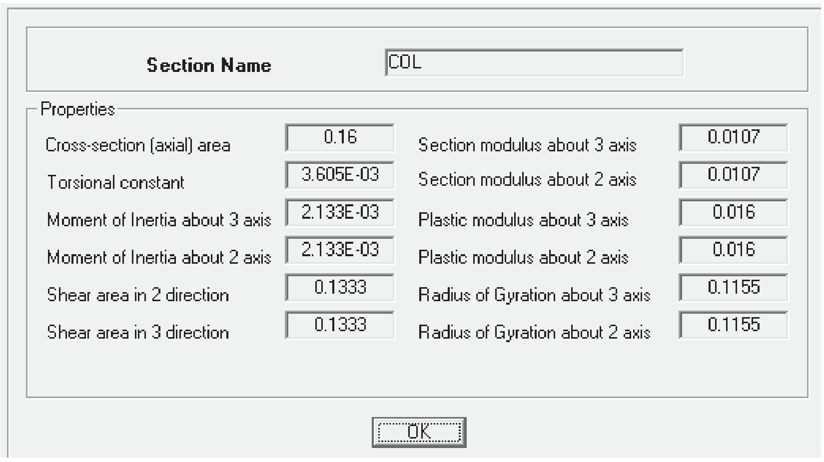


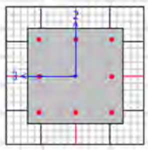
Figure 5-20 Column M-16 Properties

Following are the design values of column M-16 which, derived from the software analysis by assigning the dimensions which has been calculated by hand. It shows the designed section was sufficient for the chosen column but in the othe cases were not acceptable and we have to increase the section dimensions to 500X500 mm and use of 8 φ 20 in order to fullfil the requirements for all columns. This can be do to Torsion which applies by dynamic loads on building, which were not considered for pre dimensioning design.

ETABS Concrete Design

Engineer____________________
Project____________________
Subject____________________

```
Eurocode 2-2004 - CEN Default  COLUMN SECTION DESIGN  Type: Sway Frame  Units: N-m

Level        : STORY1
Element      : C44
Station Loc  : 0.000
Section ID   : C45X45-8F16
Combo ID     : DCON2
Combo Eq     : Eq. 6.10
2nd Order Method: Nominal Stiffness

Material Partial Factors
GammaC=1.5           GammaS=1.15
AlphaCC=1            AlphaCT=1
AlphaLCC=0.85        AlphaLCT=0.85

L=4.400
B=0.450         D=0.450         dc=0.050
fck=23535960.4  fyk=392266008.  fywk=235359604
E=2.452E+10
RLLF=0.400

AXIAL FORCE & BIAXIAL MOMENT CHECK FOR NEd, MEd2, MEd3
            Capacity      Design      Design      Design     Minimum     Minimum
               Ratio         NEd        MEd2        MEd3          M2          M3
               0.742 2407914.867   14483.371   61907.685   48158.297   48158.297

AXIAL FORCE & BIAXIAL MOMENT FACTORS
                             M0e        Madd     Minimum        Beta           L
                          Moment      Moment         Ecc      Factor      Length
   Major Bending(M3)   48158.297   13749.388       0.020       1.000       4.400
   Minor Bending(M2)    9287.116    2651.509       0.020       1.000       4.400

SHEAR DESIGN FOR V2,V3
                          Design       Shear       Shear       Shear
                           Rebar         VEd        VRdc        VRds
   Major Shear(V2)         0.000    1390.553  165506.187       0.000
   Minor Shear(V3)         0.000    2234.032  165506.187       0.000
```



ETABS v9.1.7 - File:daneshgah conc1 - N-m Units ÂæÑíá 1,2014 22:49

Figure 5-21 Design values for column M-16 Ground floor

5.5.2 Design Verification:

Compression resistance:

$N_{Ed} < N_{Rd}$, where $N_{Rd} = A_c\, f_{cd} + A_s\, f_{yd}$

2407 kN < 7442 kN satisfied!

Transverse reinforcement:

$V_{Rd,c} = [0.035 k^{3/2} (f_{ck})^{1/2} + 0.15\sigma_{cp}]\, bd > V_{Ed}$

165 kN > 1.39 kN satisfied!

5.5.3 Slab Design Verification:

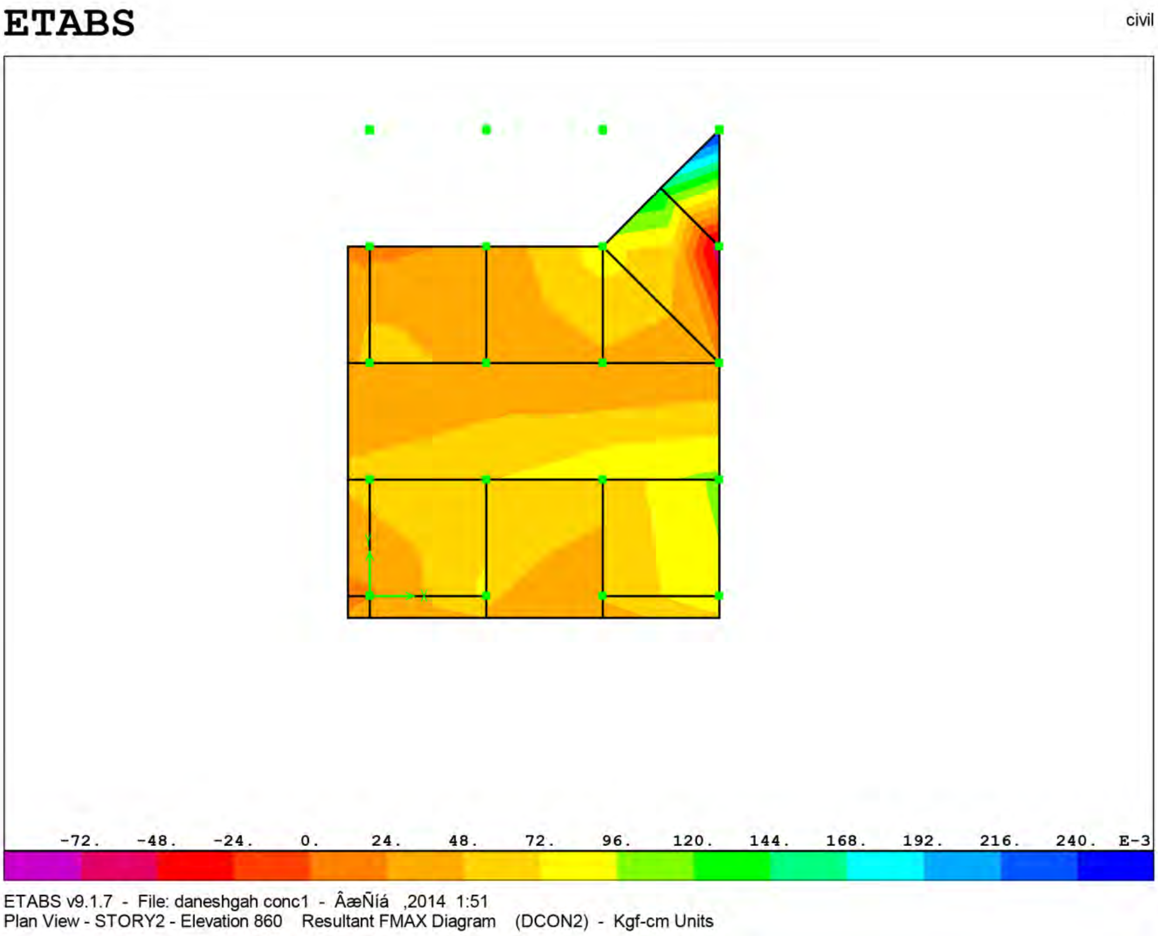


Figure 5-22 Slab Reactions – First floor (North wing)

The above diagram reflects how the forces produced due to moment reaction are distributed over the slab area. It can be witnessed that the forces are greater in magnitude at and near the column supports (yellowish colour in Figure 5-22).

5.5.3.1 Deflection check:

Span / 250 = 8 / 250 = 0.032 m

Deflection from software = 0.0080 m

0.00080 m < 0.0514 m satisfied!

REFERENCES

[1] www.areeweb.polito.it/eventi/turintogreen/

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