CHAPTER V

Technological Design

1. Methodology and scope definition

As had been highlighted earlier, Earth sheltering as a construction technique is dealing with unusual constrains, undesired effects and impacts which are completely different than the ones related to the traditional above ground structures. Part from those constrains are related to physiological, lighting and ventilation aspects which had been solved previously in the architectural chapter. The other part is related to its severe technical aspects, with respect to the soil loads, humidity proofing, raise damp, toxic gases penetration, air and water tightness, non-biodegradability, etc,.

Consequently, this chapter will comprise introduction to tested solutions for relevant technical problems. Also, clarifying the translation process of the previously proposed architectural and environmental strategies into relevant in-detail building schemes, which solve the main subterranean construction, critical issues and satisfy the LEED rating criteria. Aiming to minimize the construction impact on the environment, additional attention will be paid to some terms related to the energy demand, materials/resources efficient use and the indoor environment quality.

Taking into account that the project economical feasibility is considered as one of the main aims, so the challenge was how to optimize the performance using non-ultrahigh-tech materials, and referring to the known commercial suppliers with the avoidance of the customized non-commercial products’ usage.

In the light of the above, there will be a testing process for the building components, which will guide the solutions comparing and selecting phase, and will guarantee the adequacy of the selected techniques in terms of thermal performance, acoustical behavior, lighting comfort and durability, in relation to Valmadrera climatic analysis and inner spaces requirements.

To ensure the functionality and adequate performance of the proposed integrated building services from energy and environment point of view, Simulation and calculation results will be presented for the expected energy demand, solar radiation and day light analysis, and passive cooling/heating influence. Resultantly, a comparison with the results of the traditional construction techniques and ordinary heating/cooling systems will be made.

2. Climatic analysis

Climate is the pattern of variation temperature, humidity, pressure, wind, precipitation, atmospheric particle count and other meteorological variables in a given region over long periods. The climate of a location is affected by its latitude, terrain, and altitude, as well as nearby water bodies and their currents. Climates can be classified according to the average and the typical ranges of different variables, most commonly temperature and precipitation.

Climate change is the variation in global or regional climates over time. It reflects changes in the variability or average state of the atmosphere over time scales ranging from decades to millions of years. These changes can be caused by processes internal to the Earth, external forces (e.g. variations in sunlight intensity) or, more recently, human activities. The recent terminology of global warming also somewhat represents the same idea.

The expansion patterns of cities in terms of residential areas with a consequent loss of many green areas, natural habitats and so called inevitable usage of vehicular traffic, the comfort providing instruments and systems are playing an important role in defining the climate of urban areas, especially big cities like Milan which is only 50km from the project site in Valmadrera. The aforementioned changes are bringing drastic warm changes in the climate of a city and thus contributing in global warming effect.

In the following, we analysed the climate of Valmadrera, and put to use while designing of the building and finding solutions in an effort to achieve ideal comfort conditions for the users of the same.

2.1 Historical analysis:

The historical analysis of climate is one of the vital components in the survey for developing any project for energy efficiency and comfort conditions. In this regard the parameters like temperature, rain, wind, sunlight, etc define the boundaries which could be monitored to provide a comfort environment for the inhabitants.

The following graphs[68] very well explain how the climate of Valmadrera has been changing over the last two decades. The graphs are a mere representation of the climatic components like temperature, wind, snow, etc giving their mean and extreme values over a large time period for further analysis and better understanding of the climatic typology of the municipality of valmadrera.

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[68] http://weatherspark.com/#!graphs;ws=32257

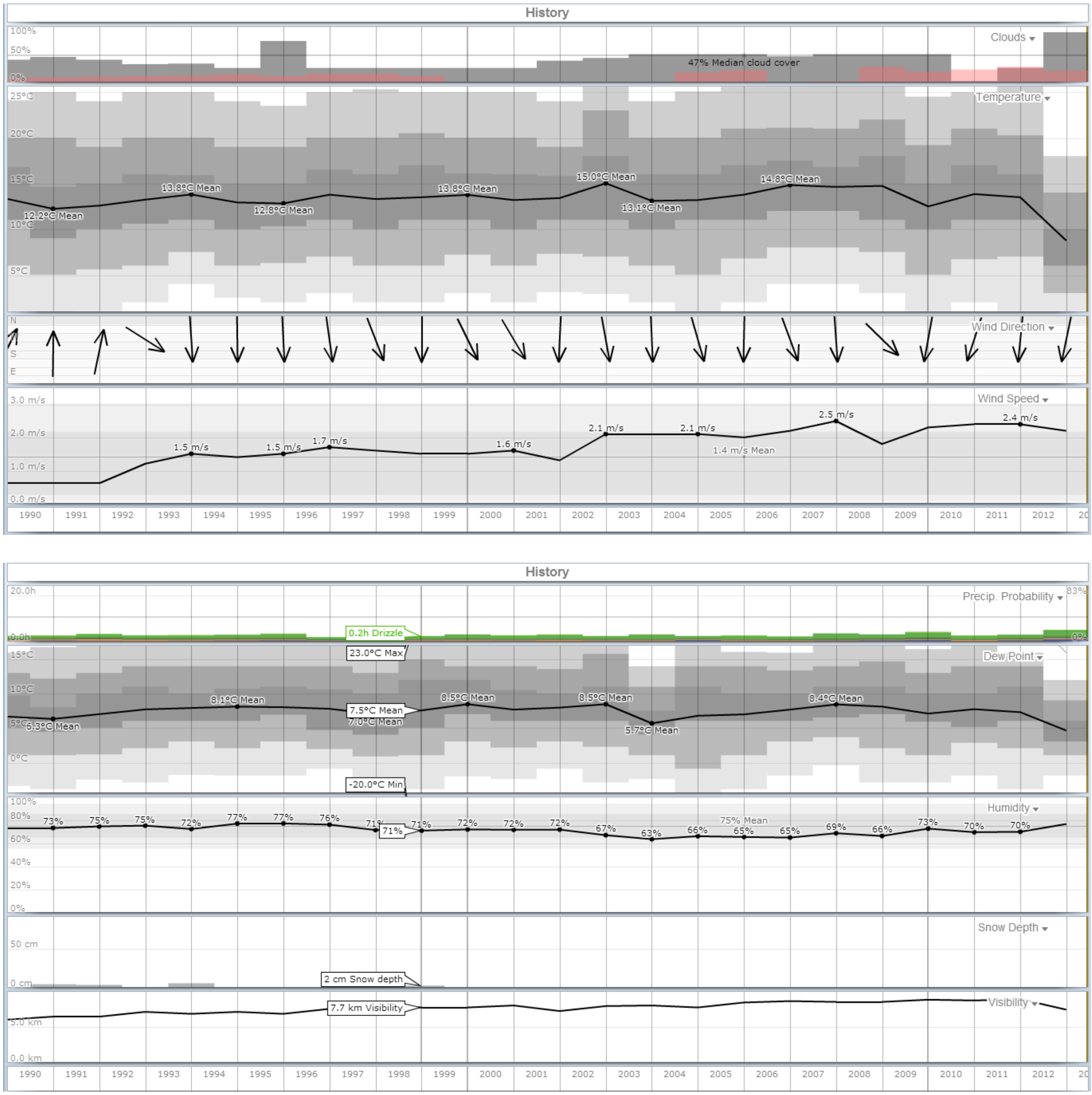

Figure 161 Historical Data Representation

The graphs gave an overview on the climate of the region and were helpful to decide which kind of technological solutions, to be implemented in the project. In the following, we will elaborate each of the aspects already mentioned above in detail to have a better understanding of the climate.

2.2 Temperature

In Valmadrera, over the course of a year, the temperature typically varies between -1°C and 29°C and is rarely below -5°C or above 32°C. The *warm season* lasts from ***June 3 to September 10*** with an average daily high temperature above ***24°C***. The hottest day of the year is July 29, with an average high of 29°C and low of 19°C. The *cold season* lasts from ***November 16 to March 2*** with an average daily high temperature below 11°C. The coldest day of the year is January 8, with an average low of ***-1°C*** and high of 6°C. The following figure is self explanatory.

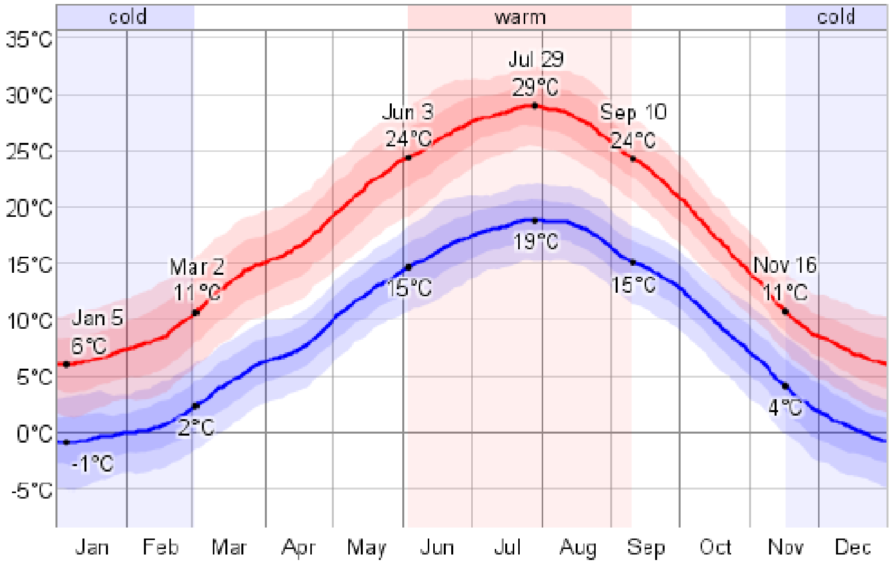

Figure 162 Daily high and low temperature

The daily average low (blue) and high (red) temperature with percentile bands (inner band from 25th to 75th percentile, outer band from 10th to 90th percentile).

Observation: The dominating season is the cold season which lasts for a major part of the year as is also obvious from the graph below, and this in turn implies that the focus of attention will be the cold season and heating would be critical in defining the inner comfort criteria.

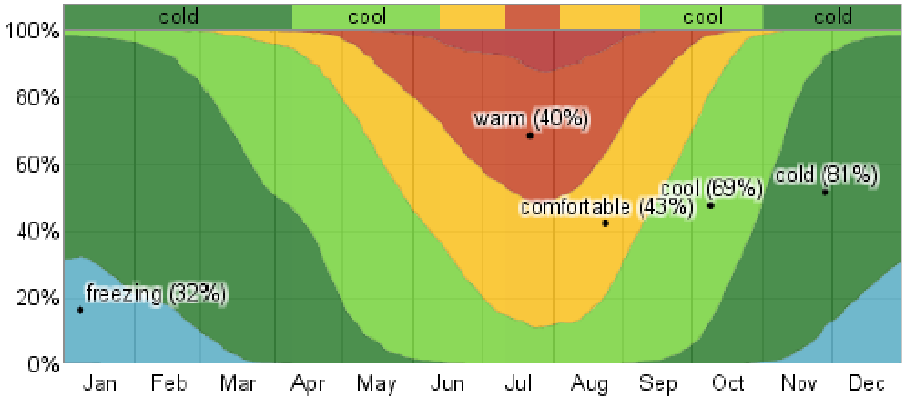

Figure 163 Fraction of time for temperature bands

The average fraction of time spent in various temperature bands: freezing (-9°C *to* 0°C*), cold (*0°C *to* 10°C*), cool (*10°C *to* 18°C*), comfortable (*18°C *to* 24°C*) and warm (*24°C *to* 29°C*).*

2.3 Sun exposure

The length of the day varies significantly over the course of the year. The shortest day is ***December 21*** with 8:40 hours of daylight; the longest day is ***June 20*** with 15:42 hours of daylight.

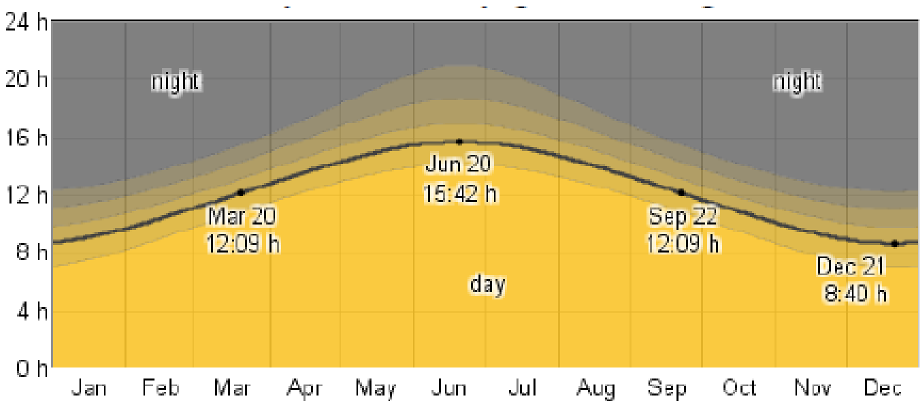

Figure 164 Daily hours of daylight and twilight

The number of hours during which the Sun is visible (black line), with various degrees of daylight, twilight, and night, indicated by the color bands. From bottom (most yellow) to top (most gray): full daylight, solar twilight (Sun is visible but less than 6° from the horizon), civil twilight (Sun is not visible but is less than 6° below the horizon), nautical twilight (Sun is between 6° and 12° below the horizon), astronomical twilight (Sun is between 12° and 18° below the horizon), and full night.

The *earliest sunrise* is at 5:31am on June 15 and the *latest sunset* is at 9:15pm on June 26. The *latest sunrise* is at 8:02am on January 3 and the *earliest sunset* is at 4:37pm on December 12. Daylight saving time (DST) is observed in this location during 2012, starting in the spring on March 25 and ending in the fall on October 28.

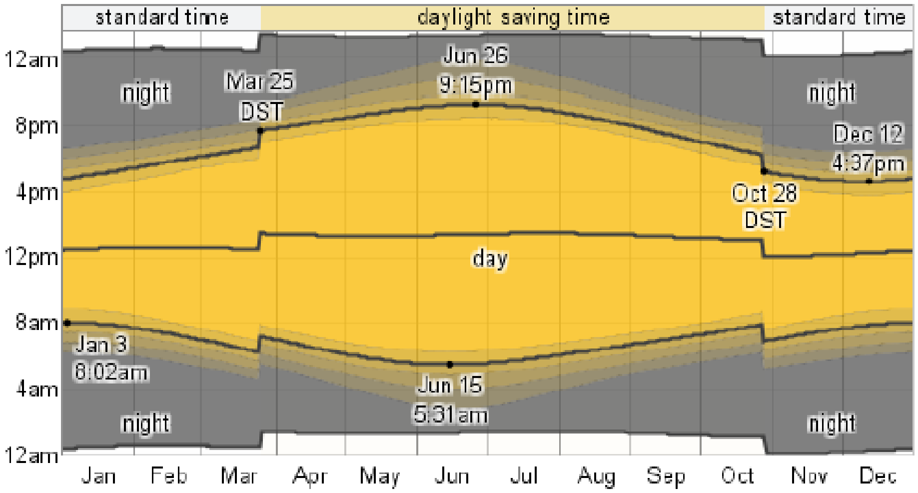

Figure 165 Daily sunrise and sunset with daylight saving time

The solar day over the course of the year 2012 . From bottom to top, the black lines are the previous solar midnight, sunrise, solar noon, sunset, and the next solar midnight. The day, twilights (solar, civil, nautical, and astronomical), and night are indicated by the color bands from yellow to gray. The transitions to and from daylight saving time are indicated by the "DST" labels.

Observation: from the data, although the best time for exposure to sun, i.e., generating energy from sunlight would be in June, but there is a great potential to have a large amount of sunlight between March 25 and October 28 as is obvious in the figure above.

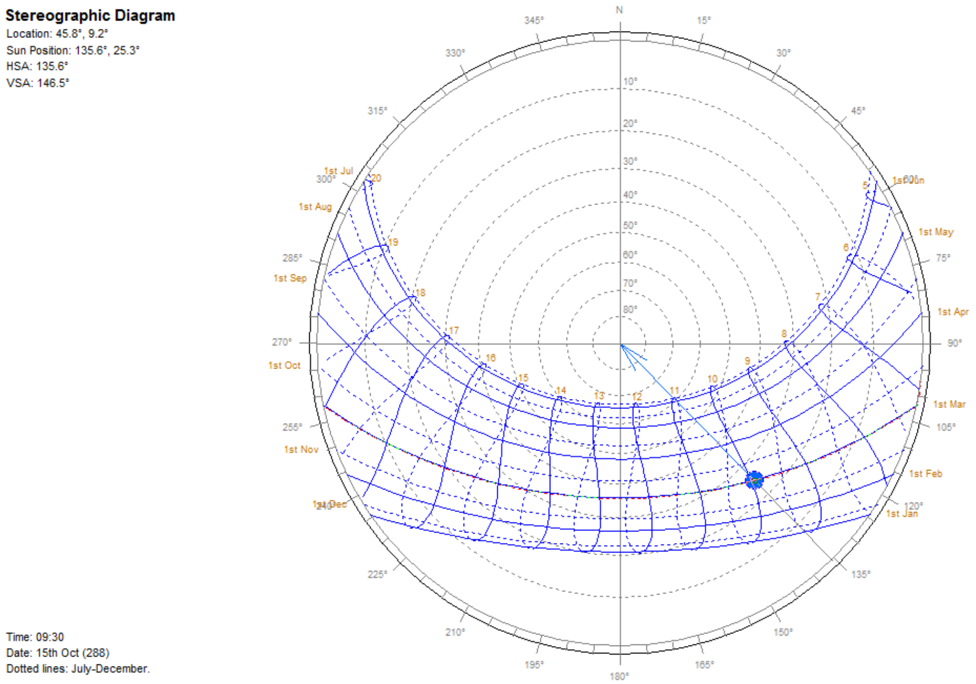

Figure 166 Annual sun path diagram from Ecotect for Valmadrera

2.4 Clouds

The median cloud cover ranges from 45% (partly cloudy) to 67% (partly cloudy). The sky is cloudiest on ***December 3*** and clearest on ***July 18***. The clearer part of the year begins around **February 14**. The cloudier part of the year begins around **October 7**.

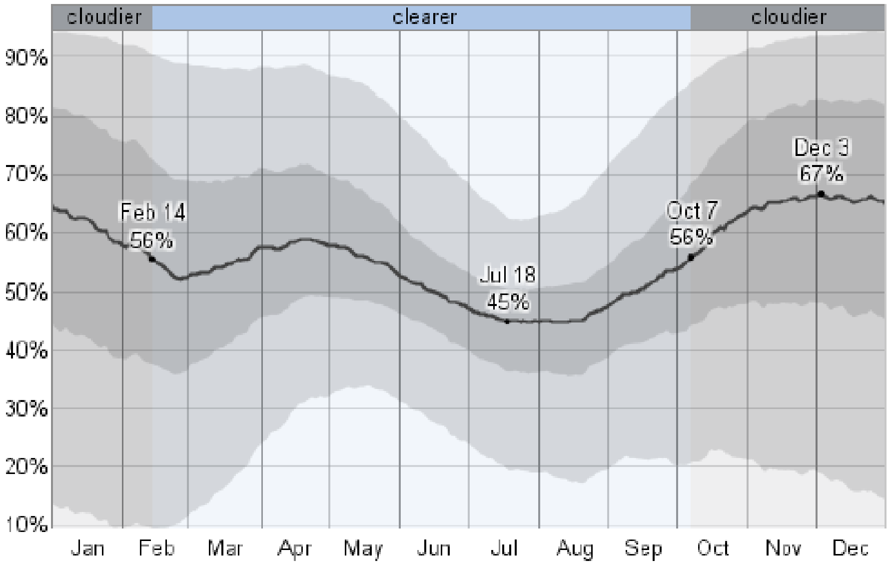

Figure 167 Median Cloud Cover

The median daily cloud cover (black line) with percentile bands (inner band from 40th to 60th percentile, outer band from 25th to 75th percentile).

On **July 18**, the *clearest day* of the year, the sky is *clear* **62%** of the time, and *overcast* 12% of the time. On **December 3**, the *cloudiest day* of the year, the sky is *overcast* **48%** of the time, and *clear* 26% of the time.

2.5 Precipitation rate

The probability that precipitation will be observed at Valmadrera varies throughout the year. Precipitation is most likely around **May 30**, occurring in **51%** of days. Precipitation is least likely around **January 26**, occurring in **32%** of days.

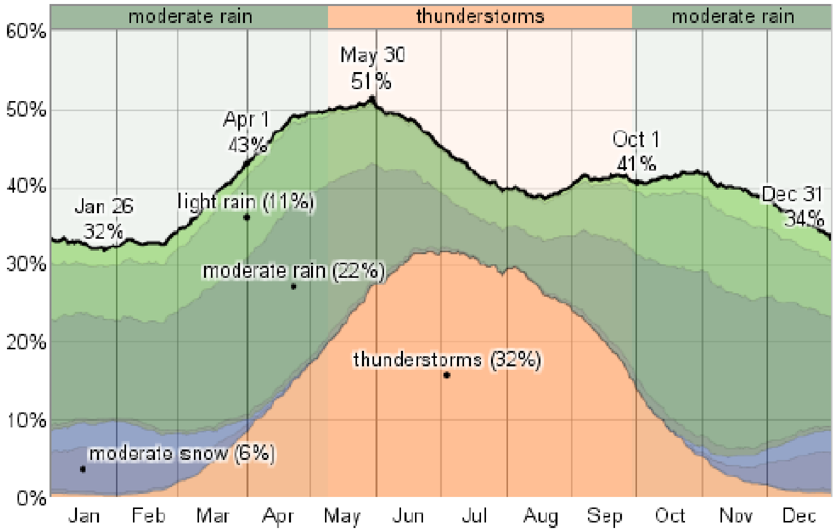

Figure 168 Probabiity of precipitation

Over the entire year, the most common forms of precipitation are moderate rain, thunderstorms, and light rain. *Moderate rain* is the most severe precipitation observed during 36% of those days with precipitation. It is most likely around April 23, when it is observed during 22% of all days. *Thunderstorms* are the most severe precipitation observed during 33% of those days with precipitation. They are most likely around July 4, when it is observed during 32% of all days. *Light rain* is the most severe precipitation observed during 19% of those days with precipitation. It is most likely around April 1, when it is observed during 11% of all days.

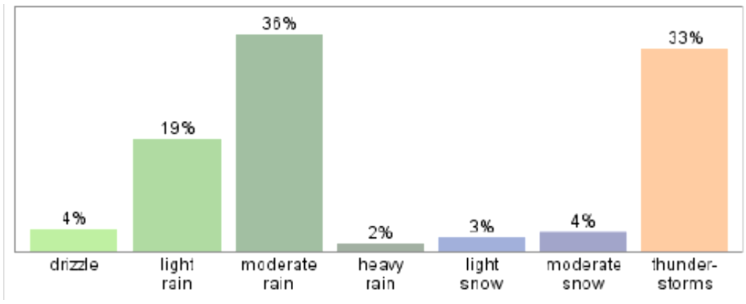

Figure 169 Types of precipitation
Relative frequency of various types of precipitation over the course of a typical year.

During the ***warm season***, which lasts from ***June 3 to September 10***, there is a ***43%*** average chance that precipitation will be observed at some point during a given day. When precipitation does occur it is most often in the form of thunderstorms (67% of days with precipitation have at worst thunderstorms), moderate rain (18%), and light rain (13%).

During the ***cold season***, which lasts from ***November 16 to March 2***, there is a ***35%*** average chance that precipitation will be observed at some point during a given day. When precipitation does occur it is most often in the form of moderate rain (44% of days with precipitation have at worst moderate rain), light rain (22%), moderate snow (12%), and drizzle (9%).

Observation: The dominant type of precipitation is thunderstorm in summer and moderate rain in winter covering 67% and 44% respectively of the total precipitation. This implies that there is a potential to collect rain water.

2.6 Relative Humidity:

The relative humidity typically ranges from 45% (comfortable) to 93% (very humid) over the course of the year, rarely dropping below 29% (dry). The air is ***driest*** around **June 28**, at which time the relative humidity drops below 51% (mildly humid) three days out of four; it is ***most humid*** around **October 29**, exceeding 90% (very humid) three days out of four.

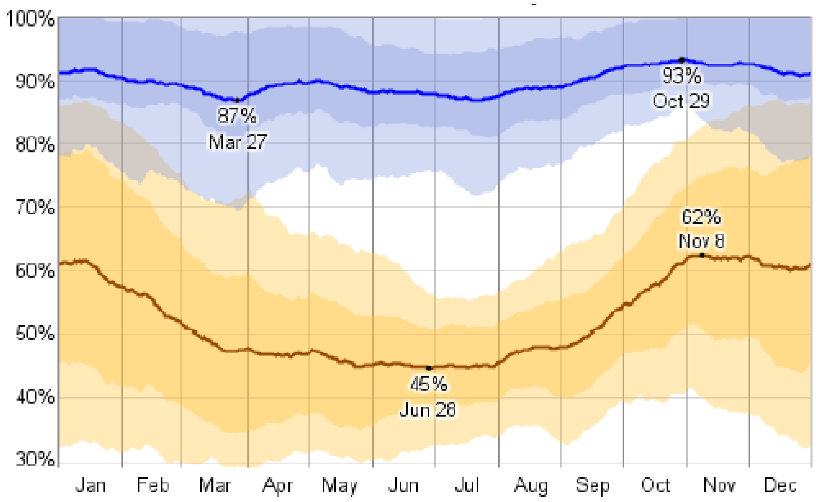

Figure 170 Relative humidity

The average daily high (blue) and low (brown) relative humidity with percentile bands (inner bands from 25th to 75th percentile, outer bands from 10th to 90th percentile).

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.

Over the course of a year, the dew point typically varies from -4°C (dry) to 19°C (muggy) and is rarely below -11°C (dry) or above 22°C (very muggy).

Observation: There are two periods in the year that are most comfortable: The first is between ***April 28 and July 19*** and the second is between ***August 19 and October 26***. The air feels neither too dry nor too muggy during these periods.

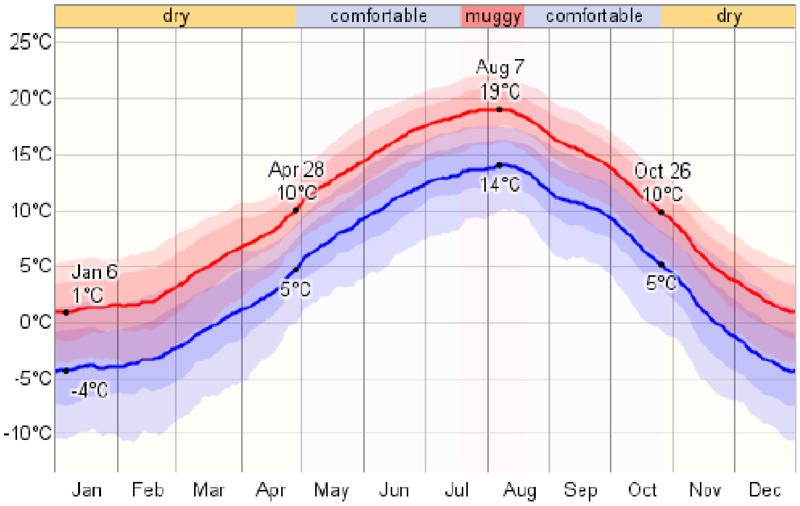

Figure 171 Dew point

2.7 Wind characteristics:

Over the course of the year typical wind speeds vary from 0 m/s to 4 m/s (calm to gentle breeze), rarely exceeding 7 m/s (moderate breeze). The *highest* average wind speed of 2 m/s (light breeze) occurs around **April 5**, at which time the average daily maximum wind speed is **4 m/s** (gentle breeze). The *lowest* average wind speed of 1 m/s (light air) occurs around **December 1**, at which time the average daily maximum wind speed is **3 m/s** (light breeze).

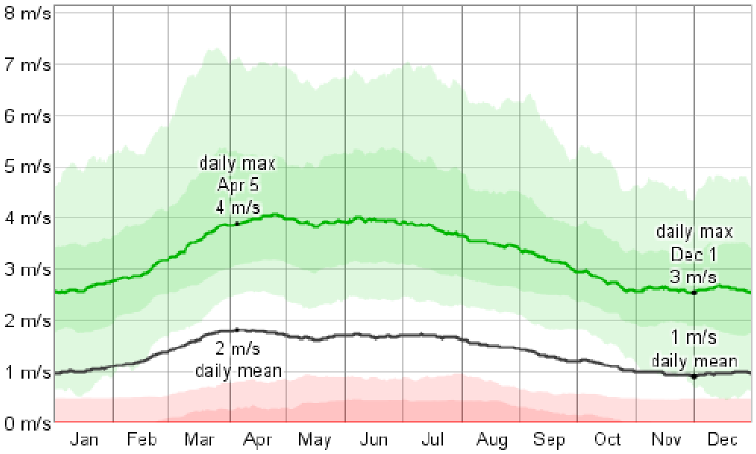

Figure 172 Wind speed

The wind is most often out of the *north* (14% of the time). The wind is least often out of the north west (3% of the time), east (4% of the time), and south east (5% of the time).

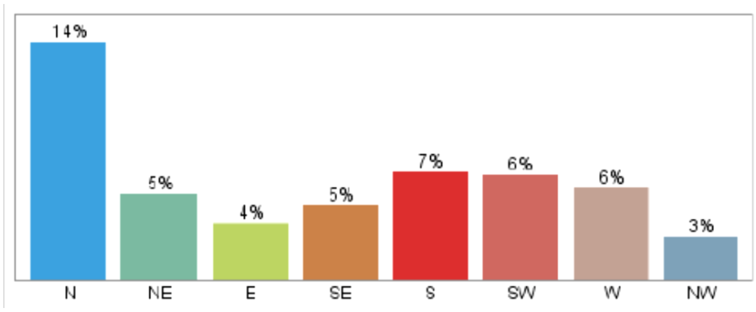

Figure 173 Wind direction over the year

The fraction of time spent with the wind blowing from the various directions over the entire year. Values do not sum to 100% because the wind direction is undefined when the wind speed is zero

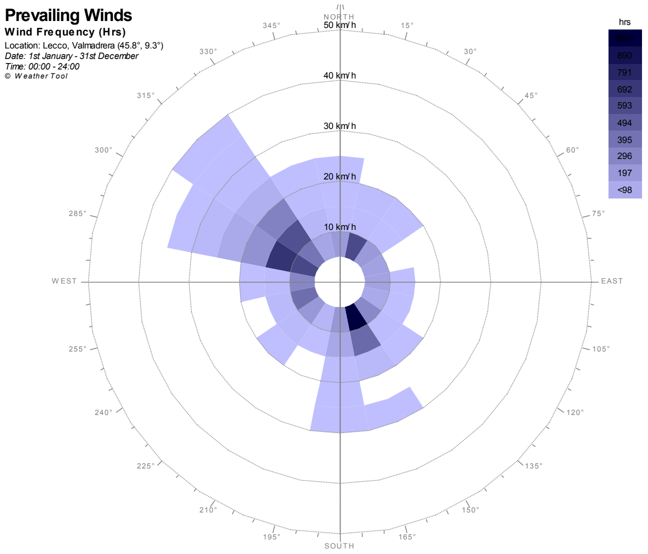

Figure 174 Prevailing wind graph from ECOTECT

Observation: since the major direction of wind is out of north, but the daily maximum is not more than 4 m/s, so it is not feasible to install a wind turbine for power production.

2.8 Solar Radiation Potential

Global irradiation and solar electricity potential

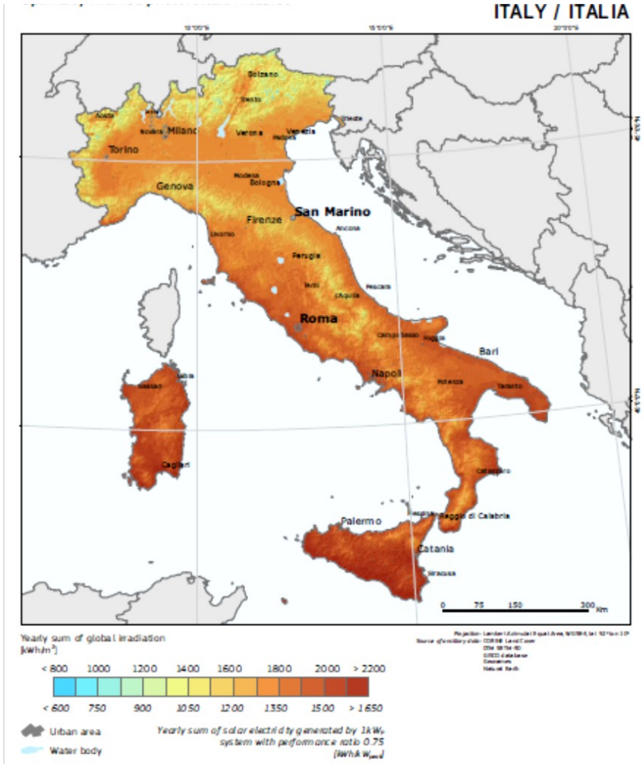

Figure 175 Graph of Italy for Optimally-inclined photovoltaic modules

2.8.1 Performance of PV

PVGIS estimates of solar electricity generation

Nominal power of the PV system: 1.0 kW (crystalline silicon)

Month	**H_{d0} (kWh/m^2.day)**	**E_{d0} (kWh)**	**H_{opt} (kWh/m2.day)**	**E_{dopt} (kWh)**
Jan	1.35	1.03	2.36	1.88
Feb	2.42	1.88	3.88	3.05
Mar	3.60	2.75	4.79	3.57
Apr	4.54	3.38	5.10	3.70
May	5.60	4.05	5.66	4.02
Jun	6.29	4.46	6.08	4.25
Jul	6.54	4.60	6.47	4.48
Aug	5.44	3.84	5.91	4.08
Sep	4.06	2.96	5.06	3.59
Oct	2.45	1.83	3.49	2.59
Nov	1.40	1.05	2.28	1.74
Dec	1.33	0.98	2.27	1.78
Average value	3.76	2.74	4.45	3.23

Table 14 Estimate of soalr PV panels potential

H_d: Average daily sum of global irradiation per square meter on horizontal plane received by the PV panels (kWh/m2)
H_{opt}: Average daily sum of global irradiation per square meter on optimally inclined plane received by the PV panels (kWh/m2)
H_{90}: Average daily sum of global irradiation per square meter on vertically inclined plane received by the PV panels (kWh/m2)
Ed: Average daily electricity production from the PV panels (kWh)

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 (4.45 kWh/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 (3.76 kWh/m2.day).

Potential parameters for PV electricity:

Month	I_{opt}	D/G	T_{24h}	NDD
Jan	65	0.53	1.8	478
Feb	59	0.43	3.9	376
Mar	47	0.42	8.2	250
Apr	32	0.44	11.8	113
May	20	0.45	17.2	19
Jun	14	0.43	21.1	5
Jul	17	0.37	22.9	1
Aug	28	0.38	22.3	8
Sep	42	0.42	17.9	56
Oct	53	0.49	13.4	223
Nov	61	0.54	7.0	403
Dec	65	0.63	2.9	495
Total for year	37	0.43	12.5	2427

Table 15 Parameters for PV electricity

Iopt: Optimal inclination (deg.)
D/G: Ratio of diffuse to global irradiation (-)
T24h: 24 hour average of temperature (°C)
NDD: Number of heating degree-days (-)

2.9 Comfort Zones

The comfort zone displayed in the chart has been derived from the energy software ECOTECT based on the parameters like occupancy activity level (assuming light), percentage glazing in equator facing façade (almost > 40% in our case), average insulation level of building fabric (high) and efficiency of solar collectors (considering average).

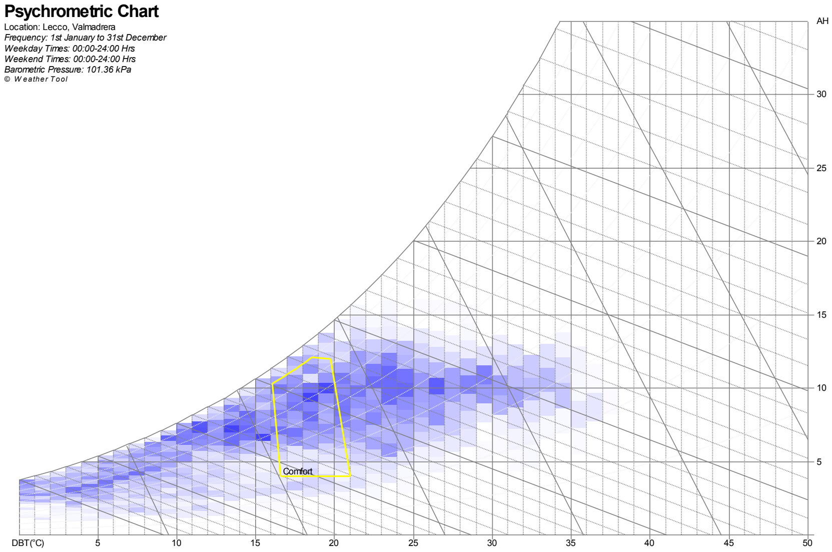

Figure 176 Comfort zone all year round frequency

The following represents the comfort zone without any strategy been implemented. The comfort zone is within the time zone representing the cyclic variations of climate. Initial comfort zone is defined by a light activity level with a 40% glazing and high insulation value of the building fabric.

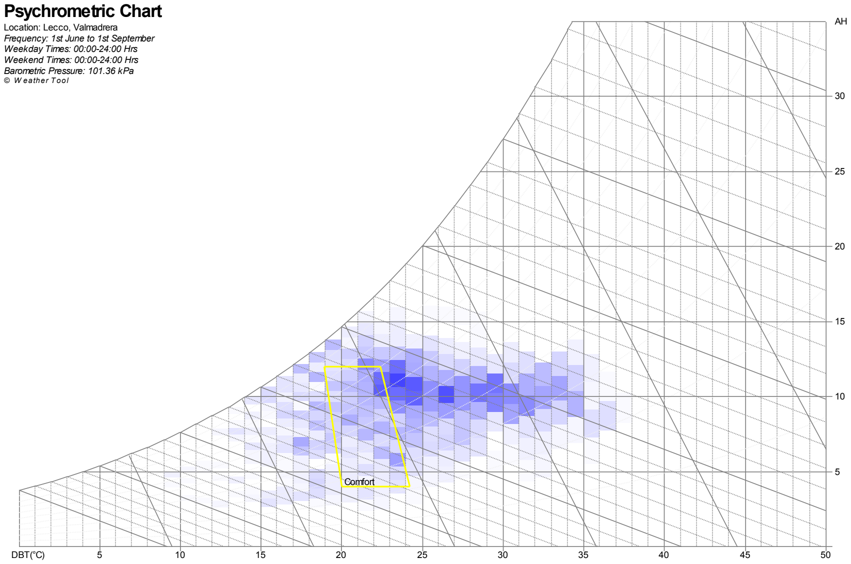

Figure 177 Summer comfort zone

The comfort zones representation for summer and winter seasons is represented in the following two diagrams. The summer comfort zone shows that the cumulative frequency of the temperature remains between 18 and 24 °C and the relative humidity also remains inside the comfort band with mostly 40 to 70 %. Thus, depicting the requirement of summer cooling with dehumidification of air.

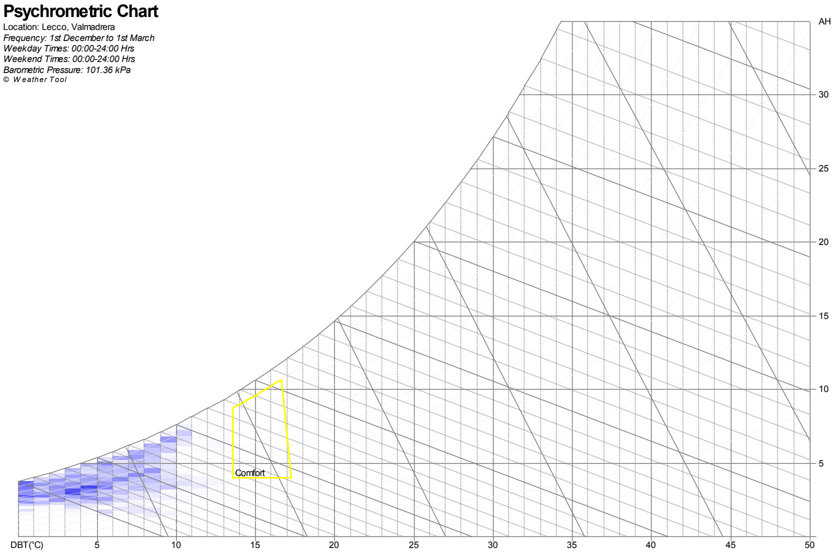

Figure 178 Winter comfort zone

For winter comfort zone the cumulative frequency for temperature falls below the comfort band and the relative humidity stays above the comfort level at around 80 to 90 %. Therefore, in winter there is a requirement of heating of air with dehumidification.

2.9.1 Passive Solar heating Technique:

Passive solar heating techniques can be used to heat the building in winter using the solar radiations. This can be made possible usually by letting the sunlight inside the building through the glazed portions of the façade which is facing the solar path direction i.e., South in our case. The following graphs give a comparison of the effect of percentage of glazing on the façade facing south. It is obvious that there is a greater chance to avail solar radiation if the percentage of glazing is more on the façade facing south.

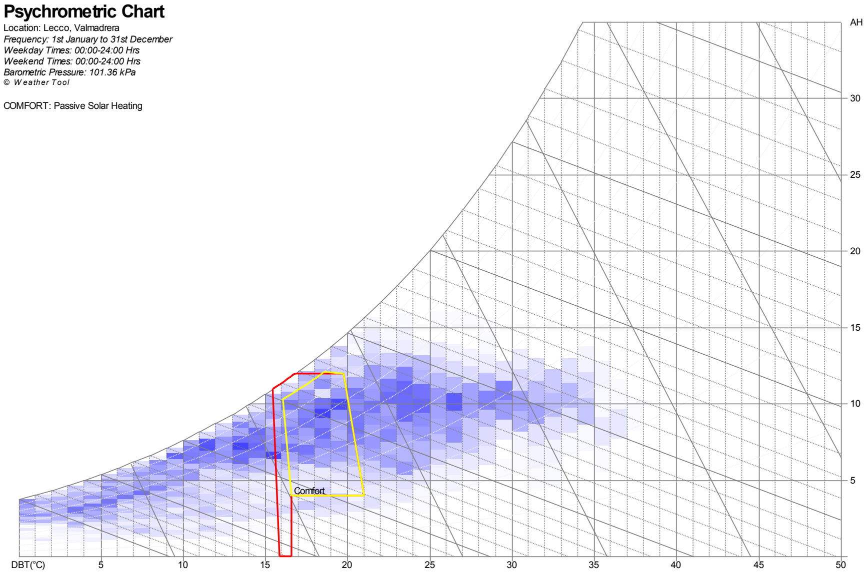

Figure 179 Passive solar heating potential area with 20% glazing

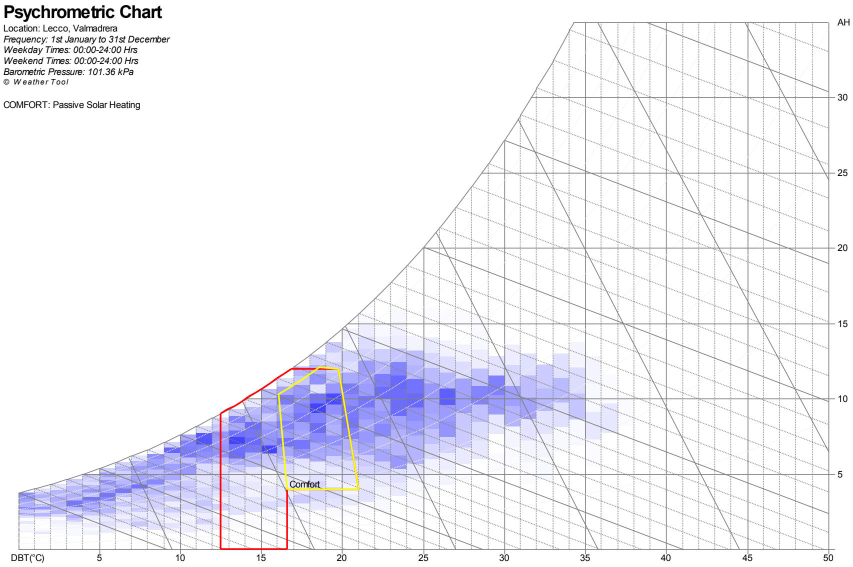

Figure 180 Passive solar heating potential area with 40% glazing

2.9.2 Thermal mass effect

Thermal mass zone is represented on the Psychrometric Chart to the right and left of the Comfort Zone. It defines conditions when using high thermal mass on the interior is a good cooling design strategy. Thus high daily outdoor temperature swings will not affect indoor temperature. This zone is defined by a Maximum Dry Bulb temperature difference above and below the Comfort temperature range.

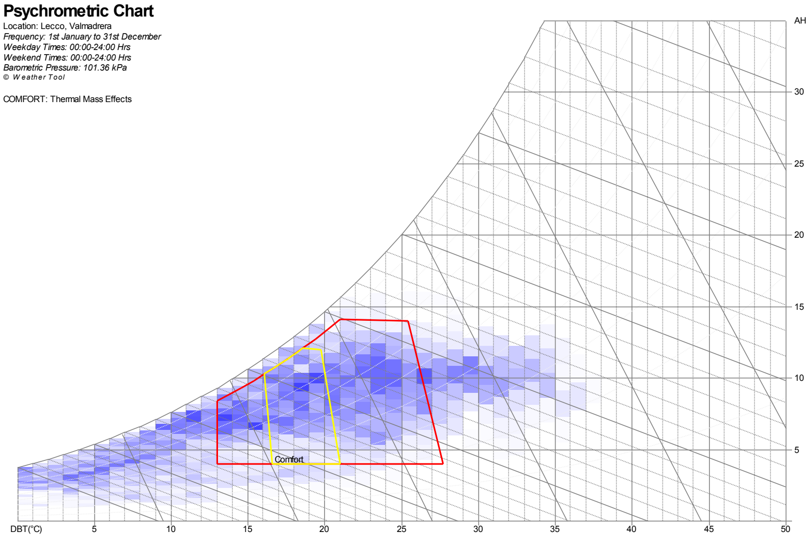

Figure 181 Thermal mass zone on psychrometric chart

2.9.3 Thermal mass with night flushing

This zone describes when the thermal mass is used in the building and night air is brought in either by natural ventilation or using a fan for cooling. For this reason the building is air tight in the day so that there is no heat infiltration. Again under this design the outdoor heat swing will not affect the indoor air conditions.

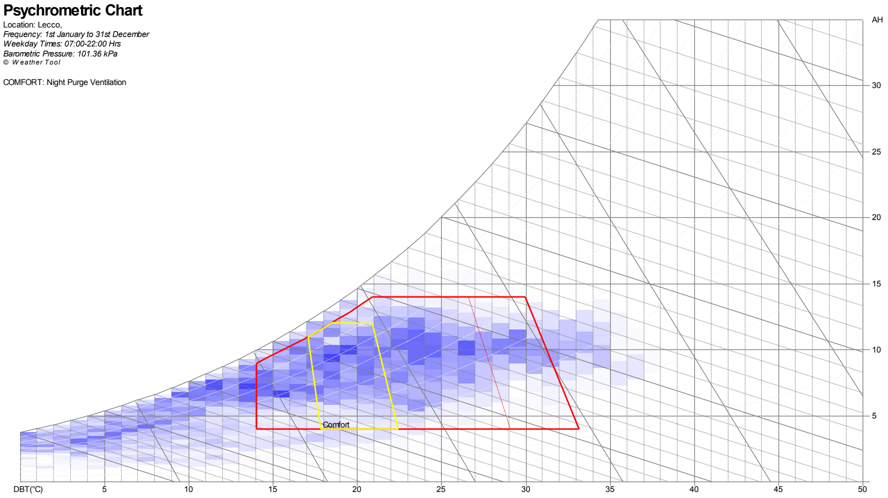

Figure 182 Thermal mass with noght flushing

2.9.4 Natural ventilation zone

This zone expands to the right and left of the comfort zone in the psychrometric chart. Natural ventilation is not only brings fresh air but have cooling effect on the human body. This also affects rate of sweat evaporation producing sensation of cooling. This design strategy can have favourable results especially in summer.

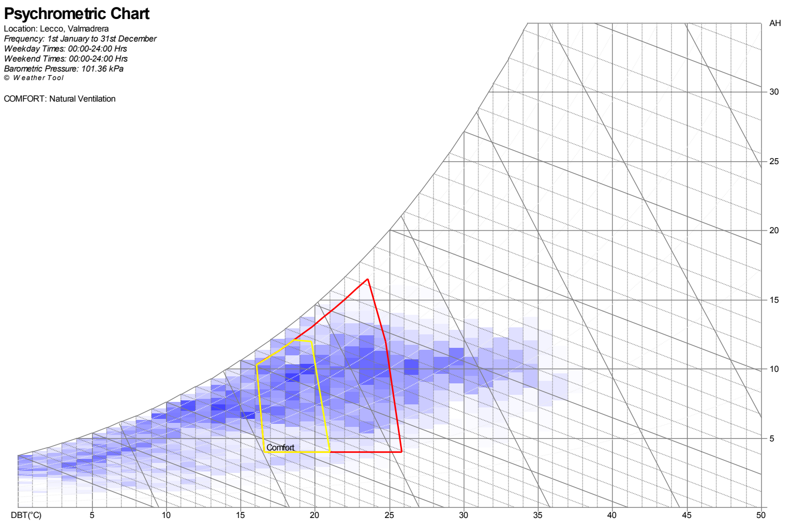

Figure 183 Natural ventilation zone

2.9.5 Direct evaporative cooling zone

This zone is expressed on the psychrometric chart towards right and downwards direction the comfort zone. Evaporative cooling takes place when water is changed from liquid water to gas, thus cooling the air but adding humidity. Evaporative cooling phenomenon is usually good cooling strategy for hot dry climates, but it can be utilized where applicable in achieving the comfort conditions.

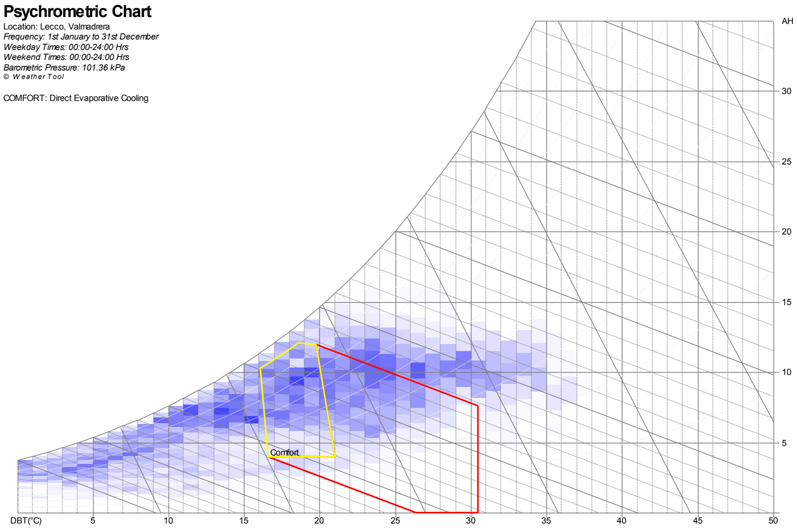

Figure 184 Direct evaporative cooling zone

2.9.6 Multiple Passive Design Techniques:

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 diagram, all the techniques are shown in combined manner.

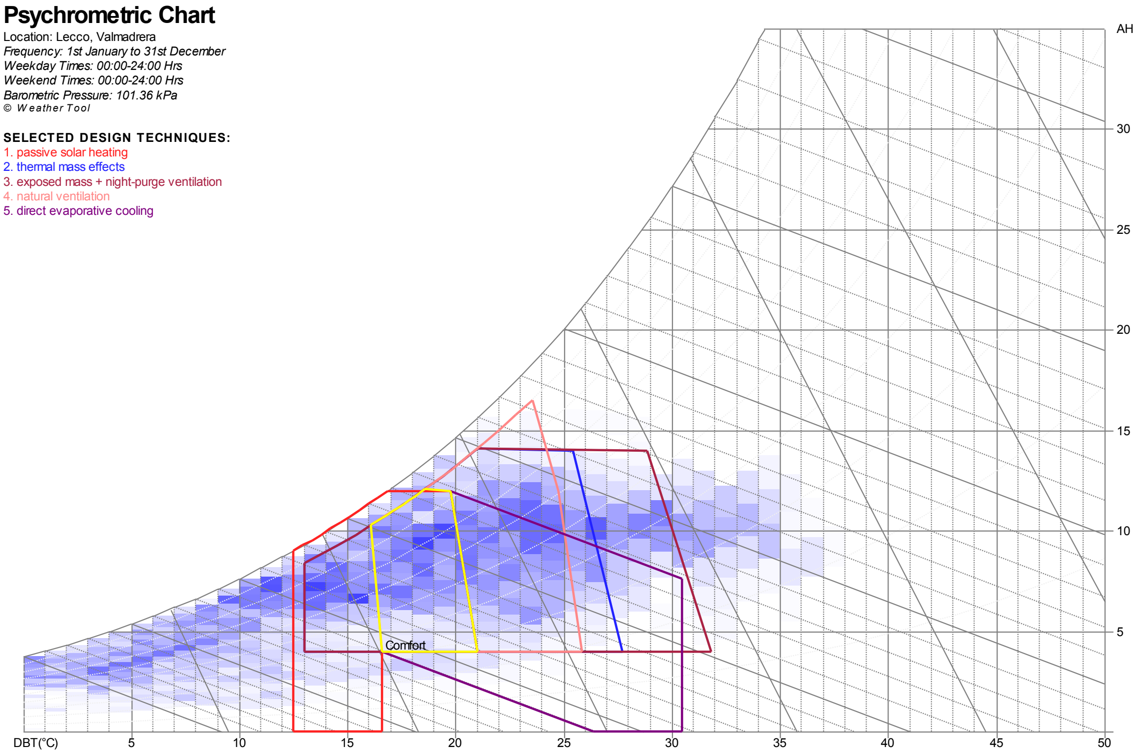

Figure 185 Multiple passive techniques

The above is also represented in graphical format in the Figure 186 below. We can clearly see in a graphical comparative analysis, the influence of all the possible passive design techniques before and after their implementation. The values are distinguished by red and yellow colour for before and afterwards values and effect. It is evident to use the advantages of these techniques to have passive design strategies fulfilled in the project.

There is a large potential to exploit the passive design techniques and have an enormous advantage in reaching the comfort level desired by the function of the building. The red bars are way higher than the yellow ones in Figure 186, thus representing the percentage difference before and after the implementation of the techniques.

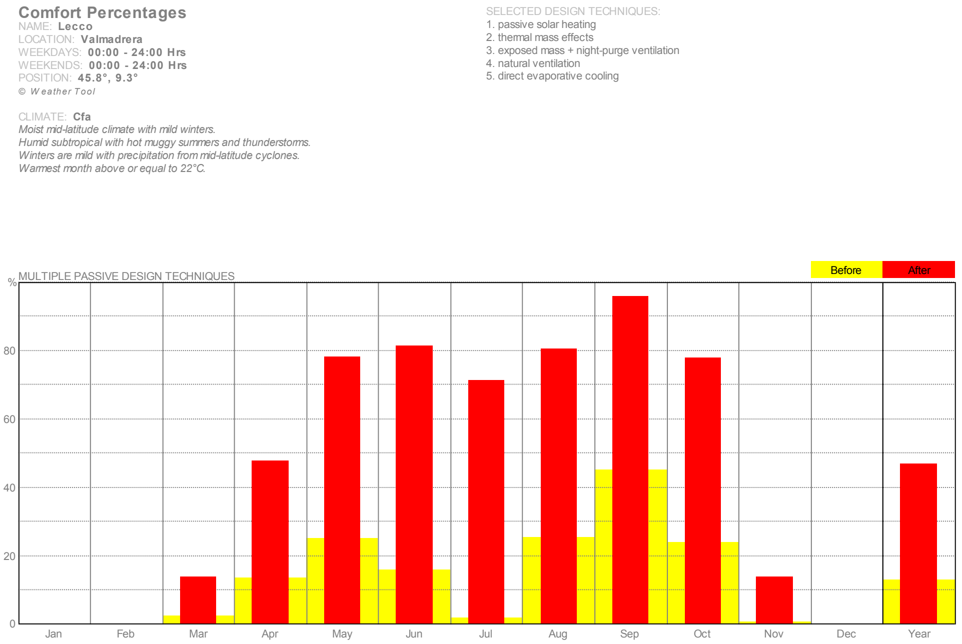

Figure 186 Effect of multiple passive techniques

The chart shows the diurnal average data for each hour of each month. The upper graph in the diagram shows the comfort temperature conditions for each month of the year in green colour. The red filled area represents the temperature variations in blue line border. The yellow line depicts the direct solar radiations and the corresponding energy incident. In the smaller graph, the daily conditions for the month of January are shown which may also be obtained for any desired month. This contains information about the relative humidity, temperature and solar radiations.

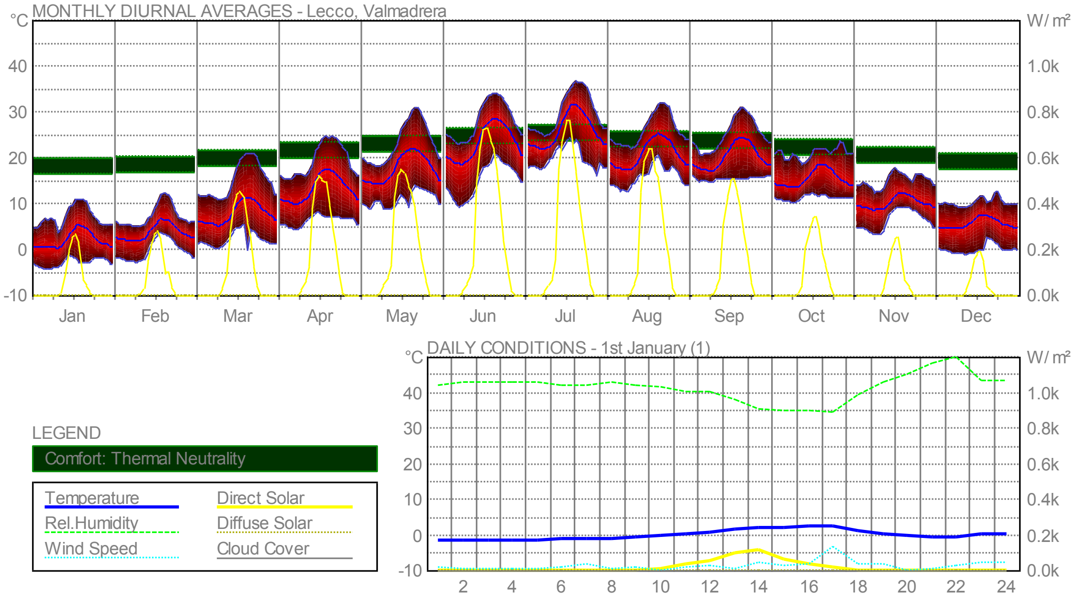

Figure 187 Monthly diurnal averages

3. SWOT

Some of the potentials of the site and the area as a whole are presented hereunder:

Strengths:

1. Potential to gain solar heat from a large façade facing south.
2. Solar heat to be used for interseasonal heat transfer technology (IHT)
3. Orientation suitable to install solar photovoltaic panels and produce energy
4. Precipitation to help in collecting rain water for various reuses.
5. Natural ventilation can be used to have passive cooling
6. The major portion of the building is buried underground, needing a relatively lesser amount of energy for comfort conditioning
7. Geothermal technique for heating/cooling coupling with heat pump

Opportunities

1.The use of Biomass from the forest area adding renewable source of energy in the project.

2. Promotion to construct small hydroelectric water systems applied to existing network of water supply.

3. Awareness for installation and usage of Photovoltaic panels for energy production

SWOT

Weaknesses

Currently natural gas is being used for domestic heating purposes in major areas of Lecco province

Average annual wind velocities (4m/s) is not enough to produce electricity from wind turbine technology

Ref: http://www.provincia.lecco.it/wp-content/uploads/2011/05/AI08E052-Sistema-Energetico-01.pdf pg 32

Threats

Urbanization leading to cutting of trees for building residential complexes etc.

Electricity production is the biggest contributor to CO_2 emission which harms the air quality

Figure 188 SWOT

4. Spaces and users' comfort

The following parameters are taken as likely standards to be followed and maintained for proper functioning of the spaces we have designed in our project:

- ASHRAE REFERENCES 1989 ASHRAE Handbook Applications Fundamentals specifies relative humidity significantly for swimming pools as 50-60% to fulfill the requirements of acceptable indoor climate with a general temperature range starting from 26°C upto 34°C for indoor/outdoor pools.
- Another important parameter for acceptable indoor climate is air change rate (ach), which should be 4-8 ach according to the 1989 ASHRAE Handbook Applications, also depending on the functions required.
- ASHRAE standard 55-2004 "Thermal environmental conditions for human occupancy" specifies parameters for acceptable thermal environment for all occupants. Guidelines about air speed require air speed may not be higher than 0.8 m/s.
- Alpine Sauna with a temperature of 90°C and humidity 10%, and residence time of about 10-15 minutes.
- Herbal sauna for a temperature of about 50-60°C and humidity of about 30-35%.
- Roman bath 10-15 minutes at a temperature range of 39°C to 46°C.
- KNEIPP hydrotherapy walk for cure hydrotherapy, alternating water at 38°C the reaction of 15°C, up to 66 cm immersed in salt water.

5. Energy efficient integrated technologies

In view of the previously shown Site potentials and constrains, presented in the climatic analysis, natural resources investigation and the project services requirements, the adoption of environmental passive strategies and eco-services technologies was the key solution to provide the minimum impact of the built environment, in order to reach a zero footprint construction.

Hereafter, we will present the used tools and techniques to minimize the demand, supply the renewable recourses and maximize the efficiency of the used building systems, of course with respect to the earlier mentioned passive strategies in the architectural chapter. The general categorization of topics will be following the main topics and keywords of the LEED rating system.

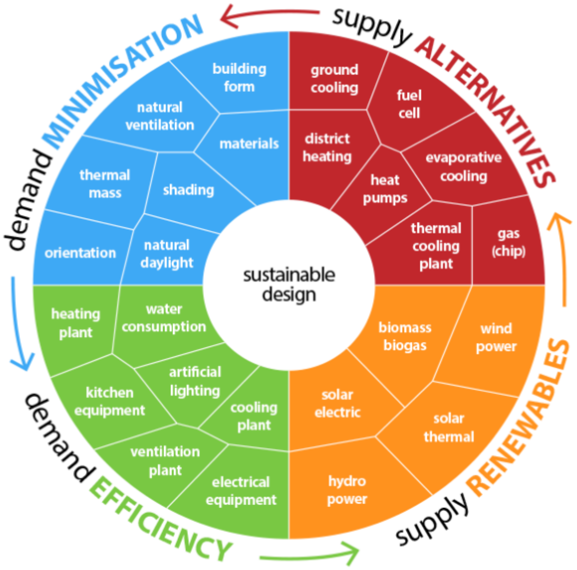

Figure 189 Sustainable Design process, Extracted from (www.mcarchitects.it)

5.1 Heating and cooling

5.1.1 Inter seasonal heat transfer and thermal bank technology

Interseasonal Heat Transfer (IHT) provides sustainable energy using a new form of onsite renewable energy that channels naturally occurring heat from the sun down to the ground in summer and back to buildings in winter to heat buildings without burning fossil fuels. Interseasonal Heat Transfer integrates solar thermal collection in summer with heat storage in earth Thermal Banks to increase the efficiency and Coefficient of Performance of ground source heat pumps in winter to twofold.

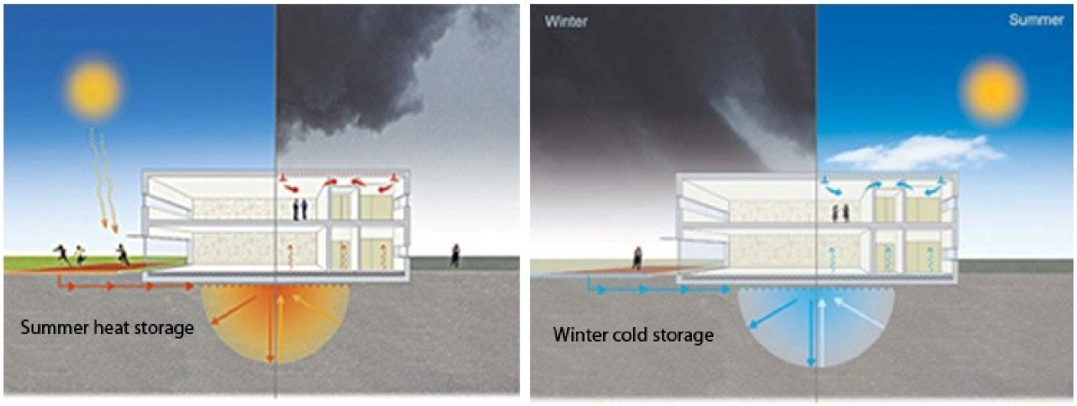

Figure 190 Thermal storage during seasons[69]

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[69] http://www.icax.co.uk/interseasonal_heat_transfer.html

IHT captures surplus heat from summer sunshine, stores it in Thermal Banks in the ground and releases it to heat buildings in winter. IHT also captures cold on winter nights, stores this in Thermal Banks in the ground and releases it to cool buildings in summer; the main advantage can be categorized as follows:

- provides reliable, low-cost on site Renewable Heat for space heating by re-cycling solar energy;
- saves over 50% of carbon emissions compared to using a gas boiler for heating;
- provides reliable, low-cost, on site Renewable Cooling by re-cycling winter cold;
- saves over 80% of carbon emissions compared to using standard air conditioning for cooling;
- reduces emissions by re-cycling solar energy instead of burning fossil fuels;
- links to standard heat pump for under floor heating, air handling units, etc; and
- very low maintenance.

A Thermal Bank is an integral part of an Interseasonal Heat Transfer system. A Thermal Bank is used to store warm temperatures over a very large volume of earth for a period of months, as distinct from a standard heat store which can hold a high temperature for a short time in an insulated tank. It is a characteristic of earth that heat only moves very slowly through it, as slowly as one meter a month. IHT exploits this thermal inertia to input surplus heat into the ground over the summer months and extract that heat over the winter months for use in the space heating of buildings and vice versa. [70]

The temperature of the ground at a depth of seven meters in Italy will normally be very close to 10°C, the temperature will vary little between summer and winter as heat only moves very slowly in the ground. IHT uses this characteristic of the ground to store heat from summer to winter. Using fluid, in an array of pipes, as the transport mechanism solves the difficulty of getting the heat into the ground and out again, using an Asphalt solar collector.

An Asphalt Solar Collector is an efficient means of collecting a large amount of warmth to raise the temperature of a Thermal Bank from the natural temperature of the ground up to over 25°C: solar recharge of the ground.

The surface temperature of roads in direct sunshine can often reach 15°C higher than the ambient air temperature. Exchange system Collects heat using fluid circulating through an array of pipes embedded in the surface of the road and deposits it in Thermal Banks constructed underneath the insulated foundation of buildings. The temperature across a large Thermal Bank can be increased from its natural temperature of 10°C to over 25°C in the course of the summer months.

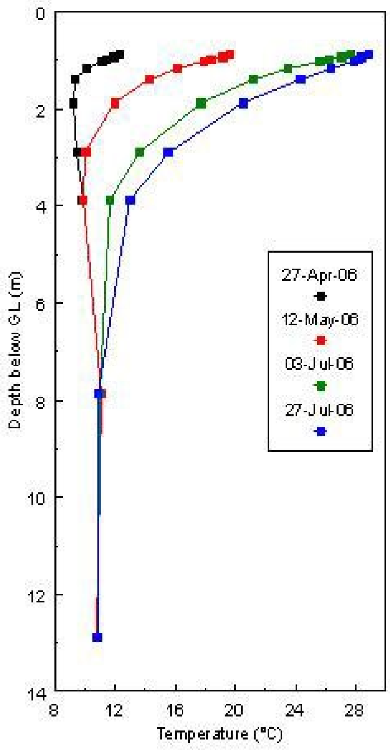

Figure 191 Soil temperature with depth

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[70] http://www.icax.co.uk/on_site_renewable_energy.html

Figure 192 Pipe array being laid[3]

It is possible to double the coefficient of performance of a Ground Source Heat Pump if used in combination with the Thermal Bank. A full Interseasonal Heat Transfer System can show a lower annual heating cost than a gas fired boiler and can save over 50% of carbon emissions compared to a gas fired boiler.

A modern heat pump should achieve a CoP of 4 if starting from a temperature of 10°C from the ground and delivering 40°C to under floor heating. If the same pump starts from a temperature of 25°C from a Thermal Bank it will have half as much work to do to achieve a 40°C output temperature, also by coupling the system with the Earth labyrinths, we can guarantee providing to the HVAC preheated/cooled air with a difference in temperature of 9 C° than the external outdoor air, which needs only to be filtered not to be treated thermally.

5.1.2 Earth labyrinths

Simply, it is a decoupled thermal mass storage and exchange system, which is often constructed directly beneath a building, only the sides and floor of the labyrinth are in contact with the earth and the top of the labyrinth is completely well insulated[71]. It is a maze created using a high thermal mass concrete undercroft with a large surface area. Due to the created air turbulence the roughness of the concrete surface and the bends of the maze, the injected fresh air exchanges heat with the walls providing pre-heated and pre-cooled air to the HVAC system, with a dramatic difference in temperature of 9-12 C° than the external air[72]. Meanwhile, the contact between the earth and the labyrinth gives the benefit of the heat exchanging with earth thermal Bank, which allows the charging process of the concrete walls during the night.

Figure 193 Labyrinths with Concrete rough wall, taken from (blog.iesve.com)

Figure 194 Labyrinths with Concrete blocks, taken from (www.building.co.uk)

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[71] http://www.designingbuildings.co.uk/wiki/Thermal_labyrinths

[72] http://www.airah.org.au/imis15_prod/Content_Files/HVACRNation/2008/September2008/HVACRNation_2008-09-F02.pdf

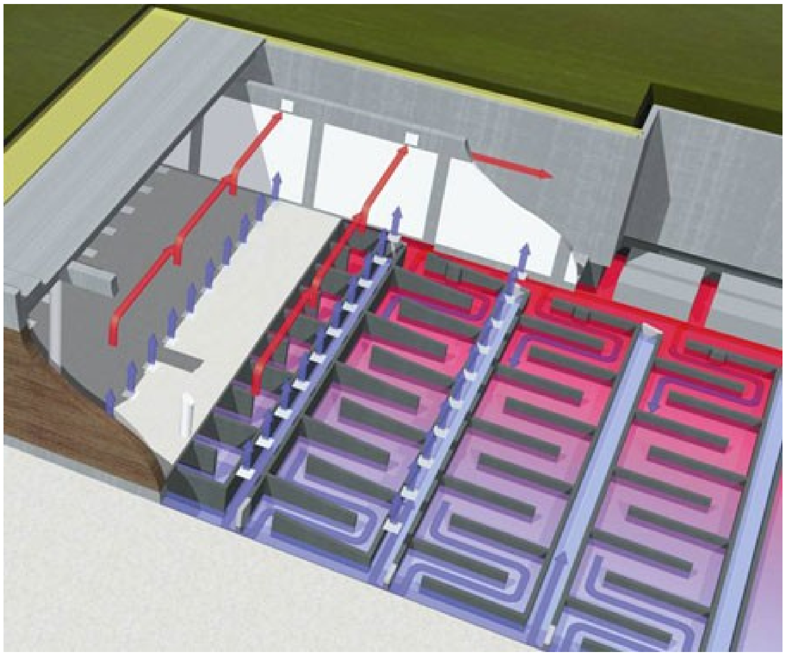

Figure 195 Labyrinths system, The Earth Centre Galleries, UK[73]

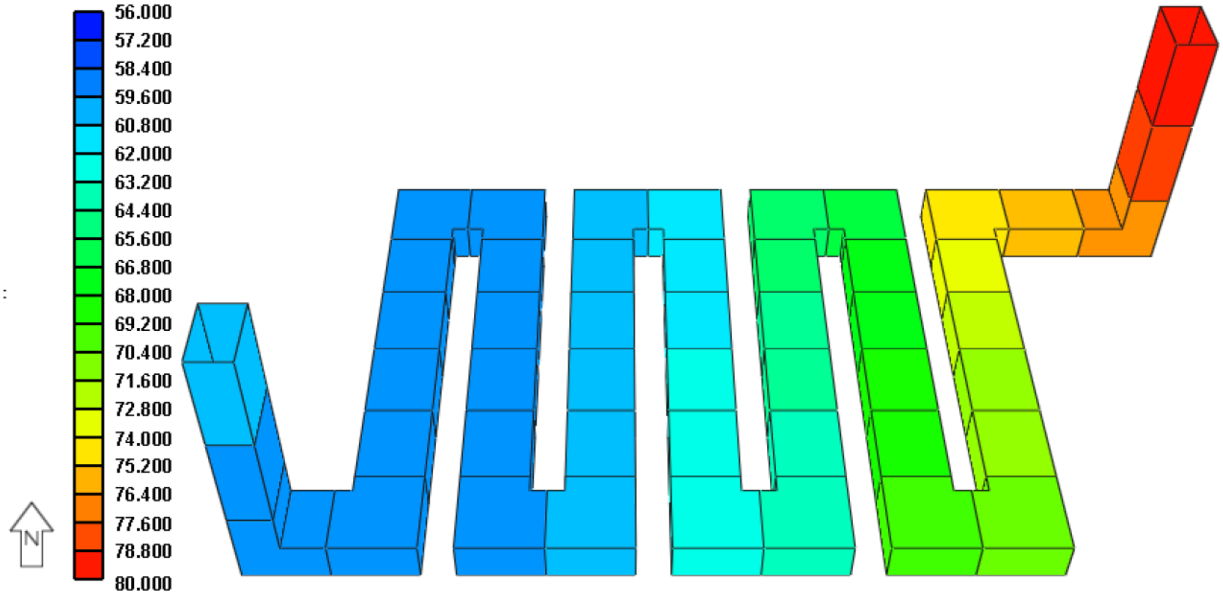

Figure 196 Difference in temperature of In/Out Air, Nanaimo Hospital, Canada [74]

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[73] http://www.atelierten.com/2012/projects/the-earth-centre-galleries/

[74] http://www.iesve.com/consulting/projects/projectdetail/3075/nanaimo+regional+general+hospital

5.1.3 Geothermal heat pump

5.1.3.1 Heating and cooling efficiencies[75]:

The heating efficiency of ground-source and water-source heat pumps is indicated by their coefficient of performance (CoP), which is the ratio of heat provided in Btu per Btu of energy input. Their cooling efficiency is indicated by the Energy Efficiency Ratio (EER), which is the ratio of the heat removed (in Btu per hour) to the electricity required (in watts) to run the unit.

5.1.3.2 Evaluating site for geothermal heat pump:

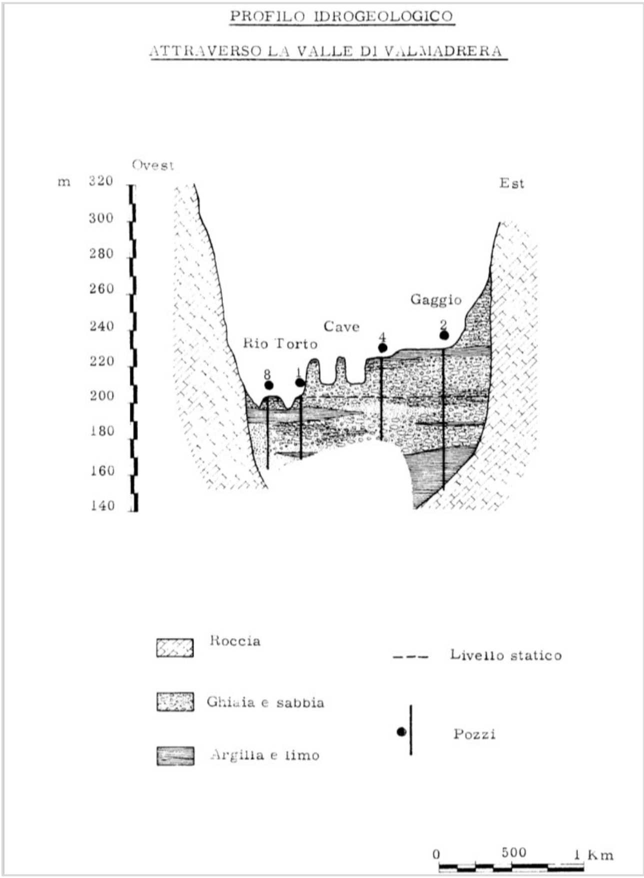

Figure 197 Cross sectional view of valmadrera (PGT Comune di Valmadrera)

Shallow ground temperatures are relatively constant throughout, so geothermal heat pumps (GHPs) can be effectively used almost anywhere. However, the specific geological, hydrological, and spatial characteristics of the land will help the local system supplier/installer determine the best type of ground loop for the site. Factors such as the composition and properties of the soil and rock (which can affect heat transfer rates) require consideration when designing a ground loop. For example, soil with good heat transfer properties requires less piping to gather a certain amount of heat than soil with poor heat transfer properties.

Horizontal Ground Loops will be the choice, which is also the most economical and is based on the geographical data available from the *Commune di Valmadrera*, showing that the major part up to about 10 meters is clay and silt which rests on gravel.

The general concept depends on the constant temperature of the earth as an exchange medium for heat. Although many parts of the country experience seasonal temperature extremes—from scorching heat in the summer to sub-zero cold in the winter—the ground a few feet below the earth's surface remains at a relatively constant temperature. Depending on the latitude, ground temperatures range from 45°F (7°C) to 75°F (21°C)[76] .

There are four types of geothermal heat pump systems. Three of these—horizontal, vertical, and pond/lake—are closed-loop systems. The fourth type is open-loop. Which, among these, is the best depends on the climate, soil conditions, available land, and local installation costs at a particular site. All of these approaches can be used for residential and commercial building applications.

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[75] http://energy.gov/energysaver/articles/choosing-and-installing-geothermal-heat-pumps
[76] http://www.eere.energy.gov/basics/buildings/geothermal_heat_pumps.html

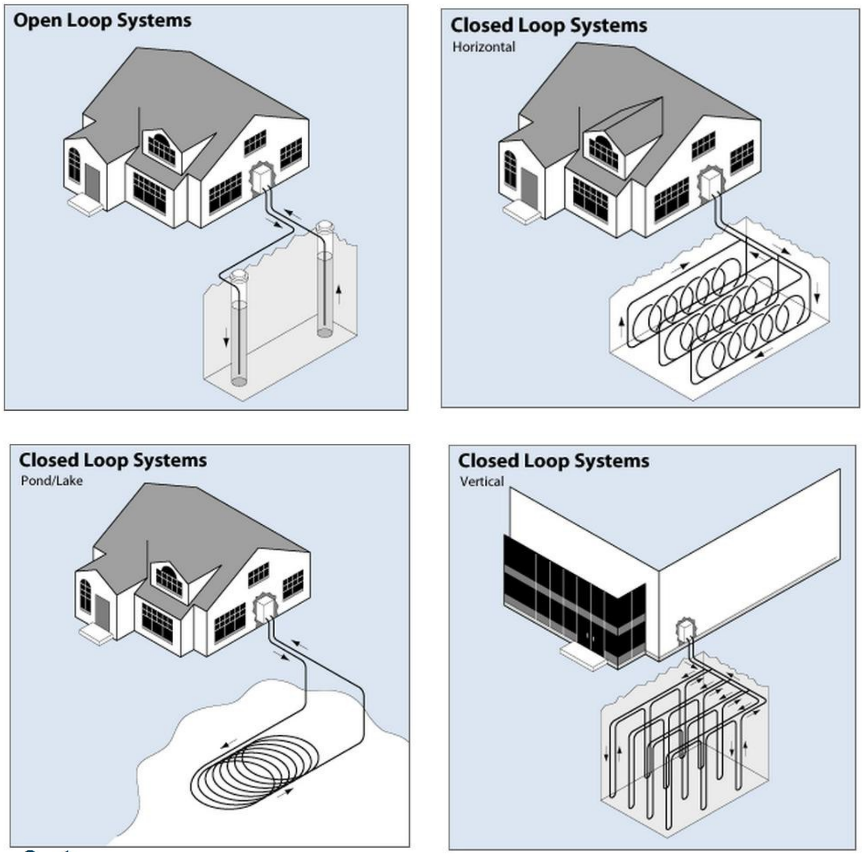

Figure 198 Types of geothermal loop systems (100 U.S department of energy: Consumer Guide, get your energy from the sun, 2001)

The biggest benefit of GHPs is that they use 25% to 50% less electricity than conventional heating or cooling systems. This translates into a GHP using one unit of electricity to move three units of heat from the earth. According to study, geothermal heat pumps can reduce energy consumption, and corresponding emissions up to 44% compared with air-source heat pumps and up to 72% compared with electric resistance heating with standard air-conditioning equipment. GHPs also improve humidity control by maintaining about 50%

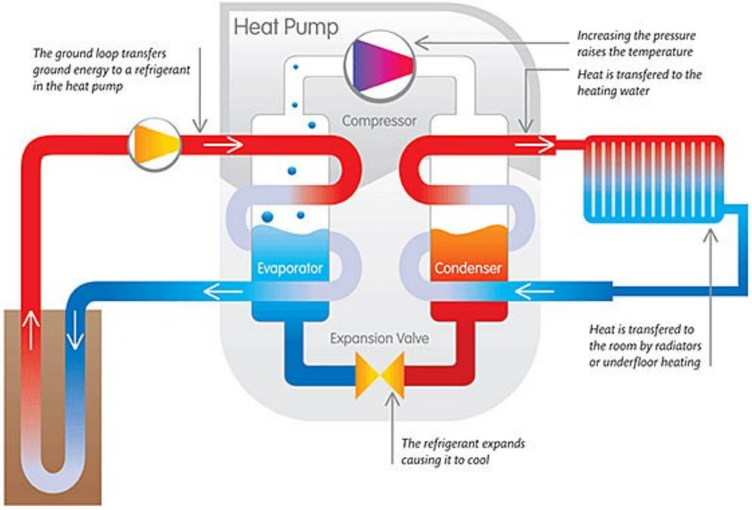

Figure 199 Heat pump illustration

relative indoor humidity, making GHPs very effective in humid areas. GHP systems (Figure 199[77]) also provide excellent "zone" space conditioning, allowing different parts of the building to be heated or cooled to different temperatures.

5.1.4 Heat recovery system

The heat recovery system is used as a technique to conserve heat energy by being extracted out of exhaust air or hot waste water. 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 in a Spa and wellness center there is a massive amount of hot water produced and drained, so a waste water heat recovery system can be installed, in addition to ETM unit will be installed in the chimney to extract heat from the exhaust air to heat the water.

5.1.4.1 Energy transfer module:

The (passively heated) exhaust air coming from the oculus lounge and outdoor pool will be released through the existing chimney by the stack effect, by installing an Energy transfer module[78] inside the reinforced chimney, to extract the heat from the released air to the water supply of the heaters, as it is can transfer energy from a clean or contaminated air stream to process water[79]. The water can be used as it is or filtered following process requirements. Relevant procedures maximize the efficiency of the heaters and minimize the energy demand as targeted.

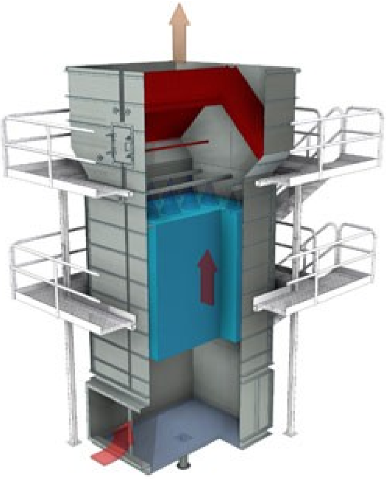

Figure 200 Air to water Heat recovery, extracted from (www.enerquin.com)

5.1.4.2 Drain water heat recovery:

Drain-water heat exchangers can recover heat from the hot water used in showers, bathtubs, sinks, dishwashers, and clothes washers. They generally have the ability to store recovered heat for later use with storage capacity. The hot water thus recovered is stored in a tank or added as an input to the heating water system. This type of system is used in small units form, but is useful as the 80-90% [80] of energy is used to heat water in a building, most of which can be recovered by this intervention. Figure 201 illustrate the same[81].

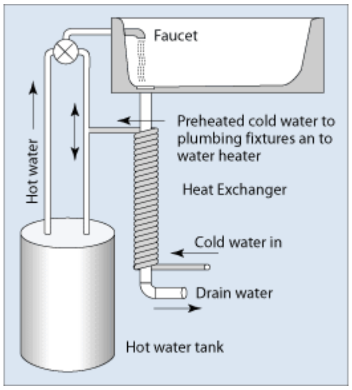

Figure 201 Drain heat recovery process

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[77] http://www.energygroove.net/heatpumps.php
[78] http://www.echofirst.com/get-to-know-echo.php#.UbnfjPlHKSo
[79] http://www.enerquin.com/paper-heat.php
[80] http://www.sustainable-buildings.org/wiki/index.php/Drain-water_heat-recovery_system
[81] http://www.energyvanguard.com/

5.1.5 Radiant ventilated raised floor

Generally, the idea of the ventilated raised floors (UFAD) is not new, as it used to provide cool air to the space through the floor grills and plenums, which is a sufficient energy conservative ventilation approach, as it provides the maximum flexibility for MEP works. In addition to maximizing the removal of the polluting substance out of breathing zone, it provides the complete avoidance of the air draft risk. On the other hand, it is not suitable for air heating systems, as the displacement effect will be lost.

Mean while, the under floor radiant water heating (UFH) 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. With respect to the Water thermal capacity (4.1813 J/g.K)[82], which is much higher than the air (1.012 J/g.K), using the water as a heat/cool carrier/exchanger was proven as a much energy efficient method, as a well installed under floor heating system can save over 30% of fuel costs and CO_2 emissions compared to using traditional wall-mounted radiators. On the other hand this system is not suitable for Cooling, with respect to the risk of condensation.

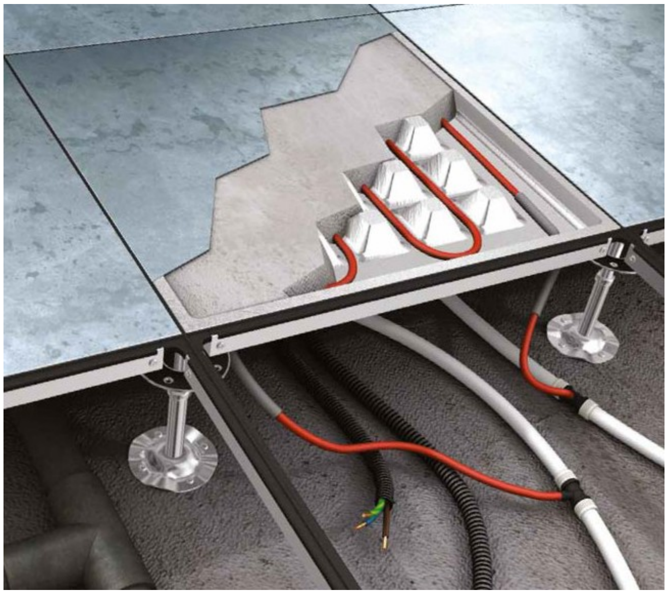

Figure 202 Radiant Raised Floor system, extracted from (www.eurotherm.info)

Resultantly, recent technology was introduced compiling the benefits of UFH and UFAD, which is the Radiant ventilated raised floors, relevant system can be used for heating and cooling with the complete avoidance of the condensation, along with taking advantage of the air displacement effect created by the cool primary air supply, direct into the occupants breathing zone.[83]

5.2 Energy Production

5.2.1 Shadovoltaic

With respect to the previously mentioned PV Solar shading usage analysis and the strategies sketches

Figure 203 Glazed louvers with PV cells, extracted from (www.coltinfo.co.uk)

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[82] http://en.wikipedia.org/wiki/Heat_capacity

[83] http://www.eurotherm.info

shown in the architectural chapter, 2 layers of pivoted glazed louvers with integrated monocrystalline photo voltaic cells in between[84] can be used to maximize the usage of natural daylight, avoid the glare or excessive solar heat gain and to produce adequate amount of energy during summer and winter, meanwhile maintaining the complete visibility. Since it is controllable - can be rotated according to the external climatic conditions and sun angles - to create semi-sealed/opened buffer spaces, the effect of the glass house can be achieved to provide pre-heated/cooled air and minimize the thermal stresses over the building envelop.

5.2.2 Bio-energy

As had been introduced in the Urban chapter, an energy park with a Biomass plant can be localized in the degraded area by the city boundaries, taking advantage of all of the massive amount of waste dry Clippings coming from the Lecco’s forests and green fields, considering that wooden areas are occupying 42% of Valmadrera alone.[85]

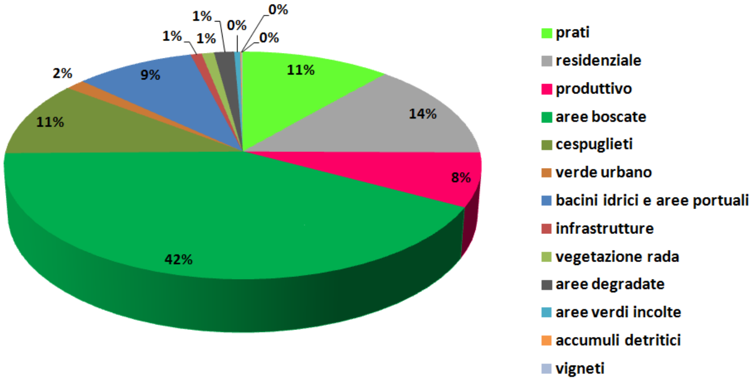

Figure 204 Valmadrera land use,
Extracted from (Rapporto Ambientale Studio Incidenza)

Biomass is basically a stored source of solar energy initially collected by plants during the process of photosynthesis whereby carbon dioxide is captured and converted to plant materials mainly in the form of cellulose, hemi-cellulose and lignin[86]. The term biomass, therefore, covers a range of organic materials recently produced from plants, and animals that feed on the plants. The biomass can be collected and converted into useful bio-energy. It includes crop residues, forest and wood process residues, animal wastes including human sewage, municipal solid waste (MSW) (excluding plastics and non-organic components), food processing wastes, purpose grown energy crops and short rotation forests.

Bio-energy projects are usually considered to be environmentally acceptable at the national and international level in that they provide renewable sources of energy with low or even zero greenhouse gas emissions.

Figure 205 Bio-mass cycle, Extracted from
(www.ncfp.wordpress.com)

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[84] http://www.coltinfo.co.uk/photovoltaic-shading-pv-shading-louvre.html

[85] Comune di VALMADRERA, PGT, rapporto preliminare

[86] http://www.iea.org/publications/freepublications/publication/biomass.pdf

Bio-energy projects can range from a small (~40kW) local on-farm heating plant to a large (~400MW) commercial cogeneration plant. Therefore not all projects will experience the same issues relating to their planning and development.

When looking across the carbon life cycle, biomass burning does produce some fossil fuel emissions from harvesting, transportation, feedstock preparation and processing. These impacts, however, are substantially more than offset by eliminating the emissions from using a fossil fuel. Sustainable removals of biomass feedstocks used for energy produce a reduction in carbon emissions year after year through a reduction in fossil fuel emissions far greater than all of the emissions from feedstock collection and processing. In addition to the Energy production, the waste can be used as fertilizers and concrete fillers, which provides a complete sustainable cycle.

5.2.3 The Greenasium

With respect to the new term of (The Human-Powered Gyms), there are many examples which appeared in Hong Kong, Australia and USA—and are spreading to Europe and other parts of the world. Using generators connected to exercise bikes and treadmills, the gyms are able to power themselves by harnessing energy from their members' workouts.[87]

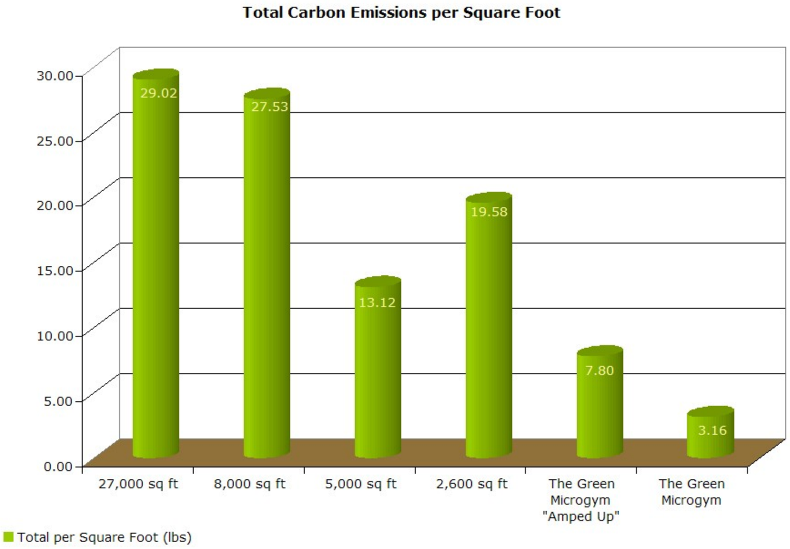

Figure 206 Comparison between Gyms footprint and relevant CO_2 emission, extracted from (www.dogonews.com)

Generally in a Gym, Treadmills alone use around 1500 watts, the same amount of energy to power 15 incandescent bulbs. Most stationary bikes are extremely inefficient and dissipate about 90% of the energy used as heat. Most exercise machines, television sets, fans, and stereos are left on all day. Noting that One person has the ability of producing 50 watts of electricity per hour when exercising at a moderate pace[88], which means that to prevent 12 liters of CO_2 from being released into the air, a person needs to produce the same amount of electricity by exercising on the specially setup machine for one hour. If a person spends one hour per day running on the machine, he/she could generate 18.2 kilowatts of electricity and prevent 4,380 liters of CO_2 released per year. So exercise can improve not only health but contributes to a greener environment.

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[87] http://www.ecohearth.com/eco-zine/travel-and-leisure/930-human-powered-gyms-one-workout-at-a-time.html

[88] http://www.californiafitness.com/sg/en/node/587

Some manufactures, like (The Green Micro gym) has developed models that can be directly plugged into the grid. Thus, the gyms electric usage is reduced in proportion to how much activity there is on those machines. And in areas where utility companies buy back excess power, the gym can actually earn money back from the utility.

5.3 Lighting and appliances solutions

5.3.1 Heliostat and Prisms systems

in view of the previously mentioned combined techniques, introduced in the architectural chapter, the usage of the of Heliostat with (sun tracking system, Mirrors, reflective colored prisms chandelier and Operable motorized vent connected to the BMS) can provide the comprehensive architectural and energy conservative solution, as it can create a remarkable interior atmosphere and proper natural illumination level, with the total avoidance of the unwanted sun radiation, heat gain and harsh light beam/column.

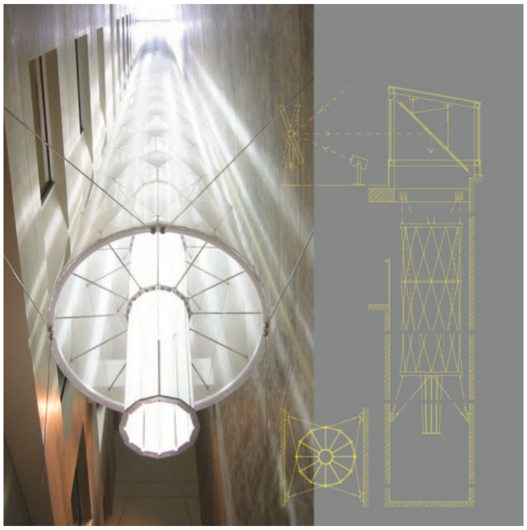

Figure 207 Heliostat with light tube, Morgan Lewis Offices, U.S.A. Extracted from (www.coltgroup.com)

In addition to the physiological benefits of nature light, if as much natural daylight as possible is brought into a building, this has a very positive effect on the energy balance since the needs for artificial light reduced dramatically. To illustrate, the energy consumption for a traditional light bulb is 95% heat and only 5% light. The production of this heat in turn increases the cooling loads where air conditioning systems have to be used. However, heliostat systems are rarely installed so as to reduce energy use, they are mostly used to improve the feeling of wellbeing and/or aesthetic effects but the positive impact on energy use should not be underestimated[89].

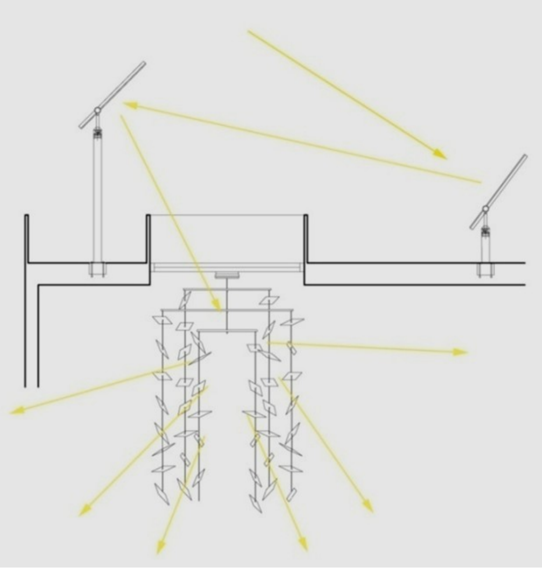

Figure 208 Heliostat with prism chandelier, Extracted from (elliscresswell.tumblr.com)

Heliostat systems bring natural daylight into buildings in two stages. The ever-changing position of the sun is tracked by the heliostat and its light is channeled either directly or via a stationary reflecting mirror on to a pre-determined area within the building. At that moment the work of the heliostat is done. The size of the mirror and the area of projection determine the brightness of the spot of light. The second stage is the distribution of the light within the building. Many different types of materials can be

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[89] http://www.coltgroup.com/news/heliostat-brochure.pdf

used to distribute the light. Natural daylight distribution systems very often consist of one or more devices[19]:

- Concave or convex reflecting mirrors either to concentrate the light or to diffuse it
- Light diffusing elements which remove the glare from the light and bring it to the working area
- Animated/fixed Prismatic panels or louvers to provide a spectral effect, which mostly made from milled acrylic base
- Colored foils which either are laminated into glazed panels or are freely hanging mobiles.
- Light tubes and mirrors duct.

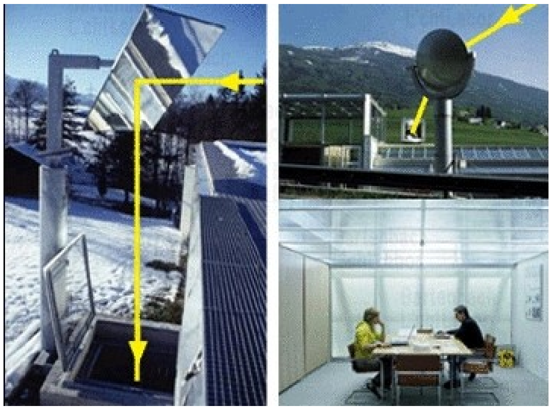

Figure 209 Heliostat with mirror duct, Extracted from (www.bartenbach.com)

5.3.2 Mirrored Tubular Skylights

Light pipe or solar tube is an energy efficient choice for capturing, and transporting or distributing natural or artificial light with the total avoidance of heat gain, harmful UV rays and glare, which maximizes the users comfort and cuts the HVAC loads. A clear, unbreakable polycarbonate dome mounted on a storm-tested, aluminum flashing on the roof collects and directs sunlight down into the inner spaces with a high-performance reflective transfer tube. This tube connects to an inner domed translucent or prismatic diffuser that distributes natural light evenly throughout the area without heat gain or loss[90].

Figure 210 Solar tube with sun tracking mirrors, extracted from (www.houzz.com)

Light pipes are more energy efficient than skylights because less energy escapes from the interior due to less surface area[91]. It is equipped with a rotating mirror to maximize the light capturing. Generally there are 2 types, the Rigid [92] with an average length of 1.85m and the

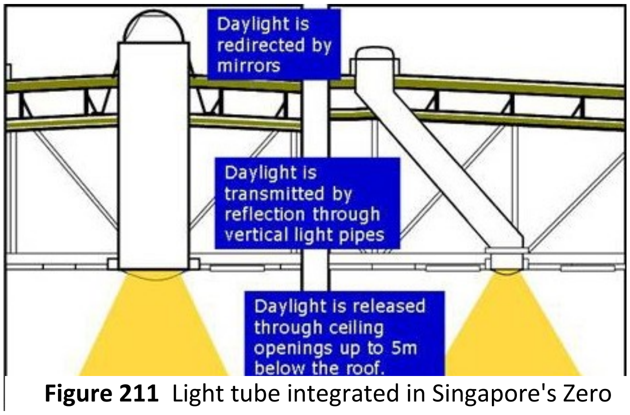

Figure 211 Light tube integrated in Singapore's Zero Energy Building roof, Extracted from (www.solaripedia.com)

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[90] http://www.sun-dome.com/tubular_skylight_features.html

[91] http://www.solaripedia.com/13/388/5461/singapore_zero_energy_building_light_pipe.html

[92] http://www.velux.com.au/Homeowners/Products/Sun_Tunnel

flexible one which can reach 5 m below the roof. Noting that Low-energy LED lamp with a daylight sensor can be attached to maintain continuous inner illumination level. It will be quite suitable for spaces like offices, receptions and the beauty center area.

5.3.3 Artificial lighting and applinces

Generally the Standard incandescent lamps are inexpensive to manufacture and have been around for over 100 years, in cold weather the heat from the incandescent lamp contributes to build heating, but in hot climates its heat increases the energy used by air conditioning system[93].

Figure 213 Led light

Mercury is present in many of today's low energy light bulbs such as compound florescent light bulbs. Mercury is toxic and the light bulbs have to be properly disposed of and cannot go into the regular waste disposal process. In order to minimize the waste impact and cut the energy demand, incandescent is to be replaced with (CFLs) Compact florescent lamps, high–intensity discharge lamps,T-5 florescent lamps and (LEDs) light emitting diodes, which are less toxic and producing more visible light with 80% less electricity, for a larger life span.

Figure 212 CFL Lamp

Also, by using the Energy star certified appliances, we minimize energy consumption, improve energy security, and reduce pollution as well as meeting the highest energy efficiency standards[94].

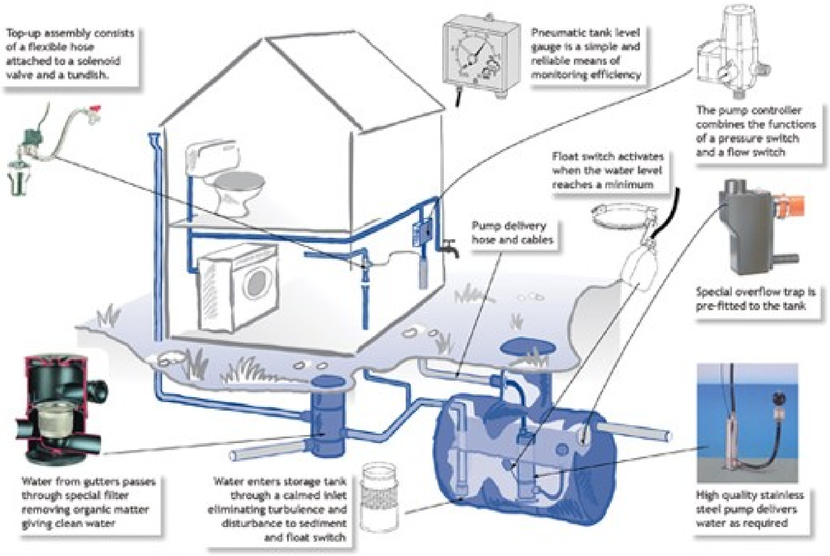

Figure 214 Rainwater storage scheme, extracted from (www.ppcb.gov.in)

5.4 Water efficiency

5.4.1 Strom water harvesting

Rainwater harvesting is the accumulation and deposition of rainwater for reuse before it reaches the aquifer. Uses include water for laundry, hygiene, water for livestock, water for irrigation, toilets, water

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[93] LEEd GA, study guide, 2010

[94] http://www.energystar.gov/index.cfm?c=about.ab_index

flushing etc,. The filtered harvested water can be used for drinking water as well (if the storage is a tank that can be accessed and cleaned when needed[95]).

There are two easy ways to store rain water, either on the over head tank which needs space and maintenance, or underground water tank which would need a pump to throw the water in pipes for reuse, but it can be linked to PV circuit. The choice of system depends on the need and utility of rain water.

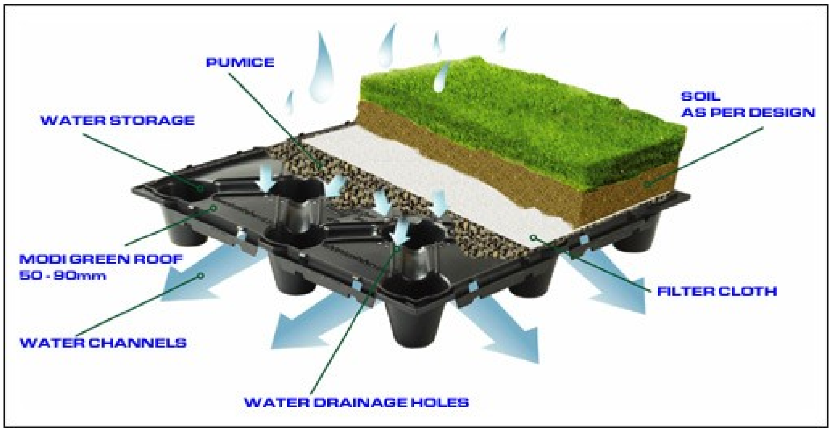

Figure 215 Green roof storage panel, extracted from (baghbam.blogfa.com)

Also with respect to the usage of earth sheltering as a constriction technique, we can take advantage of the Green and cool roofs storage ability, which are limiting the storm water runoff, as the roof compositions are provided with EPS flat water storage and over flow system, which stores the rain water and excess irrigation water for the plantation need, mean while the over flowed water will be sent to the underground storage tank.

5.4.2 Waste water management

Generally the Spa and wellness centers are wasting a massive amount of gray water, with respect to the pools, showers, bath tubs, sinks, sheets laundry, towels washing machines, condensed water from the saunas and treatment appliances. Sullage or Gray water is water that can be used twice, and can be also defined as the untreated waste water which has not come into contact with toilet waste.

It is different than the black water –untreated waste eater from toilets and urinals. Gray water comprises 50-80% of wastewater[96] , so it can be piped to storage tanks for later use. After filtration or microbial digestion processing it can be used for irrigation, washing or flushing toilet. There are two systems[97]:

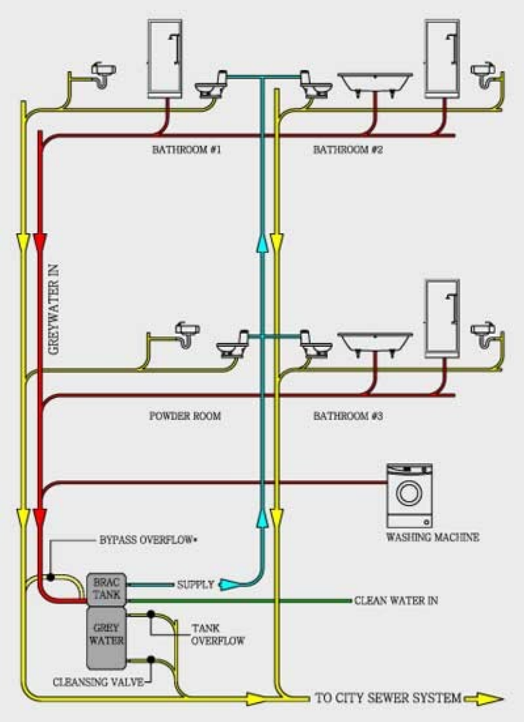

Figure 216 Grey water supply and storage, Extracted from (www.mapawatt.com)

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[95] http://green.wikia.com/wiki/Rainwater_harvesting

[96] LEEd GA,study guide, 2010

[97] https://en.wikipedia.org/wiki/Greywater

Recycle the water without purifying it: Water recycling without purification is used in certain agricultural companies and dwellings for applications where potable water is not required (e.g., garden and land irrigation, toilet flushing). This water system also needs a supply of water to recycle and reuses water as well. It is also not recommended to use water that has been in the grey water filtration system for more than 24 hours or bacteria builds up affecting the water that is being reused. Form that, this system will be recommended for our case study.

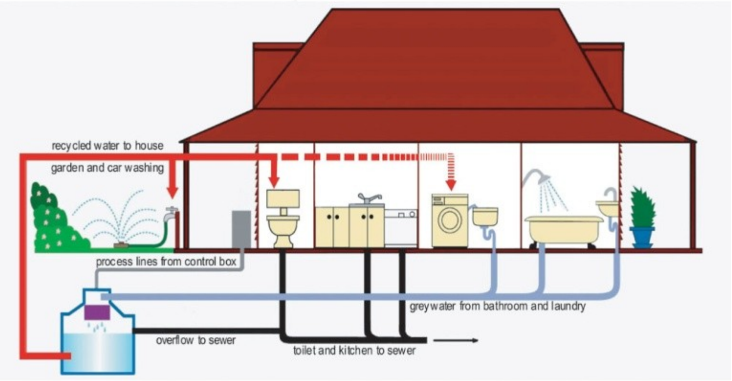

Figure 217 Grey water underground storage, Extracted from (www.designwhys.com)

Recycle the water while purifying or decontaminating it: For filtering the water to become potable (or near-potable), there are numerous systems based on soft processes. These include natural biological principles such as mechanical systems (sand filtration, lava filter systems and systems based on UV radiation), biological systems (plant systems as treatment ponds, constructed wetlands, living walls) , Bio reactors or compact systems as activated sludge systems, biorotors and aerobic and anaerobic bio-filters, and Hard system which is direct processes, such as distillation (evaporation) or mechanical processes such as membrane filtration[98].

5.4.3 Efficient water fixtures

For the outdoor usage, the proper landscaping and conservative drip irrigation techniques are the first step to minimize the water demand, including the proper selection of low maintenance type of plant and native plants, also mulching and using weather based irrigation controllers can be used .

For the indoor usage, the water efficient and conservative plumping fixtures can be used, like the Dual-flush toilets, waterless urinals, high efficient hot tubs ,low flow showerheads and faucets ,tabs with motion sensors, etc, [99].

5.5 Monitoring and metering

5.5.1 BMS

A Building Management System (BMS) is a computer-based control system installed in buildings that controls and monitors the building's mechanical and electrical equipment such

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[98] https://en.wikipedia.org/wiki/Greywater

[99] LEED GA,study guide, 2010

as ventilation, lighting, power systems, fire systems, and security systems. A BMS consists of software and hardware[100] . Systems linked to a BMS 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, BMS 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 CO_2, 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 wasted energy incase of the minor occupancy.

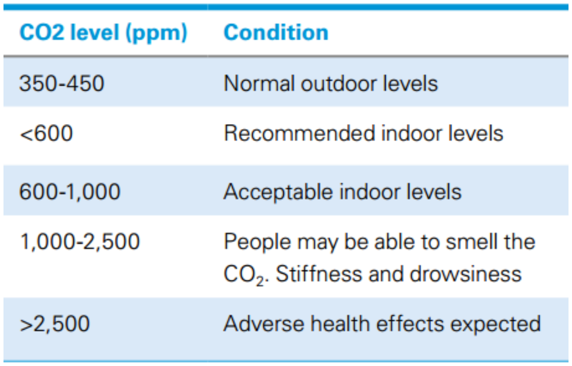
5.5.2 CO_2 and air pollution sensors

Figure 218 Air pollution sensors

Good air quality in buildings is vital for people who spend much of the day indoors. We spend an average of 90 % of our time indoors, more than 20 hours in enclosed spaces. Indoor air quality does affect our health and therefore, badly managed air quality can have economic and legal implications[101]. Typical values in Figure 31[102].

`There are many sources of indoor air pollution in buildings. Occupants of a building are the main source of carbon dioxide, in addition to the volatile organic compounds (VOCs) is emitted as gases from certain solids or liquids. Carbon dioxide is exhaled as a byproduct of living processes, as people in the office environment exhale carbon dioxide at a rate of about 0.3 l/min when performing light office duties.

The best way around this is to monitor the CO_2 and VOC levels in a space and control the level of fresh air ventilation accordingly. Sensors should be placed where they provide a true reading of the area they serve[103], mostly at the top height of the occupied area. It may be wireless, but the maximum range is around 30m. Most importantly they save the health and don't have any impact on the aesthetic behavior of the building interior.



CO2 level (ppm)	Condition
350-450	Normal outdoor levels
<600	Recommended indoor levels
600-1,000	Acceptable indoor levels
1,000-2,500	People may be able to smell the CO_2. Stiffness and drowsiness
>2,500	Adverse health effects expected

Figure 219 General CO_2 level

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[100] http://www.mikebarker.co.za/building-services/management-systems

[101] http://www.envirotech-online.com/articles/health-and-safety/10/eric_germain/the_benefits_of_air_quality_sensors_in_building_management_-_eric_germain/864/

[102] http://www.siemens.com/.htm

[103] http://www.carbontrust.com

5.5.3 Occupancy sensors

Occupancy sensors are simple devices that are found in many lighting systems. The sensor is capable of identifying when a particular space within a building is occupied, and adjusts the lighting, heating and cooling, and other appliances accordingly. When no one is currently occupying a given area of the building, the sensors note this and will turn off unnecessary lights as well as adjust temperature controls slightly[104]. This helps to minimize the use of electricity during those periods when the space is not in active use.

Figure 220 Dual Infrared sensor, Extracted from (www.cooperindustries.com)

As someone enters the space, the occupancy motion sensor recognizes the movement and automatically brings up the lights and adjusts the climate control equipment, allowing the individual to be comfortable while in the room, so it is important part of creating an environmentally responsible control system , to minimize the energy demeaned and providing a better indoor quality.

5.5.4 Daylight sensor

Daylight sensor allows control of lighting levels based on how much natural light is present[105] , when it is combined with electronic dimming ballast, it will regulate the illumination in an area to maintain a constant light level, to provide comfortable and

Controlled level of illumination throughout the working day. More importantly, it can provide energy savings up to 32% when installed near windows where natural illumination is usually greatest. It is also designed to save additional energy by reducing excess light output that occurs from design factors of lumen depreciation.

Figure 221 Analog Photo sensor, Extracted from (www.cooperindustries.com)

Lamps are dimmed slightly when new, but then raised over time to compensate for depreciation of lamp output that occurs in normal lamp aging, and the sensor will manage to provide a stable comfortable level of lighting in both cases.

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[104] http://www.wisegeek.com/what-is-an-occupancy-sensor.htm
[105] http://www.cooperindustries.com/content/public/en/lighting/controls/products/daylighting_controls.html

5.5.5 Measures

As per the Green building evaluation codes, one thing that all energy-efficiency measures have in common is the need for reliable, accurate metering and monitoring of energy consumption[106].

When it comes to commercial buildings, installing an effective WAGES (water, air, gas, electricity, steam) metering system can be a source of substantial energy and cost savings. The installation of meters to measure the Heating bills, ventilation, electricity consumption and domestic water use of buildings became mandatory, to guaranty the adequacy of the executed design and the continues proper performance of the used tools and strategies along the building life span , taking into account its benefit of giving early alerts incase of failure or needed adjustment .

Relevant system will be including meters and sensors , which will be fixated to the all of the energy and resources circuits, including refrigerant fluids, heaters, AHU, DHW, Fans VSD, Lighting dimmer switches, water fixtures , etc., then data will be assessed by the BMS to provide the final reporting and adjustment decisions.

Figure 222 60 sec. Web Metering & calculator, Extracted from (www.cooperindustries.com)

Figure 223 Removable/out of circuit Meter, Extracted from (www.cooperindustries.com)

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[106] http://www.schneiderelectric.pt/documents/solutions/solution/Eficiencia-Energetica/ee_white_paper_designing_metering_system.pdf

6. Building envelope compositions

As emphasized in the introductory statement, constructing an earth sheltered building has totally different techniques than the traditional above ground structures, for both of the physiological comfort and technical construction aspects.

Hereafter, we are going to focus more on the translation process of the previously proposed strategies sketches into technological solutions to ensure its constructability, based on the LEED as a framework and on a testing scheme for both of thermal behavior and condensation risk.

6.1 Material and resources

As has been introduced earlier, following the approach of (Reduce, Reuse, Recycle), the first steps were refurbishing the old Filanda building and preserving the existing fertile soil. For the technological detailing of new added mass, we followed an environmental scheme to compare between the used construction techniques and materials, with respect to the raw materials, manufacturing, packaging, distribution, reuse opportunities, future operation & maintenance and the final disposal impact. Generally, the environmentally preferred products are[107]:

- Recyclable
- Energy efficient
- Low embodied energy
- Low in toxic substance or have none
- Characterized by reduced packaging
- Water efficient

(LCC) Life cycle costing and (LCA) Life cycle analysis (LCA) or Cradle-to-Gravel analysis can be used as a tool to measure and compare between the products environmental impact throughout their life cycle, including the operation and maintenance. During the selection, priority was given to products with relevant performance documents. Maximizing the usage of regionally harvested, processed and manufactured products was one of the aims during the selection and detailing, to limit the energy and cost needed for transportation.

Keeping in mind the usage of the certified materials, which simply presented in the rapidly renewable materials, with recycled content, low CO_2 emitted during fabrication and low volatile organic compounds (VOC's).

Also by considering the usage of the durable goods, this will reduce the material's future demand and needed short term maintenance procedures.

Relevant above mentioned selection criteria will be considered during the detailing, with respect to the LEED related topics. Further information regarding the LEED rating system can be found in APPENDIX B.

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[107] LEED GA, study guide, 2010

6.2 Selected solutions for the earth sheltered structure

6.2.1 Roofing

With respect to the previously mentioned advantage and disadvantages of the earth sheltering techniques as a general strategy, attention was paid to four crucial aspects:

6.2.1.1 Load simplification:

Since that we are dealing with a huge amount of soil, traditional earth materials are heavy and can cause settlement, instability or lateral pressures. Other lightweight fill materials such as foamed concrete, waste tires, regular soil, woodchips, wood fiber, etc., which have higher densities, are variable in their makeup and are not engineered, due to field execution variables. They also have limitations in handling loads and can be weather sensitive, thus requiring staged construction and/or preloading, surcharging and draining, etc,. On the other hand, Foam-Control EPS Geofoam is among the most versatile lightweight materials available for usage.[108]

Thus, the usage of Geo-Foam or Styrofoam with a density of 40kg/m^3 and conductivity of 30W/m^2.K [109] was the solution, noting that relevant technology had been used by Emilio Ambasz in the building of (Fukuoka prefectural international hall), and also by Blackbird architects in the construction of the (Coyote Residence and Sandman Mixed-Use Project) as shown below.

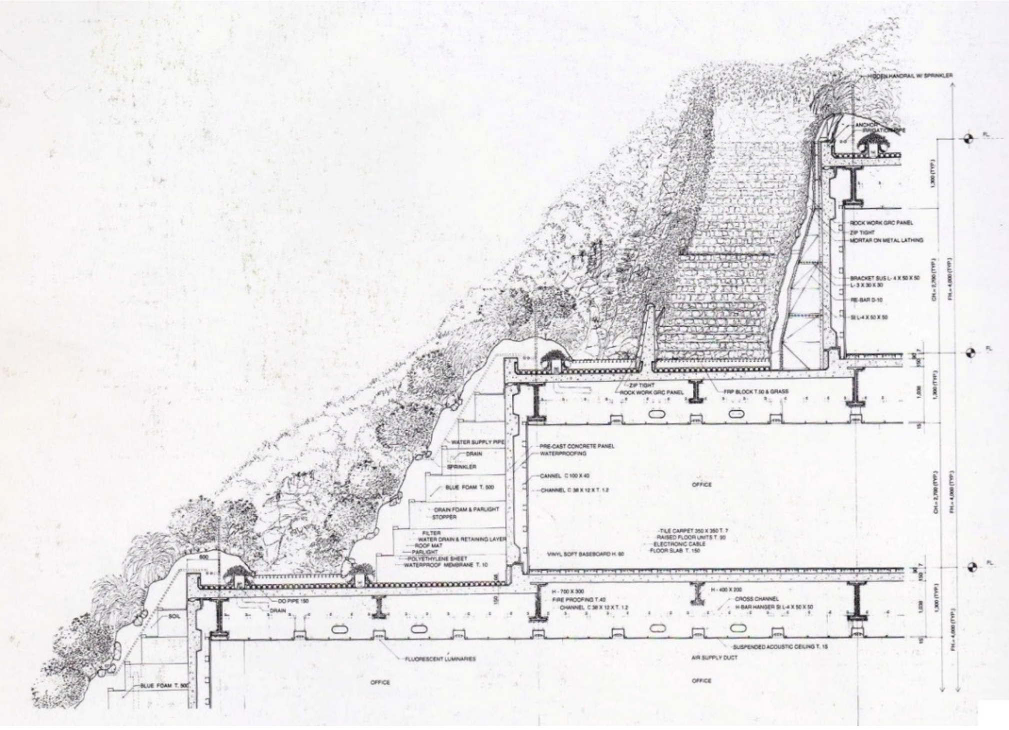

Figure 224 The usage of the foam blocks in earth sheltering, Fukuoka building, Japan[110]

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[108] www.geofoam.com

[109] www.univfoam.com

[110] Tadao Ando, Emilio Ambasz inventions, New York : Rizzoli, 1992

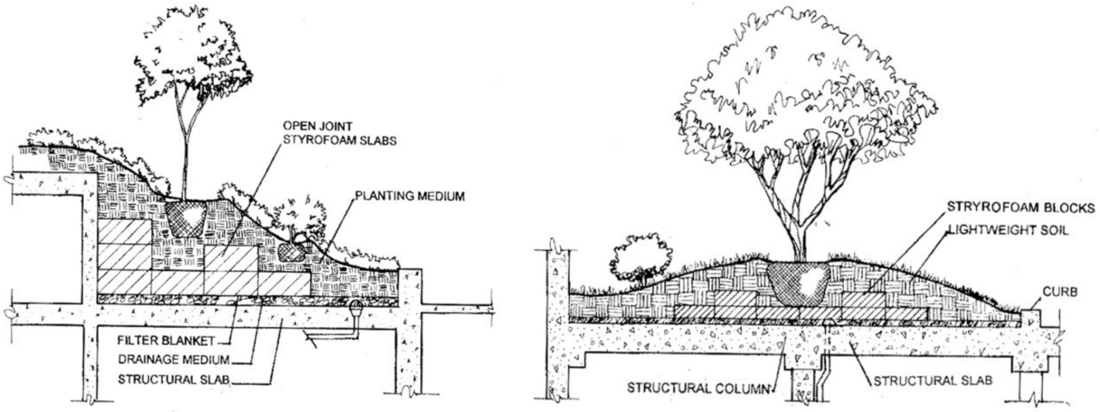


Figure 225 Example of the Styrofoam usage, Extracted from (www.bbird.com)

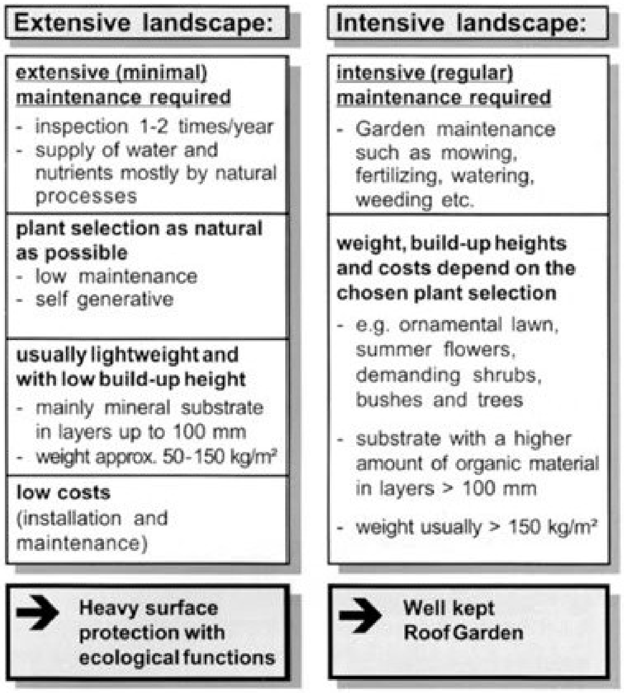
6.2.1.2 Maintenance and irrigation:

Keeping in mind the water consumption, maintaining the Bio-diversity and the economical feasibility, additional attention was paid to the soil depth and the used type of the native plantation considering their severity.

From that the limitation approach of the Intensive landscape was adopted, meanwhile maximizing the usage of the Extensive roofing, with respect to the below definitions:

Extensive landscaped roofs are an ecological alternative to conventional surface protection or ballast layers such as gravel and pavers. They are lightweight and have a shallow build-up height. Suitable plants include various Sedum species, herbs and some grasses can be used. After establishment of the vegetation, the maintenance is limited to one or two inspections a year. Biodiverse green roofs reproduce natural habitats and attract flora and fauna into the area.[111]

Intensive green roofs can most easily be compared to building a garden on a roof. They are usually multifunctional and accessible. They require more weight and a deeper system build-up. The maintenance is regular and depends on the landscape design and the chosen plant material.



Extensive landscape:	Intensive landscape:
extensive (minimal) maintenance required - inspection 1-2 times/year - supply of water and nutrients mostly by natural processes	intensive (regular) maintenance required - Garden maintenance such as mowing, fertilizing, watering, weeding etc.
plant selection as natural as possible - low maintenance - self generative	weight, build-up heights and costs depend on the chosen plant selection - e.g. ornamental lawn, summer flowers, demanding shrubs, bushes and trees - substrate with a higher amount of organic material in layers > 100 mm - weight usually > 150 kg/m²
usually lightweight and with low build-up height - mainly mineral substrate in layers up to 100 mm - weight approx. 50-150 kg/m²	
low costs (installation and maintenance)	
➔ Heavy surface protection with ecological functions	➔ Well kept Roof Garden

Figure 226 Comparison between Extensive and Intensive landscape, Extracted from lecture of Roof construction, Prof.G.Masera lectures, Polimi 2012

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[111] http://www.zinco-greenroof.com

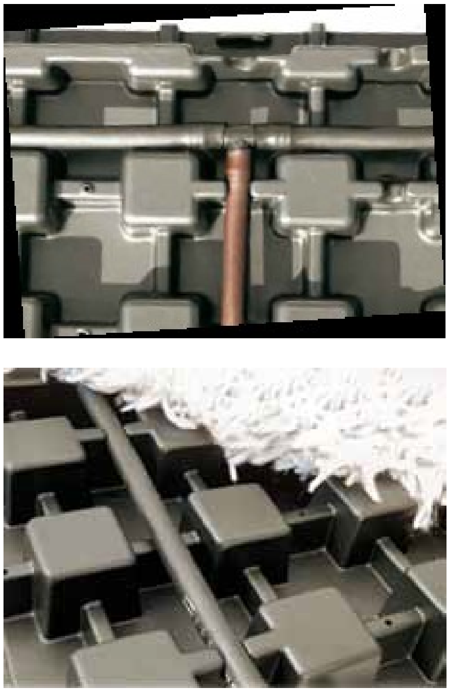

Figure 227 Irrigation with Wicks, Extracted from (www.zinco-greenroof.com)

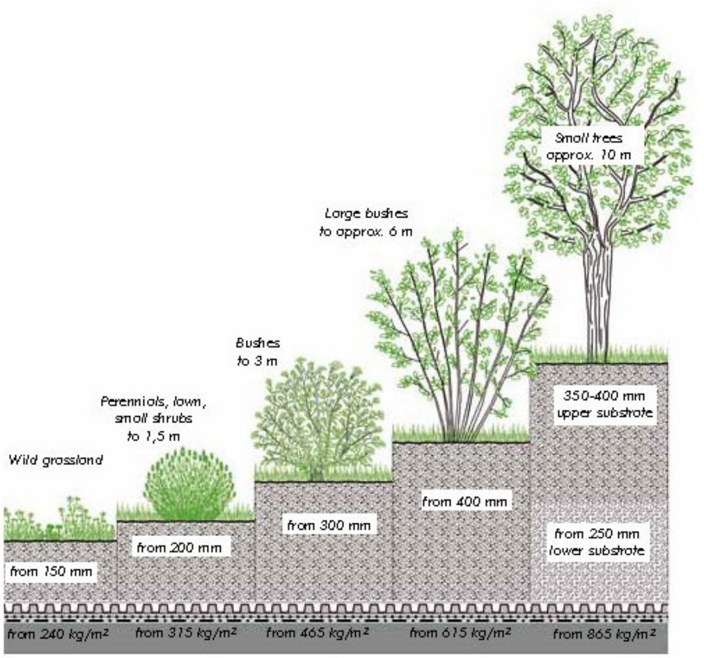

Figure 228 Intensive plantation types with soil depths, Extracted from (www.zinco-greenroof.com)

Accordingly, where the intensive roof type will be used, the usage of the EPS water drainage and storage panel is not sufficient, as an irrigation system will be needed in addition to the collected rain water. Generally water consumption is significantly lower with the soil imbedded type of irrigation than is the case with irrigation from above, as the water is available directly in the root area and there is considerably less evaporation[112].

A smart irrigation management system can be introduced, using a combination of an electronic irrigation manager and sensors. The basic principle involves the distribution and storage of water in the element cells which is then drawn upwards when required through the wicks in the mat to the substrate layer. The water is fed through dripper lines and the amount is controlled by the electronic irrigation Manager.

6.2.1.3 Shear forces and erosion resistance

Sloped Roofs are exposed to different design criteria, as the shear forces from the green roof build-up increases the steeper the roof pitch is and needs to be diverted to a sufficiently stable counter support[113].

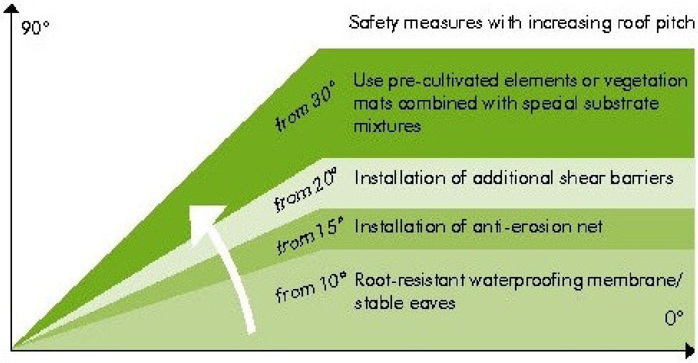

Figure 229 Shear resistance treatment according to the slope angle, extracted from (www.zinco-greenroof.com)

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[112] http://www.zinco-greenroof.com/EN/downloads/pdfs/ZinCo_Intensive_Green_Roofs.pdf

[113] http://www.zinco-greenroof.com/EN/downloads/pdfs/ZinCo_Pitched_Green_Roofs.pdf

On the other hand, the substrate layer also has to be protected from erosion. Thus the choice of plants and their application must be compatible with the roof pitch angle and the level of exposure.

From that, Shear forces are to be derived into stable eaves edgings and – if necessary – into additional shear barriers using load absorbing elements. Also due to the faster water runoff on pitched roof areas the substrate layer needs to be increased; the possibility of an additional irrigation should be given[114]. To prevent erosion on pitched roofs, plants should be applied with a higher density; in case of a steep pitch Precultivated vegetation mats are recommended.

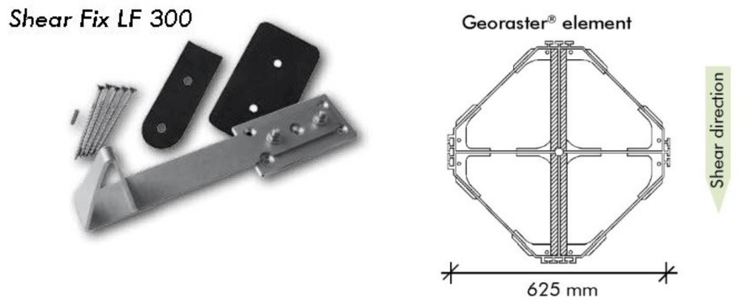

Figure 231 Examples for shear resistive fixtures, taken from (www.zinco-greenroof.com)

Figure 230 Precultivated vegetation mats, taken from (www.zinco-greenroof.com)

6.2.1.4 Solar reflective index:

The Solar Reflectance Index (SRI.) is a measure of the roof's ability to reject solar heat, as shown by a small temperature rise. It is defined so that a standard black (reflectance 0.05, emittance 0.90) is 0 and a standard white (reflectance 0.80, emittance 0.90) is 100. For example, the standard black has a temperature rise of 90°F (50°C) in full sun, and the standard white has a temperature rise of 14.6°F (8.1°C). Once the maximum temperature rise of a given material has been computed, the SRI can be computed by interpolating between the values for white and black.[115]

In addition to the Green roof high reflectivity, White ballast with SRI 84 will be used, with respect to the LEED guide lines.

COLOR	Solar Reflectivity	Emissivity	SRI
Almond	67.10	0.90	82
Aged Bronze	29.66	0.86	30
Antique Copper Cote	29.30	0.85	29
Award Blue	17.20	0.83	12
Natural White	75.93	0.84	93
Bristol Blue	30.30	0.86	31
Buckskin	39.71	0.86	43
Burgundy	30.05	0.85	30
Champagne	34.95	0.85	36
Charcoal Gray	29.64	0.87	30
Colonial Red	33.03	0.85	34
Copper Brown	29.57	0.87	30
Copper Cote	45.24	0.87	51
Dark Bronze	28.20	0.91	30
Deep Red	38.54	0.84	41
Forest Green	29.08	0.85	29
Hartford Green	28.20	0.90	30
Hemlock Green	30.92	0.83	30
Lead Cote	32.90	0.90	35
Matte Black	28.70	0.91	30
Medium Bronze	31.39	0.85	32
Parchment	51.72	0.83	58
Patina Green	34.42	0.86	36
Preweathered Galvalume	33.61	0.80	32
Royal Blue	29.90	0.90	32
Shasta White	60.00	0.84	70
Sierra Tan	34.81	0.84	36
Teal Green	28.10	0.89	29
Terra Cotta	31.66	0.83	31
Zinc Cote	52.45	0.87	61
Zinc Grey	37.88	0.84	40
Satin Finish Galvalume	74.00	0.14	67
Acrylic Coated Galvalume	67.00	0.06	55

Figure 232 SRI according to color, extracted from (www.houstoncoolmetalroofs.com)

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[114] http://www.zinco-greenroof.com/EN/downloads/pdfs/ZinCo_Pitched_Green_Roofs.pdf

[115] http://energy.lbl.gov/coolroof/ref_01.htm

6.2.2 Slabs

6.2.2.1 Earth labyrinths construction

As previously explained, the thermal Labyrinths strategy is simply based on the idea of exchanging the temperature with the earth thermal bank, to provide pre-heated/pre-cooled air.

However, with respect to the health regulation of Italy, the basement slab should be provided with a raised ventilated under floor cavities to protect the inner spaces from the Vapor, Humidity, Methane and Radon which are emitted by the soil. We can conclude that air extracted from the layer adjacent to the soil cannot be used for ventilation, as it contaminated.

Thus, another upper layer of cavities should be added in addition to a system of rough concrete walls with a high thermal mass to exchange heat/cool with the fresh air, noting that relevant Concrete walls will be charged with the earth heat/cool during the off hours.

This scheme can be constructed using a double layered modular system of **Iglu** Formwork technology with concrete walls in between, as clarified in the below sketch.

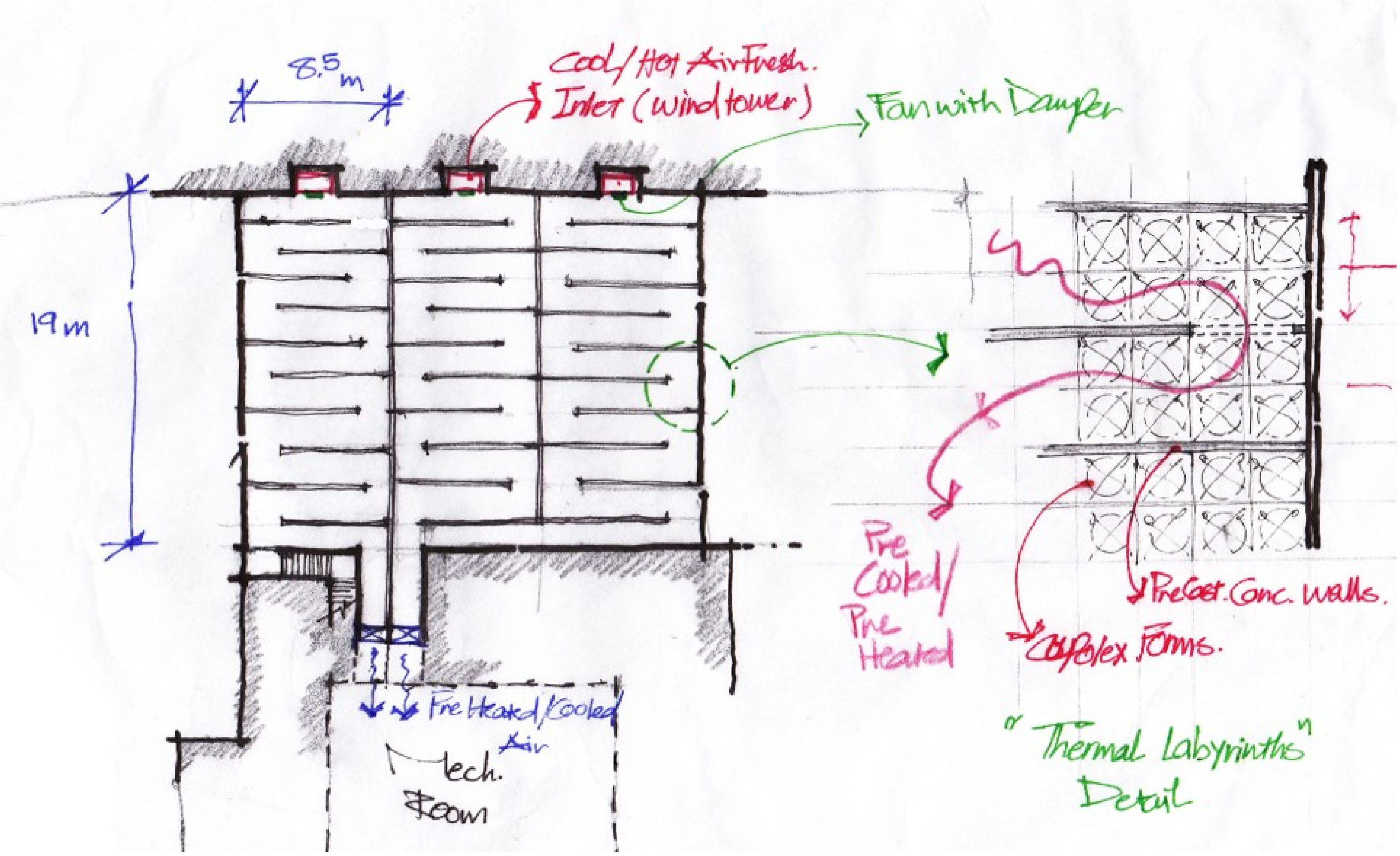

Figure 233 Detailing the Labyrinths using a combination of IGLU form work and modular non bearing concrete walls

The usage of this type of formwork which is made from 100% recycled plastic has additional economical and environmental benefit, which is minimizing the used amount of reinforcement and concrete while giving the same compressive strength[116] and performance , as well as minimizing the building loads.

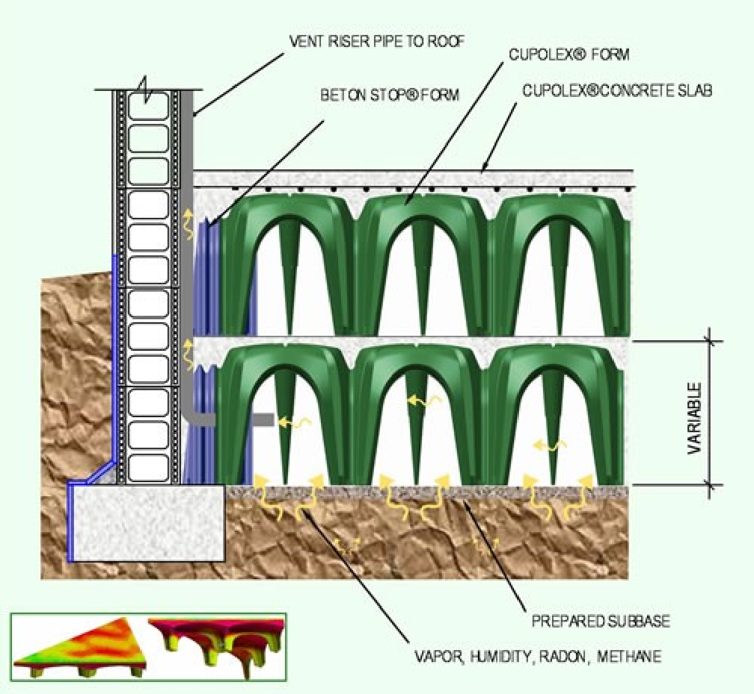

Figure 234 IGLU Form work system with 2 layers, extracted from (www.cupolex.ca)

Figure 235 Thermal labyrinths concrete walls, taken from (www.y2architecture.com.au)

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[116] http://www.cupolex.com/

6.2.3 Walls

6.2.3.1 Vegetated living walls:

With respect to the previously mentioned benefits of the Green walls in the architectural chapter, from the technical point of view there are two main types which can be applied, as per one of the top manufactures **gsky**:

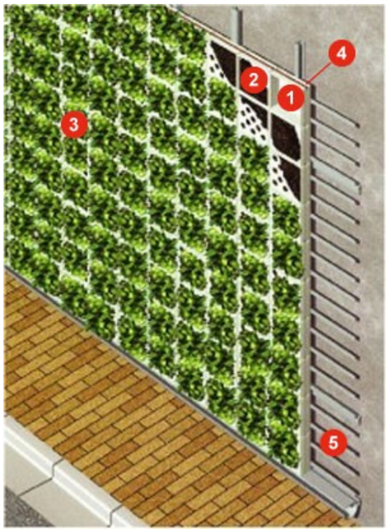

Figure 236 Soil modules, extracted from (www.gsky.com)

A-Vertical Soil Modules: it is a flexible modular system which can be installed on virtually any outdoor surface in any hot or cold climate, and it can resist heavy winds, wind drive rain and earthquakes. The system consists of five main components[117] :

1. Panels fixed to the wall mounted stainless steel chassis.
2. Non-Soil Structural Growth Medium which is non-eroding to ensure plant longevity.
3. Plants were grown into the panels for several months before shipped to the site.
4. Remote Irrigation/Fertilization System which is computerized vertical drip irrigation system with temperature and moisture sensors.
5. Stainless Steel Frame Wall Mounting System which allows panel removal for inspection as needed.

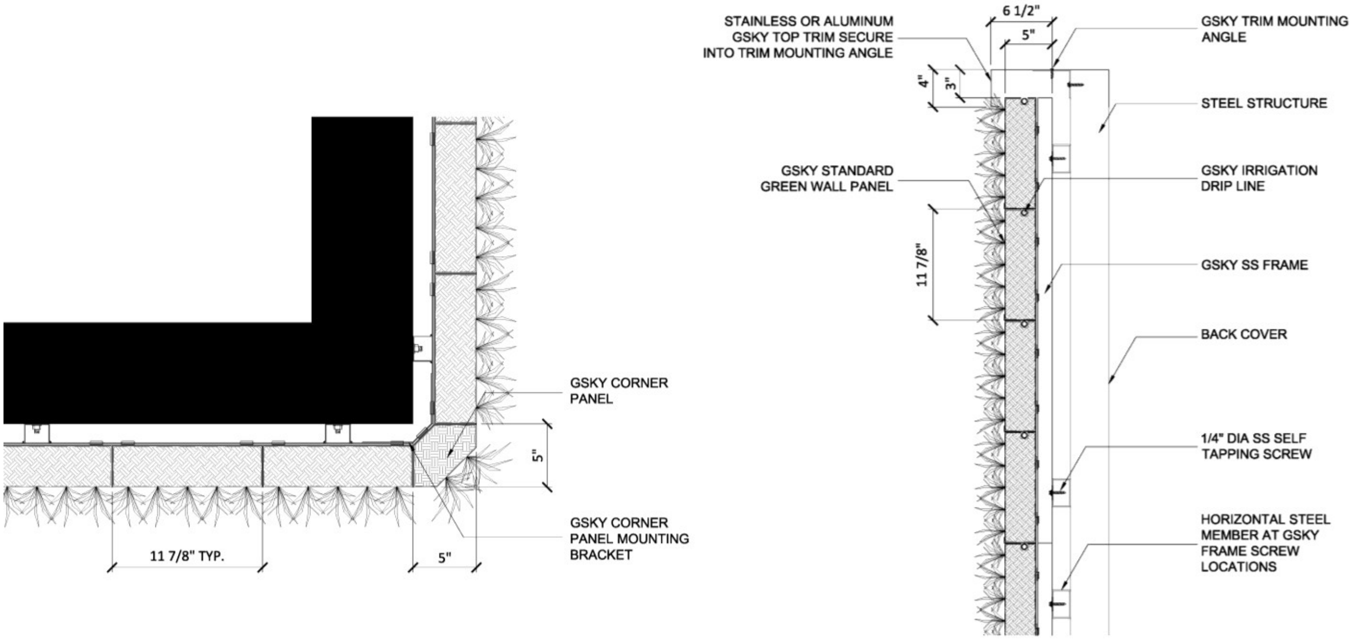

Figure 237 Soil modules plan and section details (www.gsky.com)

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[117] http://gsky.com/green-walls

B-Containers Wall System is made up of a floating stainless steel planter (vine container) system that safely trains vines over a building facade. Vine Containers can be considered the most efficient way to achieve the needed lasting coverage, without risking damage to a building’s façade. The system is comprised of five main components[118]:

1. S.S Frame Containers
2. Insulated Container which can be provided with a heat-wire traced to ensure that the root ball doesn’t die from freezing shock in the fall and spring.
3. Optional Maintenance Catwalk
4. Remote Monitored Irrigation/Fertilization System which is provided with computerized vertical drip irrigation system with temperature sensors.
5. Flexible Wall Mounting System to allow inspection and replacement.

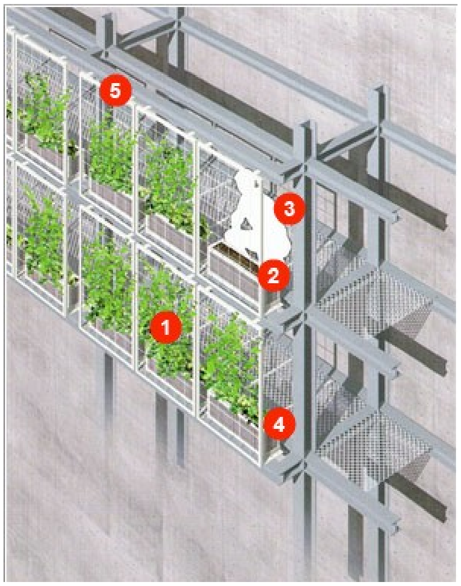

Figure 238 Containers and catwalk, extracted from (www.gsky.com)

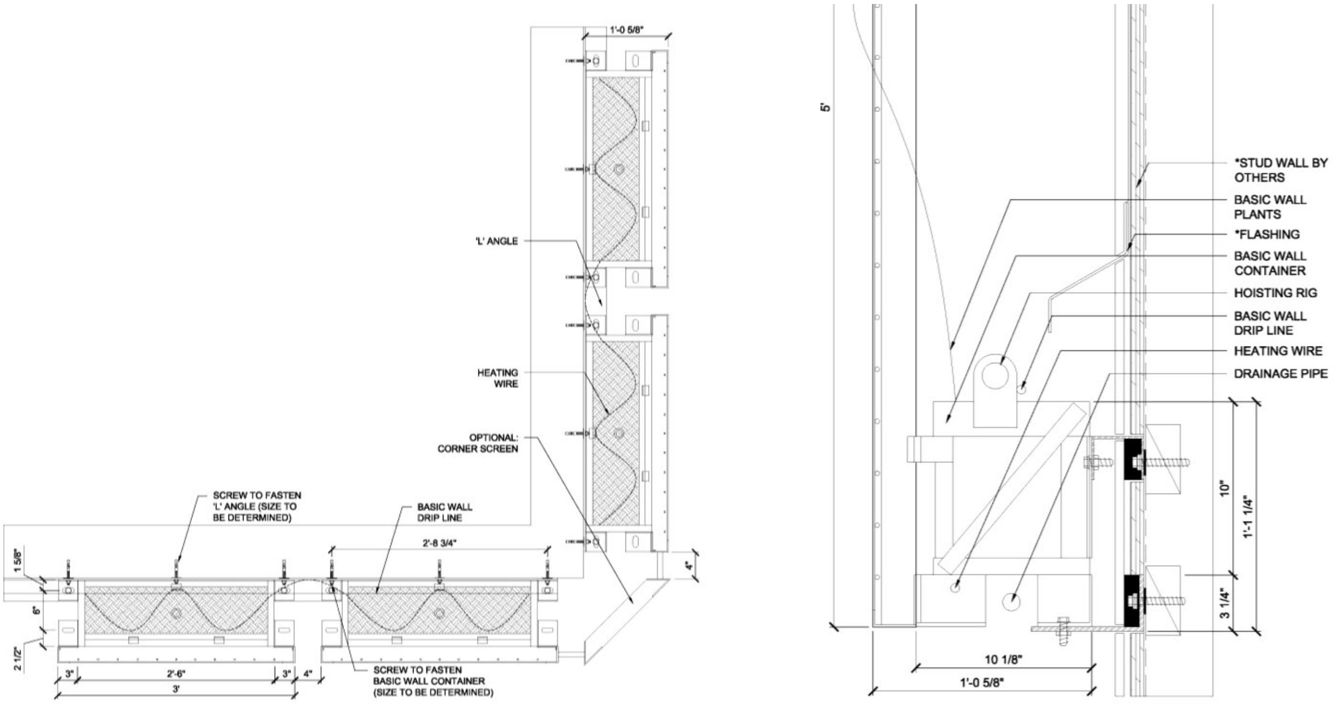

Figure 239 Container plan and section details (www.gsky.com)

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[118] http://gsky.com/green-walls

Both of the systems can act like an enlarged ventilated façade, which minimizes the thermal stress over the building, minimizes the energy consumption and extends the building life span.

On the other hand by comparing the two systems, we can find that the second solution is interacting better with the external climatic change, as during the cold seasons the leaves are falling, resulting in a low density green surface, which allows the sun to penetrate into the building openings and the ventilation cavity creating a heated buffer zone. Meanwhile, during the summer the leafy green surface will create a shaded buffer on the front of the openings and opaque surfaces.

In contrast, the first solution with the vertical soli modules provides a rigid opaque surface along the year seasons, in addition to the intensive drainage, irrigation and maintenance process needed to protect the façade from erosion and decay. Consequently, the second solution will be adopted, following the environmental and economical sustainability approaches.

6.2.3.2 TICF Retaining wall systems:

Figure 240 TICF blocks (www.durisolbuild.com)

The thermal Insulated concrete form is made from a proprietary cement-bonded wood fiber material that has only natural ingredients. ICF is composed of specially graded recycled waste wood (100% clean, natural softwood lumber).[119]

The blocks incorporate mineral fiber (Rockwool) insulation that is also non-combustible and moisture resistant. The influence of thermal insulating mass is maximized by positioning the insulated material towards the exterior, resulting in the creation of additional isolative shield. The total U-value is 0.19 [W/m²K], with respect to the concrete wall thermal mass.

Basically it is a green certified, lightweight, durable, vermin, termite and insect proof material, noting that it will not support fungus growth, so they do not rot nor decay.

With respect to its compressive strength, shear strength and rupture values, it is quite adequate for underground construction. Taking into consideration its advantage of facilitating the construction process as it is easy to cut, also faster will be pouring high-slump concrete with no need for vibration, as well as the complete avoidance of “honey-combing”, zero concrete blowouts.

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[119] http://durisolbuild.com/thermal-wall-forms-shtml/

6.2.3.3 Rain screen Fiber cement facades:

By using a Fiber cement boards cladding with a proper cavity behind, that upwards the flow of air flowing - activated by the solar radiation which heats the external surface of the Fiber cement cladding.

The cavity works like a barrier, as humidity flowing from the inner spaces is taken away, also the cavity disconnects the inner building skin from the external thermal and climatic stresses, which expands the building life span and minimizes the energy consumption.

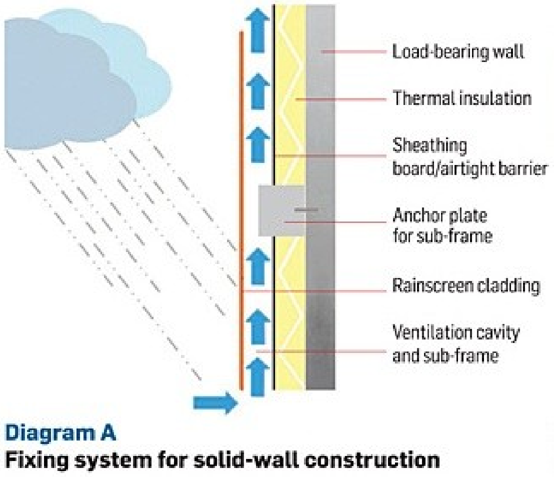

Figure 241 Rain screen facade components, extracted from (www.bdonline.co.uk)

Meanwhile, the fiber cement provides efficient environmental advantages; it is manufactured from a unique blend of Mineral Components (Cement, Quartz Sand, Fiber), and does not contain any toxic ingredients, asbestos, formaldehyde or ammonia[120]. In addition to being a fire and weather resistance, bug and mildew free, it has a good physical performance with acoustical behavior (between 44dB and 47 dB) and thermal behavior (thermal Conductivity of 0.216 W/m^{2}K).

6.2.3.4 EIFS systems:

Exterior Insulation and Finish Systems (EIFS) is multi-layered exterior wall, they are providing superior energy efficiency, maximum design flexibility, stabilization of the interior environment and envelope tightness, EIFS typically consist of the following components[121]:

- Insulation board, made of polystyrene or polyisocyanurate foam, which is secured to the exterior wall surface with a specially formulated adhesive and/or mechanical attachment
- A durable, water-resistant base coat, which is applied on top of the insulation and reinforced with fiber glass mesh for added strength
- An atheistic and durable finish coat, mostly from acrylic co-polymer technology which is both colorfast and crack-resistant.

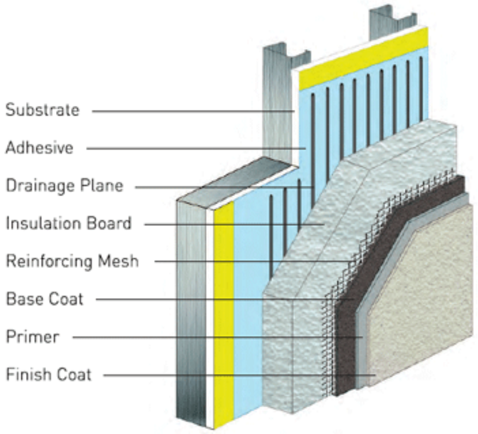

Figure 242 EIFS components, extracted from (www.eima.com)

With respect to its U-value of 0.0625 [W/m²K][122], the avoidance of thermal bridging is completely guaranteed, since it literally works as an external wrapping for the envelope as an energy-efficient thermal blanket.

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[120] http://www.arsenalas.lt/en/ventilated_facades/fibra_cementinio_fasado_plokstes/
[121] http://www.eima.com/eifs-features-benefits.shtml

6.2.4 The Meditation Room construction:

Keeping in mind the general strategy previously explained in the architectural chapter, the unit designed to behave differently according to the external climatic conditions using the living smart skin technique, to improve the indoor environment quality as well as minimizing the energy consumption. Taking into account that the project economical feasibility is considered as one of the main aims, so the challenge was how to optimize the performance using Non ultrahigh-tech materials, and referring to the commercial non-customized products.

Also by considering the humanization factor, the creation of a space which takes advantage of all of the inner space human comfort and guaranties the full connectivity with the external nature was our target, to be able to give the impression that one is relaxing completely isolated in the middle of the outdoor park but with full controllability of filtering the weather.

Thus, designing the terrace as an external translucent buffer zone was the solution, with a full controllable envelope, which maximizes the passive behavior of the unit and minimizes the thermal stress over the inner envelope, as well as maximizing the interaction with Park.

The wall section will introduce the proposed construction solutions to satisfy the previous mentioned criteria, with a clarification for the used materials thermal transmittance and tightness values. Also the proposed solution for the basement perforated ceiling will be shown to give a wider understanding about how the exhausted hot air will be collected in the basement common areas to be ventilated through the Oculus.

Further clarification regarding the Shading sizes and terrace dimensions will be provided in the simulation chapter, with respect to their influence on the daylight and heating/cooling loads.

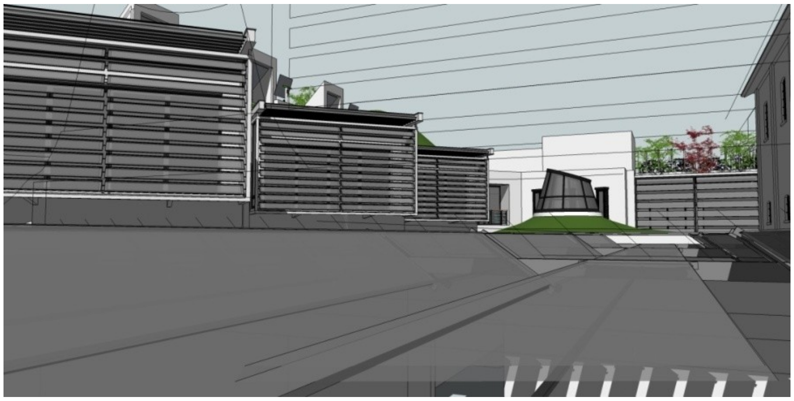

Figure 243 Meditation units external view

6.2.5 The Proposed Technological solution drawings

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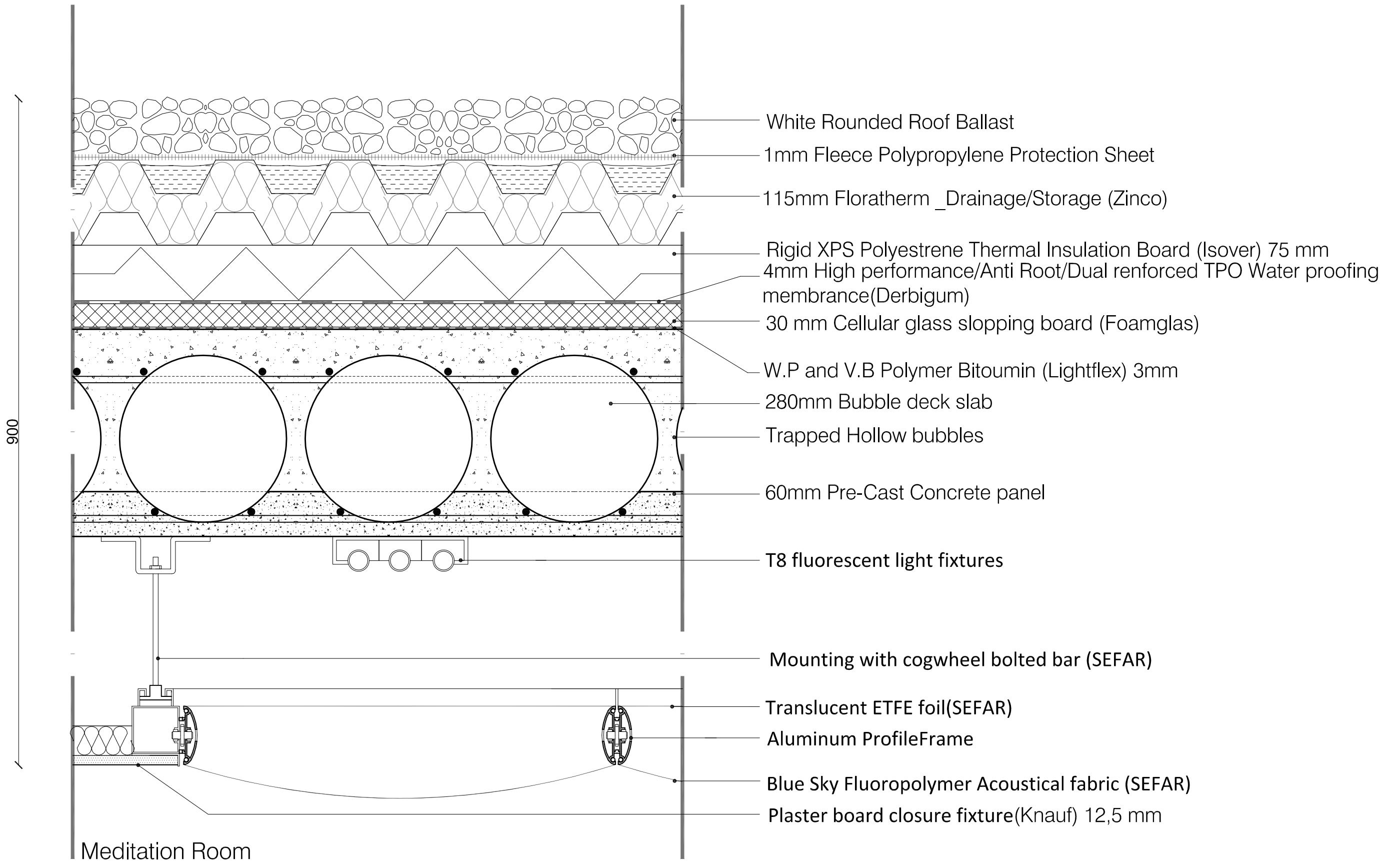
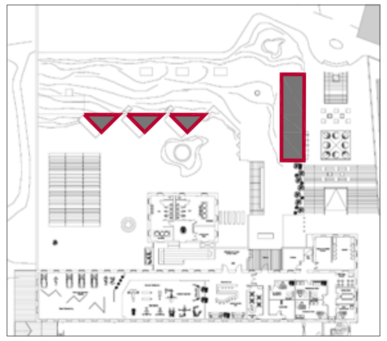
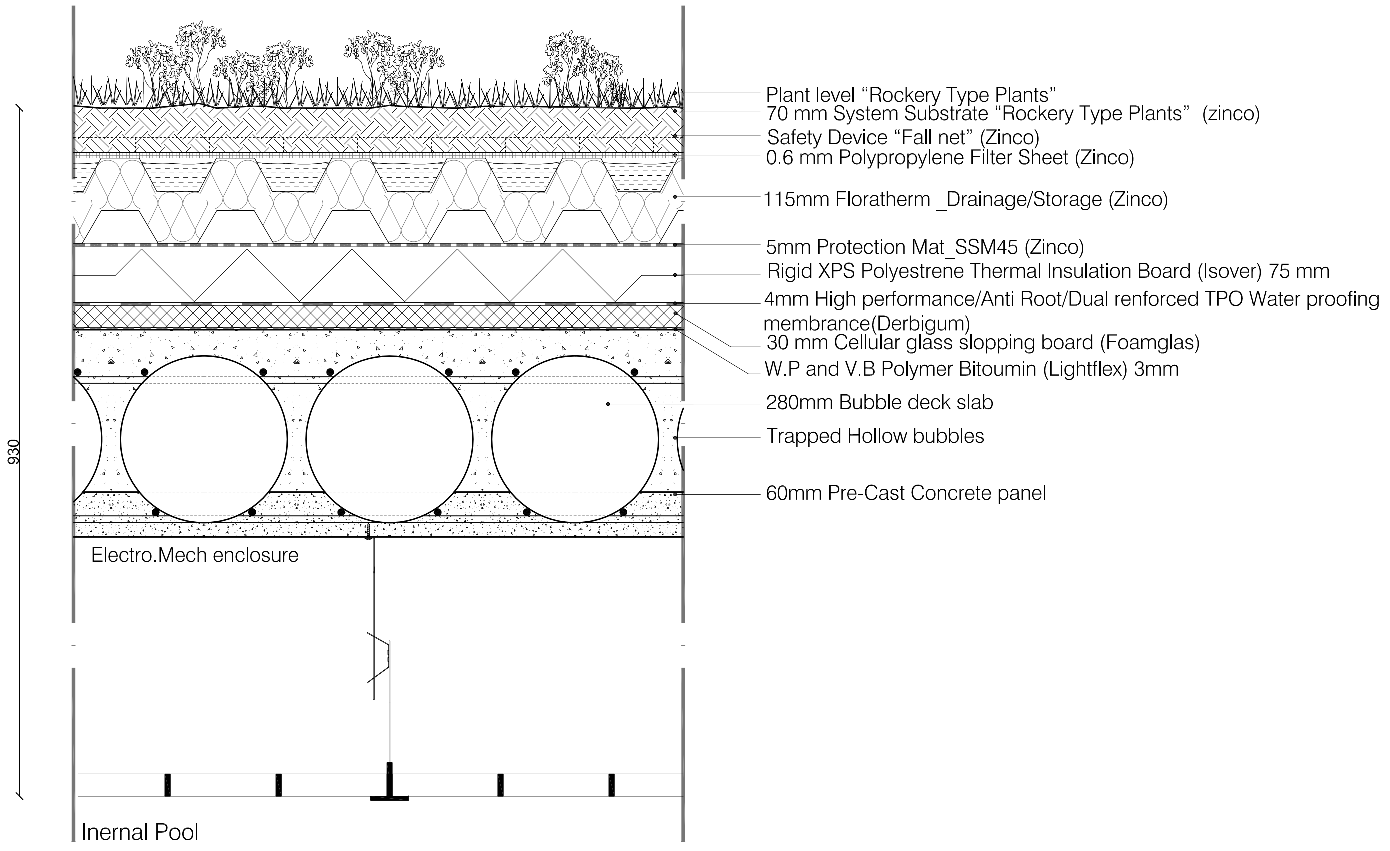
[122] http://www.ecowho.com/tools/r_value_to_u_value_calculator.php



Flat Extensive Ballast roof
U-value=.18 W/m$_2$K

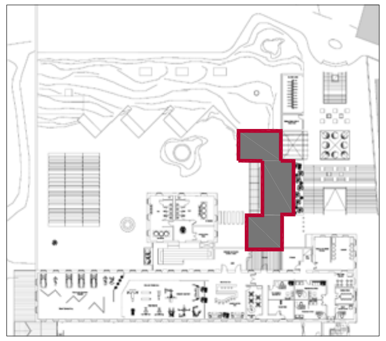
R01





Flat Extensive Green roof
U-value=.17 W/m$_2$K

R02



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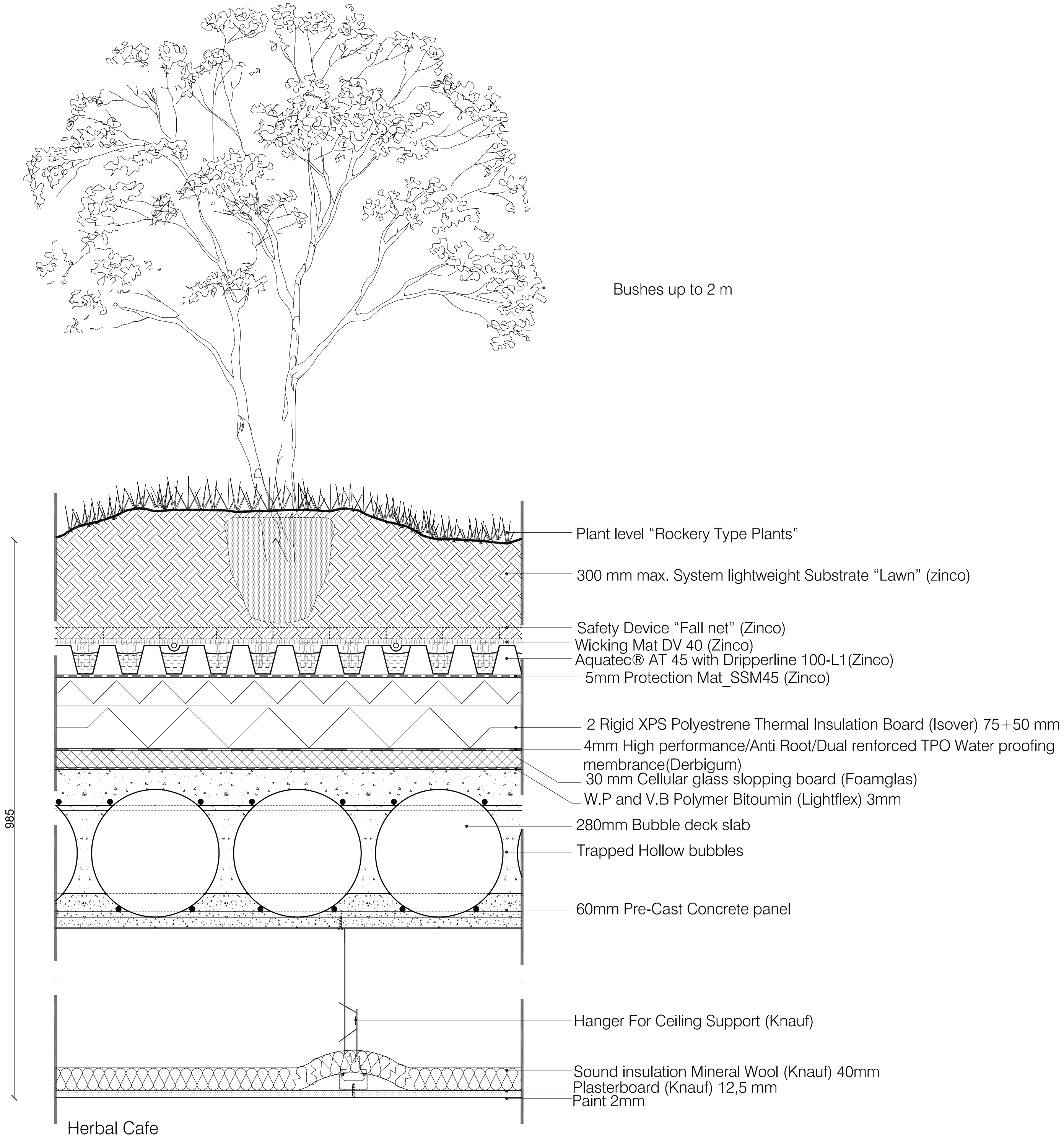
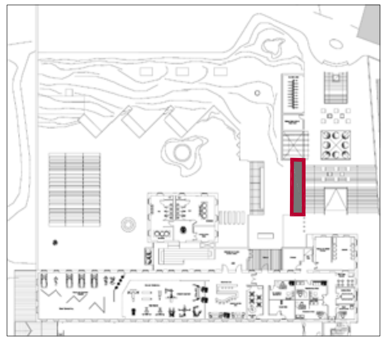
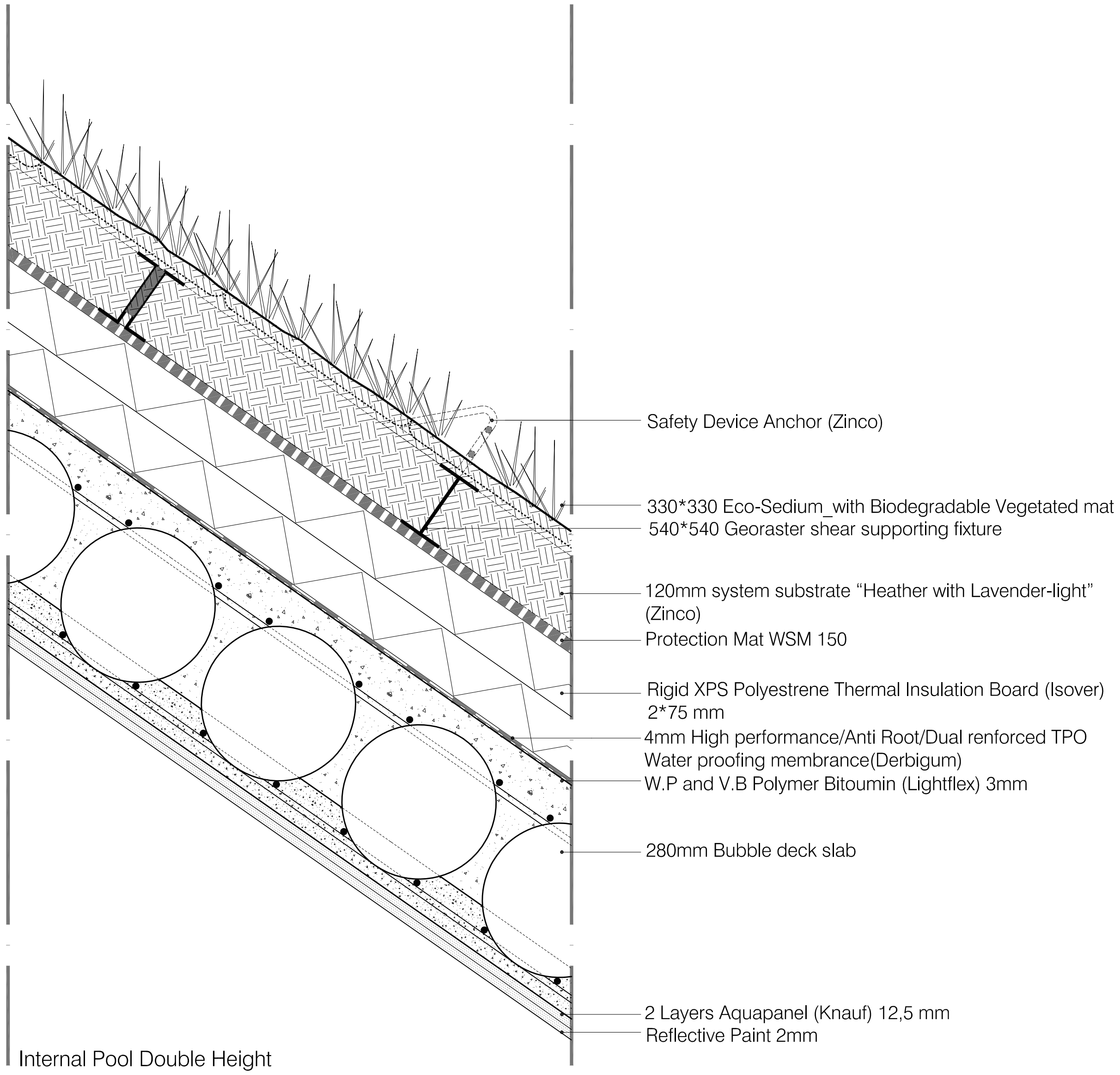
T.S 01



Flat Intensive Green roof
U-value=.19 W/m$_2$K

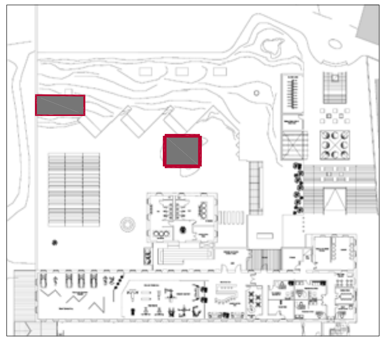
R04





Sloped Extensive (35°) Green roof
U-value=.19W/m$_2$K

R03



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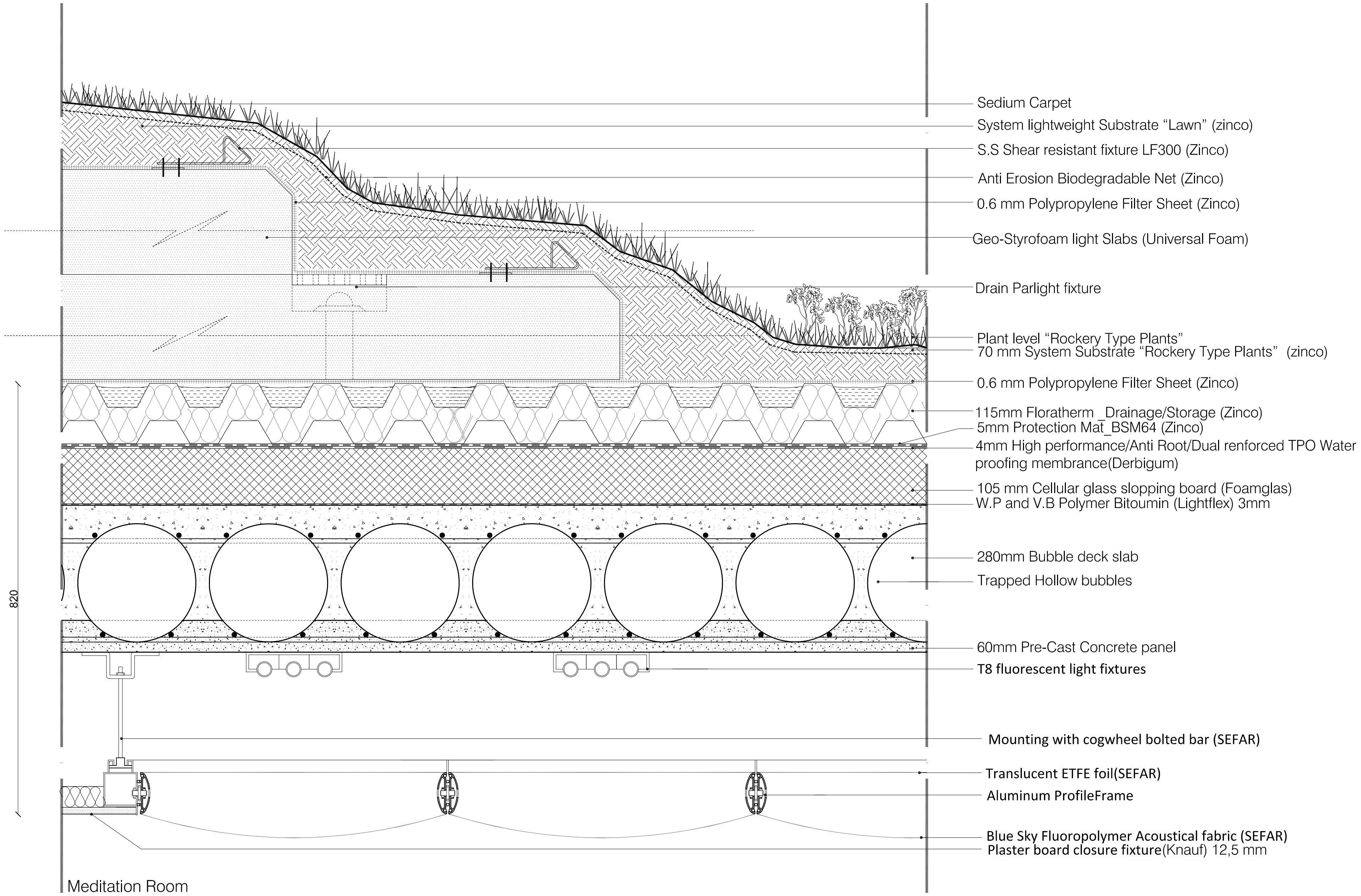
T.S 02

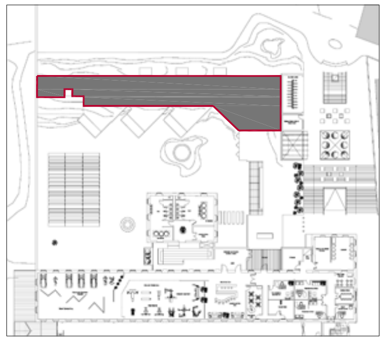


Sloped Semi-intensive (15°-20°) Green hill

U-value=.05 W/m2K_at Min. Height

U-value=.02 W/m2K_at Max.Height

R05



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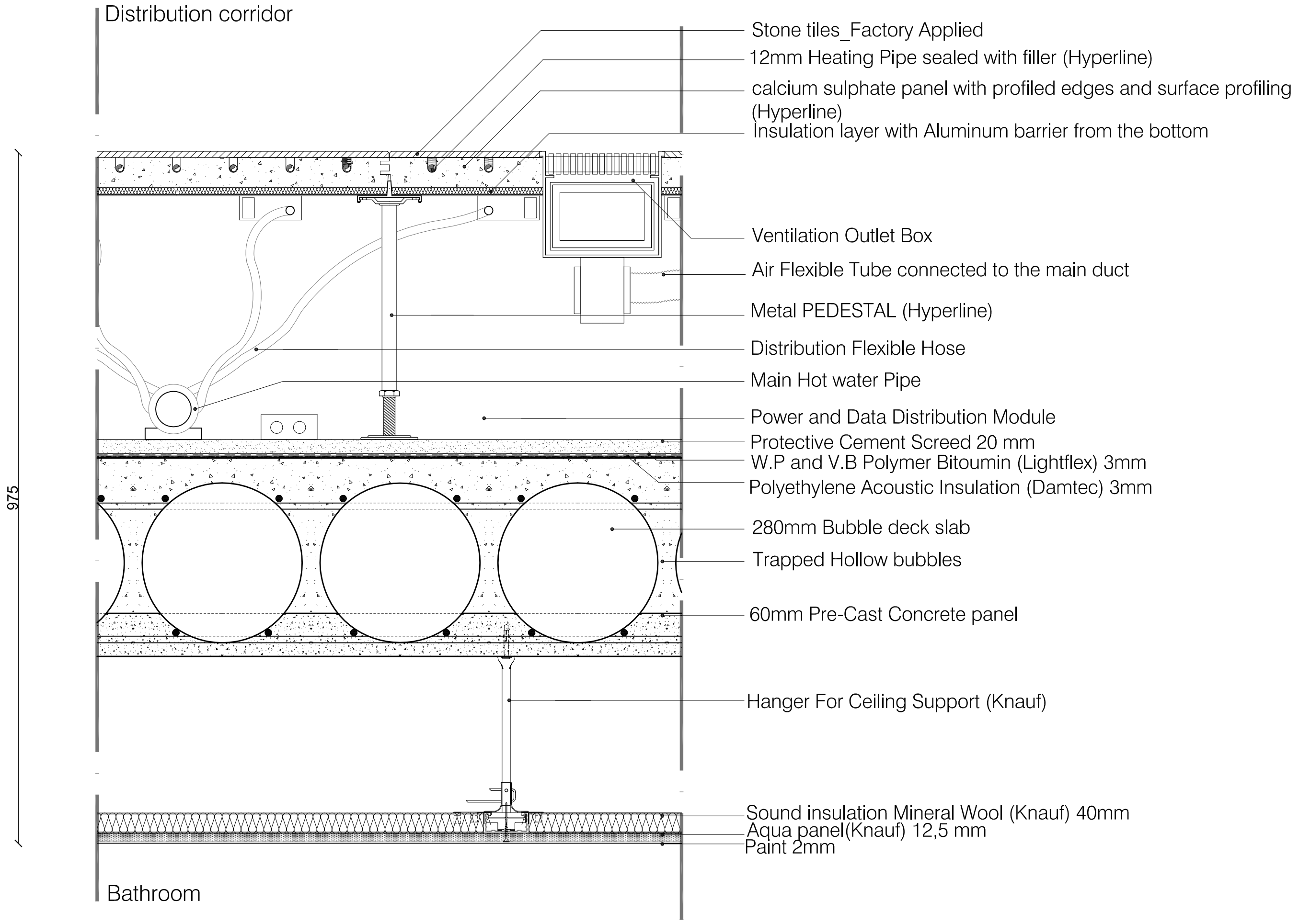

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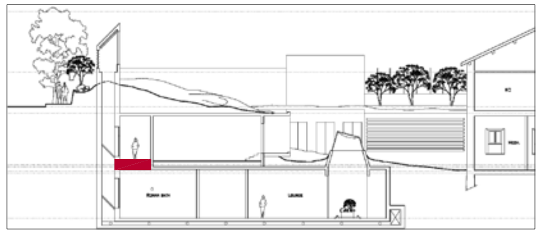

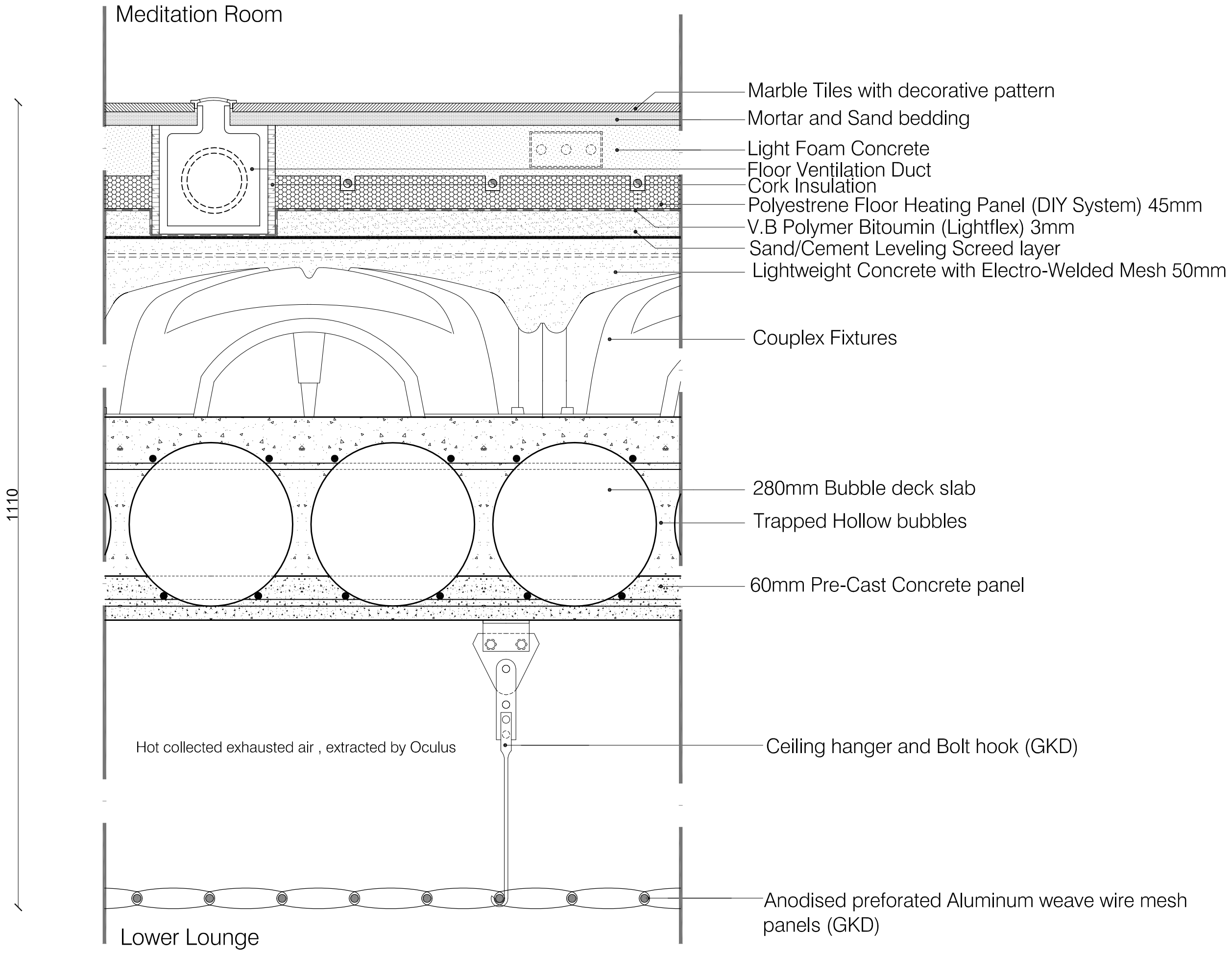

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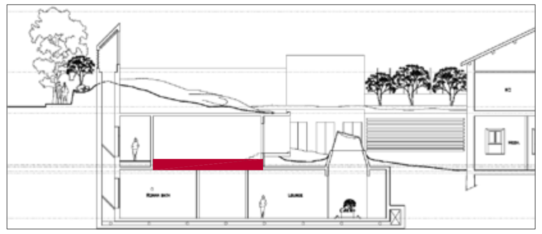

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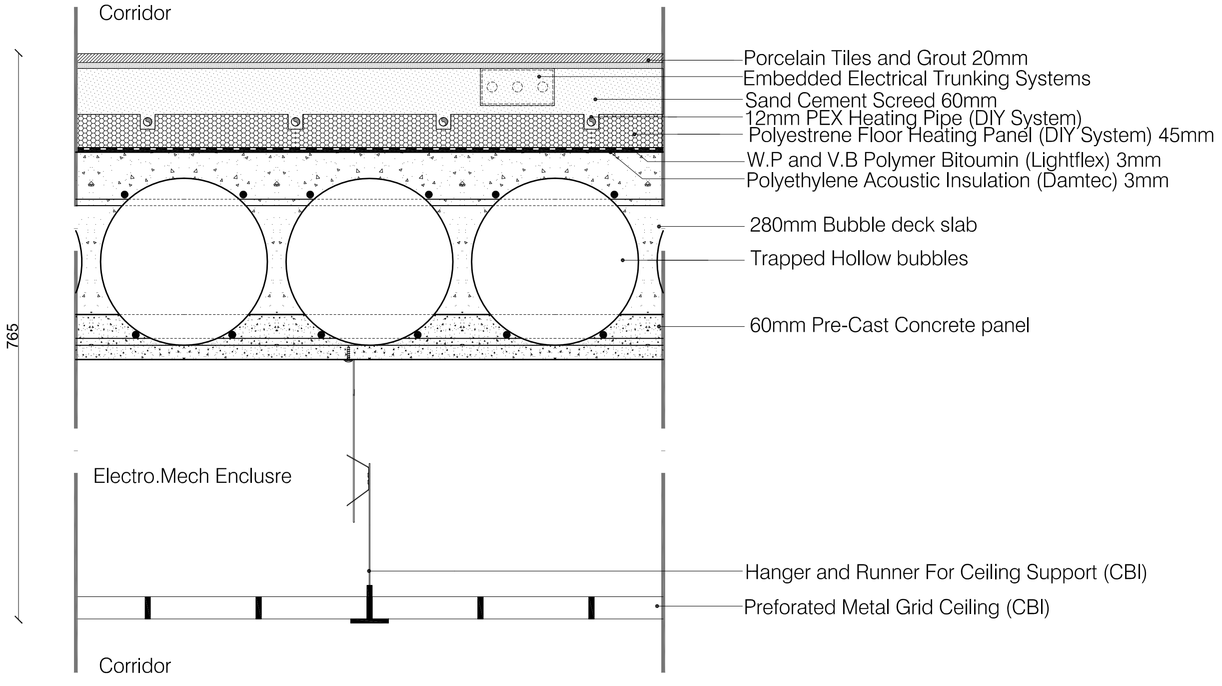

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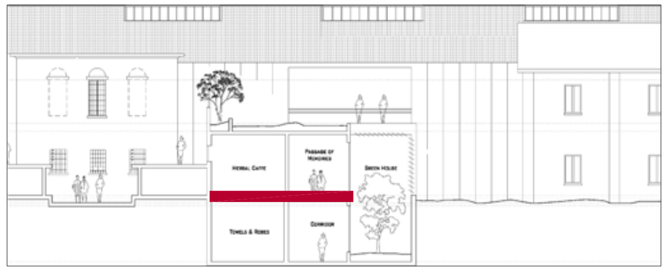

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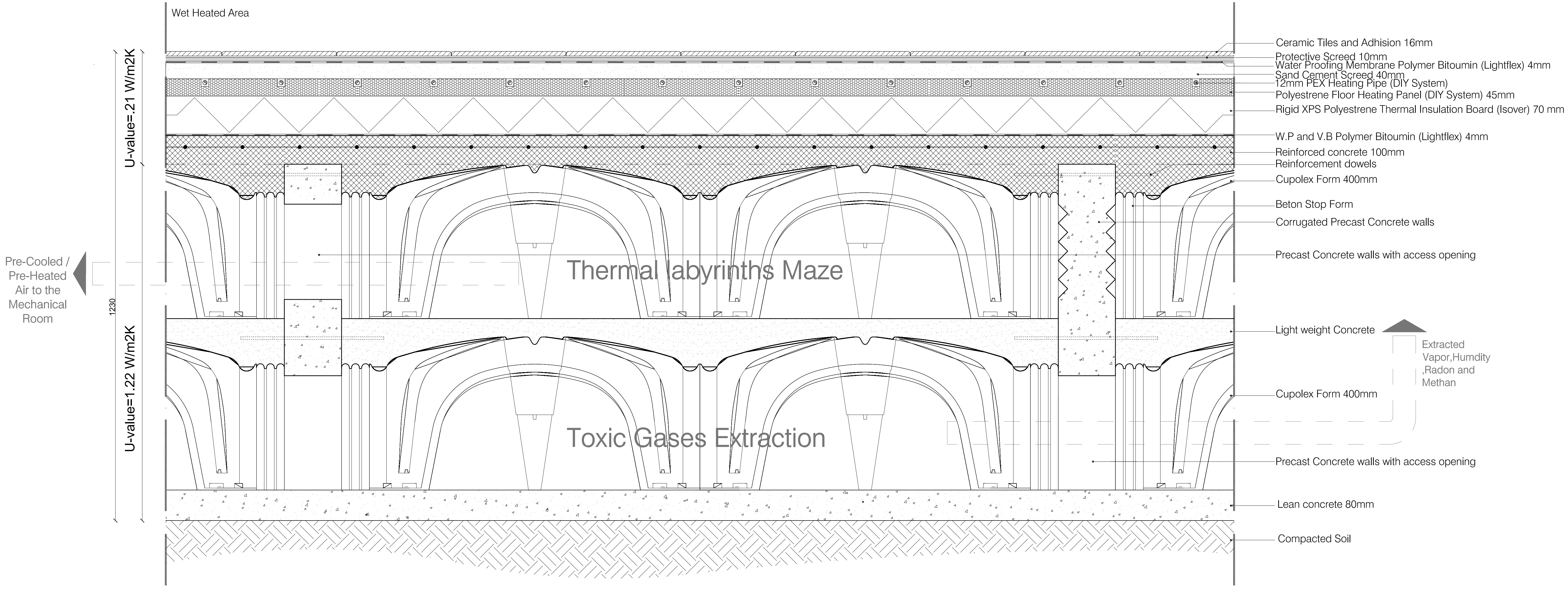

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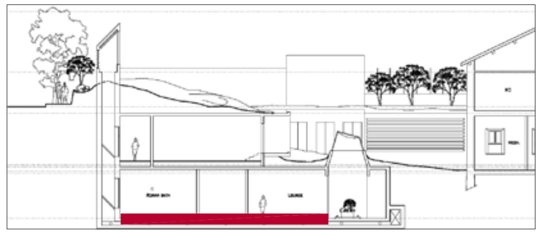

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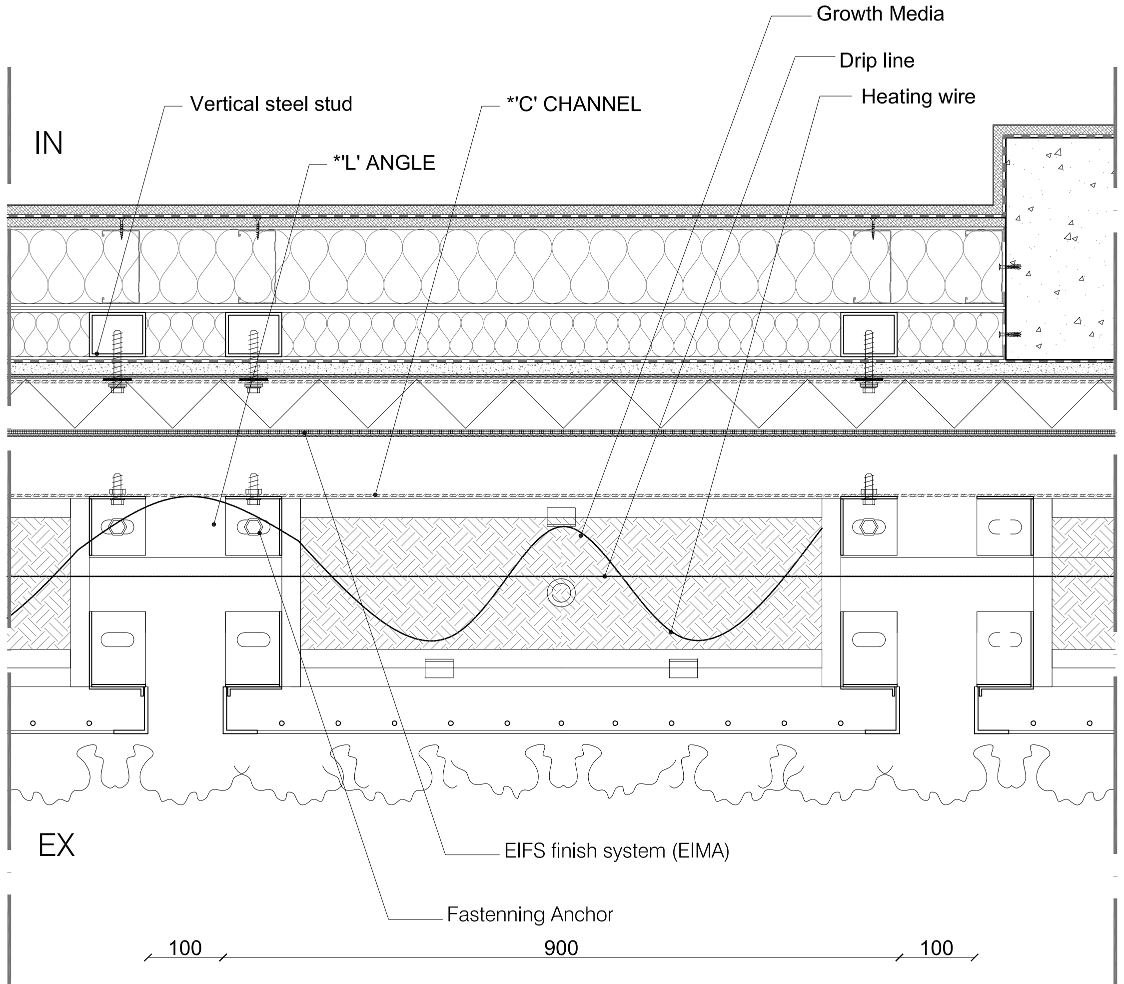
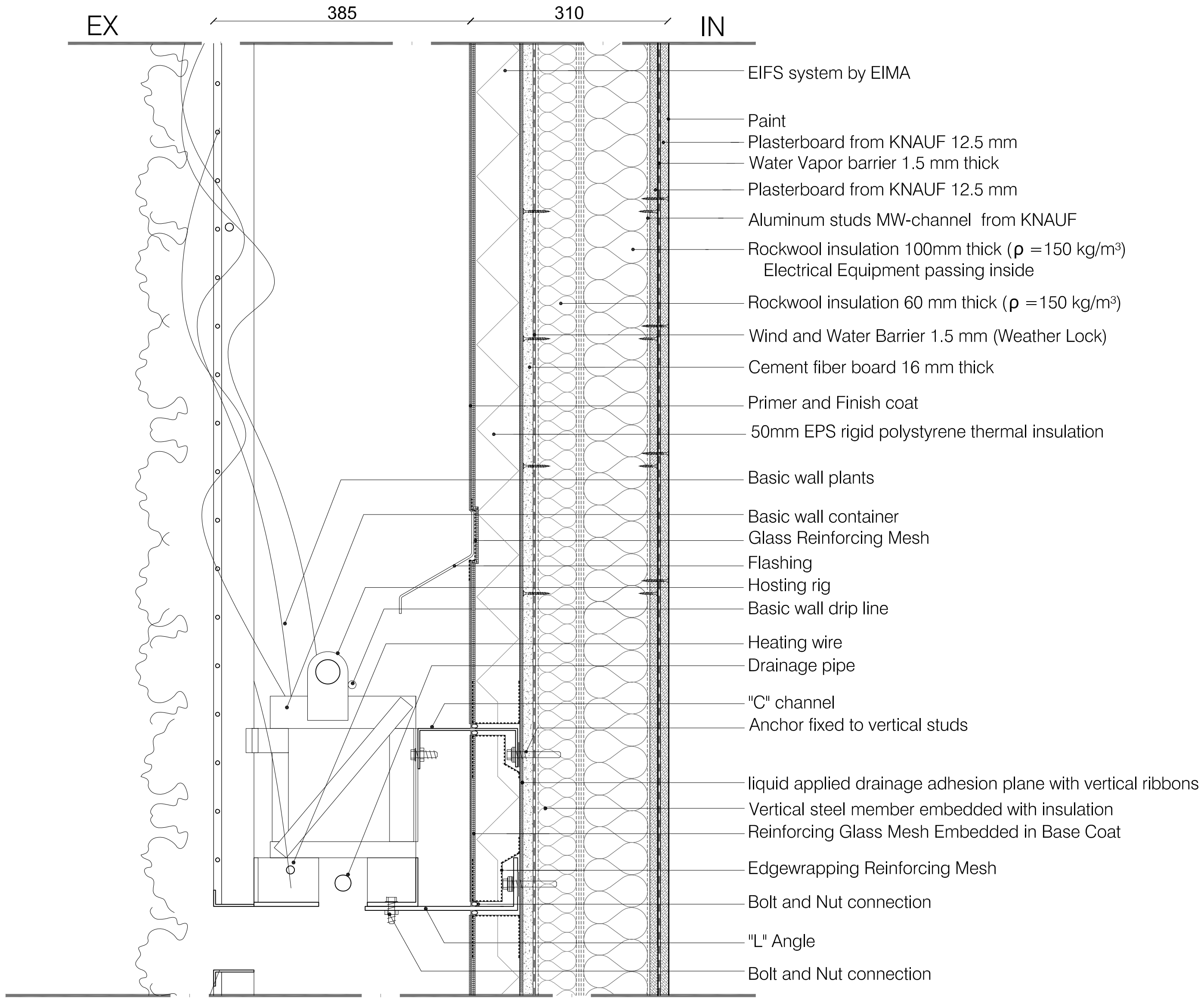


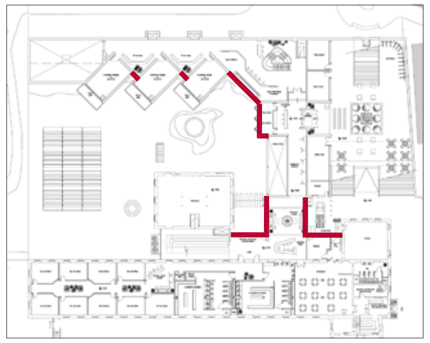
Plan



Section

U-Value 0.15 W/m2.K

W01



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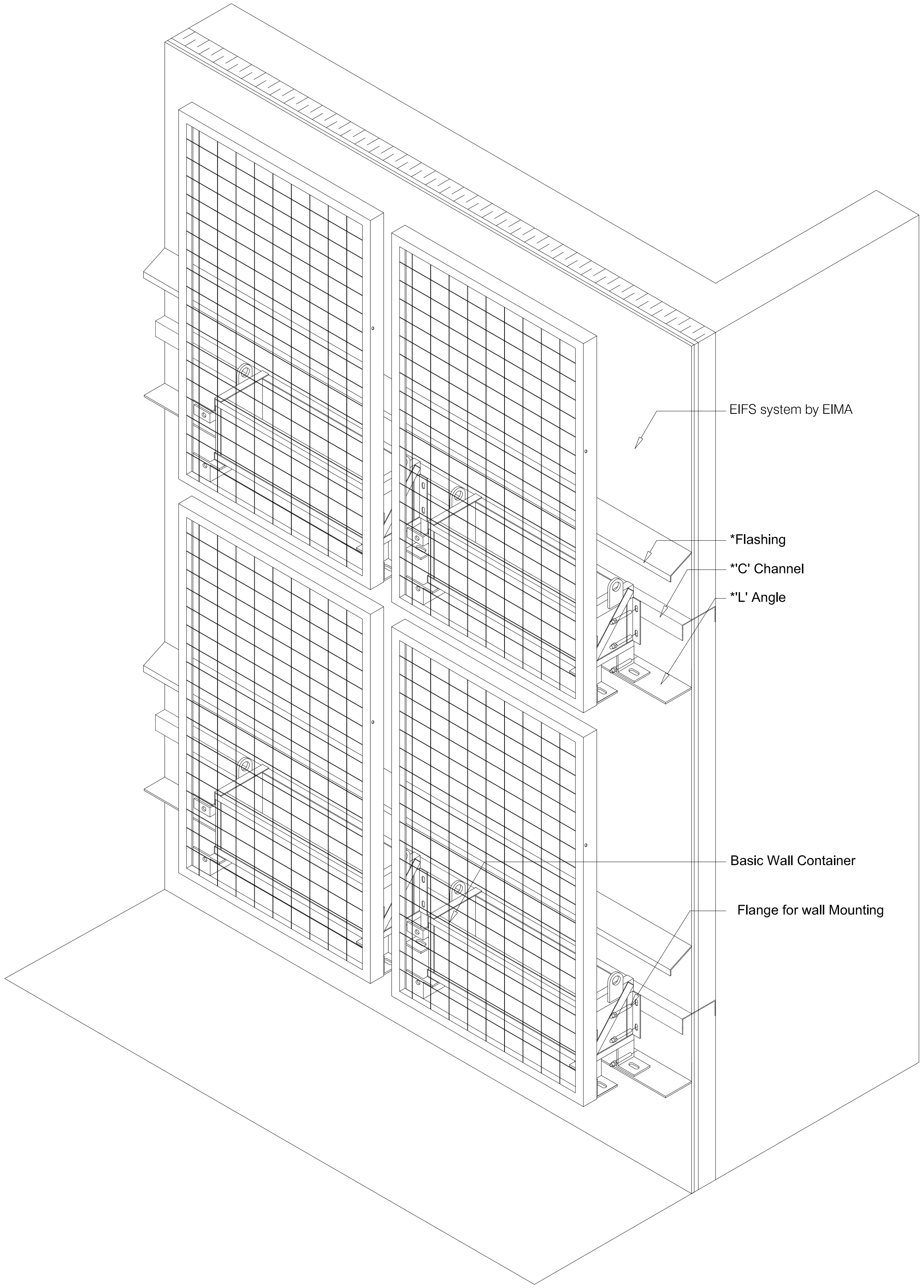
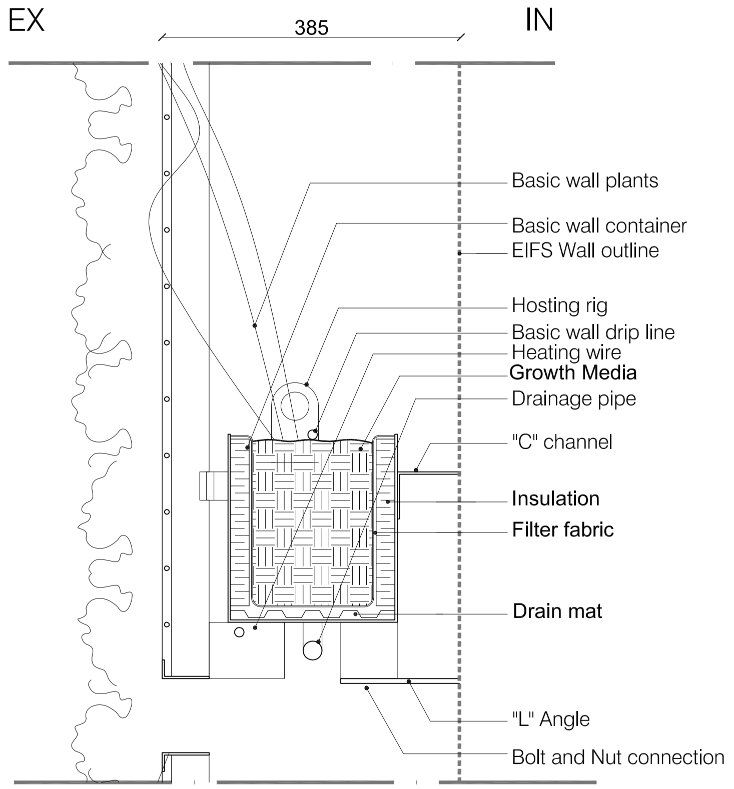
T.S 07





Section

W01

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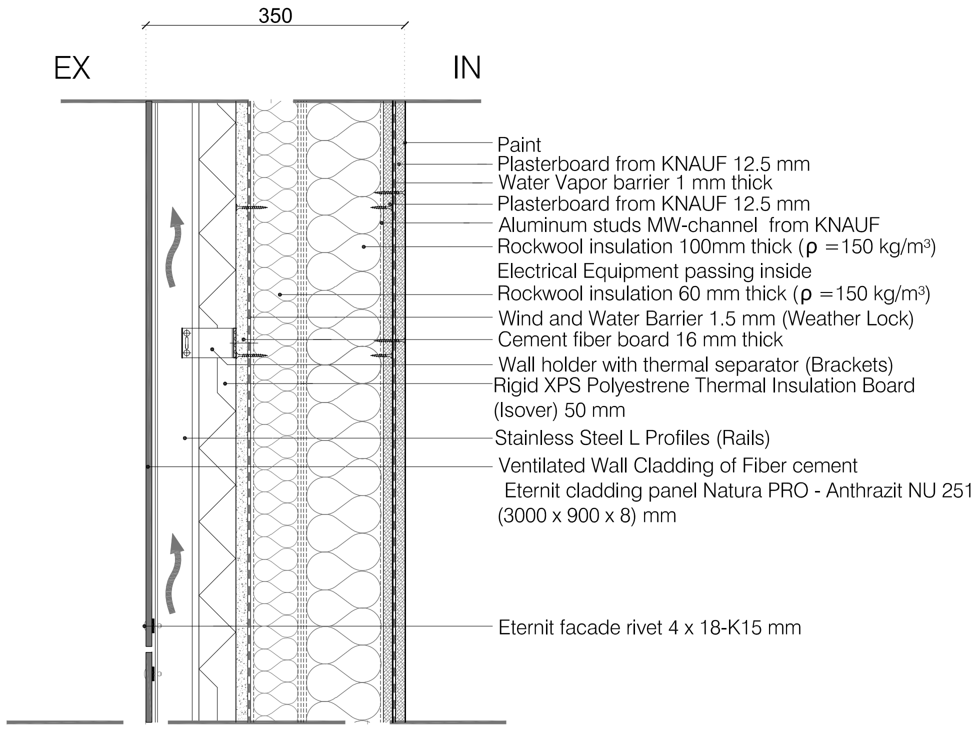
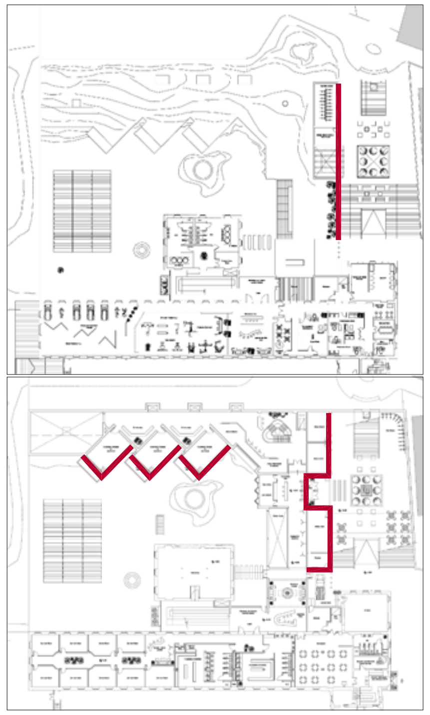
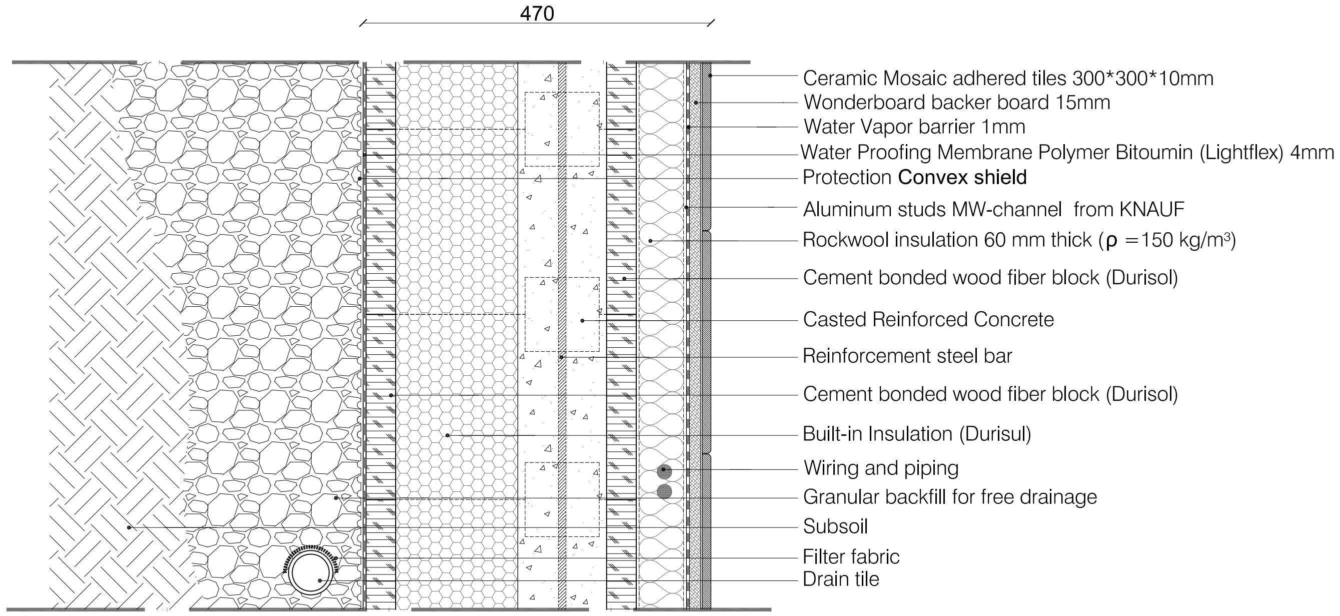
T.S 08



U-Value 0.15 W/m2.K

W02





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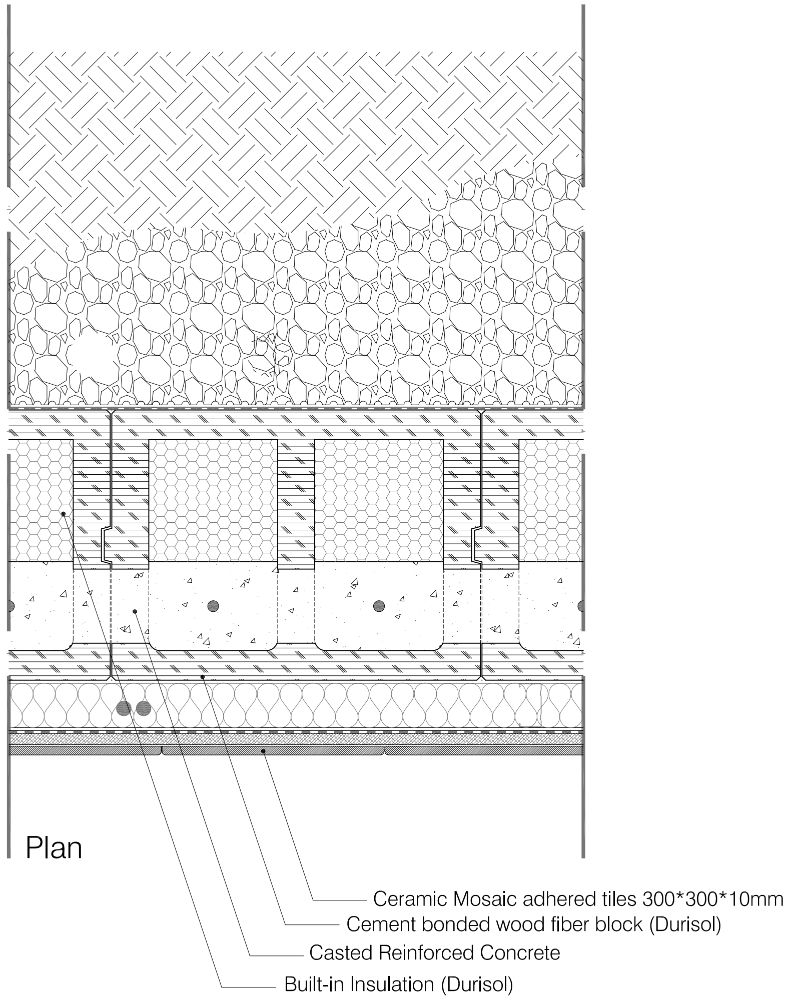
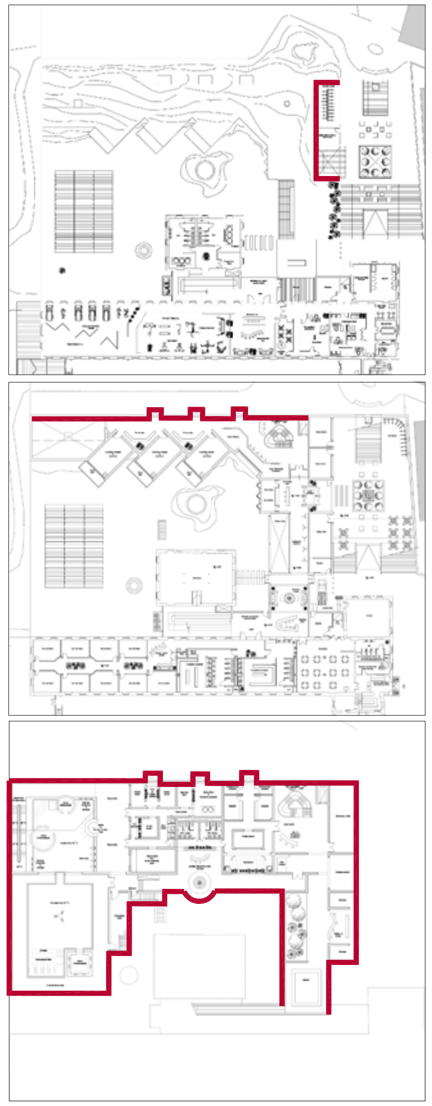


U-Value 0.19 W/m2.K

W03



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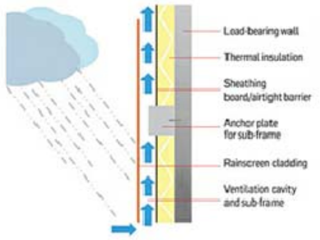
T.S 09

LIVING COOL ROOF

HIGH SOLAR REFLECTIVE INDEX + RAINWATER HARVEST + INSULATION + LIFE SPAN

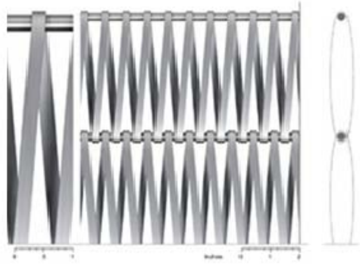
VENTILATED THERMAL BLANKET

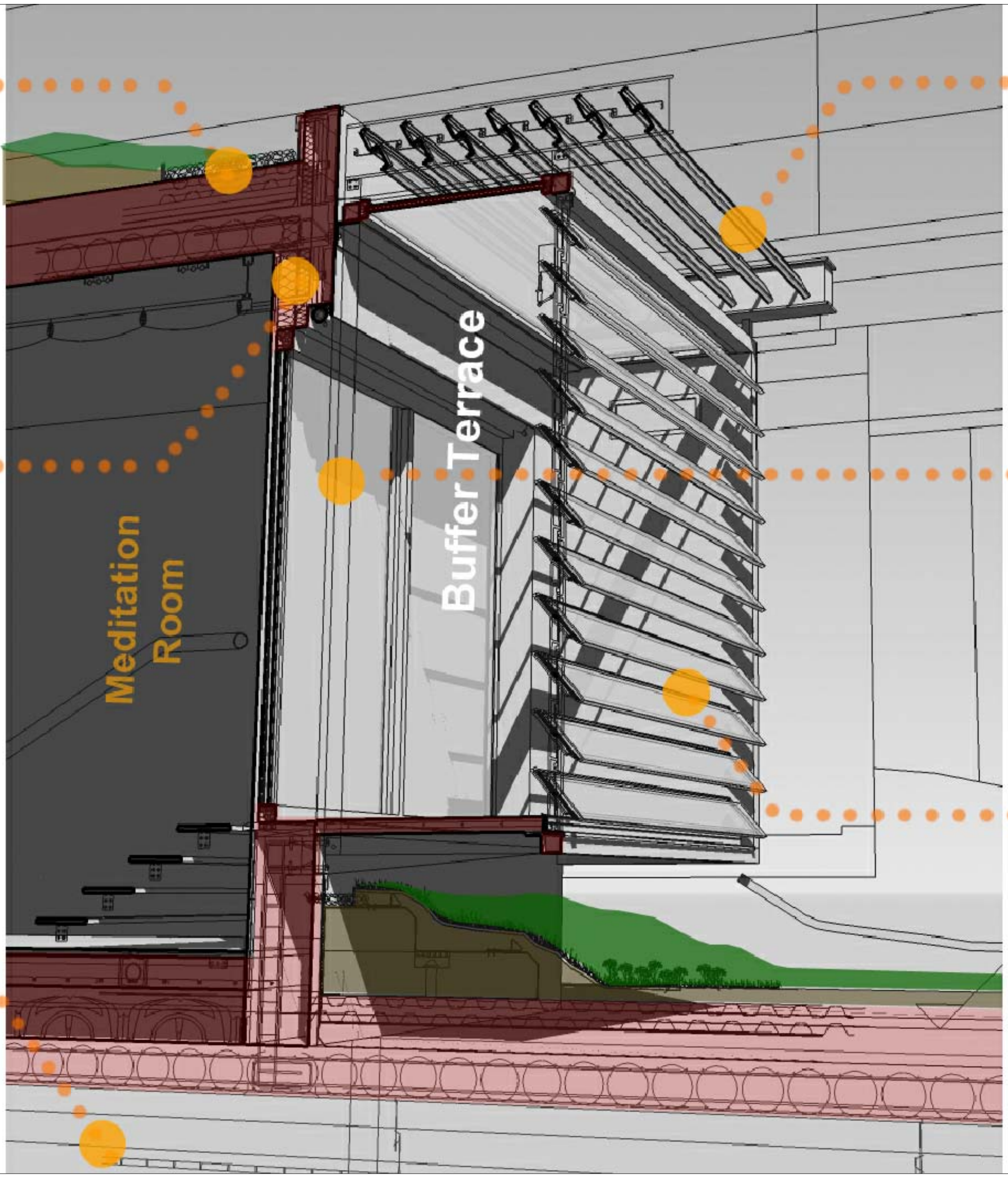
DISCONNECTTING THE EXTERNAL THERMAL AND CLIMATIC STRESSES + INTERIOR ENVIRONMENT STABILIZATION



WEAVE WIRE MESH

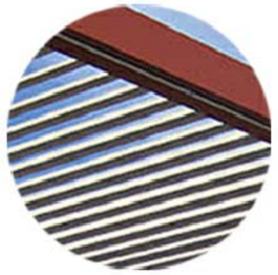
EXHAUSTED HOT AIR (NATURALLY) COLLECTED/EXTRACTED OUT OF BREATH ZONE

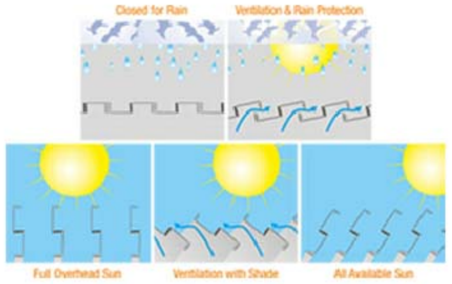




ADJUSTABLE ALUMINUM LOUVERS 180°

SHADE+HEAT GAIN+RAIN COLLECTION





FOLDED GLAZED WALL

FLEXIBILITY +W.TIGHTNESS+SILANCE+INSULATION

IGU_UG=1.1W/M²K
(THERMAL BREAK + WEBS + FOAM CORE) INSULATED
FRAM_UW = 1,2 W/M²K

MOTORIZED LOW-E GLAZED LOUVER BLADES

TRANCEPERANCY+SHADE+VENTILATION+ WEATHER SEALING

UG=4.1 W/M²K
AIR PERMEABILITY CLASS 1 - 19,5M³/HM²

Meditation Room skin

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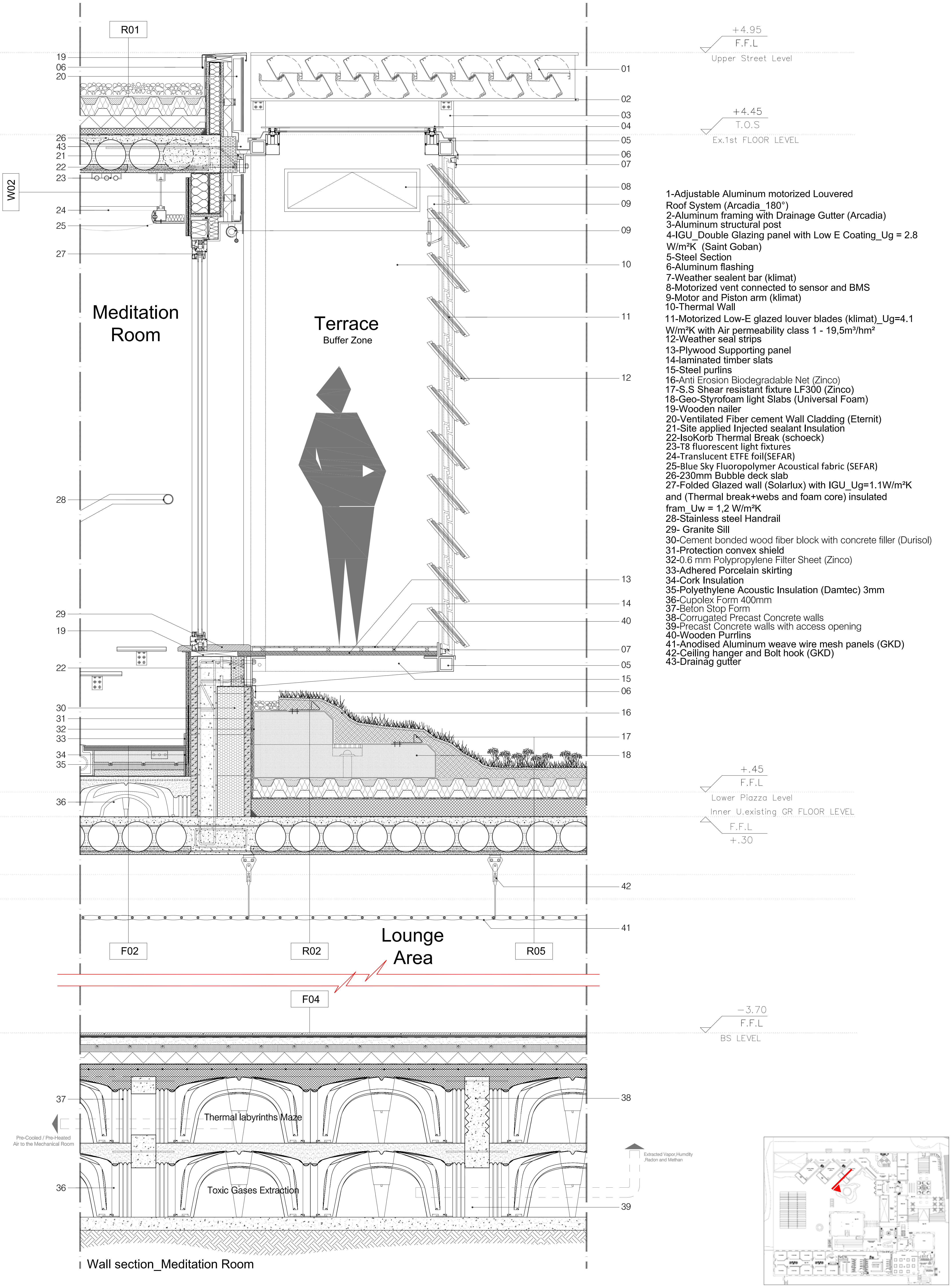
T.S 10


Wall section_Meditation Room

1-Adjustable Aluminum motorized Louvered Roof System (Arcadia_180°)
2-Aluminum framing with Drainage Gutter (Arcadia)
3-Aluminum structural post
4-IGU_Double Glazing panel with Low E Coating_Ug = 2.8 W/m^{2}K (Saint Goban)
5-Steel Section
6-Aluminum flashing
7-Weather sealent bar (klimat)
8-Motorized vent connected to sensor and BMS
9-Motor and Piston arm (klimat)
10-Thermal Wall
11-Motorized Low-E glazed louver blades (klimat)_Ug=4.1 W/m^{2}K with Air permeability class 1 - 19,5m^3/hm^2
12-Weather seal strips
13-Plywood Supporting panel
14-laminated timber slats
15-Steel purlins
16-Anti Erosion Biodegradable Net (Zinco)
17-S.S Shear resistant fixture LF300 (Zinco)
18-Geo-Styrofoam light Slabs (Universal Foam)
19-Wooden nailer
20-Ventilated Fiber cement Wall Cladding (Eternit)
21-Site applied Injected sealant Insulation
22-IsoKorb Thermal Break (schoeck)
23-T8 fluorescent light fixtures
24-Translucent ETFE foil(SEFAR)
25-Blue Sky Fluoropolymer Acoustical fabric (SEFAR)
26-230mm Bubble deck slab
27-Folded Glazed wall (Solarlux) with IGU_Ug=1.1W/m^{2}K and (Thermal break+webs and foam core) insulated fram_Uw = 1,2 W/m^{2}K
28-Stainless steel Handrail
29- Granite Sill
30-Cement bonded wood fiber block with concrete filler (Durisol)
31-Protection convex shield
32-0.6 mm Polypropylene Filter Sheet (Zinco)
33-Adhered Porcelain skirting
34-Cork Insulation
35-Polyethylene Acoustic Insulation (Damtec) 3mm
36-Cupolex Form 400mm
37-Beton Stop Form
38-Corrugated Precast Concrete walls
39-Precast Concrete walls with access opening
40-Wooden Purrlins
41-Anodised Aluminum weave wire mesh panels (GKD)
42-Ceiling hanger and Bolt hook (GKD)
43-Drainag gutter

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T.S 11

6.3 Envelope Thermal design and u-values analysis

With respect to the heat losses through the building external opaque surfaces, transparent skin, Air filtration and thermal bridging, extraordinary attention should be paid to the physical thermal behavior of the envelope components. Accordingly, the influence of the materials constituting the envelope is crucial, since it governs the final energy consumption, building life span and the indoor micro climate.

The final envelope layers arrangement and detailing will be following a thermal design and testing scheme, and driven by the compositions thermal resistivity results and building heating/cooling loads generated from ECOTECT software, as will be presented later.

The limitation of U-Values related to the skins interacting with the external Air was one of the main strategies, to be always below the 0.20 [W/m²K], with respect the economical feasibility aspect, and the avoidance of the Ultra High-tech materials usage.

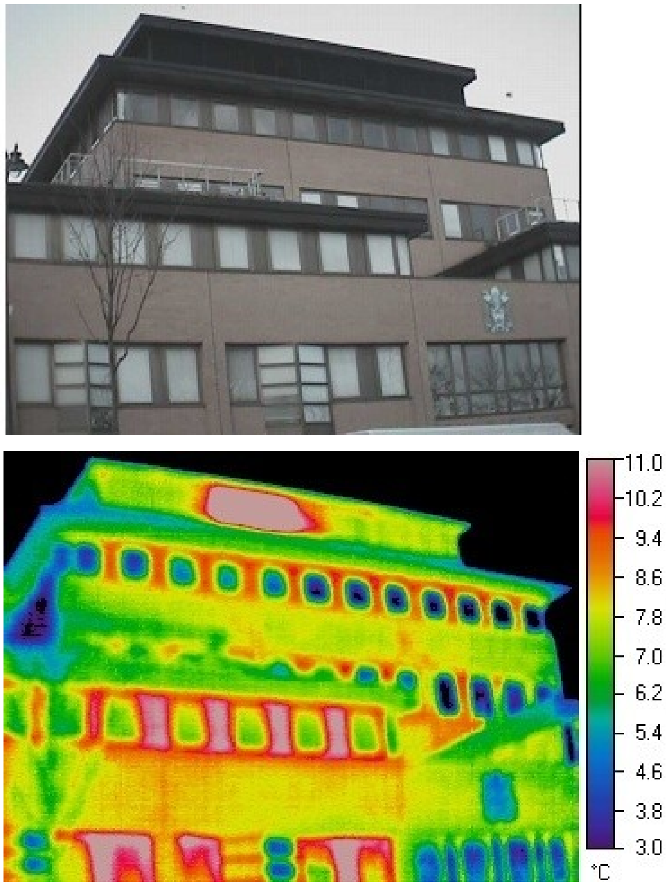

Figure 244 Building Thermal imaging, extracted from (www.cpenergy.org.uk)

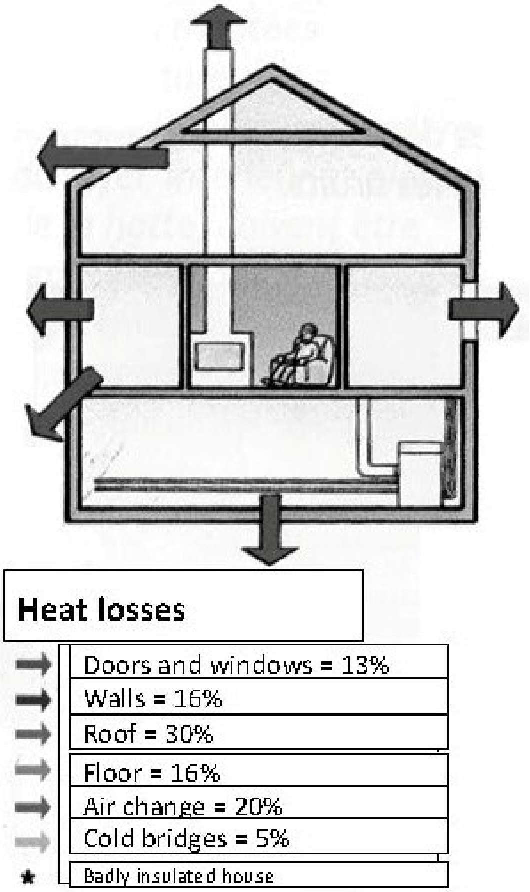

Figure 245 Heat losses through the envelope, Extracted from lecture of Roof construction, Prof.G.Masera lectures, Polimi 2012

6.3.1 Theoretical frame and general methodology

Generally the thermal transfer flux is presented in watts, and can be calculated as follows[123]:

$$\boldsymbol{\Phi = A \times U \times (T1 - T2)}$$

A: Surface area

(T1-T2): Difference in temperature between the internal and external environments.

U: U-value or the **overall heat transfer coefficient** that describes how well a building element conducts heat. It measures the rate of heat transfer through a building element over a given area under standardized conditions. The usual standard is at a temperature gradient of 24 °C (75 °F), at 50% humidity with no wind (a smaller U-factor is better at reducing heat transfer). U is the inverse of R with SI units of $W/(m^2K)$ and US units of $BTU/(h\ °F\ ft^2)$.[124]

The U-Value of a multi layered composition can be calculated as follows:

$$\boldsymbol{U = 1 / (1/h_i + \Sigma s/\lambda + 1/h_e)}\ [W/m^2K]$$

$\Sigma s/\lambda$: Presents the Sum of the layers thermal resistivity $[m^2K/W]$, which can be calculated by dividing the layer thickness (m) over its thermal conductivity value [W/mK]

hi : Internal surface Convective co-efficient $[m^2K/W]$

he: External surface Convective co-efficient $[m^2K/W]$

	Internal: 1/ hi	External: 1/ he
Vertical layer of air	0.13	0.04
Horizontal layer of air (upward flux)	0.10	0.04
Horizontal layer of air (downward flux)	0.17	0.04

Figure 246 Surface convective coefficients

Layer	Conductivity λ [W/mK]
Soil (Avg. Props)	0.837
Air Gap	5.56
Plaster Board	0.431
Cement Fibreboard	0.2
Geo-Styrofoam slabs	0.03
EPS Floratherm Drainage/Storage	0.055
Cellular Glass Foam	0.04
XPS Polystyrene insulation	0.032
EPS insulation board	0.03
Rock Wool insulation	0.034
Polyestrene Floor Heating Panel	0.042
Primer and finish Coat	1.2
Lean Concrete	0.753
Concrete Lightweight	0.209
Bubble deck Conc. Slab 280	1.5

Figure 247 Sample of the used materials conductivities

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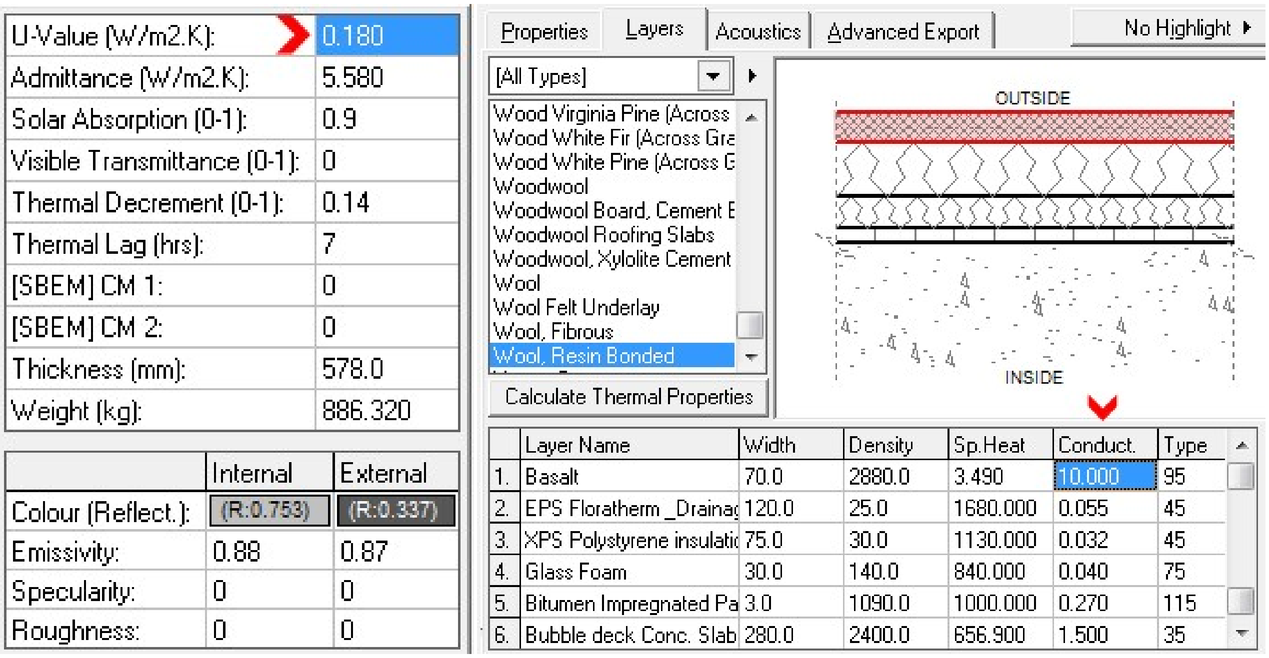
[123] Thermal Comfort Lecture, Prof. Gabriele Masera,Polimi.2012

[124] http://en.wikipedia.org/wiki/Heat_transfer_coefficient#Overall_heat_transfer_coefficient

6.3.2 ECOTECT Calculations and results

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, which will be explained in the next part.

Roof type _01



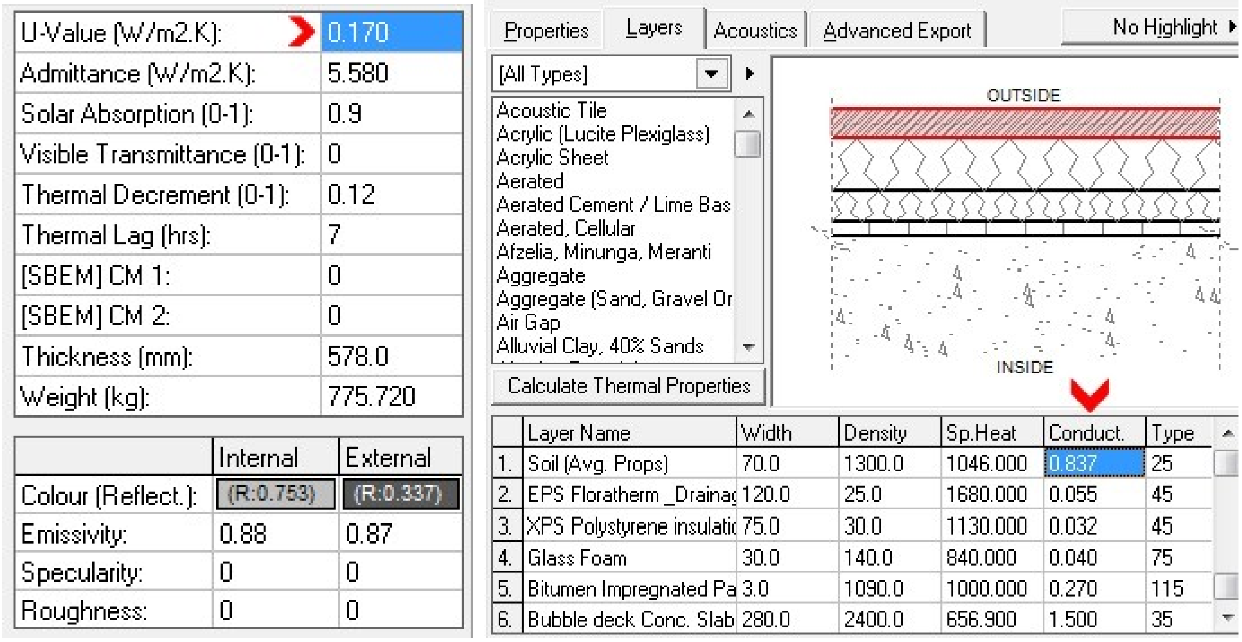
U-Value (W/m2.K):	0.180
Admittance (W/m2.K):	5.580
Solar Absorption (0-1):	0.9
Visible Transmittance (0-1):	0
Thermal Decrement (0-1):	0.14
Thermal Lag (hrs):	7
[SBEM] CM 1:	0
[SBEM] CM 2:	0
Thickness (mm):	578.0
Weight (kg):	886.320

	Internal	External
Colour (Reflect.):	(R:0.753)	(R:0.337)
Emissivity:	0.88	0.87
Specularity:	0	0
Roughness:	0	0

	Layer Name	Width	Density	Sp.Heat	Conduct.	Type
1.	Basalt	70.0	2880.0	3.490	10.000	95
2.	EPS Floratherm _Drainag	120.0	25.0	1680.000	0.055	45
3.	XPS Polystyrene insulati	75.0	30.0	1130.000	0.032	45
4.	Glass Foam	30.0	140.0	840.000	0.040	75
5.	Bitumen Impregnated Pa	3.0	1090.0	1000.000	0.270	115
6.	Bubble deck Conc. Slab	280.0	2400.0	656.900	1.500	35

Figure 248 R_01 thermal analysis

Roof type _02



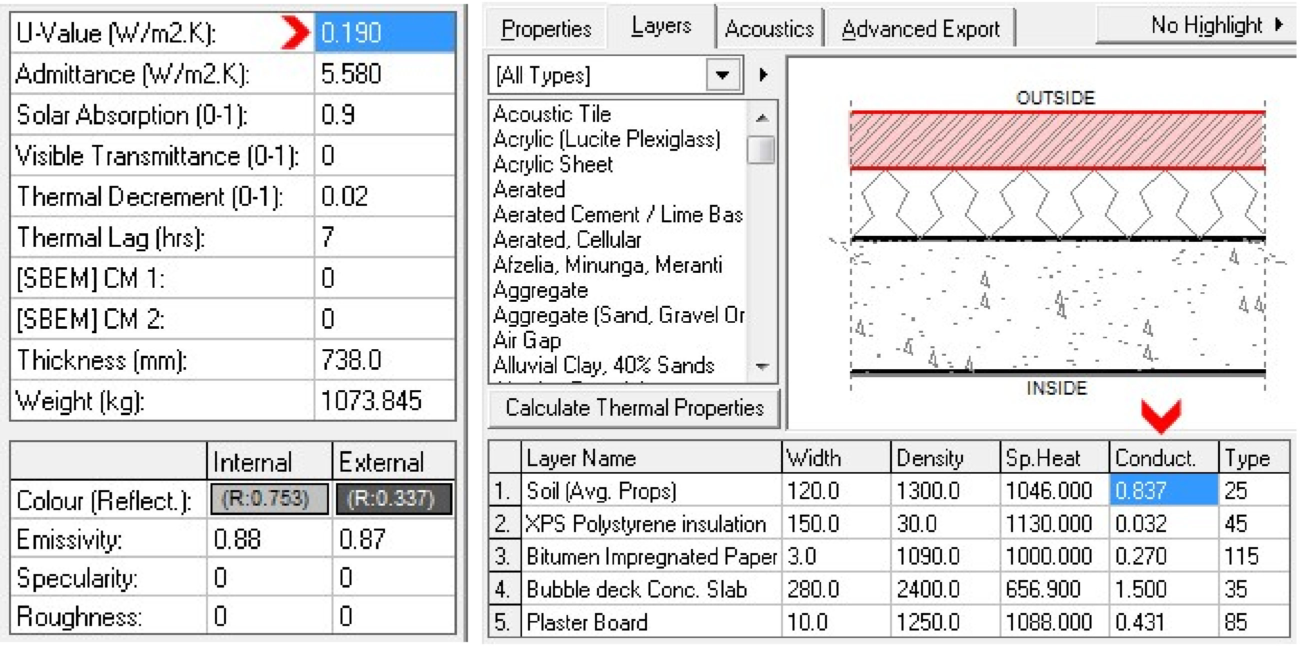
U-Value (W/m2.K):	0.170
Admittance (W/m2.K):	5.580
Solar Absorption (0-1):	0.9
Visible Transmittance (0-1):	0
Thermal Decrement (0-1):	0.12
Thermal Lag (hrs):	7
[SBEM] CM 1:	0
[SBEM] CM 2:	0
Thickness (mm):	578.0
Weight (kg):	775.720

	Internal	External
Colour (Reflect.):	(R:0.753)	(R:0.337)
Emissivity:	0.88	0.87
Specularity:	0	0
Roughness:	0	0

	Layer Name	Width	Density	Sp.Heat	Conduct.	Type
1.	Soil (Avg. Props)	70.0	1300.0	1046.000	0.837	25
2.	EPS Floratherm _Drainag	120.0	25.0	1680.000	0.055	45
3.	XPS Polystyrene insulati	75.0	30.0	1130.000	0.032	45
4.	Glass Foam	30.0	140.0	840.000	0.040	75
5.	Bitumen Impregnated Pa	3.0	1090.0	1000.000	0.270	115
6.	Bubble deck Conc. Slab	280.0	2400.0	656.900	1.500	35

Figure 249 R_02 thermal analysis

Roof type _03



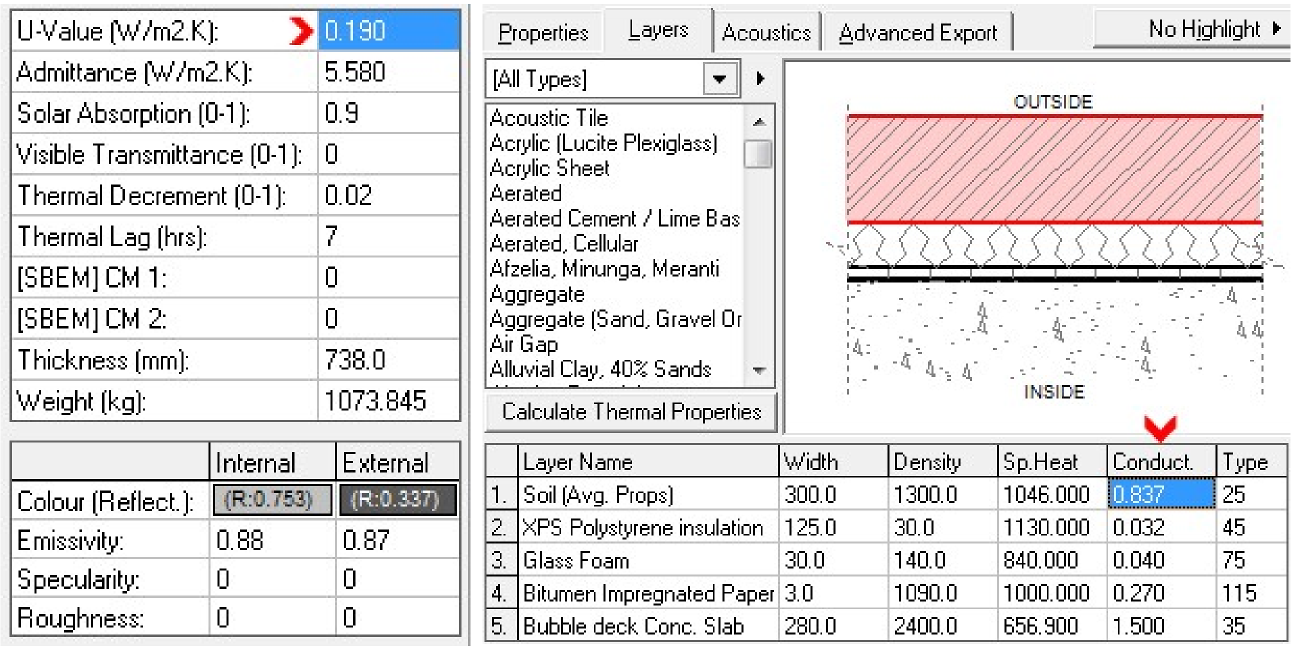
U-Value (W/m2.K):	0.190
Admittance (W/m2.K):	5.580
Solar Absorption (0-1):	0.9
Visible Transmittance (0-1):	0
Thermal Decrement (0-1):	0.02
Thermal Lag (hrs):	7
[SBEM] CM 1:	0
[SBEM] CM 2:	0
Thickness (mm):	738.0
Weight (kg):	1073.845

	Internal	External
Colour (Reflect.):	(R:0.753)	(R:0.337)
Emissivity:	0.88	0.87
Specularity:	0	0
Roughness:	0	0

	Layer Name	Width	Density	Sp.Heat	Conduct.	Type
1.	Soil (Avg. Props)	120.0	1300.0	1046.000	0.837	25
2.	XPS Polystyrene insulation	150.0	30.0	1130.000	0.032	45
3.	Bitumen Impregnated Paper	3.0	1090.0	1000.000	0.270	115
4.	Bubble deck Conc. Slab	280.0	2400.0	656.900	1.500	35
5.	Plaster Board	10.0	1250.0	1088.000	0.431	85

Figure 250 R_03 thermal analysis

Roof type _04



U-Value (W/m2.K):	0.190
Admittance (W/m2.K):	5.580
Solar Absorption (0-1):	0.9
Visible Transmittance (0-1):	0
Thermal Decrement (0-1):	0.02
Thermal Lag (hrs):	7
[SBEM] CM 1:	0
[SBEM] CM 2:	0
Thickness (mm):	738.0
Weight (kg):	1073.845

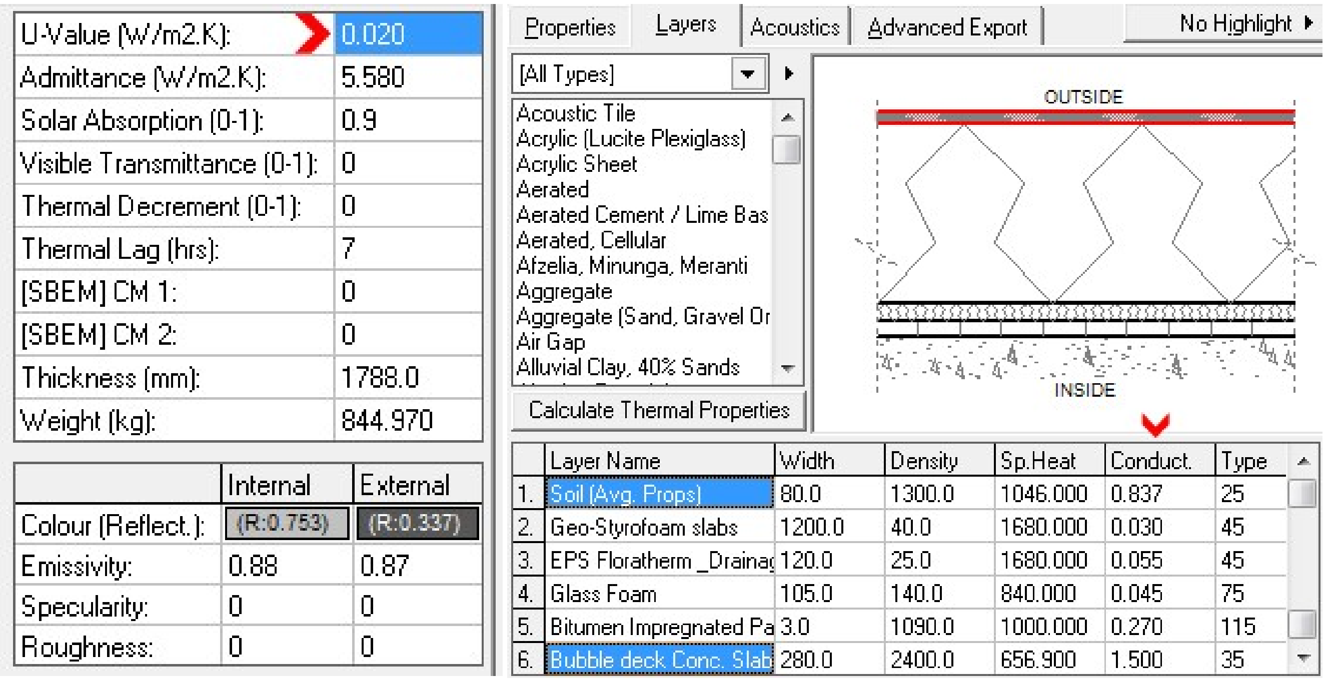
	Internal	External
Colour (Reflect.):	(R:0.753)	(R:0.337)
Emissivity:	0.88	0.87
Specularity:	0	0
Roughness:	0	0

	Layer Name	Width	Density	Sp.Heat	Conduct.	Type
1.	Soil (Avg. Props)	300.0	1300.0	1046.000	0.837	25
2.	XPS Polystyrene insulation	125.0	30.0	1130.000	0.032	45
3.	Glass Foam	30.0	140.0	840.000	0.040	75
4.	Bitumen Impregnated Paper	3.0	1090.0	1000.000	0.270	115
5.	Bubble deck Conc. Slab	280.0	2400.0	656.900	1.500	35

Figure 251 R_04 thermal analysis

Roof type _05

At the top of Green hill



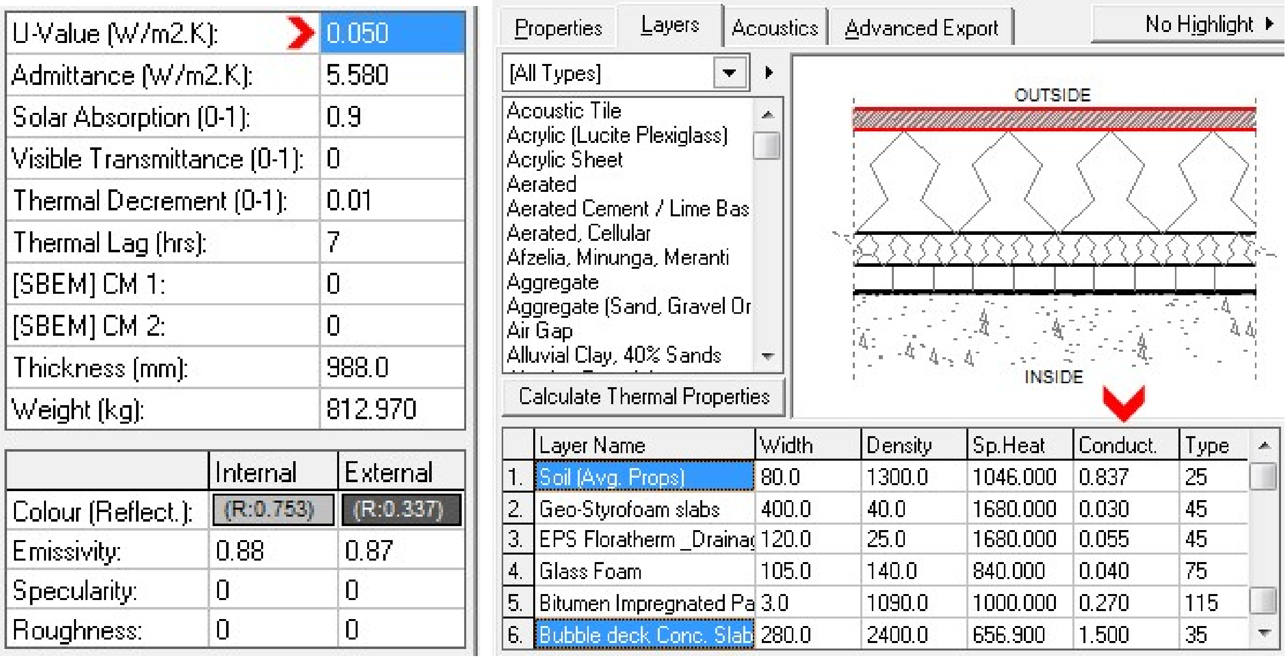
U-Value (W/m2.K):	0.020
Admittance (W/m2.K):	5.580
Solar Absorption (0-1):	0.9
Visible Transmittance (0-1):	0
Thermal Decrement (0-1):	0
Thermal Lag (hrs):	7
[SBEM] CM 1:	0
[SBEM] CM 2:	0
Thickness (mm):	1788.0
Weight (kg):	844.970

	Internal	External
Colour (Reflect.):	(R:0.753)	(R:0.337)
Emissivity:	0.88	0.87
Specularity:	0	0
Roughness:	0	0

	Layer Name	Width	Density	Sp.Heat	Conduct.	Type
1.	Soil (Avg. Props)	80.0	1300.0	1046.000	0.837	25
2.	Geo-Styrofoam slabs	1200.0	40.0	1680.000	0.030	45
3.	EPS Floratherm _Drainag	120.0	25.0	1680.000	0.055	45
4.	Glass Foam	105.0	140.0	840.000	0.045	75
5.	Bitumen Impregnated Pa	3.0	1090.0	1000.000	0.270	115
6.	Bubble deck Conc. Slab	280.0	2400.0	656.900	1.500	35

Figure 252 R_05/Upper thermal analysis

At the bottom of Green hill



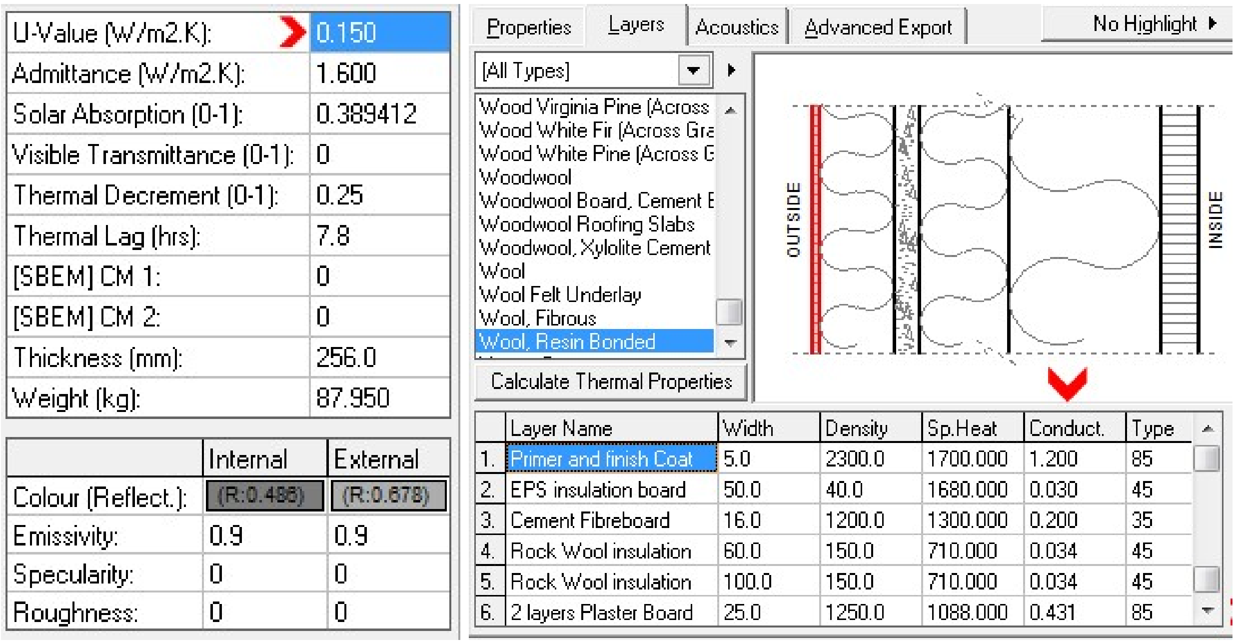
U-Value (W/m2.K):	0.050
Admittance (W/m2.K):	5.580
Solar Absorption (0-1):	0.9
Visible Transmittance (0-1):	0
Thermal Decrement (0-1):	0.01
Thermal Lag (hrs):	7
[SBEM] CM 1:	0
[SBEM] CM 2:	0
Thickness (mm):	988.0
Weight (kg):	812.970

	Internal	External
Colour (Reflect.):	(R:0.753)	(R:0.337)
Emissivity:	0.88	0.87
Specularity:	0	0
Roughness:	0	0

	Layer Name	Width	Density	Sp.Heat	Conduct.	Type
1.	Soil (Avg. Props)	80.0	1300.0	1046.000	0.837	25
2.	Geo-Styrofoam slabs	400.0	40.0	1680.000	0.030	45
3.	EPS Floratherm _Drainag	120.0	25.0	1680.000	0.055	45
4.	Glass Foam	105.0	140.0	840.000	0.040	75
5.	Bitumen Impregnated Pa	3.0	1090.0	1000.000	0.270	115
6.	Bubble deck Conc. Slab	280.0	2400.0	656.900	1.500	35

Figure 253 R_05/Lower thermal analysis

Wall type _01



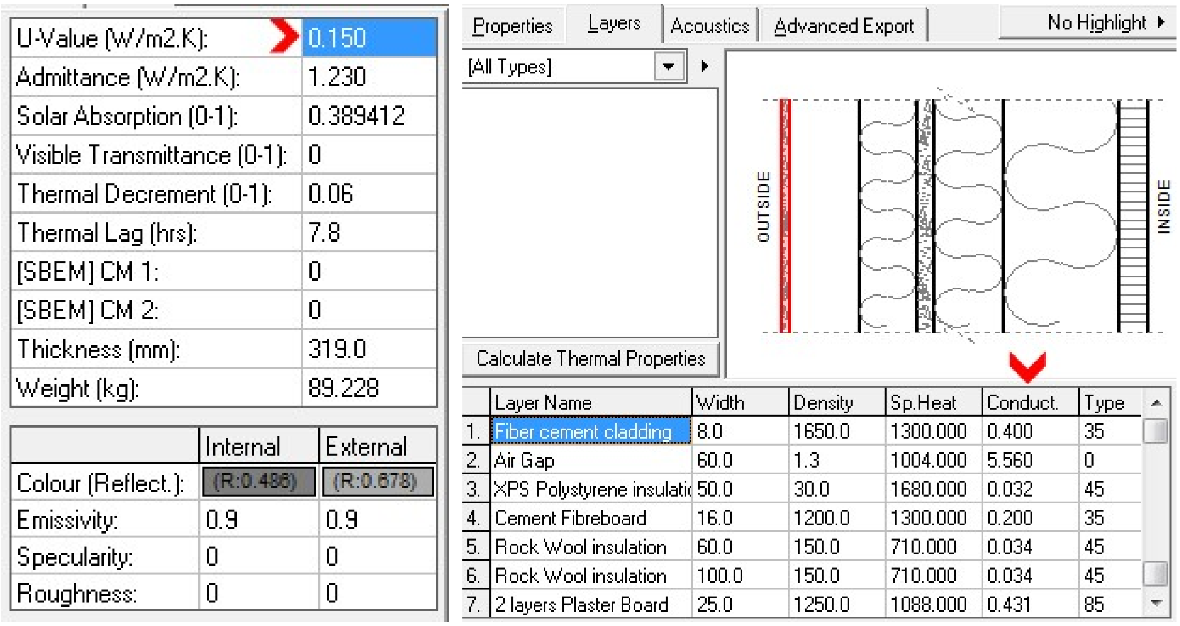
U-Value (W/m2.K):	0.150
Admittance (W/m2.K):	1.600
Solar Absorption (0-1):	0.389412
Visible Transmittance (0-1):	0
Thermal Decrement (0-1):	0.25
Thermal Lag (hrs):	7.8
[SBEM] CM 1:	0
[SBEM] CM 2:	0
Thickness (mm):	256.0
Weight (kg):	87.950

	Internal	External
Colour (Reflect.):	(R:0.486)	(R:0.678)
Emissivity:	0.9	0.9
Specularity:	0	0
Roughness:	0	0

	Layer Name	Width	Density	Sp.Heat	Conduct.	Type
1.	Primer and finish Coat	5.0	2300.0	1700.000	1.200	85
2.	EPS insulation board	50.0	40.0	1680.000	0.030	45
3.	Cement Fibreboard	16.0	1200.0	1300.000	0.200	35
4.	Rock Wool insulation	60.0	150.0	710.000	0.034	45
5.	Rock Wool insulation	100.0	150.0	710.000	0.034	45
6.	2 layers Plaster Board	25.0	1250.0	1088.000	0.431	85

Figure 254 W_01 thermal analysis

Wall type _02



U-Value (W/m2.K):	0.150
Admittance (W/m2.K):	1.230
Solar Absorption (0-1):	0.389412
Visible Transmittance (0-1):	0
Thermal Decrement (0-1):	0.06
Thermal Lag (hrs):	7.8
[SBEM] CM 1:	0
[SBEM] CM 2:	0
Thickness (mm):	319.0
Weight (kg):	89.228

	Internal	External
Colour (Reflect.):	(R:0.486)	(R:0.678)
Emissivity:	0.9	0.9
Specularity:	0	0
Roughness:	0	0

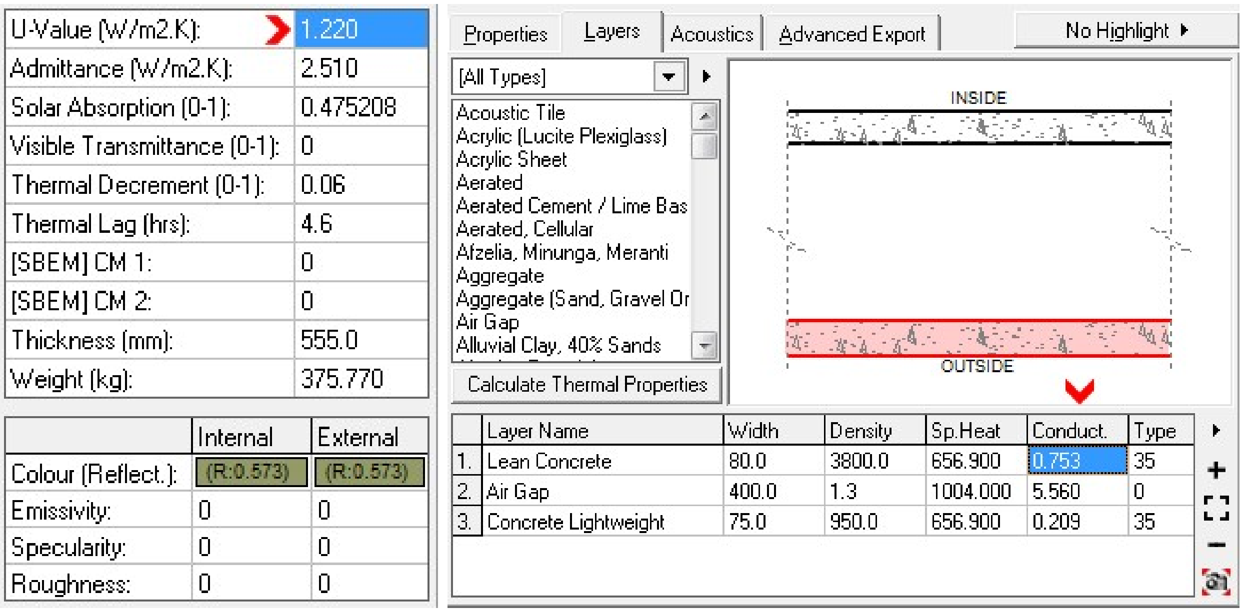
	Layer Name	Width	Density	Sp.Heat	Conduct.	Type
1.	Fiber cement cladding	8.0	1650.0	1300.000	0.400	35
2.	Air Gap	60.0	1.3	1004.000	5.560	0
3.	XPS Polystyrene insulatic	50.0	30.0	1680.000	0.032	45
4.	Cement Fibreboard	16.0	1200.0	1300.000	0.200	35
5.	Rock Wool insulation	60.0	150.0	710.000	0.034	45
6.	Rock Wool insulation	100.0	150.0	710.000	0.034	45
7.	2 layers Plaster Board	25.0	1250.0	1088.000	0.431	85

Figure 255 W_02 thermal analysis

Slab type _04

Lower Labyrinths

Maximum transmittance is needed.



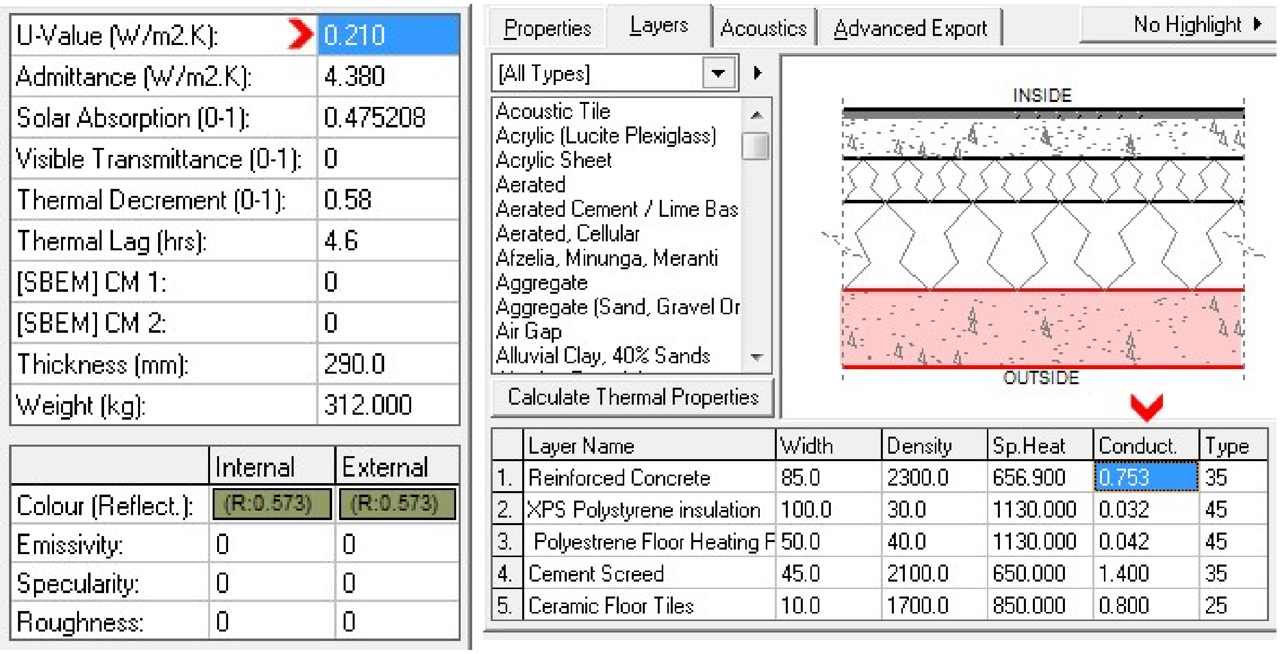
U-Value (W/m2.K):	1.220
Admittance (W/m2.K):	2.510
Solar Absorption (0-1):	0.475208
Visible Transmittance (0-1):	0
Thermal Decrement (0-1):	0.06
Thermal Lag (hrs):	4.6
[SBEM] CM 1:	0
[SBEM] CM 2:	0
Thickness (mm):	555.0
Weight (kg):	375.770

	Internal	External
Colour (Reflect.):	(R:0.573)	(R:0.573)
Emissivity:	0	0
Specularity:	0	0
Roughness:	0	0

	Layer Name	Width	Density	Sp.Heat	Conduct.	Type
1.	Lean Concrete	80.0	3800.0	656.900	0.753	35
2.	Air Gap	400.0	1.3	1004.000	5.560	0
3.	Concrete Lightweight	75.0	950.0	656.900	0.209	35

Figure 256 S_04/Lower thermal analysis

Upper floor slab



U-Value (W/m2.K):	0.210
Admittance (W/m2.K):	4.380
Solar Absorption (0-1):	0.475208
Visible Transmittance (0-1):	0
Thermal Decrement (0-1):	0.58
Thermal Lag (hrs):	4.6
[SBEM] CM 1:	0
[SBEM] CM 2:	0
Thickness (mm):	290.0
Weight (kg):	312.000

	Internal	External
Colour (Reflect.):	(R:0.573)	(R:0.573)
Emissivity:	0	0
Specularity:	0	0
Roughness:	0	0

	Layer Name	Width	Density	Sp.Heat	Conduct.	Type
1.	Reinforced Concrete	85.0	2300.0	656.900	0.753	35
2.	XPS Polystyrene insulation	100.0	30.0	1130.000	0.032	45
3.	Polyestrene Floor Heating F	50.0	40.0	1130.000	0.042	45
4.	Cement Screed	45.0	2100.0	650.000	1.400	35
5.	Ceramic Floor Tiles	10.0	1700.0	850.000	0.800	25

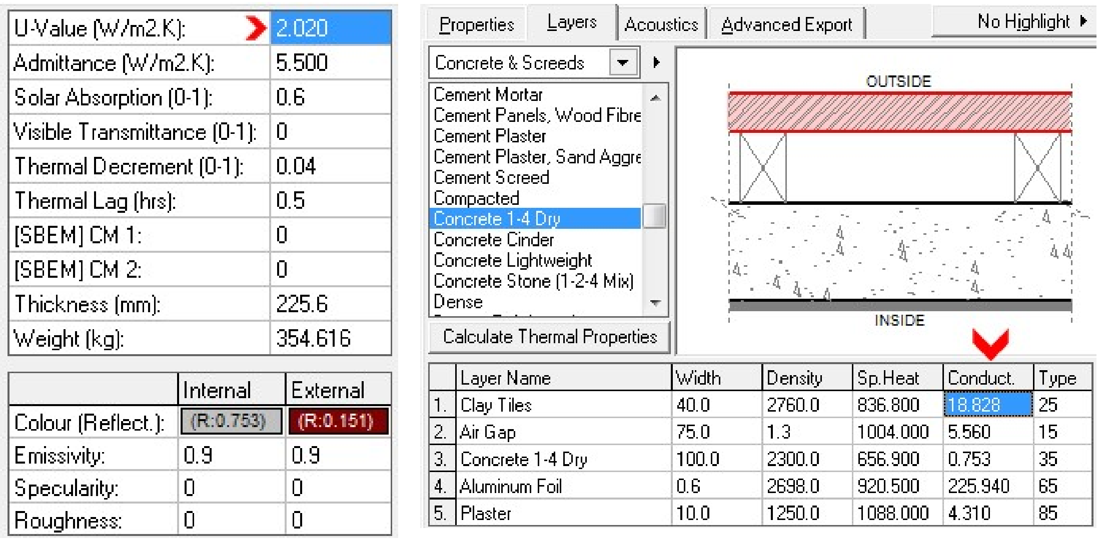
Figure 257 S_04/Upper thermal analysis

6.3.3 Comparison with a traditional envelop composition

With respect to the selected optimized envelop compositions, the thermal resistive performance of the skin is dramatically enhanced with U-values lower than 0.20 [W/m²K], compared to the traditional construction techniques, as shown below.

Relevant traditional techniques affect badly the indoor comfort, user's health and building components' life span, in addition to the failure in meeting the minimum energy saving requirements. Further analysis and comparison will be provided in the heating /cooling loads analysis.

Traditional Roof



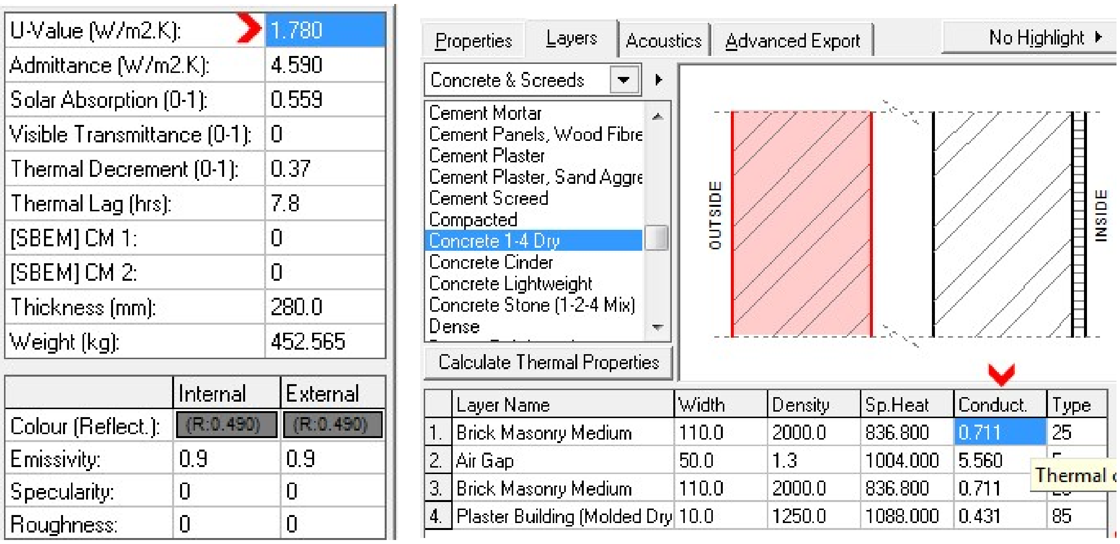
U-Value (W/m2.K):	2.020
Admittance (W/m2.K):	5.500
Solar Absorption (0-1):	0.6
Visible Transmittance (0-1):	0
Thermal Decrement (0-1):	0.04
Thermal Lag (hrs):	0.5
[SBEM] CM 1:	0
[SBEM] CM 2:	0
Thickness (mm):	225.6
Weight (kg):	354.616

	Internal	External
Colour (Reflect.):	(R:0.753)	(R:0.151)
Emissivity:	0.9	0.9
Specularity:	0	0
Roughness:	0	0

	Layer Name	Width	Density	Sp.Heat	Conduct.	Type
1.	Clay Tiles	40.0	2760.0	836.800	18.828	25
2.	Air Gap	75.0	1.3	1004.000	5.560	15
3.	Concrete 1-4 Dry	100.0	2300.0	656.900	0.753	35
4.	Aluminum Foil	0.6	2698.0	920.500	225.940	65
5.	Plaster	10.0	1250.0	1088.000	4.310	85

Figure 258 Traditional Roof thermal analysis

Traditional wall



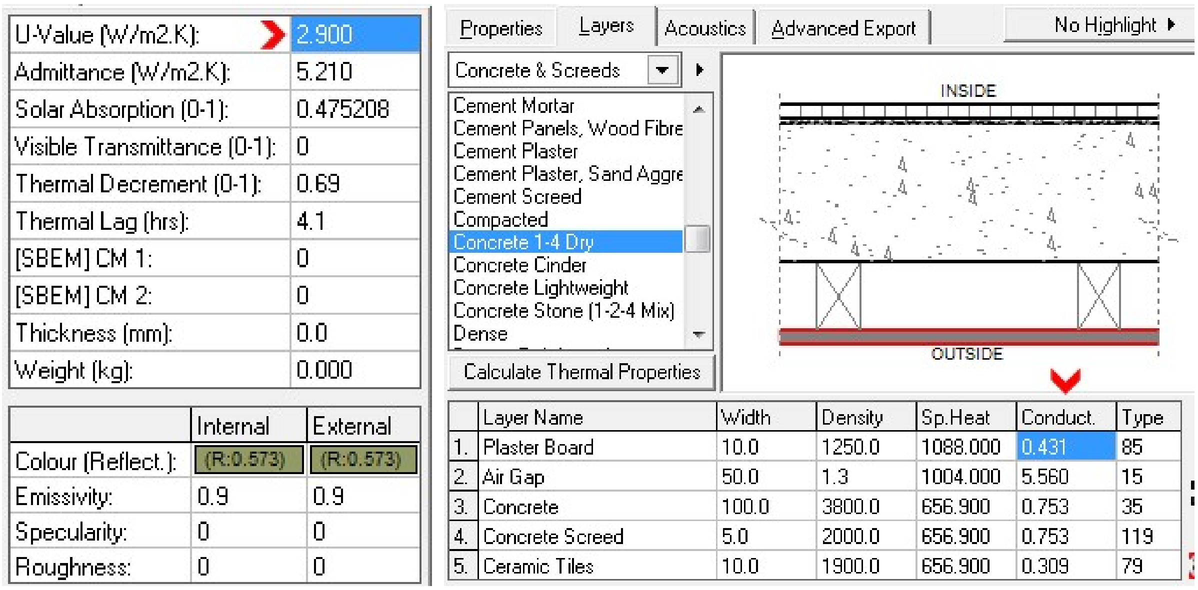
U-Value (W/m2.K):	1.780
Admittance (W/m2.K):	4.590
Solar Absorption (0-1):	0.559
Visible Transmittance (0-1):	0
Thermal Decrement (0-1):	0.37
Thermal Lag (hrs):	7.8
[SBEM] CM 1:	0
[SBEM] CM 2:	0
Thickness (mm):	280.0
Weight (kg):	452.565

	Internal	External
Colour (Reflect.):	(R:0.490)	(R:0.490)
Emissivity:	0.9	0.9
Specularity:	0	0
Roughness:	0	0

	Layer Name	Width	Density	Sp.Heat	Conduct.	Type
1.	Brick Masonry Medium	110.0	2000.0	836.800	0.711	25
2.	Air Gap	50.0	1.3	1004.000	5.560	[illegible]
3.	Brick Masonry Medium	110.0	2000.0	836.800	0.711	[illegible]
4.	Plaster Building (Molded Dry	10.0	1250.0	1088.000	0.431	85

Figure 259 Traditional wall thermal analysis

Traditional Slab



U-Value (W/m2.K):	2.900
Admittance (W/m2.K):	5.210
Solar Absorption (0-1):	0.475208
Visible Transmittance (0-1):	0
Thermal Decrement (0-1):	0.69
Thermal Lag (hrs):	4.1
[SBEM] CM 1:	0
[SBEM] CM 2:	0
Thickness (mm):	0.0
Weight (kg):	0.000

	Internal	External
Colour (Reflect.):	(R:0.573)	(R:0.573)
Emissivity:	0.9	0.9
Specularity:	0	0
Roughness:	0	0

	Layer Name	Width	Density	Sp.Heat	Conduct.	Type
1.	Plaster Board	10.0	1250.0	1088.000	0.431	85
2.	Air Gap	50.0	1.3	1004.000	5.560	15
3.	Concrete	100.0	3800.0	656.900	0.753	35
4.	Concrete Screed	5.0	2000.0	656.900	0.753	119
5.	Ceramic Tiles	10.0	1900.0	656.900	0.309	79

Figure 260 Traditional slab thermal analysis

6.4 Condensation Risk:

6.4.1 Introduction:

Since the building envelope separates two environments with different concentrations of water vapor, a vapor flow will start between the two (higher to lower concentration)[125]. As a role condensation does not occur in single-layer or homogeneous walls, while it is very likely to happen if the inner layers are insulated and with small resistance to the passage of vapor.

Foregoing in view, relevant phenomena will lead to the accumulation of high amounts of water drops into the multi layered envelop composition, and severely affecting the building life span and users heath , in addition to the below :

- In terms of building pathology aspects ,it may result creation of biological growth, efflorescence and deterioration
- Decreasing the components reliability and durability
- If it happens in insulating materials, it makes them ineffective (condensed water fills the air gaps), which is affecting the thermal performance and energy consumption.

The accruing mechanism is mainly depending on the relation between the vapor pressure and the temperature, as the highest partial vapor pressure Pv is generally found where temperature is higher. With vapor flowing through the wall at different temperatures, Pv moves from the indoor to

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[125] Thermal Comfort Lecture, Prof. Gabriele Masera,Polimi.2012

the outdoor value. The decrease in Pv value is proportional to the resistance of every homogeneous layer to the passage of vapor .If Pv reaches the saturation value of Ps, condensation occurs.

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).

6.4.2 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 261 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.

a) 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

$K_i = \lambda / s$ 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]

$T_{pi} = T_i - (\Phi/S)*(1/h_i)$

T$_{pi}$ = Internal Surface Temperature [C°]

T$_i$ = Internal ambient temperature [C°]

S = Total thickness of Section [m]

H$_i$ = Internal Convective co-efficient [m^2K/W]

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

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

b) Partial Vapor pressure at each interface calculations:

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

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

ρ$_{tot}$ **= Σρ**$_j$

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

ρ$_i$ = $s_j/\delta_j$is 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)

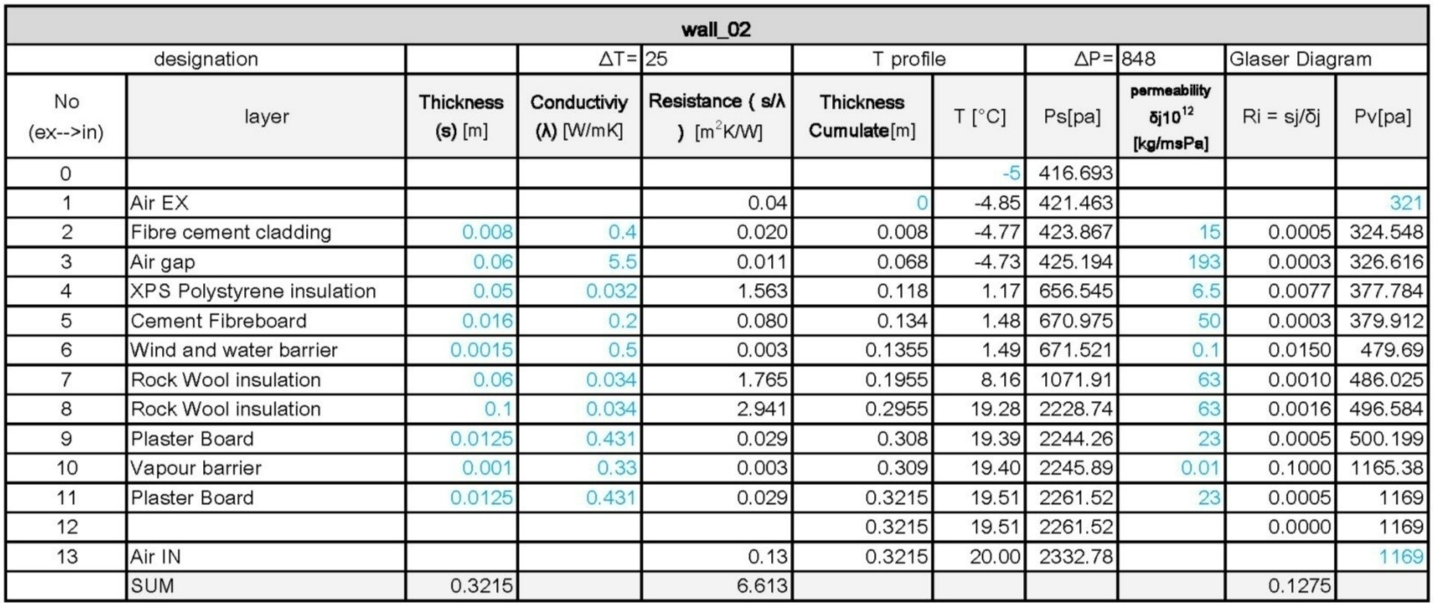
Psychometric chart can be found in APPENDIX_E for further clarification.

6.4.3 Calculations and 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.

Wall type_02



wall_02										
designation			ΔT=	25	T profile		ΔP=	848	Glaser Diagram	
No (ex-->in)	layer	Thickness (s) [m]	Conductiviy (λ) [W/mK]	Resistance (s/λ) [m^2K/W]	Thickness Cumulate[m]	T [°C]	Ps[pa]	permeability $\delta j 10^{12}$ [kg/msPa]	Ri = sj/δj	Pv[pa]
0						-5	416.693			
1	Air EX			0.04	0	-4.85	421.463			321
2	Fibre cement cladding	0.008	0.4	0.020	0.008	-4.77	423.867	15	0.0005	324.548
3	Air gap	0.06	5.5	0.011	0.068	-4.73	425.194	193	0.0003	326.616
4	XPS Polystyrene insulation	0.05	0.032	1.563	0.118	1.17	656.545	6.5	0.0077	377.784
5	Cement Fibreboard	0.016	0.2	0.080	0.134	1.48	670.975	50	0.0003	379.912
6	Wind and water barrier	0.0015	0.5	0.003	0.1355	1.49	671.521	0.1	0.0150	479.69
7	Rock Wool insulation	0.06	0.034	1.765	0.1955	8.16	1071.91	63	0.0010	486.025
8	Rock Wool insulation	0.1	0.034	2.941	0.2955	19.28	2228.74	63	0.0016	496.584
9	Plaster Board	0.0125	0.431	0.029	0.308	19.39	2244.26	23	0.0005	500.199
10	Vapour barrier	0.001	0.33	0.003	0.309	19.40	2245.89	0.01	0.1000	1165.38
11	Plaster Board	0.0125	0.431	0.029	0.3215	19.51	2261.52	23	0.0005	1169
12					0.3215	19.51	2261.52		0.0000	1169
13	Air IN			0.13	0.3215	20.00	2332.78			1169
	SUM	0.3215		6.613					0.1275	

Figure 262 W_02 inner temperatures and partial pressure values

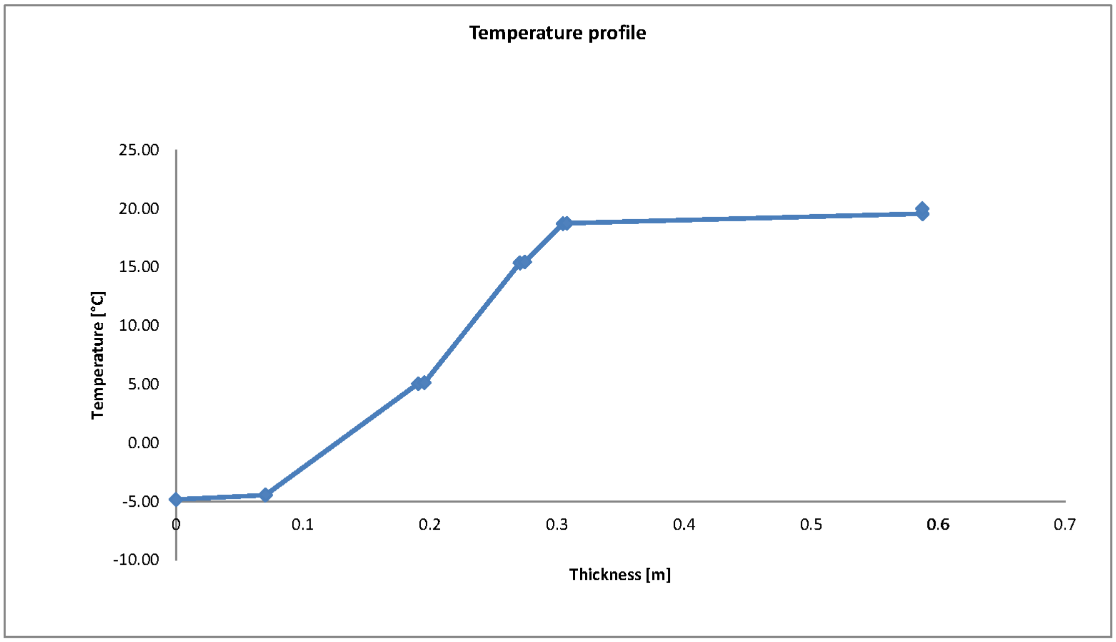


Figure 263 W_02 inner layers temperature profile

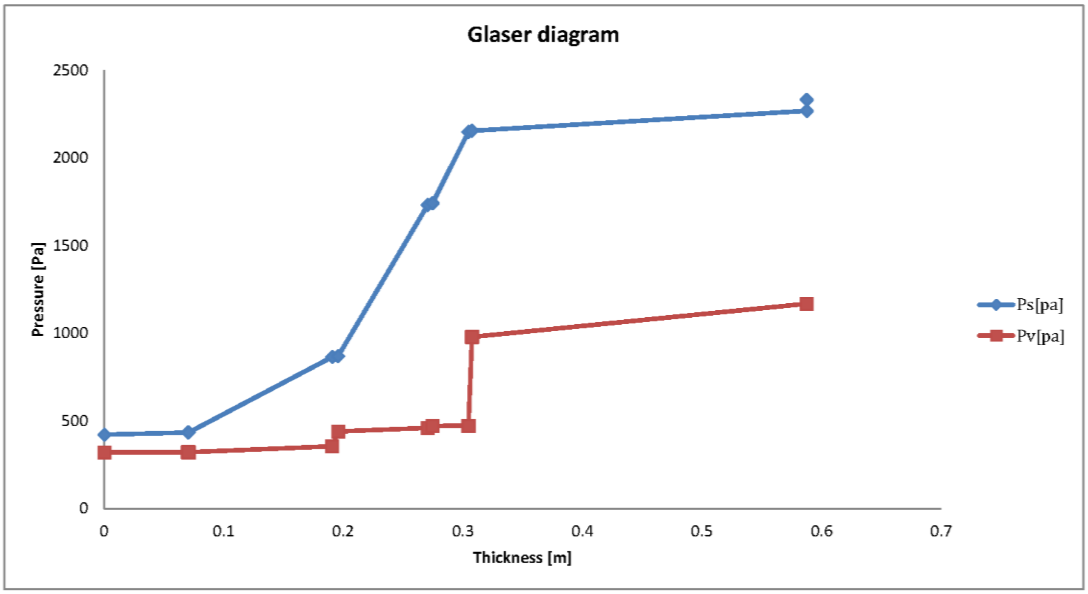


Figure 264 W_02 Inner layers Partial and Saturation pressures profiles

Roof type_02

Roof_02										
designation			ΔT=	25	T profile		ΔP=	848	Glaser Diagram	
No (ex-->in)	layer	**Thickness (s)** [m]	**Conductiviy (λ)** [W/mK]	**Resistance (s/λ)** [m^2K/W]	**Thickness Cumulate**[m]	T [°C]	Ps[pa]	**permeability δj10^{12} [kg/msPa]**	Ri = sj/δj	Pv[pa]
0						-5	416.693			
1	Air EX			0.04	0	-4.83	422.195			321
2	Soil (Avg. Props)	0.07	0.837	0.084	0.07	-4.46	433.912	200	0.0004	321.592
3	Polypropylene Filter Sheet	0.0006	0.137	0.004	0.0706	-4.44	434.534	3.9	0.0002	321.852
4	Insulation Floratherm + Drainage/Storag	0.12	0.055	2.182	0.1906	5.06	865.209	6	0.0200	355.686
5	Protection mat	0.005	0.27	0.019	0.1956	5.14	870.106	0.1	0.0500	440.27
6	XPS Polystyrene insulation	0.075	0.032	2.344	0.2706	15.36	1732.74	6.3	0.0119	460.409
7	High performance/Anti Root/Dual renforced W.P	0.004	0.2	0.020	0.2746	15.44	1742.59	0.6	0.0067	471.687
8	Glass Foam	0.03	0.04	0.750	0.3046	18.71	2150.05	150	0.0002	472.026
9	Vapour barrier	0.003	0.33	0.009	0.3076	18.75	2155.47	0.01	0.3000	979.531
10	Bubble deck Conc. Slab	0.28	1.5	0.187	0.5876	19.56	2269.5	2.5	0.1120	1169
11				0.000	0.5876	19.56	2269.5		0.0000	1169
12				0.000	0.5876	19.56	2269.5		0.0000	1169
13	Air IN			0.1	0.5876	20.00	2332.78			1169
	SUM	0.5876		5.738					0.5013	

Figure 265 R_02 inner temperatures and partial pressure values

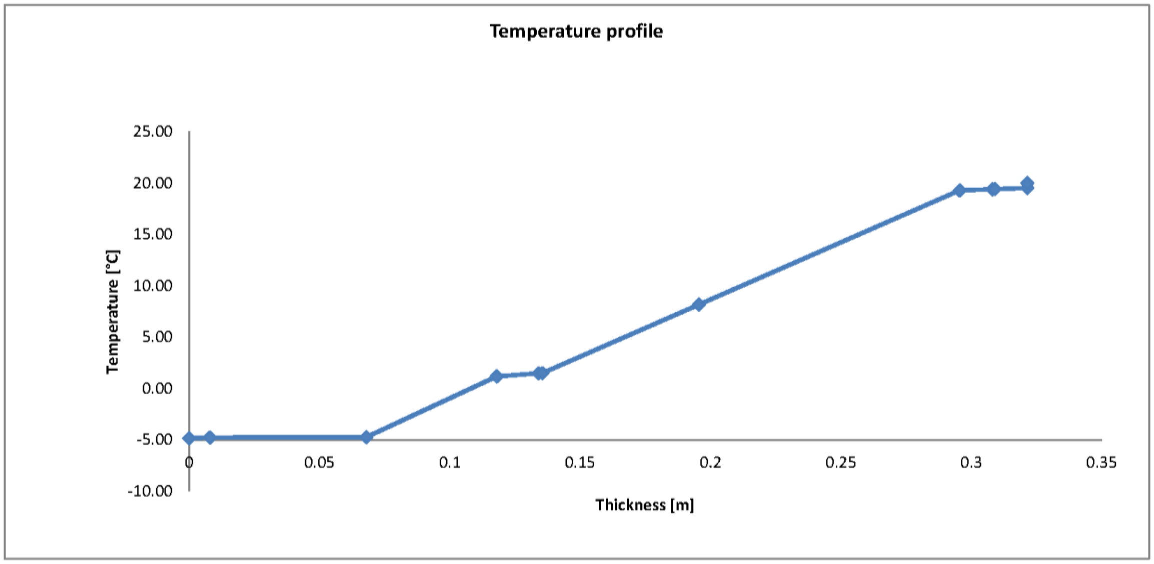


Figure 266 R_02 inner layers temperature profile

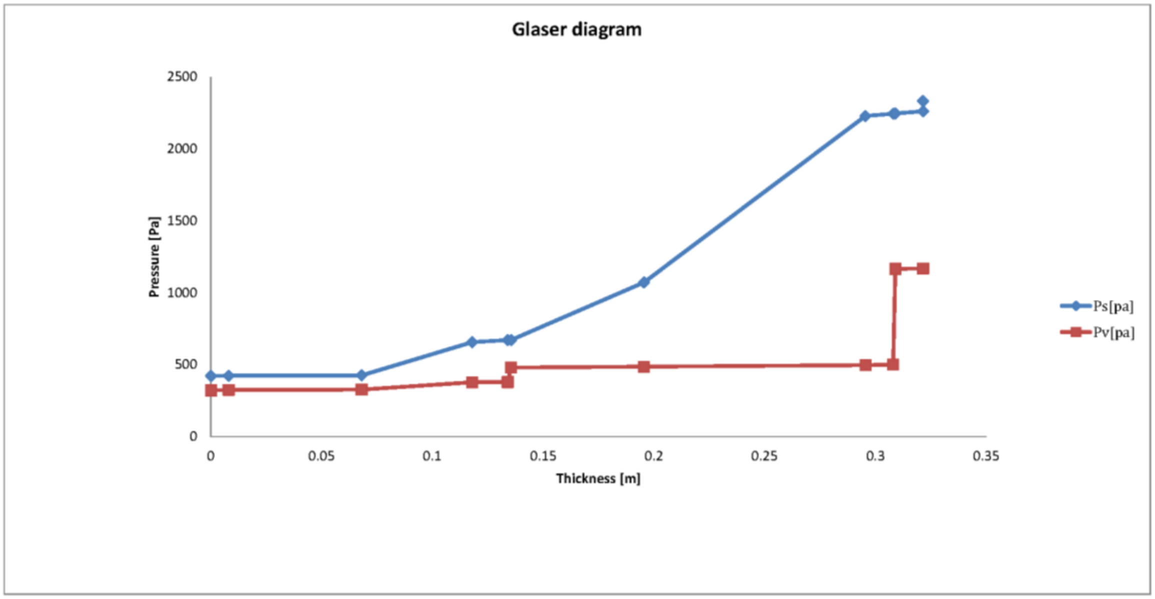


Figure 267 R_02 Inner layers Partial and saturation pressures profiles

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.

7. Thermal Analysis

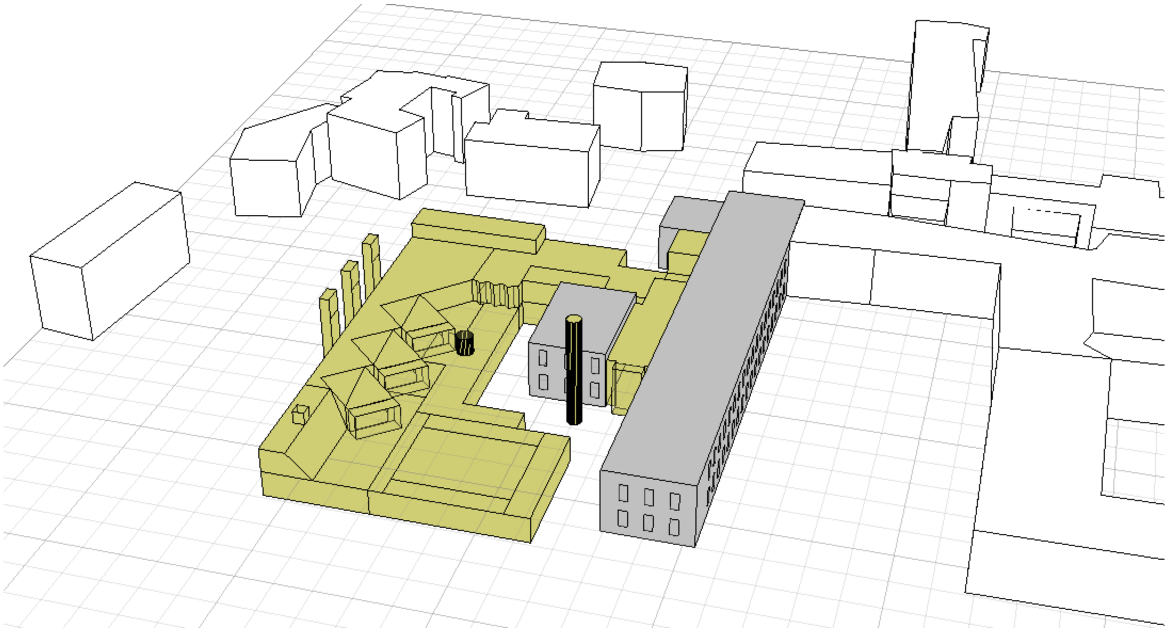


Figure 268 Model on ECOTECT

As a preamble, we would like to mention that the scope of the thermal analysis is limited to new added building only. 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 volume of the building underground i.e., the earth sheltering, low conductivity materials, green roofing, solar gain, using buffer zone and green house for summer air treatment, earth labyrinth 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, upon which rests the real success of the project.

The observation hereunder elaborates the significance of the earth sheltering and the usage of earth labyrinths in reducing the conditioning loads of the building. This was done by studying the soil temperature and by comparing the equations for thermal conductance ‘U-value’ etc, and air change rate per hour (ach) for conditions above and below ground, as explained below. We were able to calculate the improvised value of thermal conductance and air change rate to be used as an input to the software, as there were certain limitations regarding the analysis, explained in the relevant sections. All the thermal analysis is done using the energy simulation software ECOTECT 2010.

The following table shows the value of soil temperature for the whole year based on design conditions as mentioned in *Climate Design Data 2009 ASHRAE Handbook*. The data is in reference to the *Italian Climate Data Set Gianni de Giorgio; Period of record 1951-1970*, from Milan-Malpensa location[126].

Temperature of soil at 4 meters depth below ground level			
Month	Temperature °C	Month	Temperature °C
Jan	10.53	Jul	11.55
Feb	8.09	Aug	14.02
Mar	6.59	Sep	15.67
Apr	6.13	Oct	16.07
May	7.01	Nov	15.12
Jun	9.04	Dec	13.14

Table 16 Temperature of soil below ground

For the purpose of calculation of loads the average value of temperature was taken which comes out to be approximately 10°C.

7.1 Calculation 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 22:00 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 occupancy of the building was heterogenic from zones that would have sufficiently large number of people like pool and those with a specific number to account for, like massage and meditation unit. 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.

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[126] http://apps1.eere.energy.gov/buildings/energyplus/cfm/weather_data3.cfm/region=6_europe_wmo_region_6/country=ITA/cname=Italy

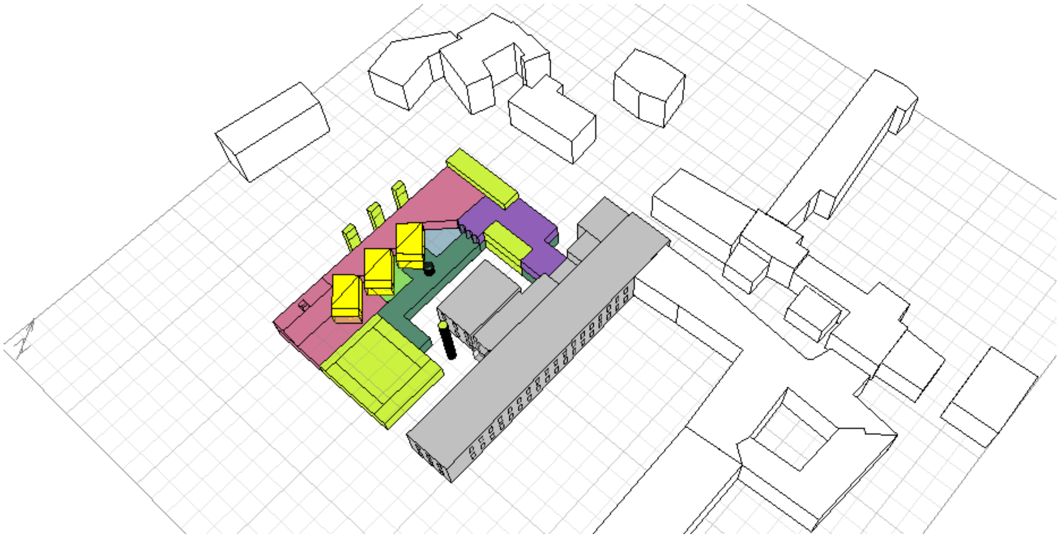

Figure 269 Zoning of the building

The software ECOTECT does not directly understand the complexity of below ground structures. In order to integrate the effect of earth sheltering and earth labyrinths in the software, we manipulated the U-values and the air change rate (ach) and use it as an input to the ECOTECT. The U-values of the walls which were below ground were adjusted to give a lower magnitude of U-value and eventually used in the software for analysis. Similarly, the values for air change per hour (ach) were adjusted considering the earth sheltering and labyrinths. The following explains the procedure of improvisation adopted for the same reason.

7.1.1 U-value improvisation:

Generally, the temperature values in winter for Valmadrera are in the range

Internal temperature = $T_i = 20^oC$

External air temperature = $T_e = -5^oC$

Soil temperature at 4 m depth = $T_s = 10^oC$

Internal temperature of specified area = T_{xi} = as mentioned under 'x' area

Using, $Ø = U.\ S\ .\ \Delta T$ for the flux

Where ΔT_1 = difference of internal air temperature (T_{xi}) and external air temperature (-5^o)

and ΔT_2 = difference of internal air temperature (T_{xi}) and soil temperature (10^oC)

U_1 = original value without earth sheltering and labyrinths

U_x = value with earth sheltering and labyrinths effect (to be found)

For different areas in the building the temperature requirements are different so we calculated for specific areas the effect of earth sheltering.

Sauna rooms (below ground):

Internal temperature = $T_{si} = 80^oC$; $U_1 = 0.19\ W/m^2K$

$U_s = 0.19(80+5)/(80-10)$

$U_s = 0.15\ W/m^2K < U_1$

Massage area (below ground):

$T_{mi} = 22^oC$[127]; $U_1 = 0.19\ W/m^2K$

$U_m = 0.19(22+5)/(22-10)$

$U_m = 0.084\ W/m^2K < U_1$

Indoor pool area (below ground):

$T_{pi} = 29^oC$[128]; $U_1 = 0.19\ W/m^2K$

$U_p = 0.19(29+5)/(29-10)$

$U_p = 0.106\ W/m^2K < U_1$

Common areas (below and above ground):

$T_{pi} = 26^oC$; $U_1 = 0.19\ W/m^2K$

$U_p = 0.19(26+5)/(26-10)$

$U_p = 0.106\ W/m^2K < U_1$

7.1.2 Air change rate improvisation:

The general formula for air change rate is $ach = V^o / V$

where V^o = volume change rate (m^3/s); V = volume of air (m^3)

As the earth labyrinth aids in bringing down the temperature of air by around 10^oC, so using the equation $\text{Ø} = V^o \cdot \Delta T$ and equating for air change rate before and after the drop in temperature.

---

[127] Neufert's Architects Data, pg 542

[128] ASHRAE standard 55-2004 "Thermal environmental conditions for human occupancy" /2/.

Sauna rooms (below ground):

An ach = 8 and temperature of 80°C is recommended for sauna, so the value after adding the effect of earth labyrinth is

ach = 8(80-5) / (80+5) = 7.05 ach

Massage area (below ground):

An ach = 8 and temperature of 22°C is recommended for massage, so the value after adding the effect of earth labyrinth is

ach = 8(22-5) / (22+5) = 5.03 ach

Indoor pool area (below ground):

An ach = 6 and temperature of 29°C is recommended[129] for indoor pool, so the value after adding the effect of earth labyrinth is

ach = 6(29-5) / (29+5) = 4.2 ach

Common areas (below and above ground):

An ach = 1 and temperature of 26°C is recommended for common areas, so the value after adding the effect of earth labyrinth is

ach = 6(26-5) / (26+5) = 0.7 ach

---

[129] ASHRAE standard 62-2001 “Ventilation for acceptable indoor air quality” /1/; ASHRAE 1999-b

7.2 Heating loads

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:

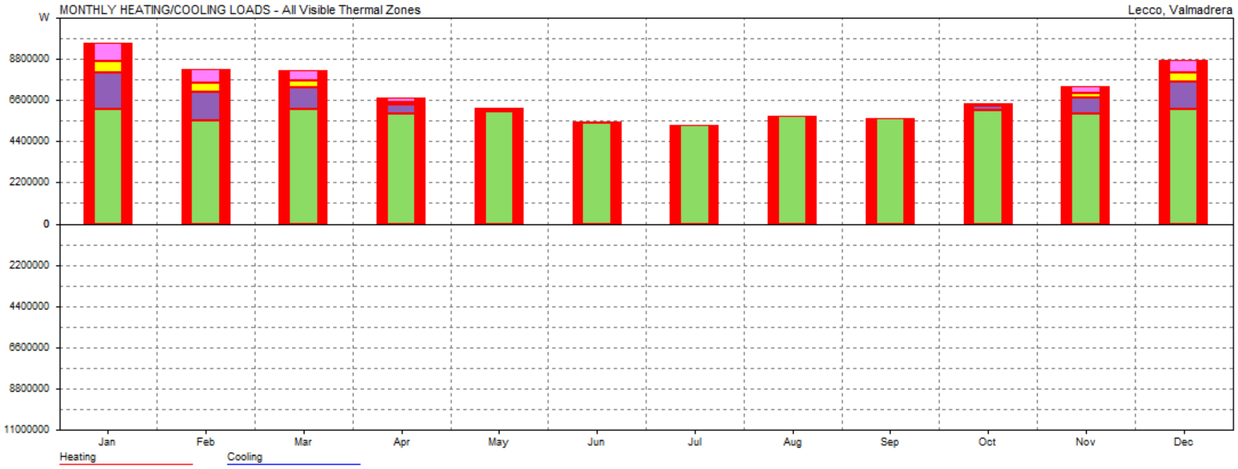

Figure 270 Heating loads

MONTHLY HEATING LOADS
All Visible Thermal Zones
Comfort: Zonal Bands
System type: Heating only
Max Heating: 29540 W at 09:00 on 26th January
Max Cooling: 0°C - No Cooling.

MONTH	HEATING (Wh)
Jan	7840748
Feb	6682176
Mar	6556408
Apr	5334546
May	5055685
Jun	4598952
Jul	4551972
Aug	4838049
Sep	4720750
Oct	5183610
Nov	5849590
Dec	7048016
TOTAL	**68260504**
PER M^2	**21389**
Floor Area:	**3191.324 m2**

Table 17 Monthly heating load

7.3 Cooling loads

In the similar way, the cooling loads were calculated after making necessary changes in accordance with the improvised values. The following loads were achieved:

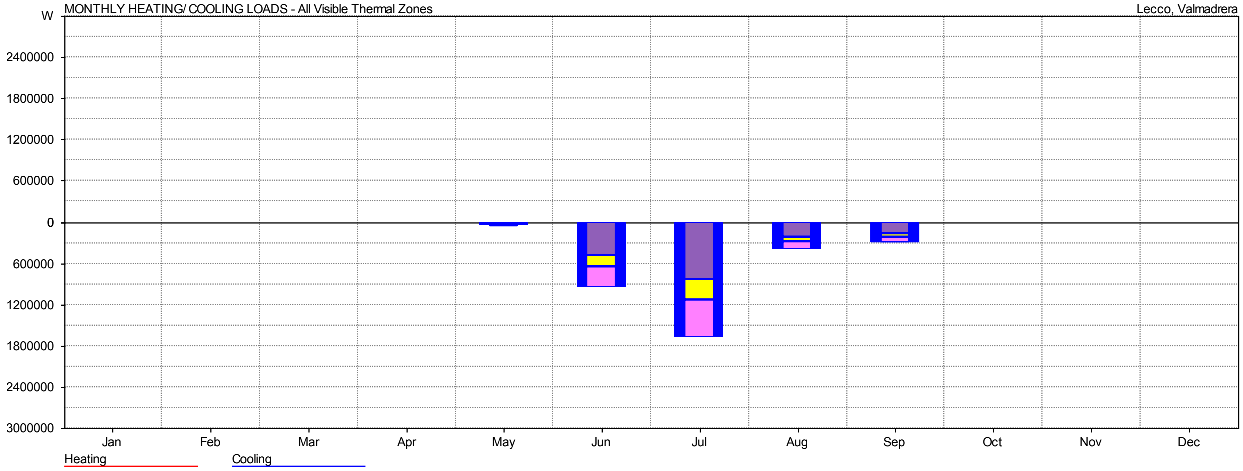

Figure 271 Cooling loads

MONTHLY COOLING LOADS
All Visible Thermal Zones
Comfort: Zonal Bands
System type: Cooling only
Max Heating: 0°C - No Heating
Max Cooling: 7546 W at 12:00 on 22nd July

MONTH	COOLING (Wh)
Jan	0
Feb	0
Mar	0
Apr	0
May	53087
Jun	957452
Jul	1689876
Aug	408999
Sep	312429
Oct	0
Nov	0
Dec	0
TOTAL	**3421843**
PER M²	**1072**
Floor Area:	**3191.324 m2**

Table 18 Monthly cooling load

Heading load kW/m^2	Cooling load kW/m^2	Total load kW/m^2
21.389	1.072	22.46

Table 19 Total load

7.4 Comparison with traditional U-values

In this part, we analysed the building by changing the previously mentioned improvised values, with the traditional values for the envelope exposed to the external environment. The traditional values are presented in the section related to the U value, were used to manipulate the zonal parameters in ECOTECT to obtain the analysis. This comparison was to test and simulate the building as it is not under ground, so that its effect on loads could be studied. The following results were obtained:

Heating loads

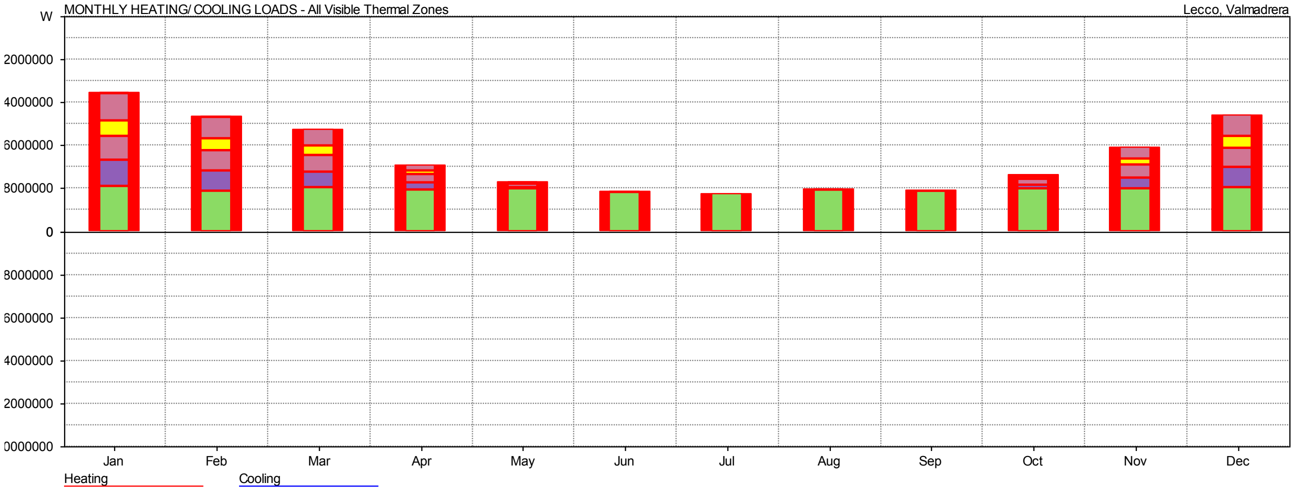

Figure 272 Heating load with traditional walls

MONTHLY HEATING LOADS

All Visible Thermal Zones

System type: Heating only

Max Heating: 82520 W at 08:00 on 25th January

Max Cooling: 0°C - No Cooling

MONTH	HEATING (Wh)
Jan	25839228
Feb	21241856
Mar	18886508
Apr	12292899
May	9212580
Jun	7335942
Jul	7064778
Aug	7752936
Sep	7688834
Oct	10547228
Nov	15689553
Dec	21582652
TOTAL	**165134992**
PER M^2	**51745**
Floor Area:	**3191.324 m2**

Cooling loads

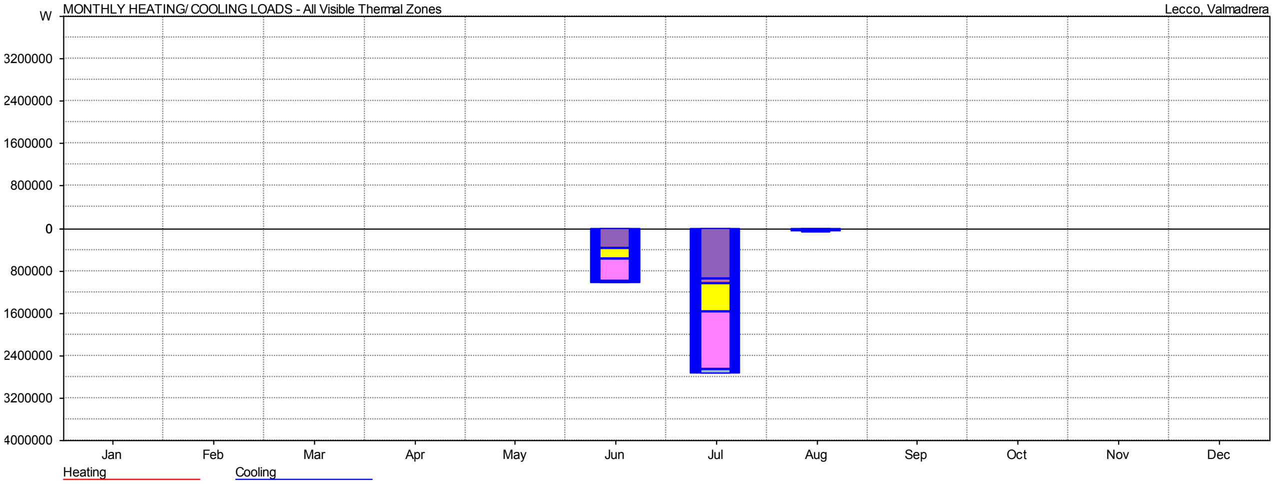

Figure 273 Cooling load with traditional walls

MONTHLY COOLING LOADS

All Visible Thermal Zones

System type: Cooling only

Max Cooling: 25896 W at 15:00 on 21st July

Max Heating: 0°C - No Heating

MONTH	**COOLING (Wh)**
Jan	0
Feb	0
Mar	0
Apr	0
May	0
Jun	1043436
Jul	2758408
Aug	71509
Sep	0
Oct	0
Nov	0
Dec	0
TOTAL	**3873352**
PER M²	**1214**
Floor Area:	**3191.324 m2**

Heating load kW/m^2	Cooling load kW/m^2	Total load kW/m^2
51.745	1.214	52.95

7.4.1 Comparative analysis:

Loads	With Improvised values (kW/m^2)	With Traditional values (kW/m^2)	Percentage Difference (%)
Heating	21.389	51.745	58.7
Cooling	1.072	1.214	11.7

7.5 Comparison without earth sheltering and earth labyrinths

In this experimentation, we observe the changes in conditioning loads for the building by changing the U values and air change rate (ach) in the sense to neglect the presence of earth sheltering and earth labyrinths. This was done by managing the zonal parameters of ECOTECT and then the building was analysed thereafter. The following results were obtained:

Heating loads

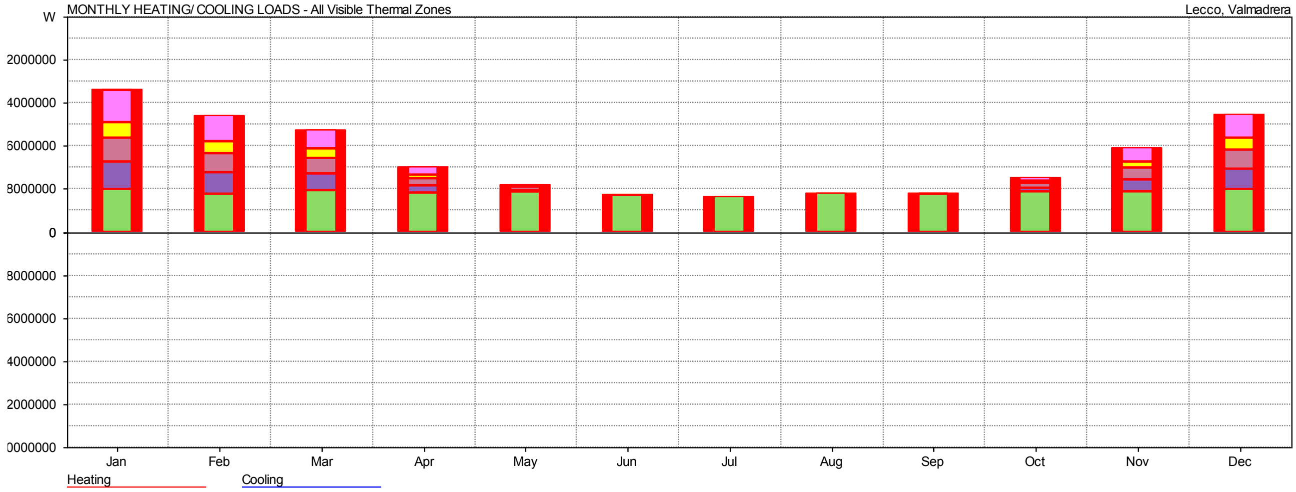

Figure 274 Heating loads without earth sheltering and labyrinths

MONTHLY HEATING LOADS
All Visible Thermal Zones
System type: Heating only
Max Heating: 85036 W at 08:00 on 25th January
Max Cooling: 0°C - No Cooling

MONTH	HEATING (Wh)
Jan	26408362
Feb	21601796
Mar	18934528
Apr	11959145
May	8706532
Jun	6865572
Jul	6607694
Aug	7241270
Sep	7177510
Oct	10051961
Nov	15575315
Dec	21851746
TOTAL	**162981440**
PER M²	**51070**
Floor Area:	**3191.324 m2**

Cooling loads

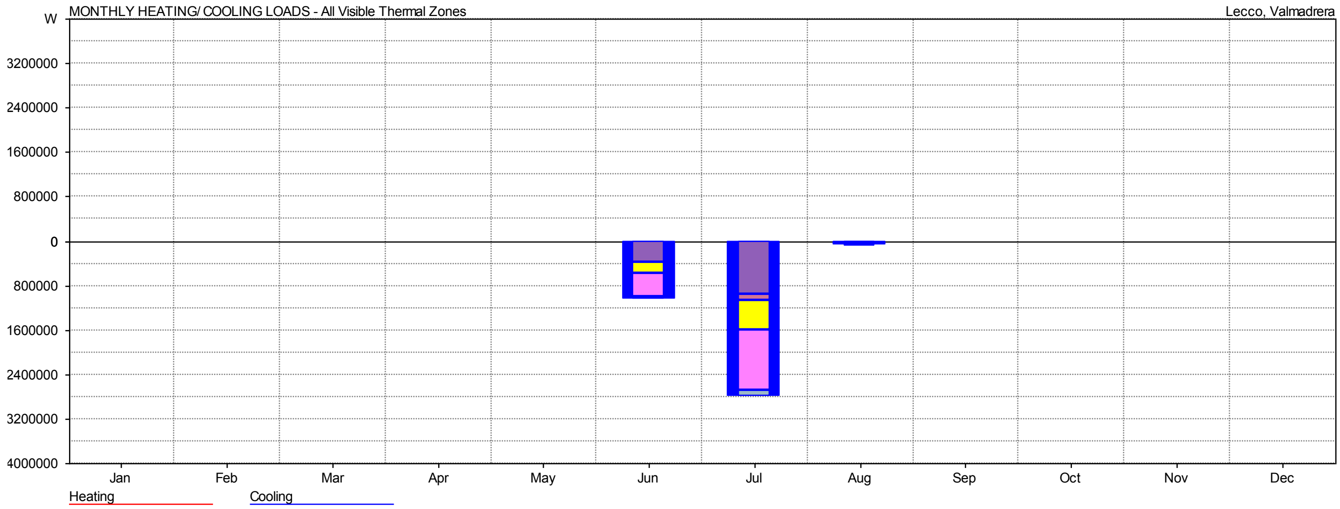

Figure 275 Cooling loads without earth sheltering and labyrinths

MONTHLY COOLING LOADS
All Visible Thermal Zones
System type: Cooling only
Max Cooling: 26643 W at 15:00 on 21st July
Max Heating: 0°C - No Heating.

MONTH	COOLING (Wh)
Jan	0
Feb	0
Mar	0
Apr	0
May	0
Jun	1048535
Jul	2795621
Aug	72139
Sep	0
Oct	0
Nov	0
Dec	0
TOTAL	**3916295**
PER M^2	**1227**
Floor Area:	**3191.324 m2**

heating load kW/m^2	cooling load kW/m^2	Total load kW/m^2
51.070	1.227	52.3

7.5.1 Comparative analysis:

Loads	With Improvised values (kW/m^2)	Without earth sheltering and earth labyrinths (kW/m^2)	Percentage Difference (%)
Heating	21.389	51.070	58.1
Cooling	1.072	1.227	12.6

Table 20 Comparison of loads

7.6 Conclusion:

In view of the foregoing discussion and analysis, the reason and effect of earth sheltering and earth labyrinth on the heating and cooling loads is obvious. The comparative analysis, at the end of the two comparisons made above, makes it clear that the decision of using the topographical effect as shelter and adopting the earth labyrinth to pre-heat/cool the air had a significant effect on the required loads. The following summary is self explanatory:

Loads	With Improvised values (kW/m^2)	Without earth sheltering and earth labyrinths (kW/m^2)	With Traditional values (kW/m^2)
Heating	21.389	51.070	51.745
Cooling	1.072	1.227	1.214

Table 21 Summary of loads for different approaches

8. Lighting Analysis

8.1 Introduction

In a primary building system, lighting has a critical role to play in sustainable buildings. Sustainable lighting encompasses the satisfaction of the lighting system's design intent for the lowest life-cycle environmental impact. And, it has become associated with quality lighting practices that do not directly save energy but are related to worker or inhabitant satisfaction, such as providing access to daylight and views.

Even without concentration, the renewable solar resource is often more than adequate for building heating and lighting. The amount of solar energy available at any given site varies both seasonally and daily. Typically, the closer the sun is to a position directly overhead, the more solar energy that reaches a horizontal site. Fortunately, sunlight's embodied heat energy is not its only resource; direct sun is our most intense light source. When direct sun in winter is desirable at the ground floor of all sites, the buildable volume is sharply reduced in height due to the low angle of the winter sun in northern latitudes. In the northern hemisphere in June, the sun's direct radiation is perpendicular to the Earth's surface; in December, there are fewer hours of sun, and the radiation passes through a longer, non-perpendicular, length of atmosphere to reach the Earth. The position of the sun at any instant with respect to an observer on the ground is defined by its altitude angle and its azimuth angle (fig below), and must be studied to have a n effective lighting design.

In the following section, we have analysed using the data and experimental data from ECOTECT software, 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, louvers, skylights, outdoor pool's ceiling, heliostats, etc., serving the purpose of daylight and shading, as required.

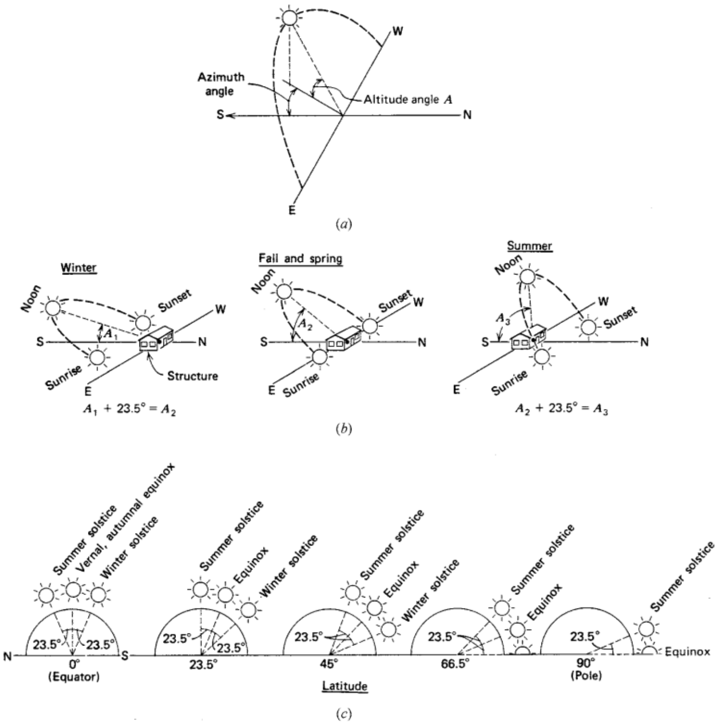

Figure 276 Altitude and azimuth angles[130]

8.2 Local path and shadows

Shading for orientation: Shading windows from solar heat gain is a key design strategy for passive cooling and to reduce cooling loads on active HVAC systems. Because of the high altitude of the sun, the most effective shading device for south-facing windows during the summer is a horizontal overhang, which also protects from the sun heat (fig below). While in winter, allows the sunlight to penetrate inside, for both, needed light and heat energy. Operable exterior shading devices are also useful because they respond to daily and seasonal variations in solar and weather patterns in ways that fixed shading devices simply cannot do, thus rendering them necessary at times for east or west facades of a building.

In the project, in pursuit of sustainability, we have devised techniques to implement the aforementioned potentials and make the project as close to zero energy as possible. The fixed and operable shading devices help in achieving the desired results.

The shadow casted by a shading device like an overhang is defined by two angles: the vertical shadow angle (VSA), which indicates the position of the leading edge of the shadow as defined from the leading edge of the overhang, and the horizontal shadow angle (HSA), which defines the leading edge of a shadow cast by a vertical element (indicated by a dashed line) as defined with respect to that element’s leading edge.

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[130] Mechanical and Electrical Equipment for Buildings - W. Grondzik, et al., (Wiley, 2010) BBS

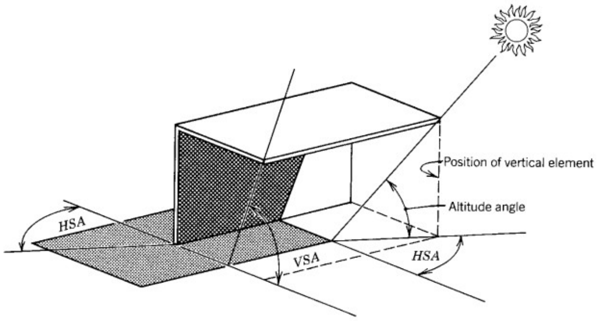

Figure 277 Solar angles[131]

Winter solstice

By analyzing the weather data of Lecco in ECOTECT, we came up with the following diagram, showing the availability of sunlight falling on the building, highlighted in pink colour.

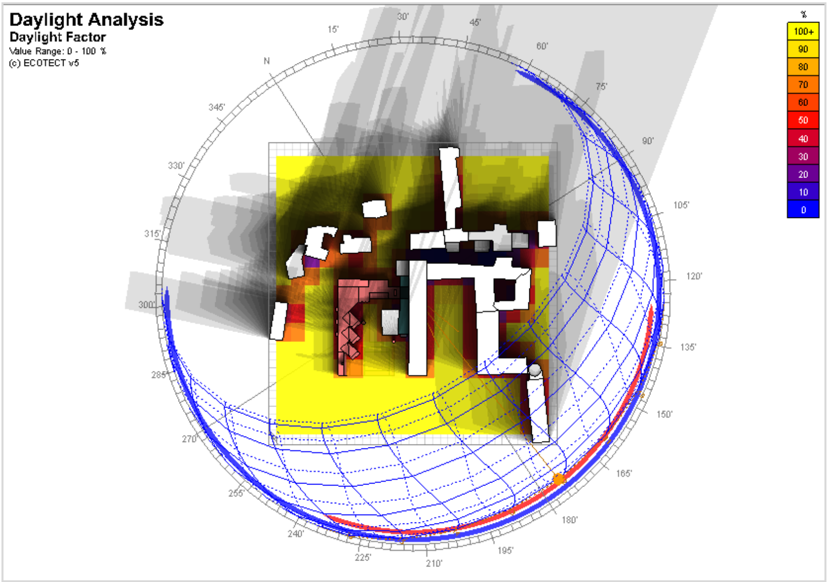

Figure 278 Winter solstice

Latitude 45.8 °

Longitude 9.3 °

Sunrise 08:06

Sunset 16:34

Date 21st December

Local Correction -20.7 mins

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[131] Mechanical and Electrical Equipment for Buildings - W. Grondzik, et al., (Wiley, 2010) pg.168

Local Time (hrs)	Solar Time (hrs)	Azimuth angle (degree)	Altitude angle (degree)
8.30	8.09	129.1	3.2
9.00	8.39	134.8	7.1
9.30	9.09	140.8	10.6
10.00	9.39	147.1	13.7
10.30	10.09	153.6	16.3
11.00	10.39	160.5	18.3
11.30	11.09	167.7	19.8
12.00	11.39	174.9	20.6
12.30	12.09	-177.7	20.7
13.00	12.39	-170.4	20.2
13.30	13.09	-163.2	19.0
14.00	13.39	-156.2	17.1
14.30	14.09	-149.5	14.8
15.00	14.39	-143.1	11.9
15.30	15.09	-137.0	8.5
16.00	15.39	-131.2	4.7
16.30	16.09	-125.7	0.7

Table 22 Solar data fro winter solstice

In winter, we 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 20.7° at 12:30 in the afternoon.

Vernal equinox

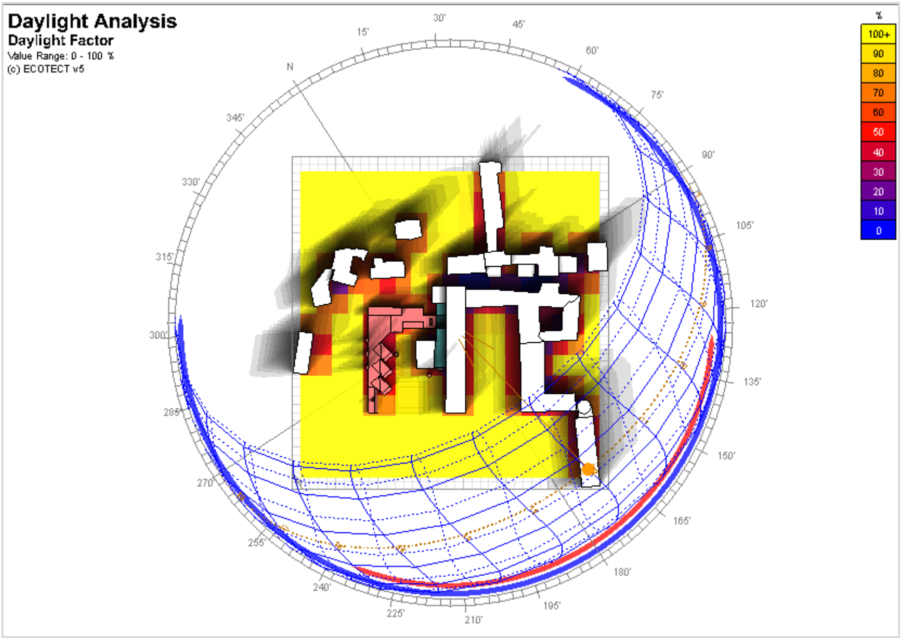


Figure 279 Vernal equinox

Local Time (hrs)	Solar Time (hrs)	Azimuth angle (degree)	Altitude angle (degree)
7.00	6.30	95.6	5
7.30	7.00	101.1	10.2
8.00	7.30	106.7	15.3
8.30	8.00	112.7	20.2
9.00	8.30	119	24.9
9.30	9.00	125.8	29.3
10.00	9.30	133.2	33.4
10.30	10.00	141.3	36.9
11.00	10.30	150.1	39.9
11.30	11.00	159.6	42.1
12.00	11.30	169.6	43.5
12.30	12.00	-180	43.9
13.00	12.30	-169.9	43.5
13.30	13.00	-159.6	42.1
14.00	13.30	-150.1	39.9
14.30	14.00	-141.3	36.9
15.00	14.30	-133.2	33.4
15.30	15.00	-125.8	29.3
16.00	15.30	-119	24.9
16.30	16.00	-112.7	20.2
17.00	16.30	-106.7	15.3

Table 23 Solar data for vernal equinox

For vernal equinox, i.e., March 21st, the sun is up till 18.26 in the evening. The highest solar altitude angle is equal to 43.9° at 12:00 in the afternoon, which is more than that in December.

Summer solstice

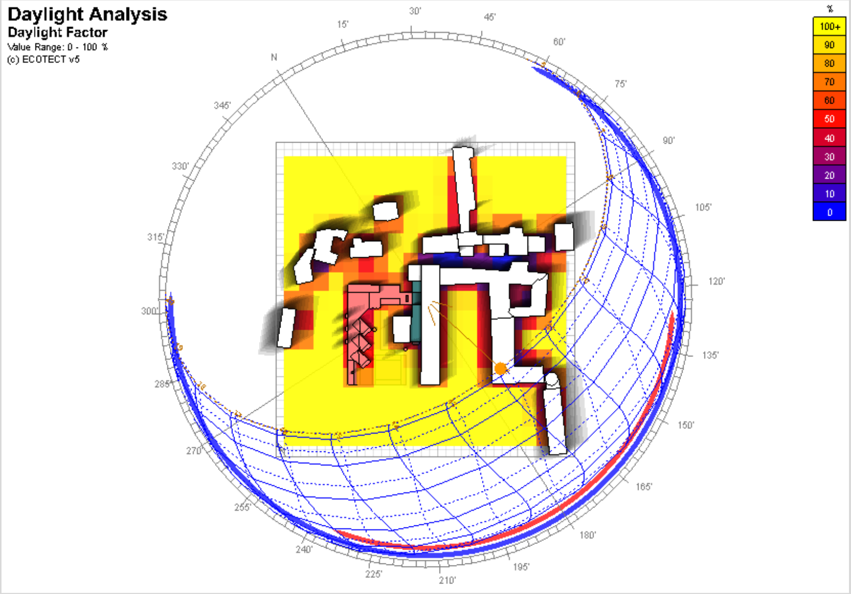


Figure 280 Summer solstice

Local Time (hrs)	Solar Time (hrs)	Azimuth angle (degree)	Altitude angle (degree)
5.00	4.35	59.0	3.1
5.30	5.05	64.2	7.7
6.00	5.35	69.2	12.5
6.30	6.05	74.1	17.5
7.00	6.35	79.0	22.6
7.30	7.05	84.1	27.8
8.00	7.35	89.3	33.0
8.30	8.05	94.8	38.2
9.00	8.35	100.8	43.4
9.30	9.05	107.5	48.5
10.00	9.35	115.2	53.3
10.30	10.05	124.4	57.9
11.00	10.35	135.5	61.9
11.30	11.05	149.2	65.1
12.00	11.35	165.5	67.1
12.30	12.05	-176.6	67.6
13.00	12.35	-159.1	66.5
13.30	13.05	-143.2	64.0
14.00	13.35	-131.1	60.4
14.30	14.05	-120.7	56.2
15.00	14.35	-112.2	51.5
15.30	15.05	-104.9	46.6
16.00	15.35	-98.5	41.4
16.30	16.05	-92.7	36.2
17.00	16.35	-87.3	31.0
17.30	17.05	-82.2	25.8
18.00	17.35	-77.2	20.7
18.30	18.05	-72.3	15.6

Table 24 Solar data for summer solstice

In summer, we 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 67.6° at 12:30 in the afternoon. The figure also depicts the shadow range for the whole month, which is making quite less impact on the ground.

Autumnal equinox

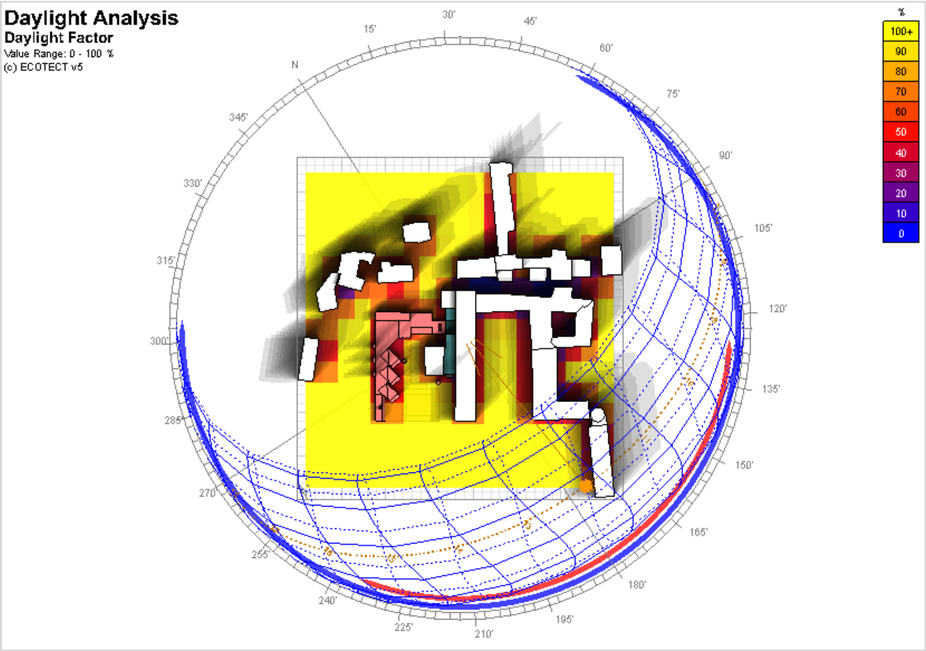


Figure 281 Autumnal equinox

Local Time (hrs)	Solar Time (hrs)	Azimuth angle (degree)	Altitude angle (degree)
6.30	6.14	91.8	3.2
7.00	6.44	97.3	8.4
7.30	7.14	102.8	13.5
8.00	7.44	108.6	18.6
8.30	8.14	114.7	23.4
9.00	8.44	121.3	28.0
9.30	9.14	128.4	32.3
10.00	9.44	136.2	36.2
10.30	10.14	144.7	39.5
11.00	10.44	154.0	42.2
11.30	11.14	163.9	44.1
12.00	11.44	174.4	45.0
12.30	12.14	-175.0	45.1
13.00	12.44	-164.5	44.1
13.30	13.14	-154.4	42.3
14.00	13.44	-145.2	39.7
14.30	14.14	-136.7	36.4
15.00	14.44	-128.9	32.6
15.30	15.14	-121.7	28.3
16.00	15.44	-115.1	23.7
16.30	16.14	-109.0	18.8

17.00	16.44	-103.2	13.8
17.30	17.14	-97.6	8.7
18.00	17.44	-92.2	3.5

Table 25 Soalr data for autumnal equinox

For autumnal equinox, i.e., September 21st, the sun is up almost for the same time as for the vernal equinox until 18:19. The highest solar altitude angle is equal to 45.1° at 12:30 in the afternoon. The figure also depicts the shadow range for the whole month of September.

8.3 Solar radiation exposure

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 following graph generated from ECOTECT reflects the direct solar radiations incident on the whole building area, and the energy associated with it.

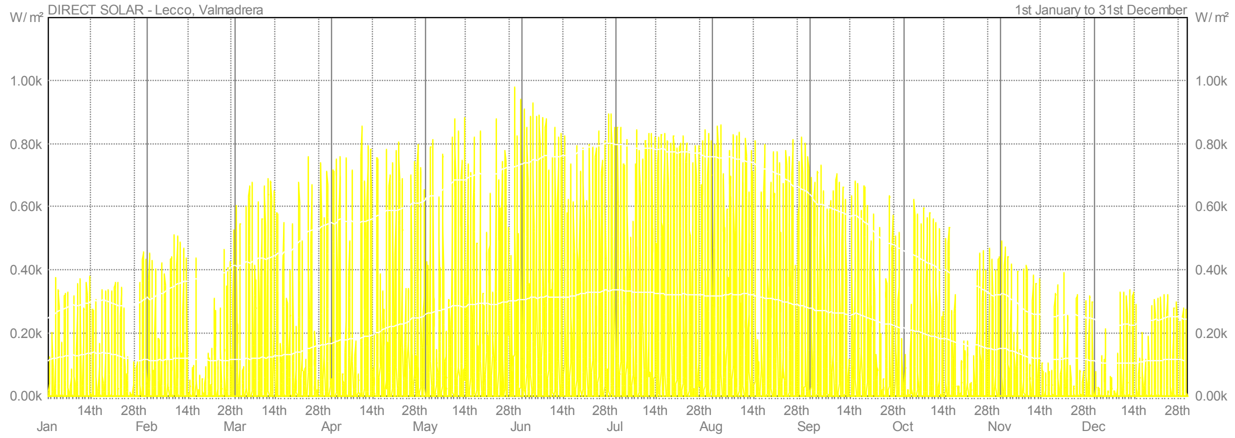


Figure 282 Direct solar radiation

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.

8.3.1 Total Monthly Solar Exposure

Lecco, Valmadrera (Direct Only)
Exposed Area: 13497.603 m^2

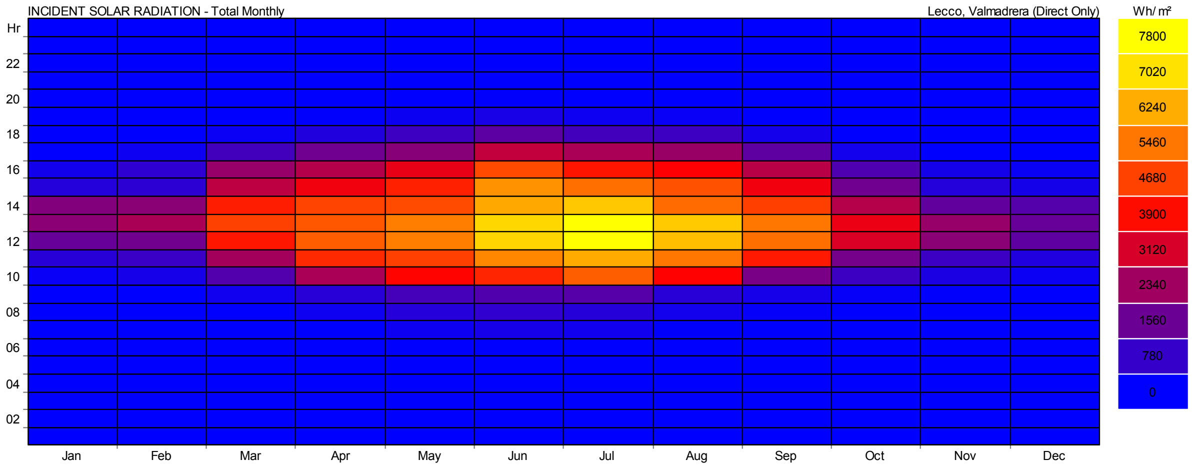


Figure 283 Incident solar radiation

MONTH	**AVAILABLE ENERGY Wh/m^2**	**INCIDENT ENERGY Wh/m^2**
Jan	37719	7401
Feb	40342	8900
Mar	91046	23682
Apr	107335	30544
May	125402	36551
Jun	165706	48133
Jul	162456	48121
Aug	137821	40360
Sep	101550	28684
Oct	58155	14750
Nov	36322	7666
Dec	25795	4946
TOTALS	**1089649**	**299736**

Table 26 Solar energy available

The above 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. 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 ceiling of outdoor pool, the louvers of the green house and meditation units. Therefore, contributing in bringing the building, one step closer to being a sustainable one.

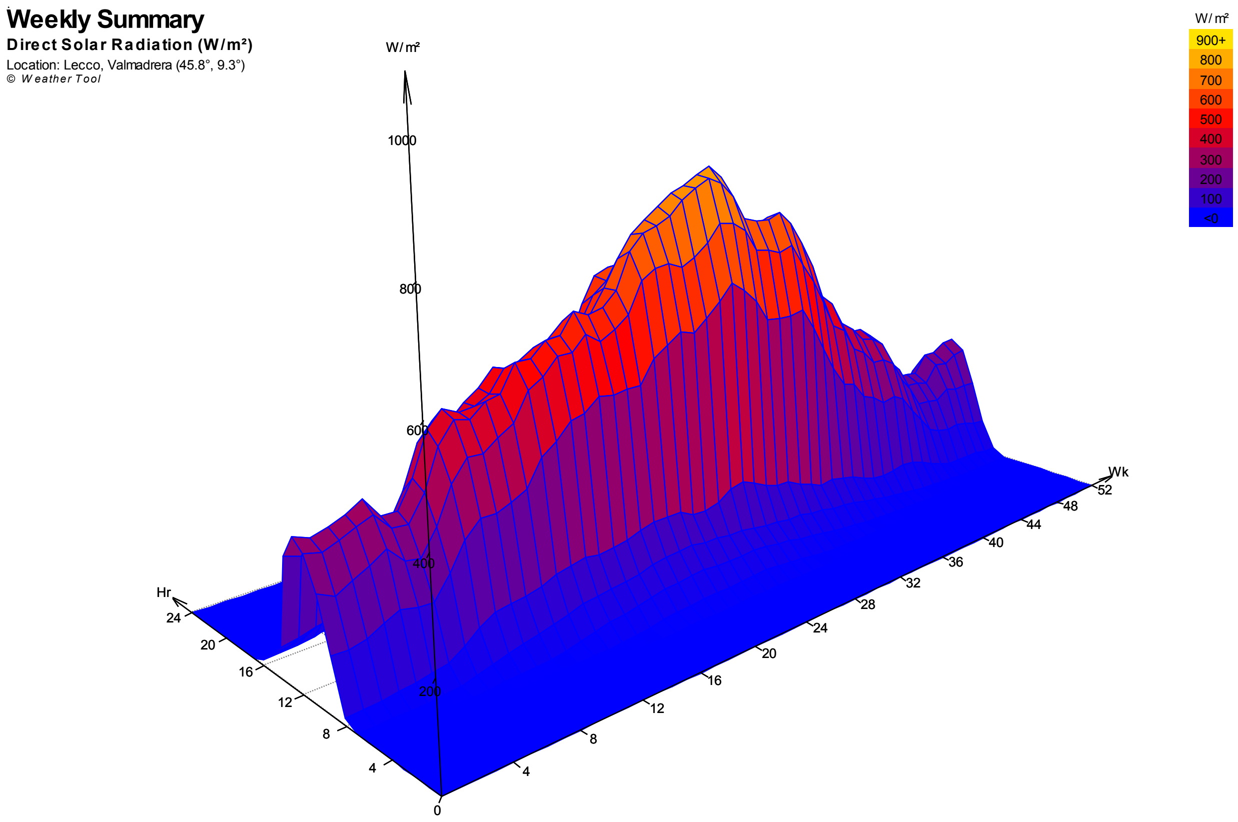


Figure 284 Weekly direct solar radiations

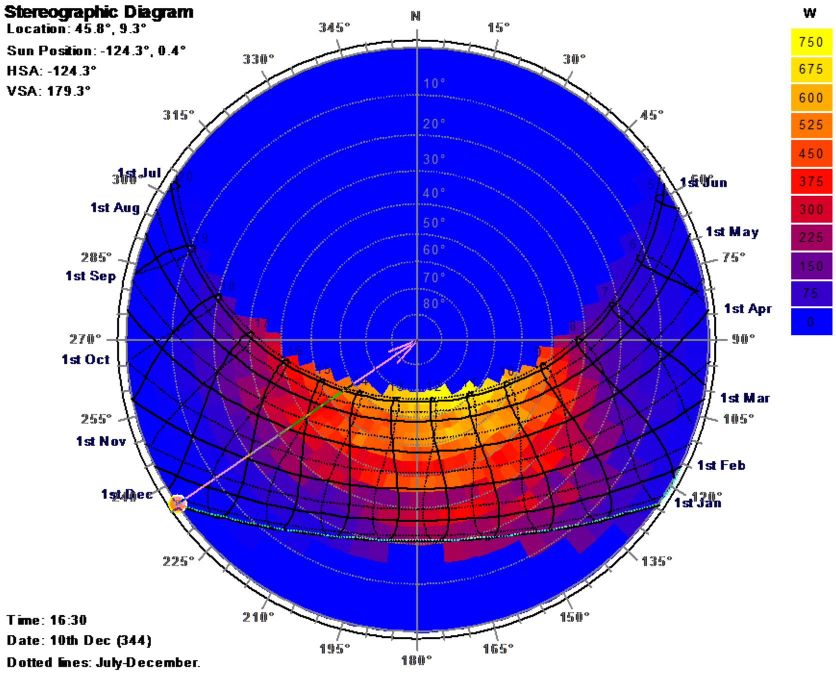


Figure 285 Steoreographic representation - solar radiation

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. Either the ***solar photovoltaic (PV) panels*** installed on the louvers as a cover to the outdoor pool and the top and front of green house .. These are highlighted in yellow colour on the figure below. The ***heliostat*** installed on the inner pool ceiling and adjacent to the mirror towers, serve the purpose of reflecting daylight into the building and allowing the users to facilitate from natural lighting.

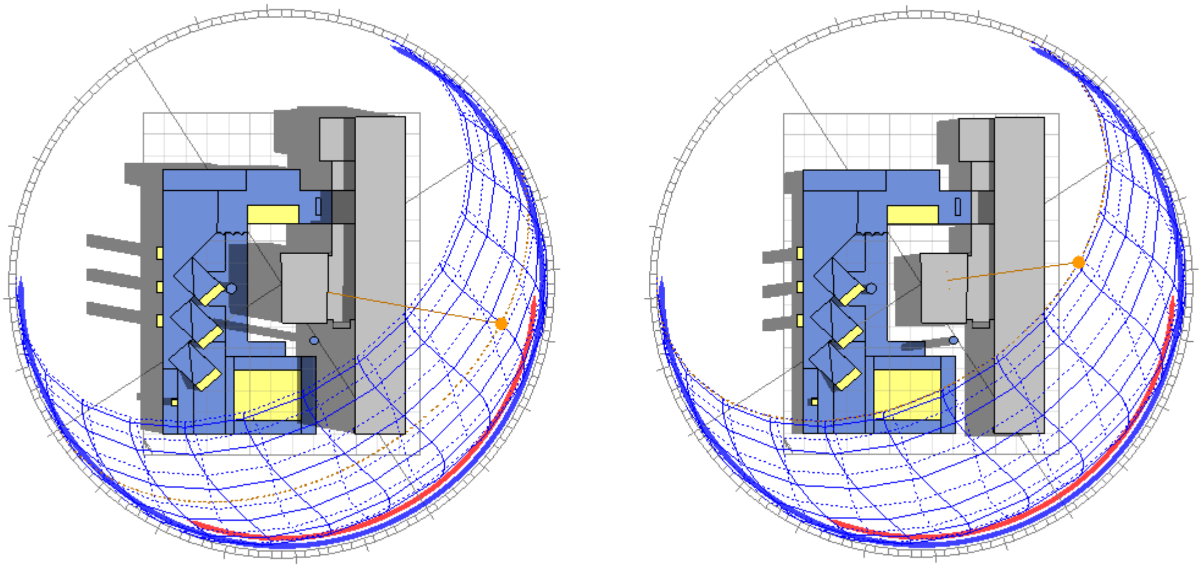
Figure 286 Heliostat and solar photovoltaic panels

In the following, we demonstrate in the project layout that the above mentioned elements would work rather efficiently to guarantee their function, because of the constant presence of solar radiations in sufficient quantity. The positions of solar PV panels and heliostats are highlighted in *yellow* colour, to differentiate from the rest of the building. The study of solar radiations at different times of the year proves that the elements are working properly throughout the day for almost the year round.

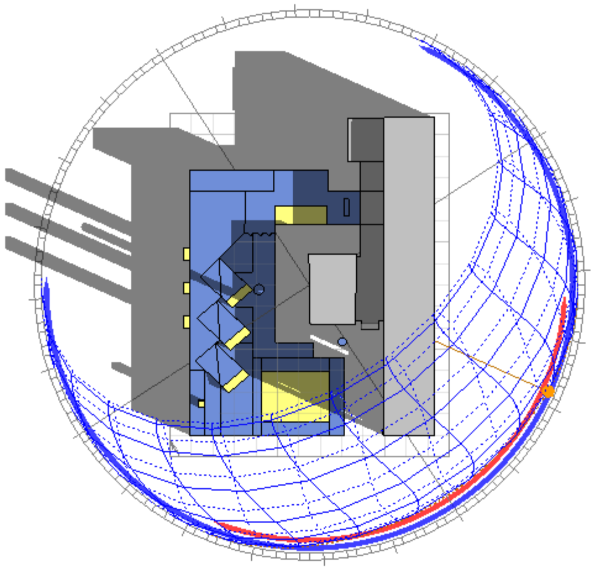
8.3.2 Analysis cases

In this regard, we analysed two cases, for the solstices and the equinoxes at 10.00 hrs in the morning as a start-up period, and at 17.00 hrs in the evening as the other extreme (except for December 21) of time period.

At Time = 10.00 hrs



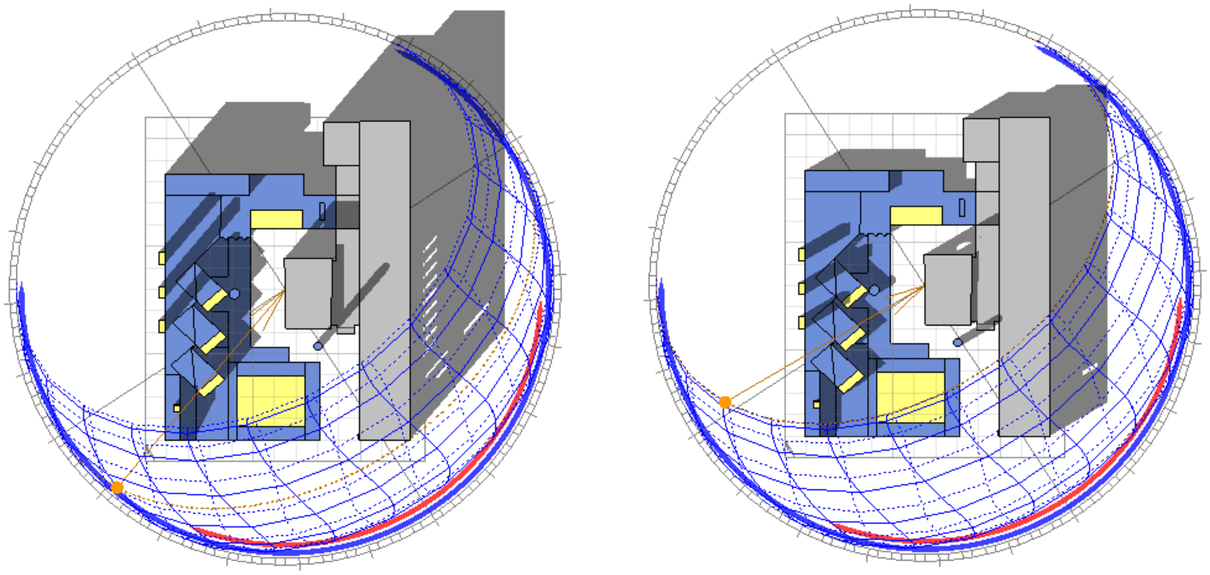
march 21 June 21



September 21 December 21

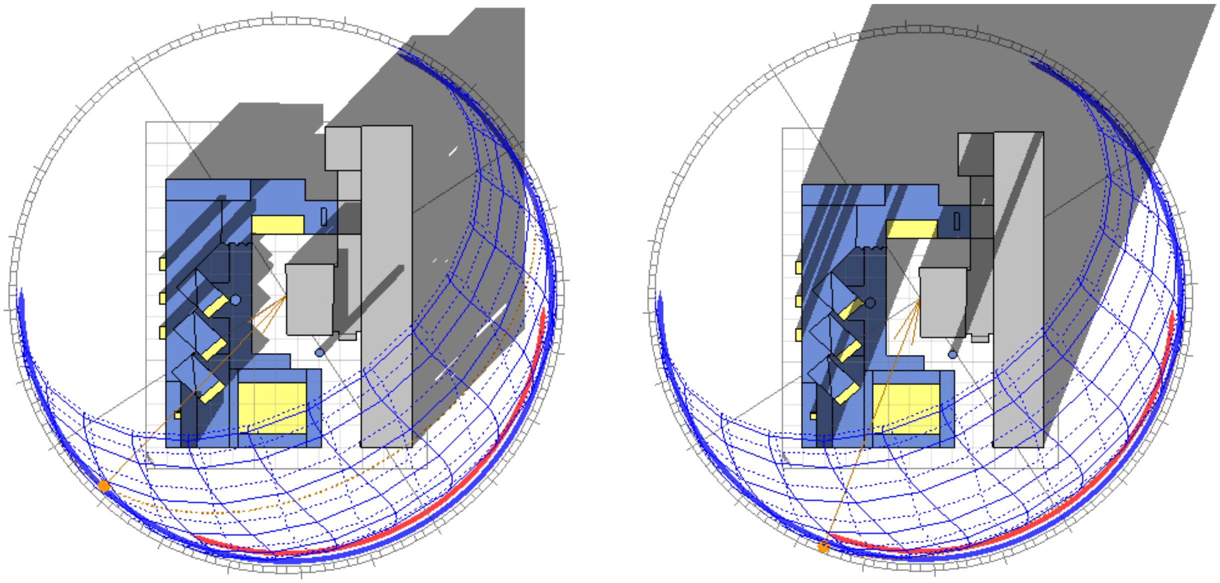
Figure 287 Daylight on the project building at 10.00 hrs

At Time = 17.00 hrs



March 21

June 21



September 21

December 21 @ 16.30 hrs

Figure 288 Daylight on the project building at 17.00 hrs

8.3.3 Conclusion:

After analyzing the above graphical representations for different times of the year, it becomes evident that solar radiations will be present for most time of the year. The PV panels at different places and the heliostats will receive sunlight to function efficiently and therefore play an important role in reduction of the energy consumed and playing their role in sustainability.

8.4 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 our project, we have analysed two spaces for the purpose of daylight levels i.e, the Meditation Units and the Reception area. The Meditation units are oriented towards south with their buffer area directly facing the south for better working. The Reception area is oriented towards south-west and comprises of three triangular windows in the office area and the green house glazing for the circulation area.

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 (see Fig.)

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

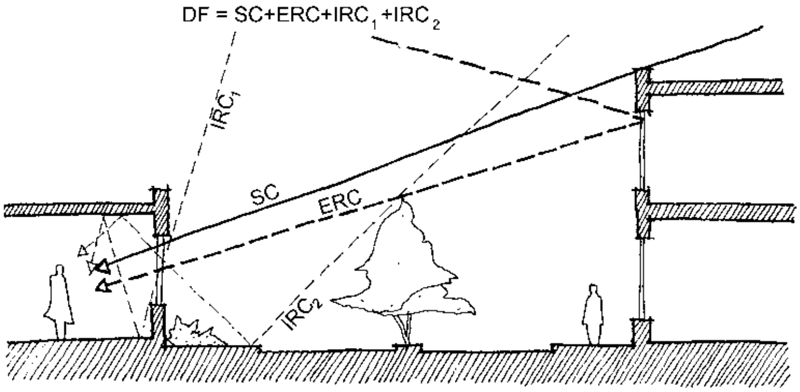


Figure 289 Components of daylight

Daylighting is an easily achievable LEED strategy if a building can provide a minimum daylight factor of roughly 2% in 75% of all occupied spaces.

8.4.1 Criteria adopted:

We are following the general values range for daylight factor and daylight levels in an activity area like office / retail etc., the range being as below:

Typically[132], Daylight factor = 2%

And, Daylight level = 300 – 500 lux

8.4.2 Meditation units:

Daylight analysis was performed using ECOTECT for the three meditation rooms oriented directly towards south to exploit the daylight and the following results were obtained. The following graphs reflect the daylight factor and daylight level. The internally reflected component, externally reflected component and the sky component are also presented which directly affect the daylight factor as previously mentioned.

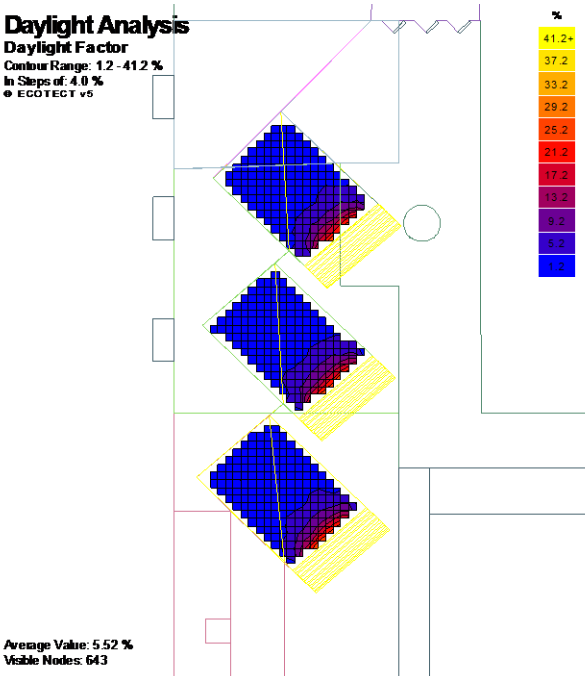


Figure 290 Daylight factor for meditation units

Daylight factor = 5.52 %
Daylight level = 469.41 lux

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[132] Mechanical and Electrical Equipment for Buildings - W. Grondzik, et al., (Wiley, 2010) BBS pg.588 , 493

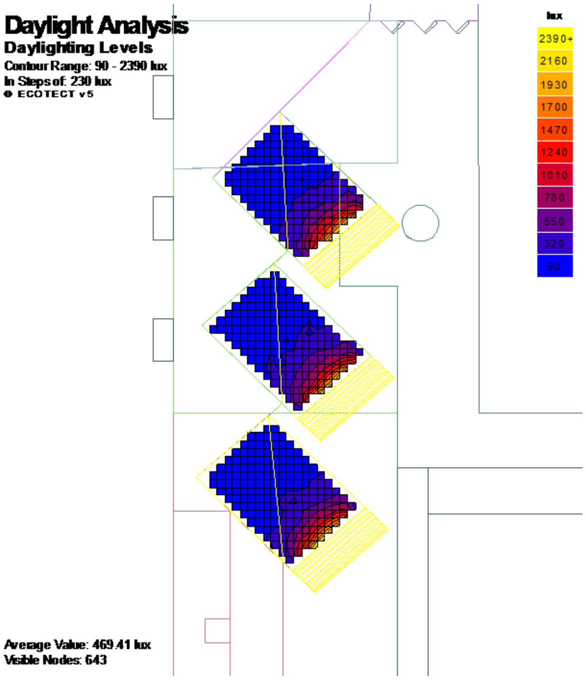


Figure 291 Daylight level for meditation units

From the above graphical representation it is evident that the values for daylight factor and daylight level falls in the range recommended. Thus satisfying the criteria and fulfilling the purpose of daylight comfort.

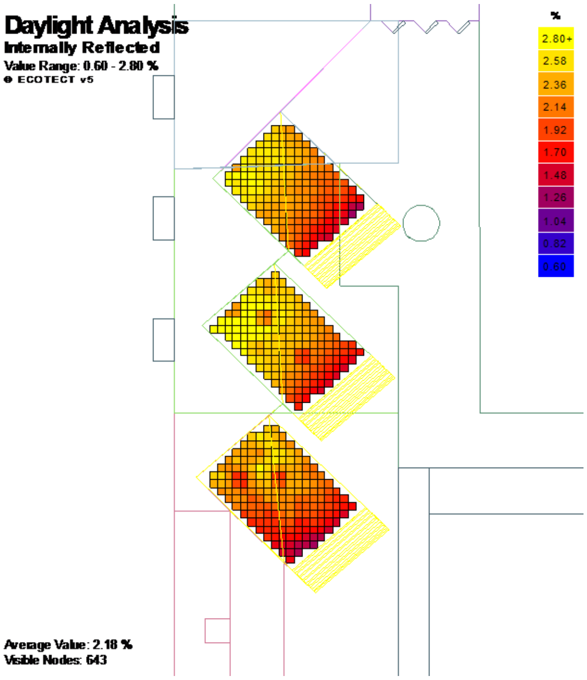


Figure 292 Internally reflectd daylight for meditation units

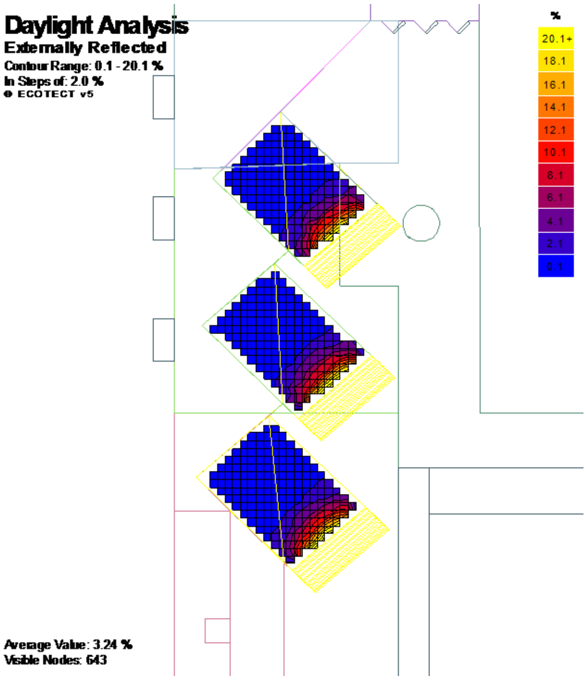


Figure 293 Externally reflected daylight for meditation units

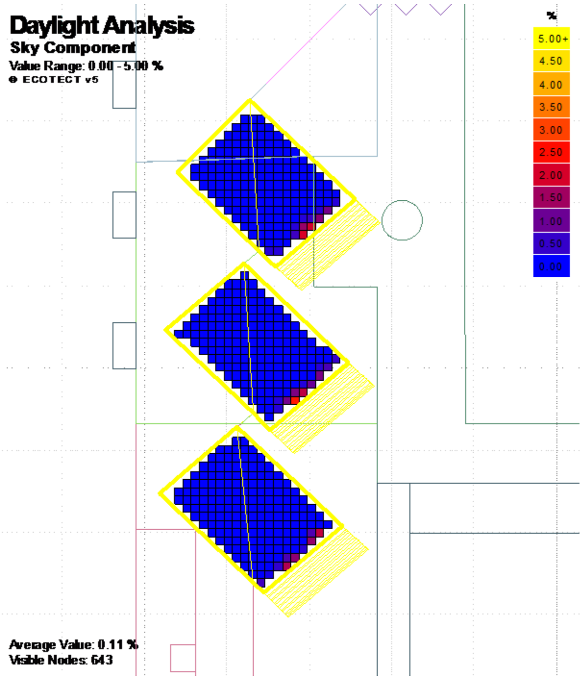


Figure 294 Sky component for meditation units

8.4.3 Reception:

Since the reception area is oriented south-west and has three triangular glazed windows in opening into the office area and a large glazing covering the green house along the circulation area, its analysis from ECOETCT is as below. The following graphs reflect the daylight factor and daylight level. The internally reflected component, externally reflected component and the sky component are also presented which directly affect the daylight factor as previously mentioned.

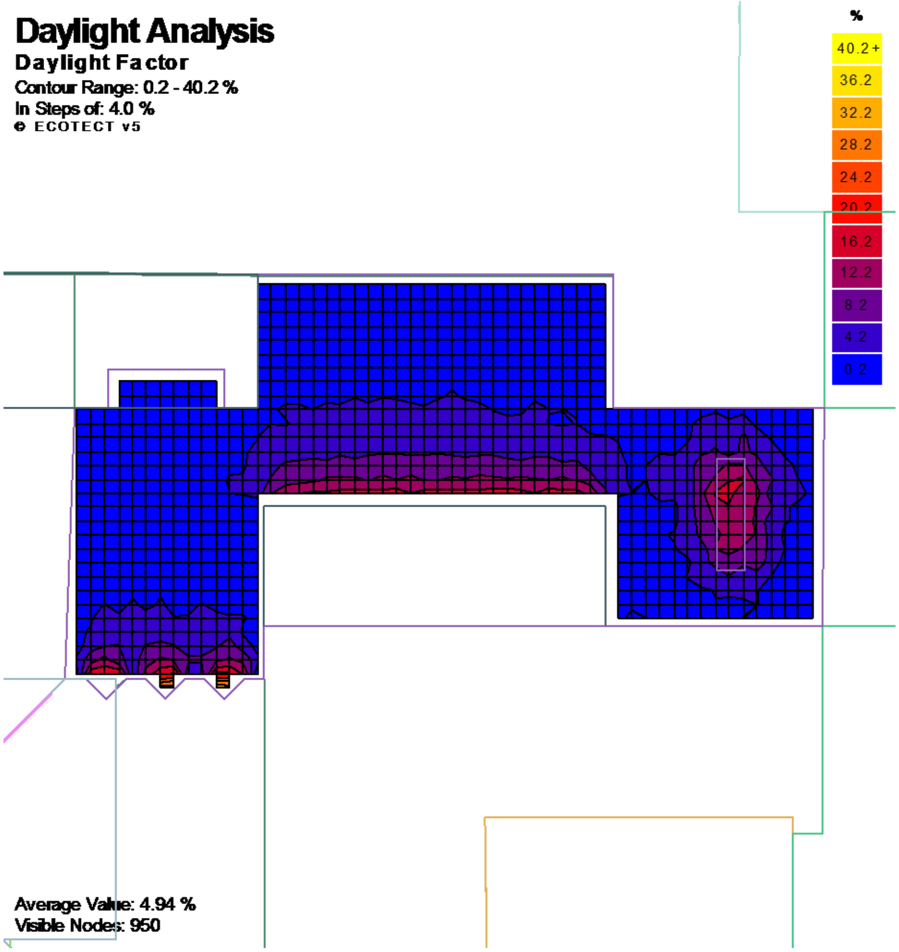


Figure 295 Daylight factor for reception area

Daylight factor = 4.94 %

Daylight level = 420.30 lux

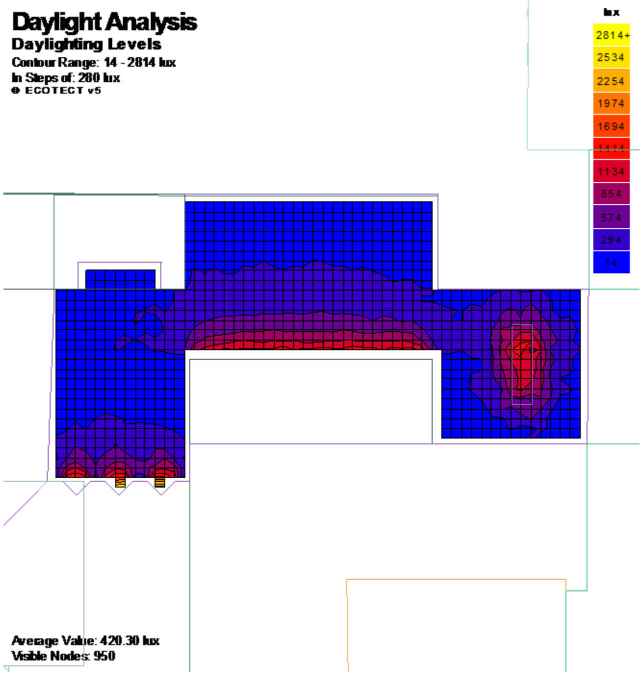


Figure 296 Daylight level for reception area

It can be observed that in the above graphical representation values for daylight factor and daylight level falls in the range recommended. Thus satisfying the criteria and fulfilling the purpose of daylight comfort.

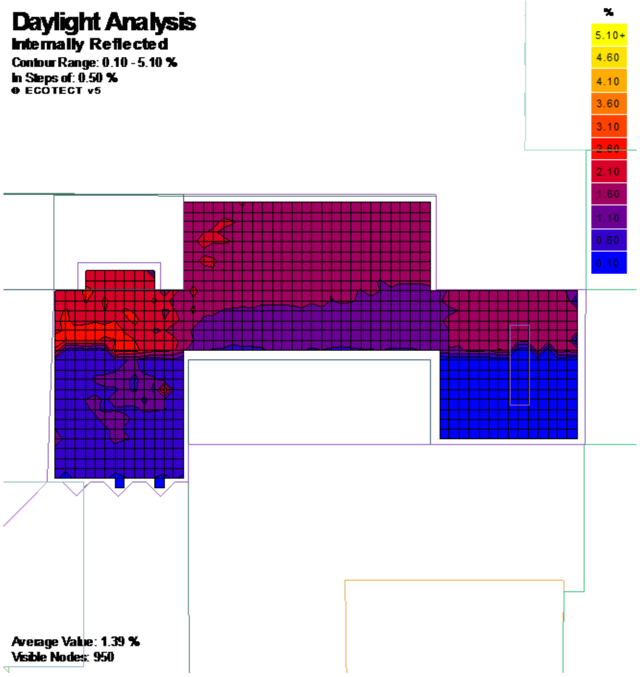


Figure 297 Internally refelcted daylight for reception area

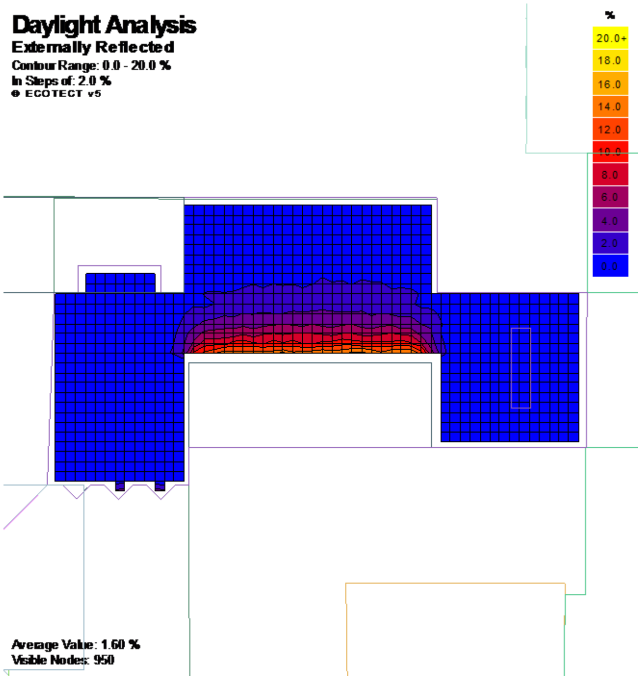


Figure 298 Externally reflected daylight for reception area

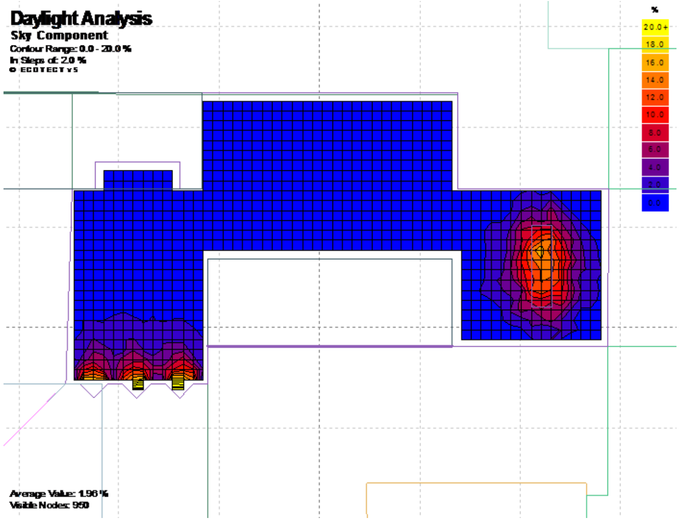


Figure 299 Sky component daylight for reception area

9. Services and Integrated system schemes

In light of the analysis and technological advances discussed in the foregoing sections, the schematic integration of all these technologies for different modes is presented herebelow:

9.1 Heating and cooling schemes

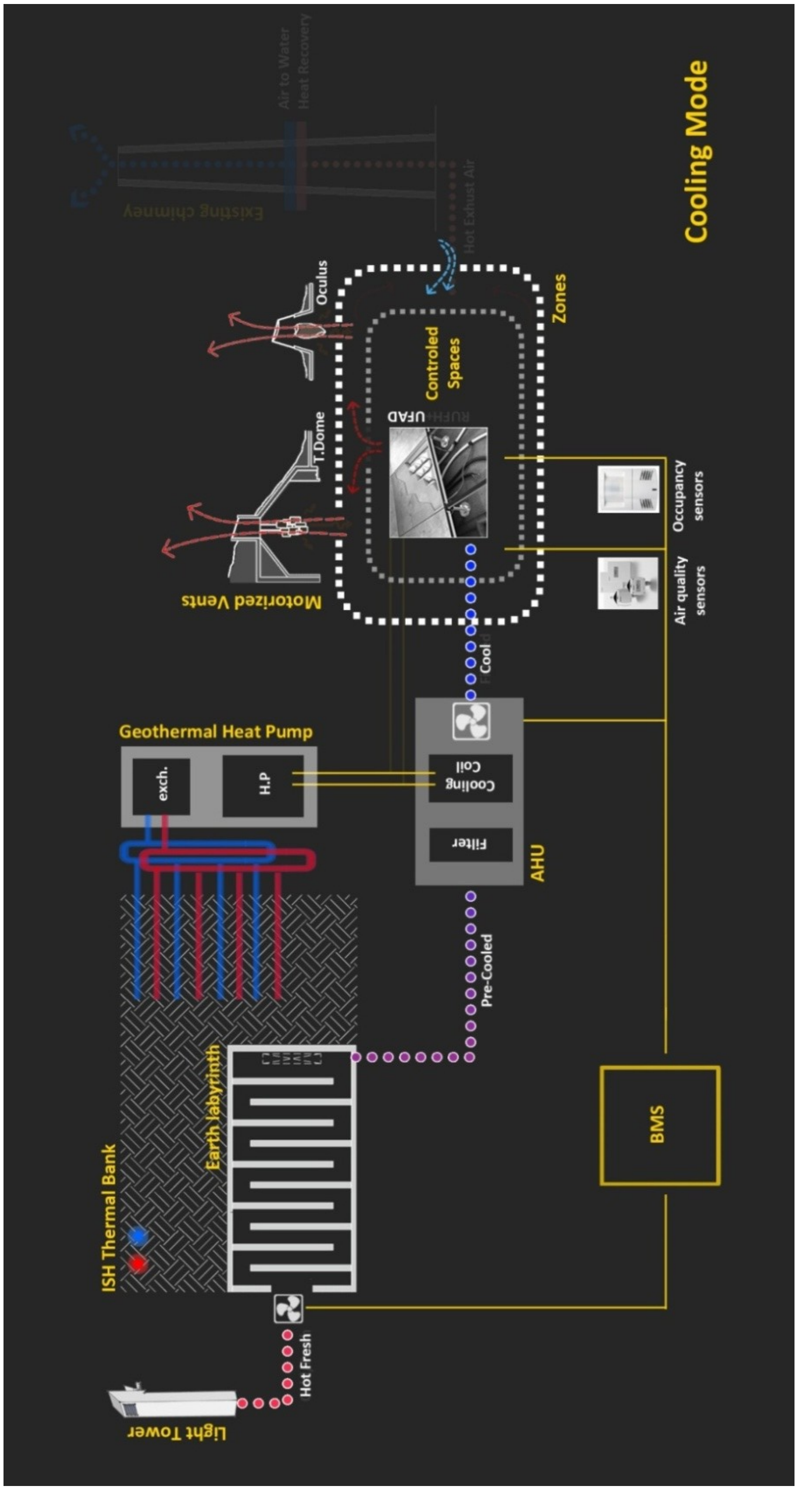


Figure 300 Summer cooling mode

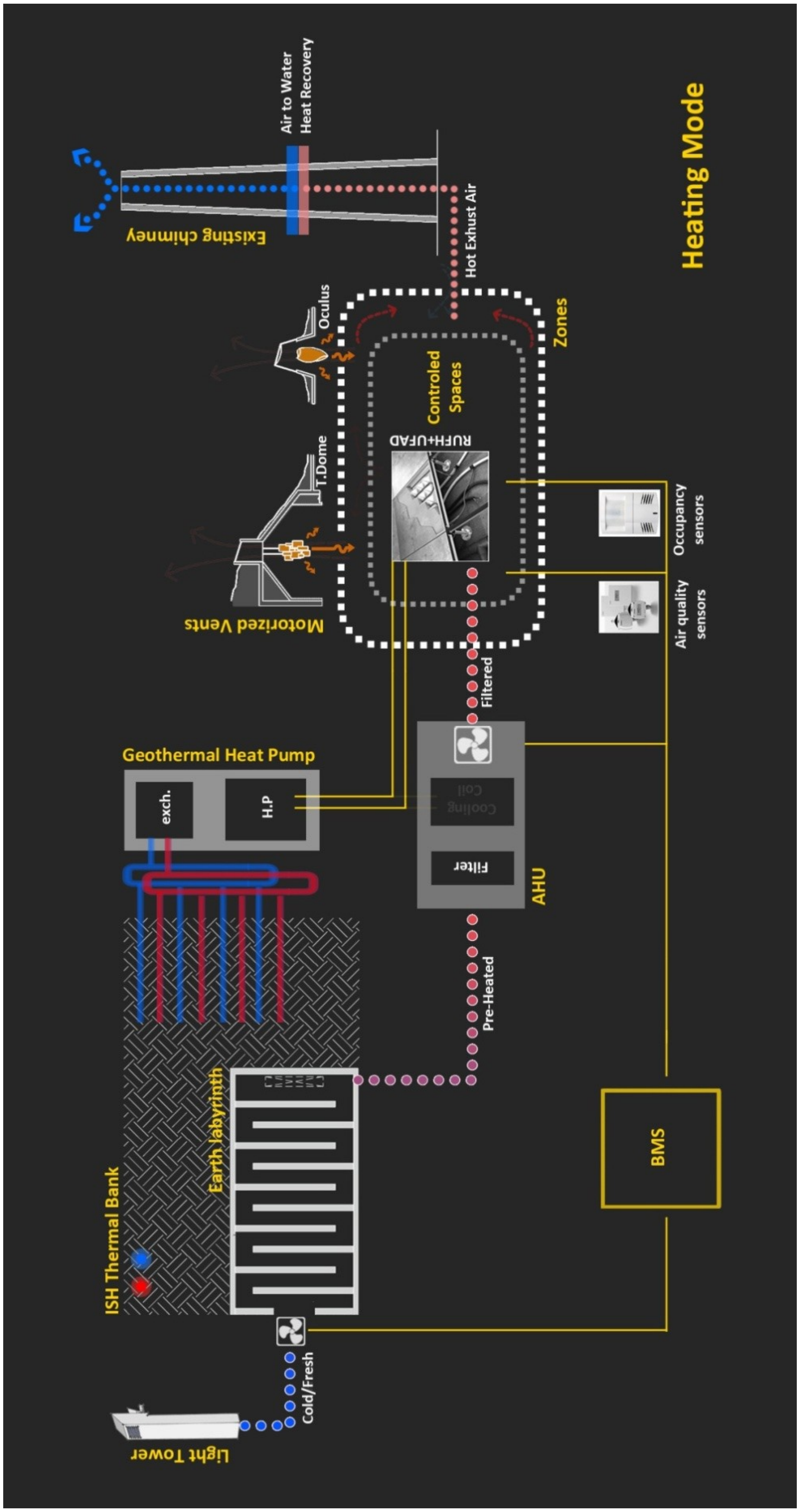


Figure 301 Winter Heating mode

9.2 Heat and water schemes

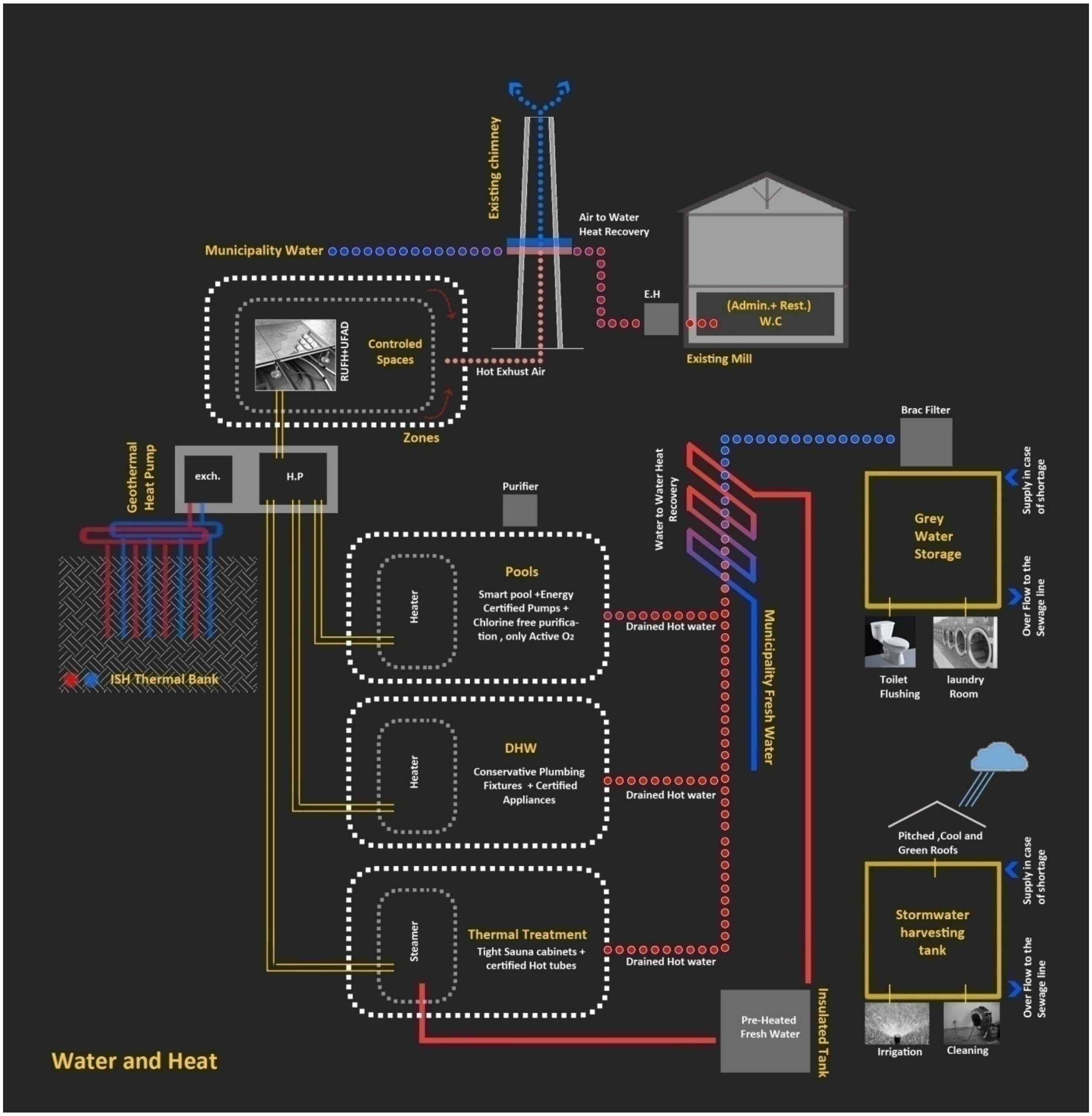


Figure 302 Water consumption and generation of heated water scheme

9.3 Electricity network

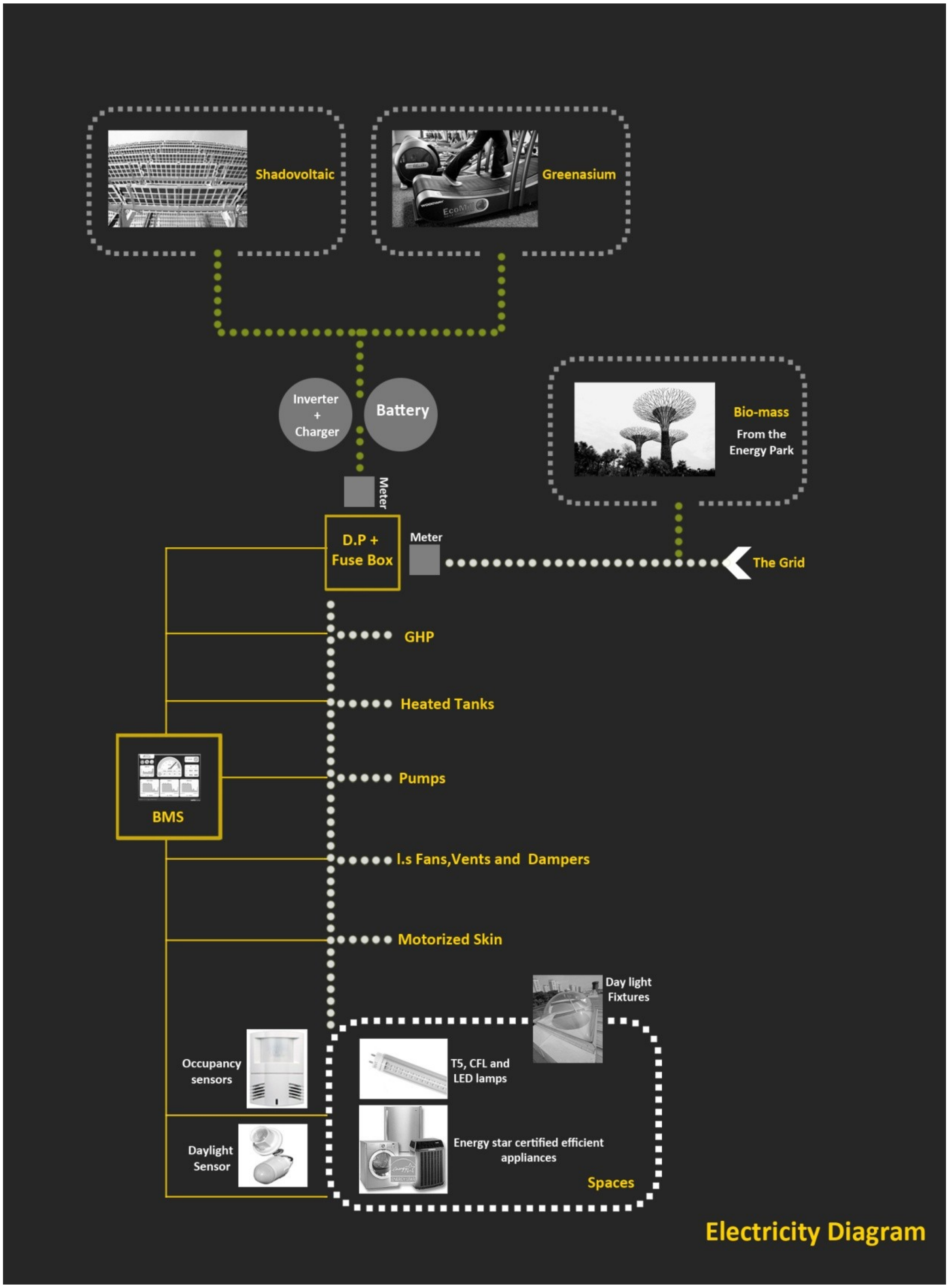


Figure 303 Electrical network scheme

10. Simulation and testing

10.1 Simulation of the Meditation Units

10.1.1 Designing the proper shade

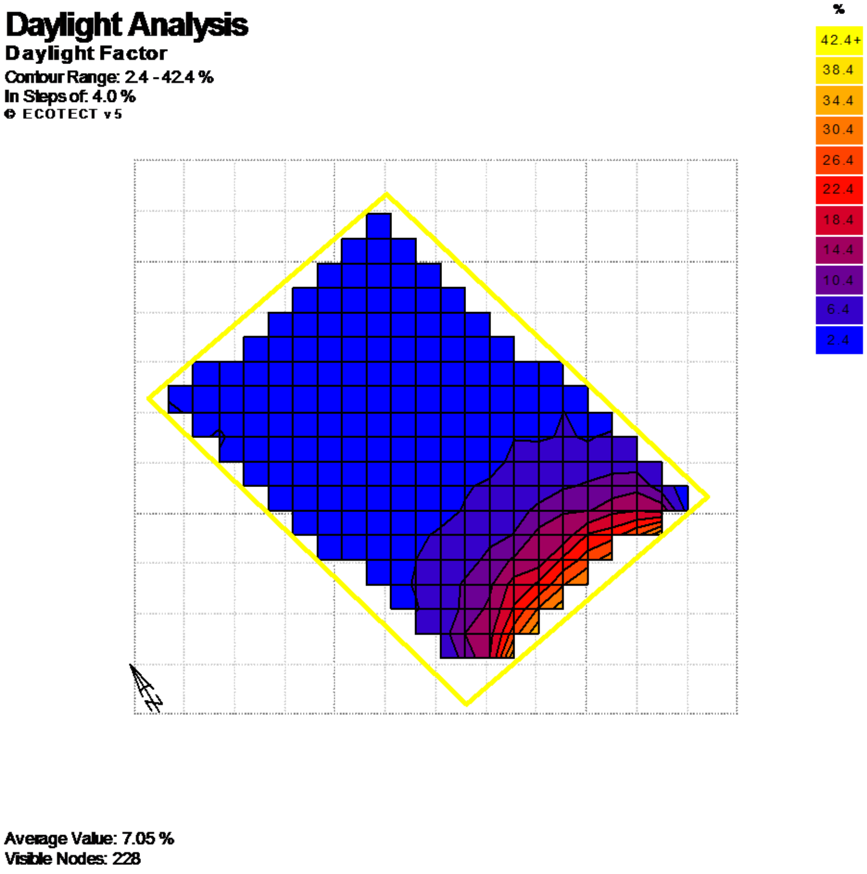
After designing the building for optimum daylight, and in lieu of the observations and research, it seems obligatory to at least test one of the components and see if it works properly and serves the purpose. This is done again taking help from ECOTECT for analyzing the shade for an area in the building. We are restricting ourselves to only two experiments that the proper shading has been provided i.e., daylight factor and the thermal load analysis.

10.1.2 Meditation units

We have taken one component of the building which is important part of the functional category as well as playing an important role in the aesthetics of the project i.e., the Meditation units. Since their orientation was specifically directed towards the south for the purpose of catching daylight and also solar radiations in the winter season, thus rendering it the best part to have the analysis.

10.1.3 Daylight factor comparison

10.1.3.1 Option 1: Without shade



Daylight Analysis
Daylight Factor
Contour Range: 2.4 - 42.4 %
In Steps of: 4.0 %
© ECOTECT v5

Average Value: 7.05 %
Visible Nodes: 228

Figure 304 Daylight factor without shade

10.1.3.2 Option 2: With normal shade

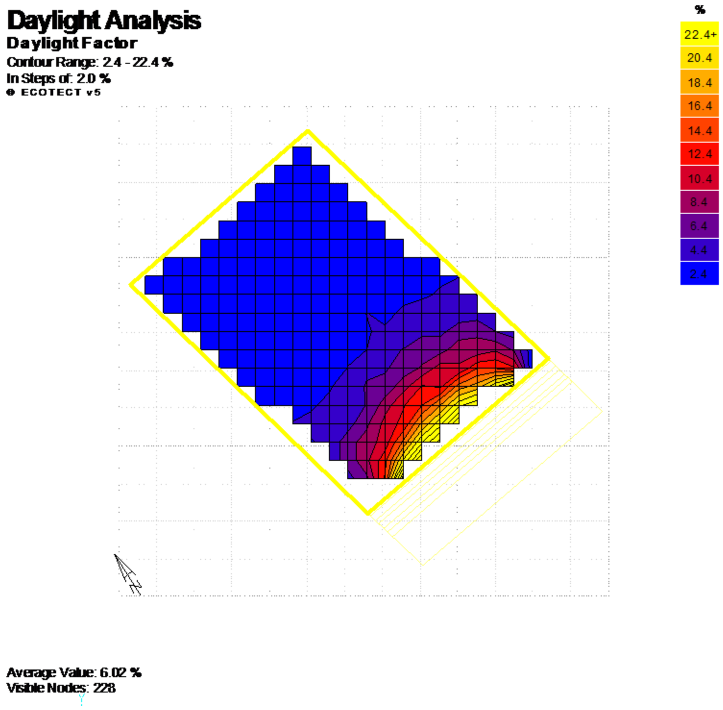


Figure 305 Daylight factor with normal shade

10.1.3.3 Option 3: With optimum shade

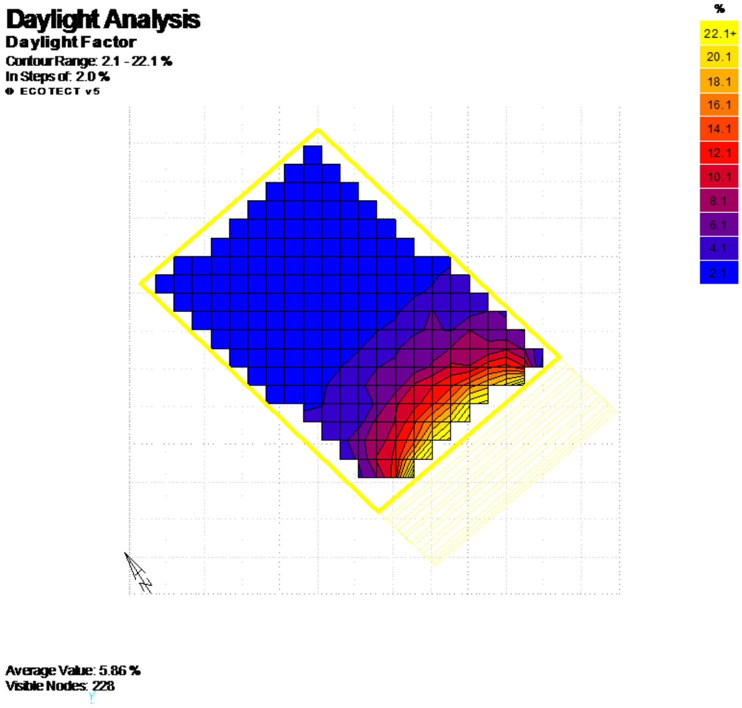


Figure 306 Daylight factor with normal shade

Comparison of options	**Option 1**	**Option 2**	**Potion 3**
Shade type	Without shade	Normal shade	Optimum shade
Daylight factor (%)	7.05	6.02	5.88

Table 27 Daylight comparison for meditation units

10.1.3.4 Conclusion:

We can see that although with the *Option 1* we are receiving the most percentage of daylight but as evident from the range on the graph, there is glare factor near the opening. In comparison, the optimum shading *Option 3* not only provides the optimum daylight factor but also omitting the chance of glare relatively.

10.1.4 Air-conditioning loads comparison

10.1.4.1 Option 1: Without shade

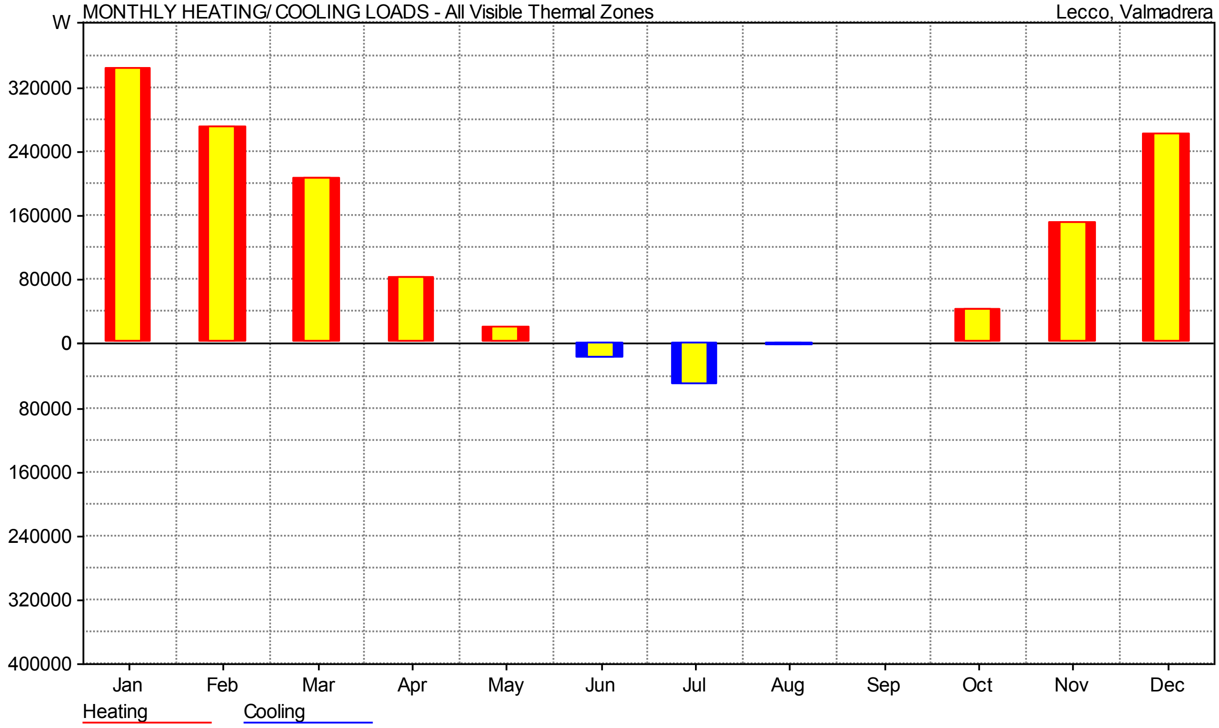


Figure 307 Air conditioning load without shade

MONTHLY HEATING/COOLING LOADS
Max Heating: 1055 W at 08:00 on 25th January
Max Cooling: 501 W at 15:00 on 21st July

Loads	Heating load (Wh)	Cooling load (Wh)	Total load (Wh)
Per year	1382273	72232	1454505
Per m^2	25292	1322	26614
Floor area	54.652 m^2		

Table 28 Air conditioning load without shade

10.1.4.2 Option 2: With general shade

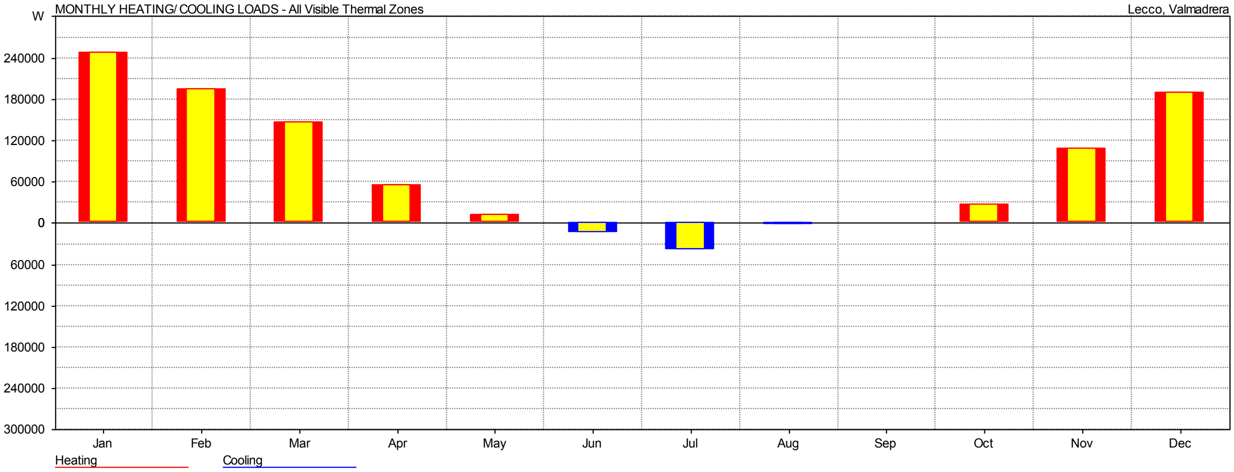


Figure 308 Air conditioning load with normal shade

MONTHLY HEATING/COOLING LOADS
Max Heating: 820 W at 09:00 on 25th January
Max Cooling: 620 W at 15:00 on 21st July

Loads	Heating load (Wh)	Cooling load (Wh)	Total load (Wh)
Per year	983949	53390	1037339
Per m^2	17990	976	18966
Floor area	54.652 m^2		

Table 29 Air conditioning load with normal shade

10.1.4.3 Option 3: With optimum shade

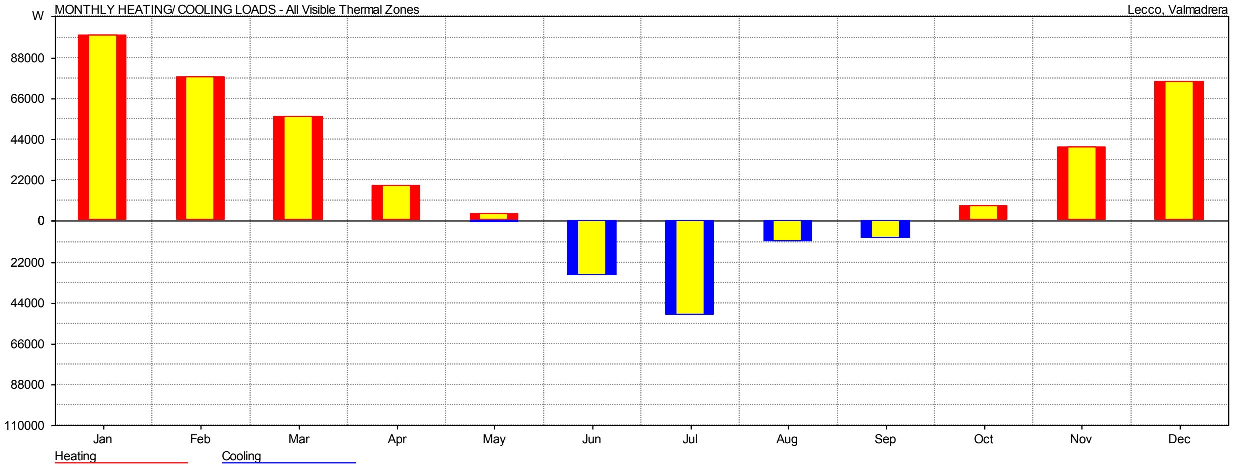


Figure 309 Air conditioning load with optimum shade

MONTHLY HEATING/COOLING LOADS
Max Heating: 355 W at 13:00 on 26th January
Max Cooling: 262 W at 14:00 on 21st July

Loads	Heating load (Wh)	Cooling load (Wh)	Total load (Wh)
Per year	379905	101525	481431
Per m^2	6946	1856	8802
Floor area	54.652 m^2		

Table 30 Air conditioning load with optimum shade

Comparison of options	Option 1	Option 2	Option 3
Shade type	Without shade	Normal shade	Optimum shade
Air-conditioning load (Wh/m^2)	26614	18966	8802

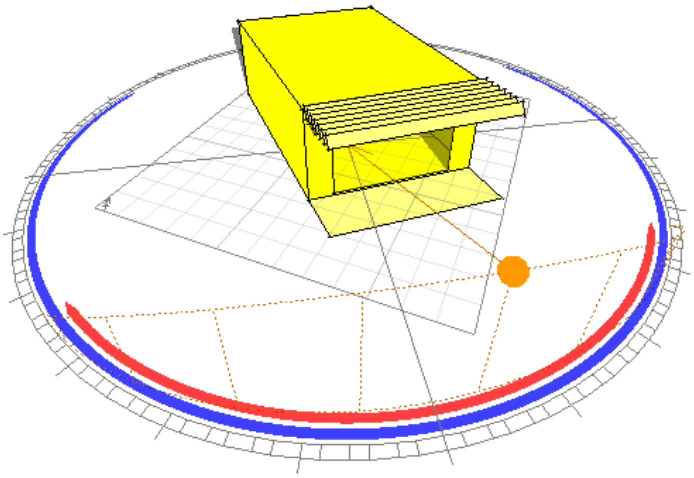
Table 31 Air conditioning load comparison for meditation units

10.1.4.4 Conclusion

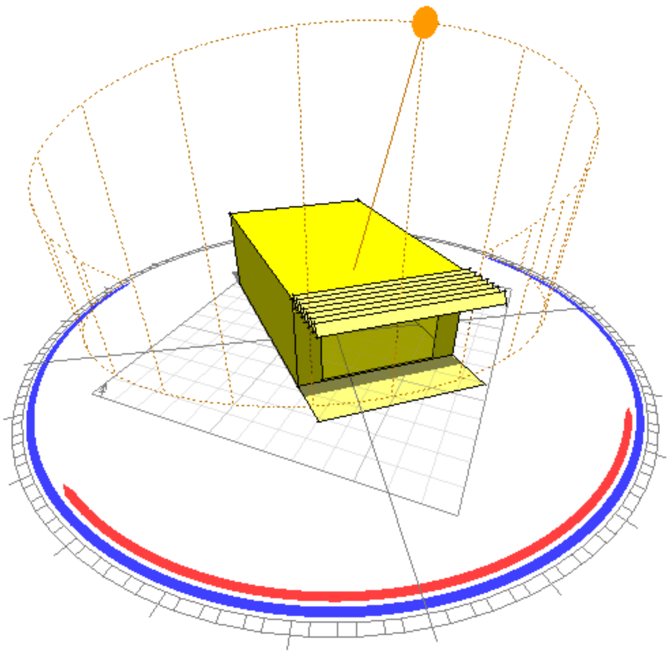
From the above comparative tabular data it is evident that with the without shade *Option 1* we are receiving the highest load for airconditioning while the lowest overall load is with the optimum shade *Option 3*.

The following diagrams are a clear evidence that the optimum shade is the most effective one, letting the daylight inside in winter when with the additional advantage of solar heat radiations needed therein. Apart from this, it is acting as an excellent shading device, covering literally all the opening area of the meditation unit.

Figure 310 Sun shade analysis for meditation units



Sun-path for December at 12.00 hrs casting no shadow



Sun-path for June at 12.00 hrs, optimum shadow

10.2 Simulation of the Oculus

10.2.1 Introduction and hypothesis

With respect to the previously presented **Combined integrated techniques** and **Living smart skins,** which had been used to form the final architectural shape and to develop relevant technological solutions, the below study will be focusing on the ventilation schemes of the Oculus lounge and the 2 building lungs (the Outdoor pool and the Glass house), specially during the summer mood.

Figure 311 Basement Key plan

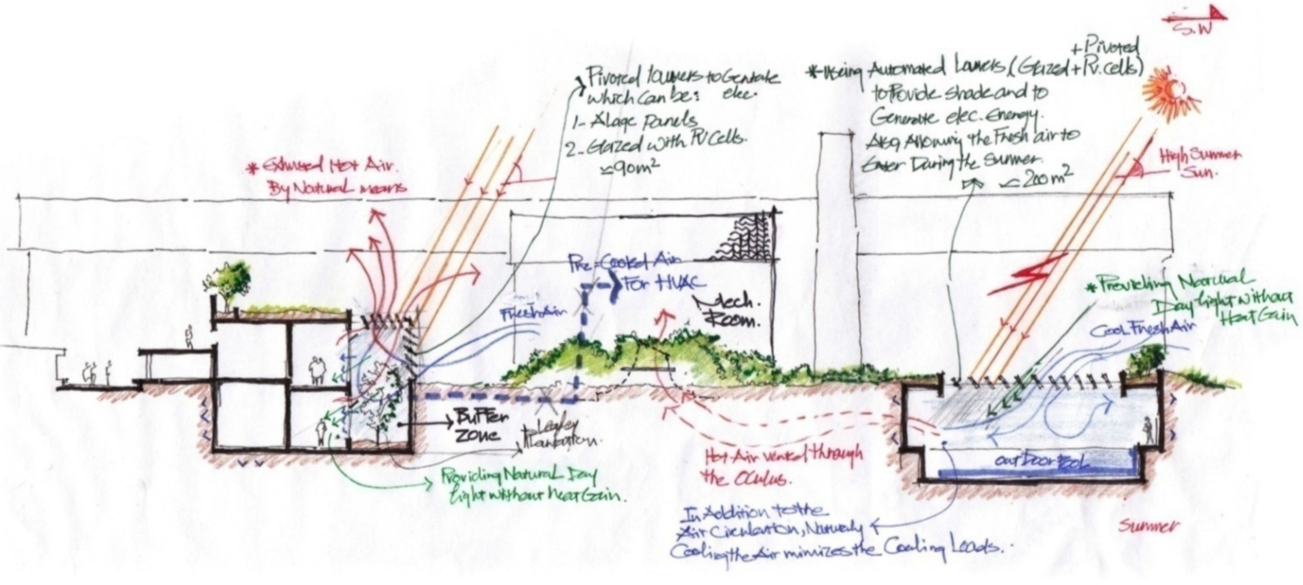


Figure 312 Schematic section through the Pool and the Glass house

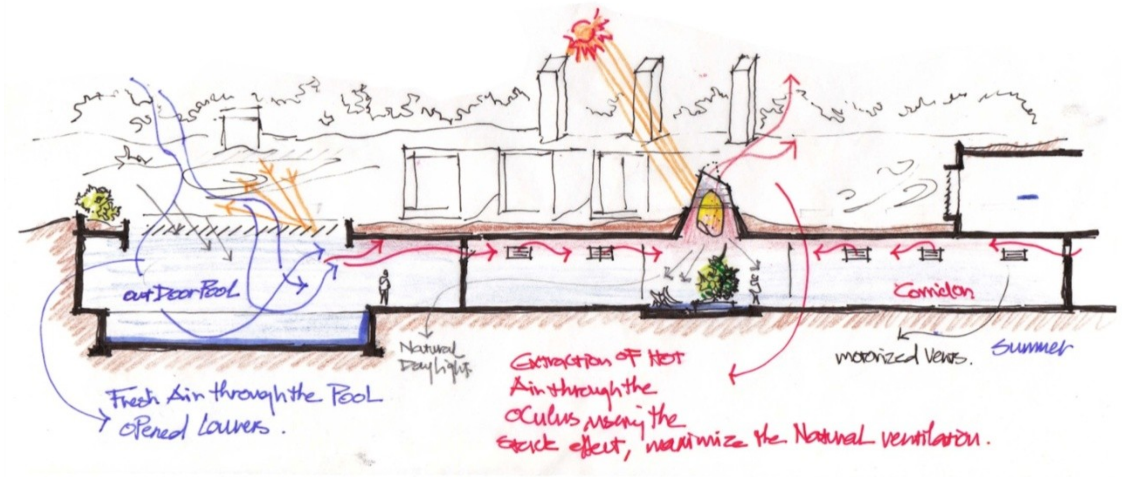


Figure 313 Schematic section through the Lounge

As introduced earlier, we were hypothesizing that during the summer period a "Building air wash" process can take place, as the cool air will be naturally dragged from the shaded outdoor pool and glass house, through the operable motorized vents which are located by the 2 ends of the corridor.

Taking into account the presence of the oculus opening, which will be opened simultaneously with the two door vents of the corridor after receiving a signal from the BMS, the hot exhausted air which is collected above the corridor high perforated ceiling will be naturally extracted through the oculus using the Buoyancy effect. Relevant effect will be favored using the Heat sink chandelier which will create air convection currents, as explained in the architectural chapter.

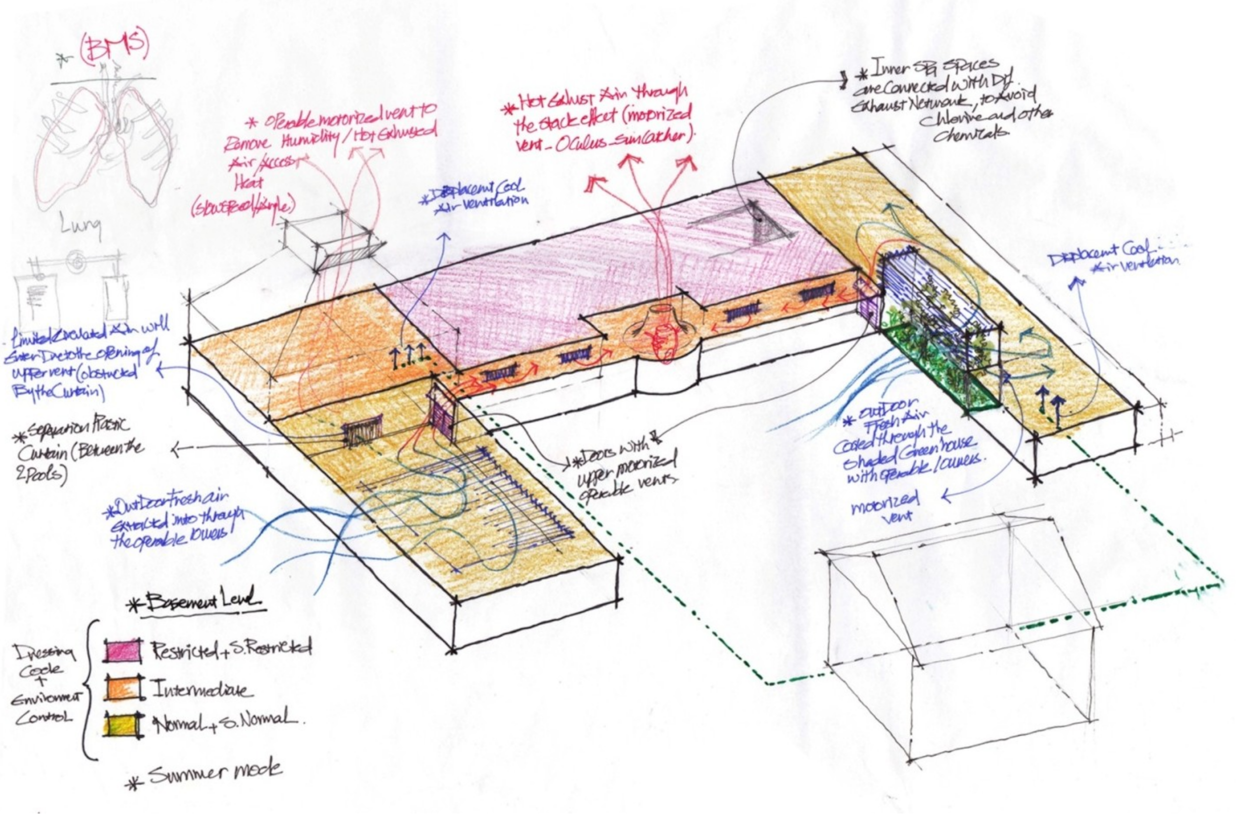


Figure 314 Summer mood ventilation scheme

10.2.2 Methodology and testing:

Since that the criteria adopted for this thesis is based on the practical analysis and assessment, it was essential to test the air circulation behavior in the centralized area of the lounge, especially with its role in the whole mechanism of the “Building breathing”. The Oculus lounge can be considered like an intermediately semi-sensitive area, with respect to its location as a common preparatory zone for the Spa and Pools areas. Thus, attention should be paid to the intermediate clothing and user’s general comfort beside the building breathing behavior.

With the help of IES-VE software (Integrated environmental solutions) and Lecco weather data, we were able to simulate the air circulation behavior from the intake point till the final extraction, with respect to its velocity, temperature, pressure, etc., in order to ensure the efficiency of the whole mechanism and to guarantee the maximum comfort as well as the indoor air quality.

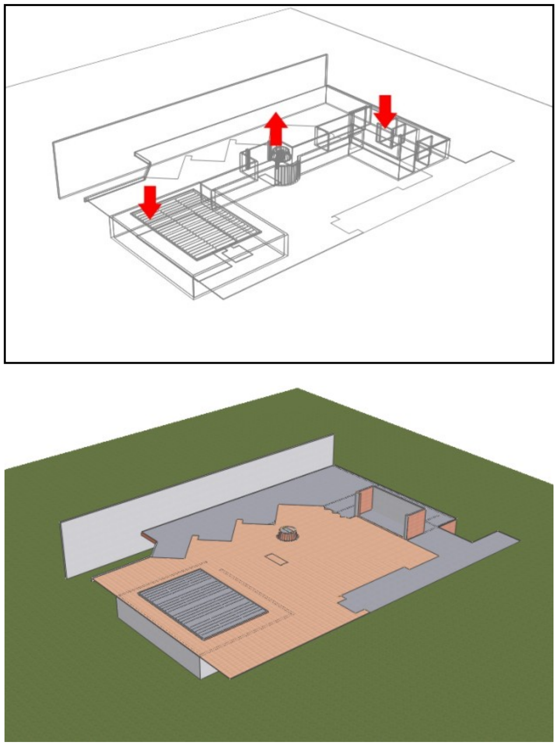


Figure 315 Schematic 3d view by IES

10.2.2.1 Experiment conditions and inputs:

- The testing will take place during the hottest summer month –July, with respect to the previously introduced climatic analysis, considering the most proper periods for natural ventilation and mixed mode.
- The Heat sink chandelier will be modeled as a radiator, with a range of temperature of 60C°, noting that the original situation is the Heat sink will be heated by the sun radiation during the summer day.
- The inlet air temperature is lower than the External air temperature (as per the EIS results), as the air stream is coming from 2 shaded cool areas.
- The UFAD which is originally used to ventilate this area will be excluded from this test—the mixed mode is not included, as the main aim of the study is to assess the process of Naturally washing the building with fresh Air, which can take place whenever is needed – with respect to BMS and relevant sensors – or during the night hours.
- For the ease of the simulation, the corridor and the lounge areas were the only activated zones during the calculations and the rest of the building (including the SPA zone) were disconnected from the model.

10.2.3 Results and analysis

The below schemes will be showing the resulted behavior of air, in terms of comfort, distribution and circulation, as extracted from IES software.

Also it is important to highlight that the limits of the colored margin scales shown in the schemes extracted from IES are only referring to the highest and lowest values which can be found in the case study , as it is not referring to any external references. For example, the Red color does not mean that the value is referring to a too hot area or odd air velocity, but it means that it the highest value among the results, excluding if it is extreme or too high as per the comfort norms.

Some of the limits related to the margin scales will be modified, only for the clearance of the results as will be introduced.

10.2.3.1 Air flow characteristics

We can observe from the below scheme the efficiency of the hypothesized air movement mechanism, as by opening the 2 motorized vents by the ends of the corridor and the Oculus vent simultaneously , the cool air will be naturally dragged in , mean while the warm collected air will be released through the upper oculus.

During some months of the year the process may not work efficiently as it can be reversed, further clarification will be provided in the conclusion part.

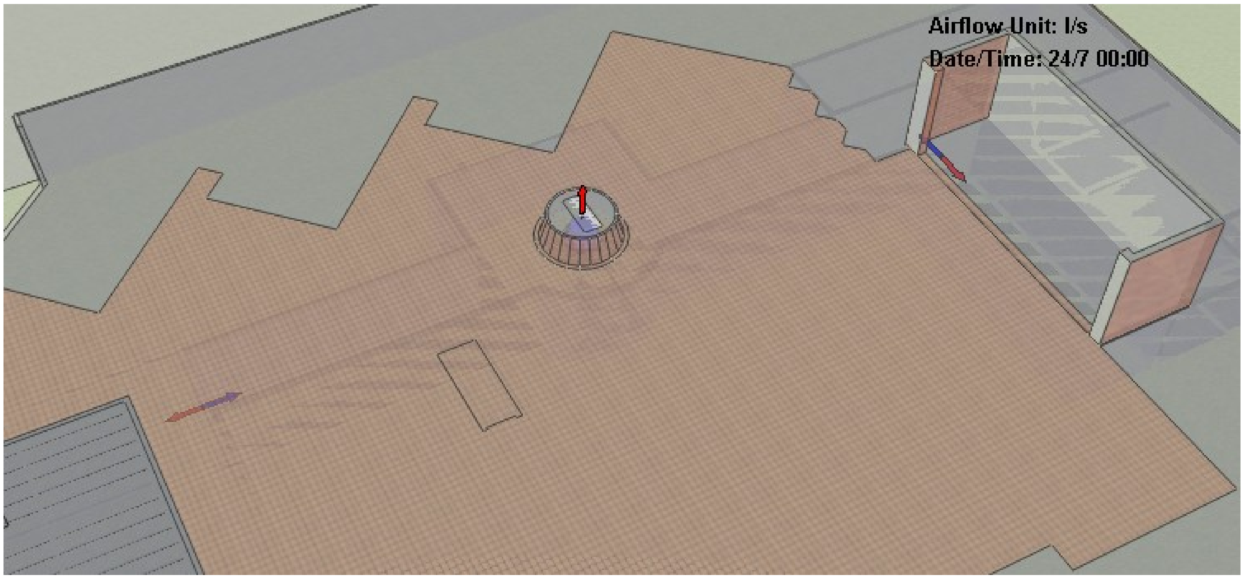


Figure 316 Expected air in/out scheme as extracted from the IES

10.2.3.2 Thermal comfort

It can be defined as the condition of mind which expresses satisfaction with the thermal environment and is assessed by subjective evaluation.[133] The person's sensation of warmth is influenced by main physical parameters, which constitute the thermal environment[134] as:

- Air temperature
- Mean radiant temperature
- Relative air speed
- Humidity
- Personal factors (clothing and metabolic heat production)

Air Temperature:

By checking the below schemes, we can observe that the cool air coming through the motorized vents will be uniformly distributed and got slightly warmed. Due to the high perforated ceiling of the corridor, the warm air will be collected at the upper portion of the space out of the breathing zone, and then it will be naturally released through the motorized operable oculus, thanks to the buoyancy and air convection favored by the hot chandelier.

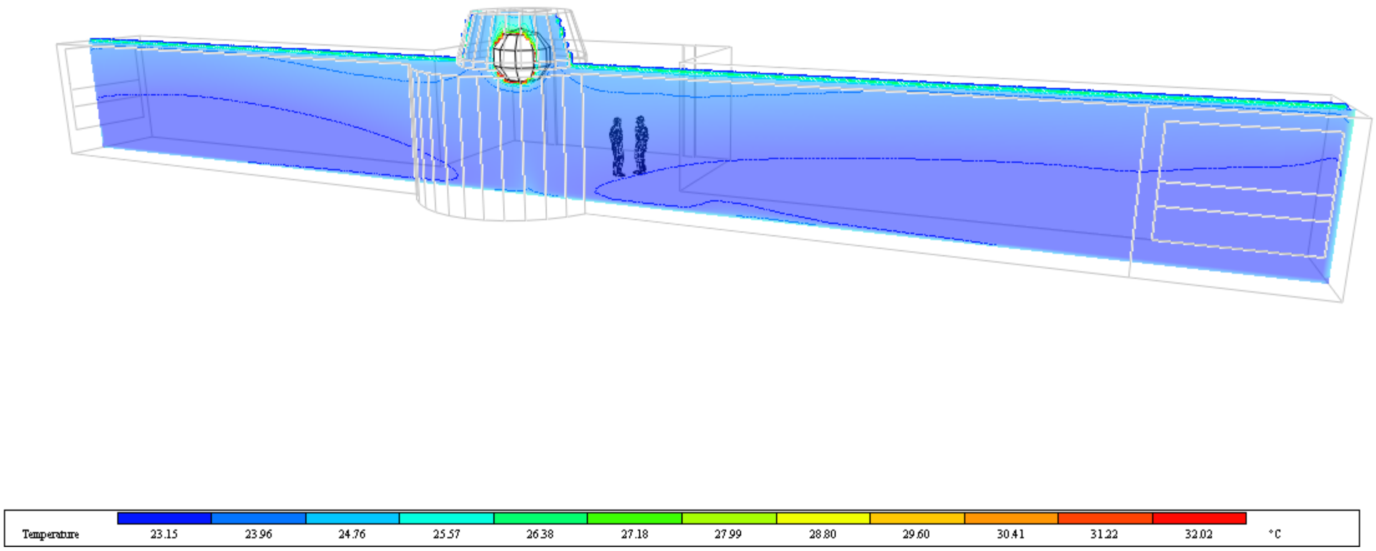


Figure 317 Temperature profile with original scale

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[133] ASHRAE Standard 55

[134] Thermal Environmental Criteria lecture ,Prof. Giuseppe Rapisarda, Polimi 2012

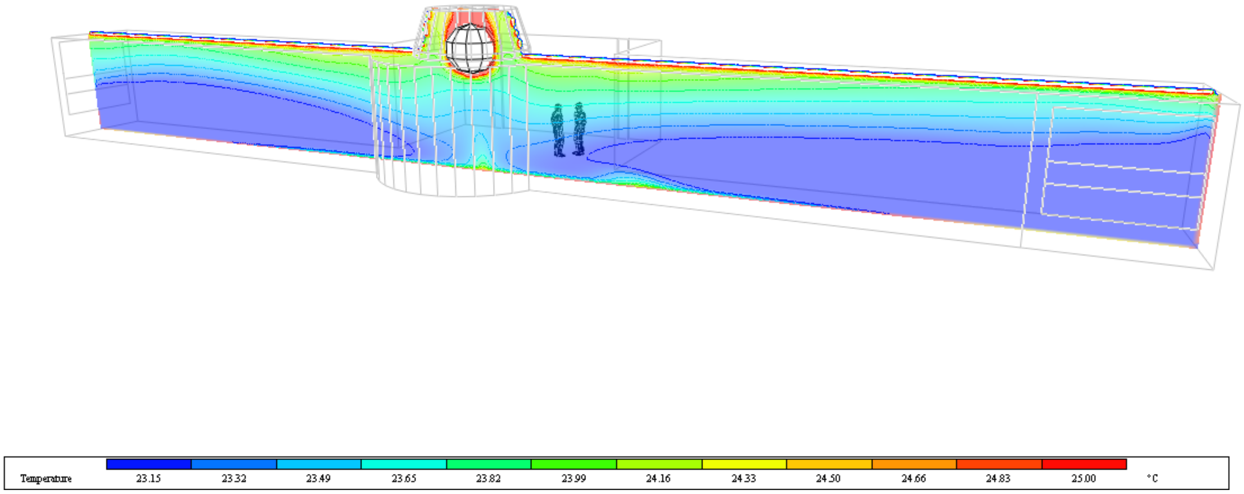


Figure 318 Temperature profile _ Modified scale

From the above figures we can see the uniform temperature distribution of (23 C°) in the breathing zone; meanwhile the hot air will be collected above the ceiling to be extracted through the oculus, Thanks to the hot sink chandelier and the stack effect, as shown below.

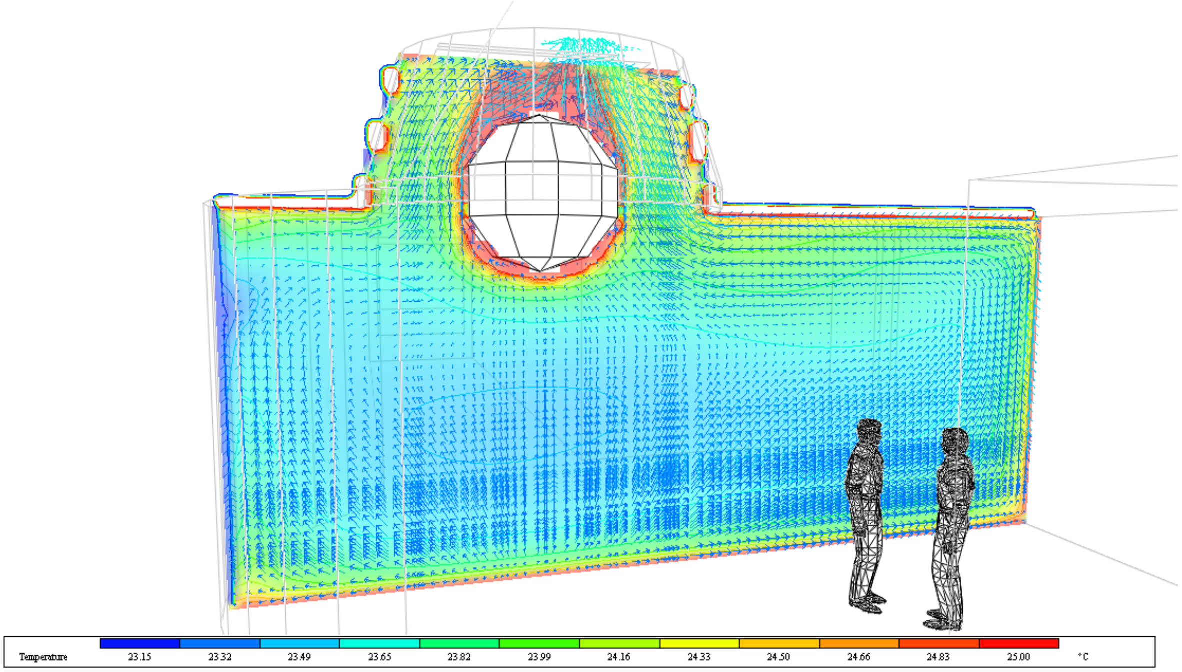


Figure 319 Combined temperature and air circulation schemes _Lounge Cross section

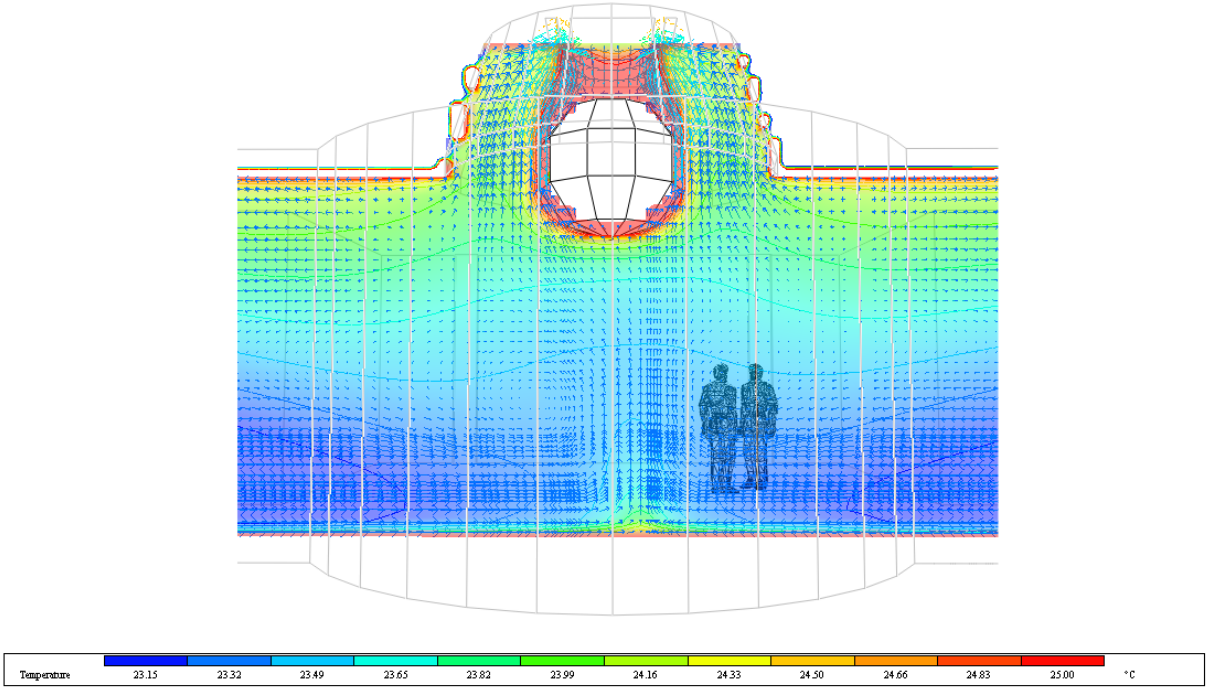


Figure 320 Combined temperature and circulation schemes _ Lounge Long. Section

Air velocity:

Moving-air velocity in normally occupied rooms is between 0 to 2 m/s, also the comfort velocity required for this type of buildings around 0.35 m/s and 0.1 m/s near neck head to avoid the draft localized feeling. Relevant criteria was met as shown in the below scheme.

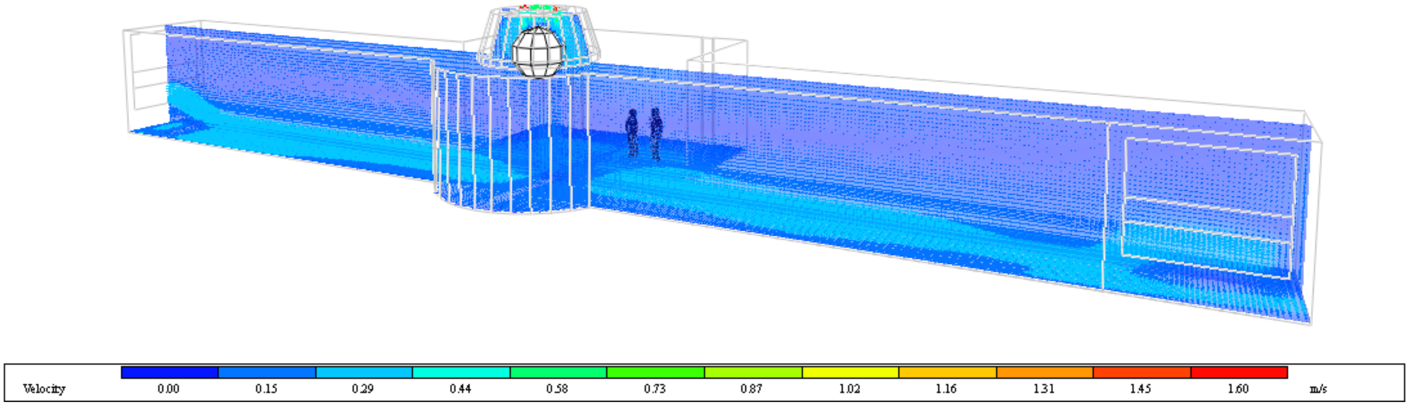


Figure 321 Air velocity inside the lounge and corridor_ Modified scale

Air Turbulence:

As shown in the below scheme, an uniform air flow - starting from the opening on both sides of the lounge in the direction of the oculus - was achieved, even for the corners and recessed areas.

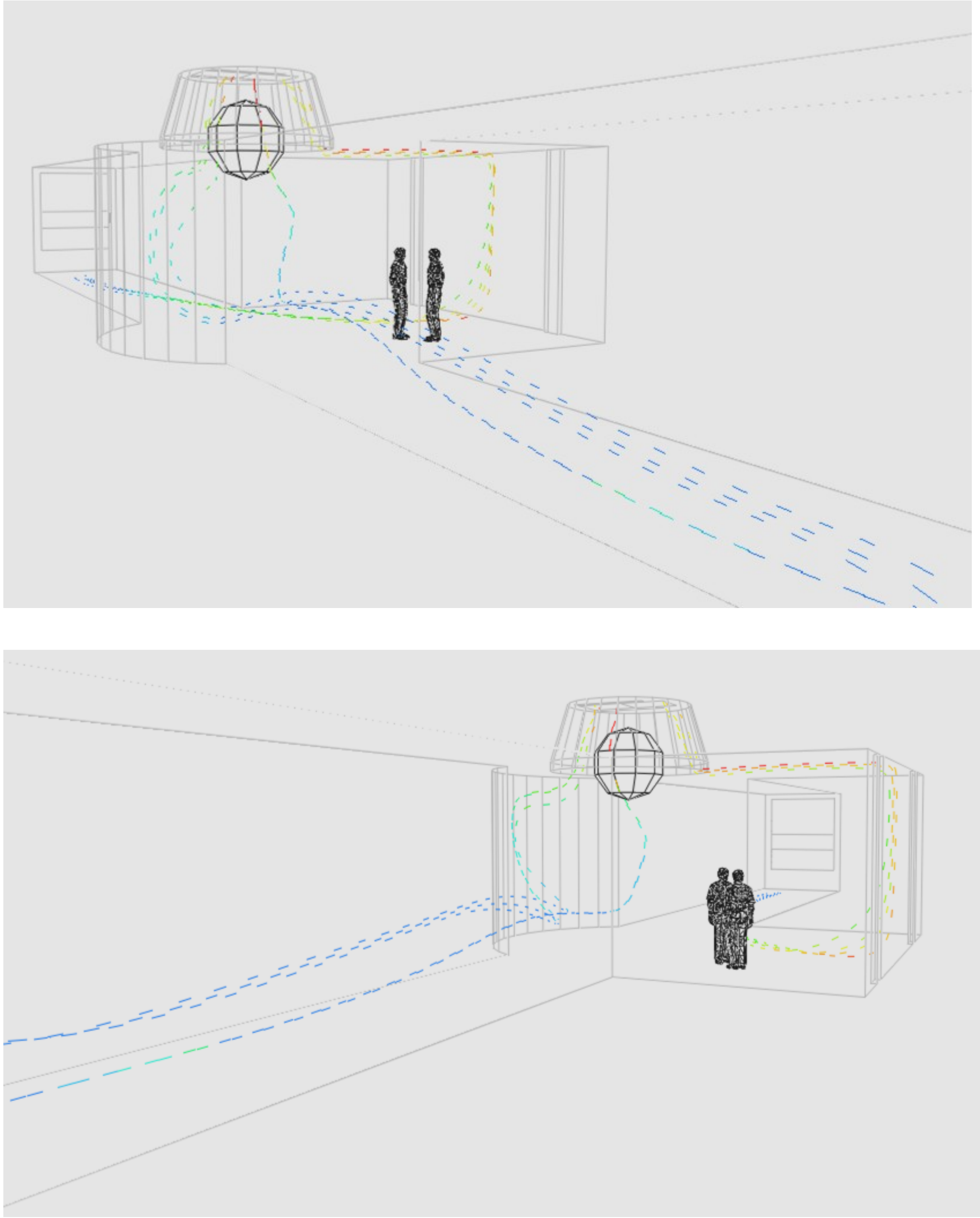


Figure 322 Air circulation schemes to/from the lounge

User’s satisfaction:

Relevant satisfaction can be clarified by PPD and PMV, as Percentage of people dissatisfied (PPD) and predicted mean vote (PMV) which is the average comfort vote, using a seven-point thermal sensation scale from cold (-3) to hot (+3), both of indexes are used for the assessment of indoor thermal environments. The chart demonstrates that dissatisfaction among less than one-third of the occupants is achieved in indoor environments within the slightly cool to slightly warm categories[135].

As observed in the results of the simulation, the achieved PPD index was around 20% in most of the regions and the PMV index was between -0.10 to -0.55 except for the regions beside the windows. Relevant achievement maximizes the quality of the indoor environment, with respect to the sensitivity of the area.

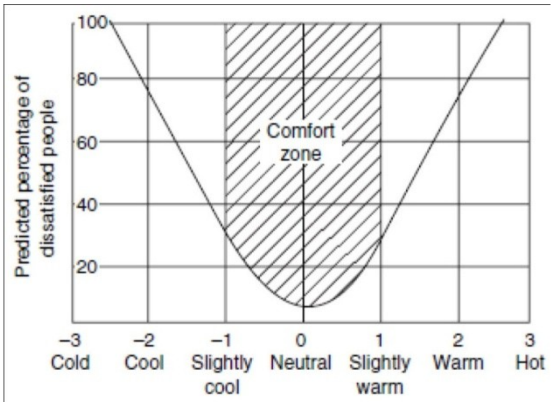
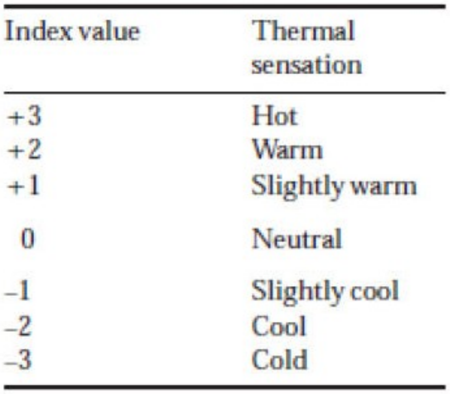


Figure 323 PPD VS PMV chart



Index value	Thermal sensation
+3	Hot
+2	Warm
+1	Slightly warm
0	Neutral
–1	Slightly cool
–2	Cool
–3	Cold

Figure 324 Thermal sensation scale table

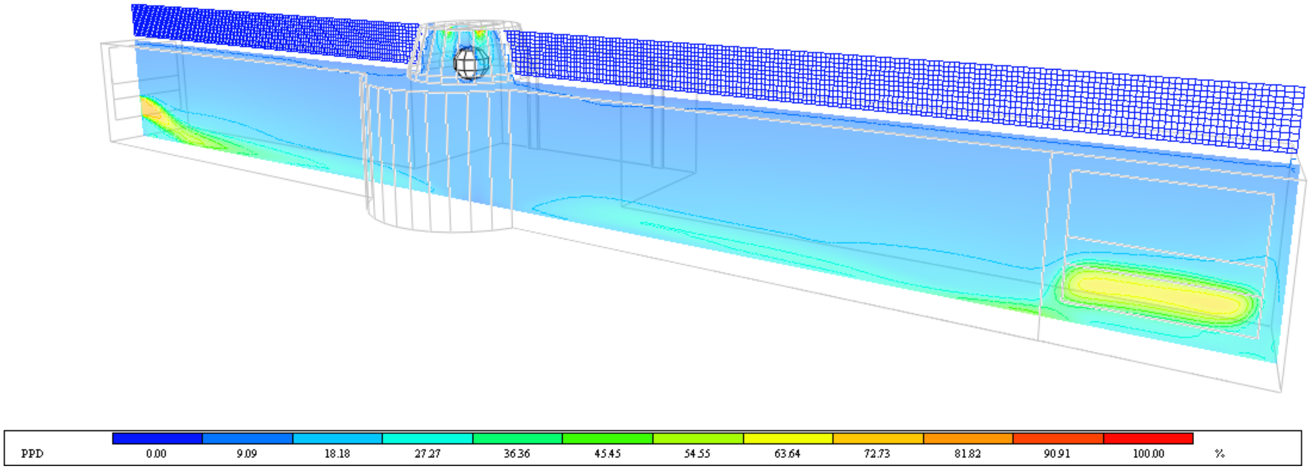


Figure 325 PPD inside the lounge space_ Modified scale

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[135] Thermal Environmental Criteria lecture ,Prof. Giuseppe Rapisarda, Polimi 2012

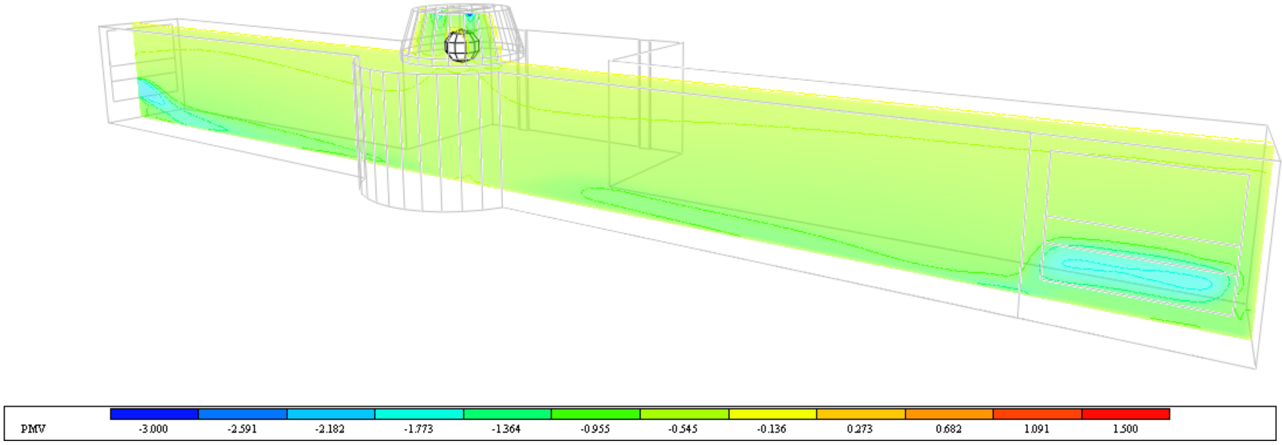

Figure 326 PMV inside the lounge space_ Modified Scale

10.2.3.3 Indoor air quality

With respect to the results below, our main aim was to provide the maximum indoor air quality by avoiding any weak ventilated areas or the presence of the contamination in the breathing zones. From that, the values of ACE and LMA shown below are presenting the air distribution inside the space, taking into account the below definitions:

Local mean air age (LMA): is also called the age of make-up at point P is defined as the elapsed time between entering the room and reaching point P. After passing point P, the parcel travels to the exhaust.

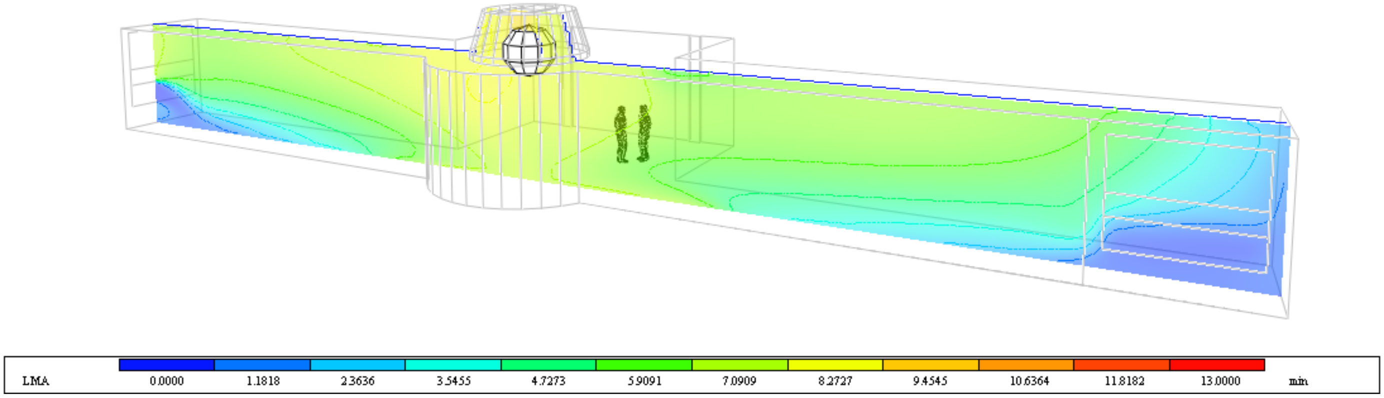

Figure 327 local mean air age scheme _Modified Scale

The air change effectiveness (ACE): is defined as the age of air that would occur throughout the room if the air was perfectly mixed, divided by the average age of air where occupants breathe. The age of air at a particular location is the average time elapsed since molecules of air at that location entered the building. Because the average age of air exiting the room is identical to the age of air that would occur throughout the room if the indoor air were perfectly mixed, the ACE is also the exhaust-air age divided by the average age of air where occupants breathe. In practical terms, the ACE equals the effective ventilation rate at the breathing zone divided by the ventilation rate that would occur throughout the building with perfect mixing and at the same outdoor air supply[136].

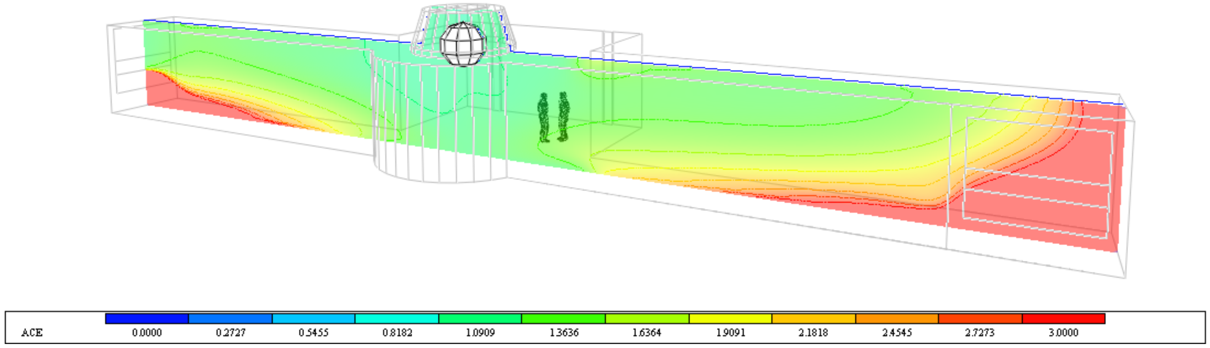

Figure 328 Air change effectiveness scheme _Modified Scale

10.2.4 Conclusions and recommendations:

As a result of the above, we can observe the efficiency of the hypothesized air movement mechanism, with respect to the criteria related to the users comfort and the sensitivity of the indoor environment.

Also, some design recommendations can be provided to maximize of the efficiency of the relevant strategy, with respect to the climatic analysis of Lecco:

- The 2 inlet vents integrated in the doors—located by the ends of the corridors—should be positioned in the lower part of the door.
- Relevant technique will not work efficiently during the coldest seasons (January and December), with respect to the external wind direction which might cause the reverse of the process.
- During the summer season, it is not recommended to open the oculus in the morning hours (7, 8 and 9 am) as the reverse of the mechanism may occur, especially that the heat sink chandelier will not be hot enough to favor relevant air current and releasing process. On the other hand we can observe that we can gain the maximum efficiency during the night period, which is also quite suitable for afterhours night air wash to remove relevant thermal loads and contaminants away.

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[136] http://energy.lbl.gov/IED/viaq/v_rates_11.html

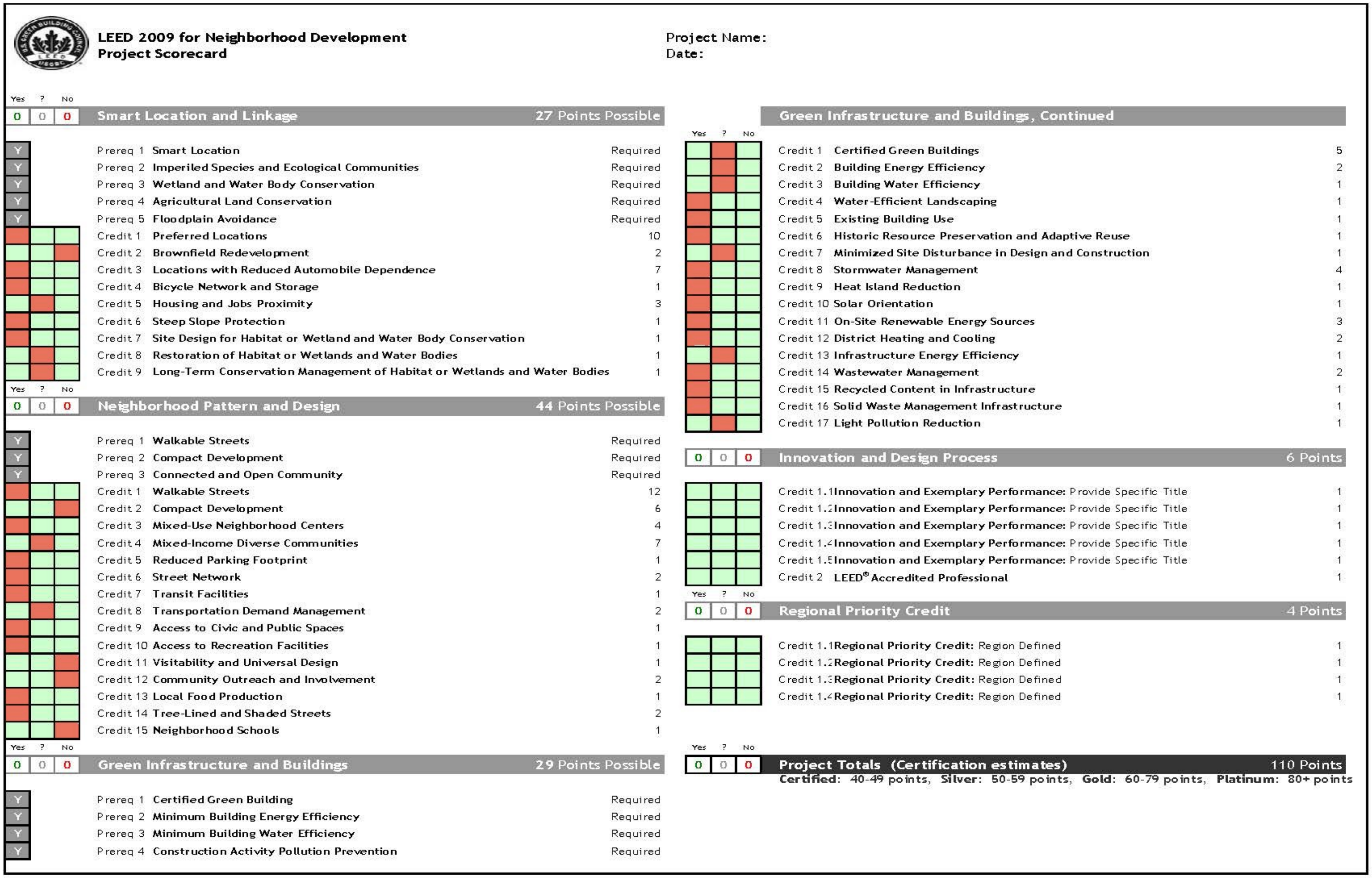
CHAPTER VI

Conclusions

Since that our aim is to create a New Paradigm in Environmentally Responsible Design and Construction using the Earth sheltering, it was essential to test and evaluate our accommodated strategies and building behavior, in order to guarantee the adequacy of the developed product performance. From that, the following parts will present the evaluation criteria and relevant approximate results, to ensure that the main terms and topics of sustainability were covered.

1. LEED Check list

With respect to the LEED ND (Neighborhood design) and NC (New construction)_2009, which were been used as general design and detailing guide lines , the below Checklists will present the main credits and perquisites which have been covered , noting that we have been focusing on the points related to the design and technical detailing , not managerial or operational related points.



LEED 2009 for Neighborhood Development
Project Scorecard

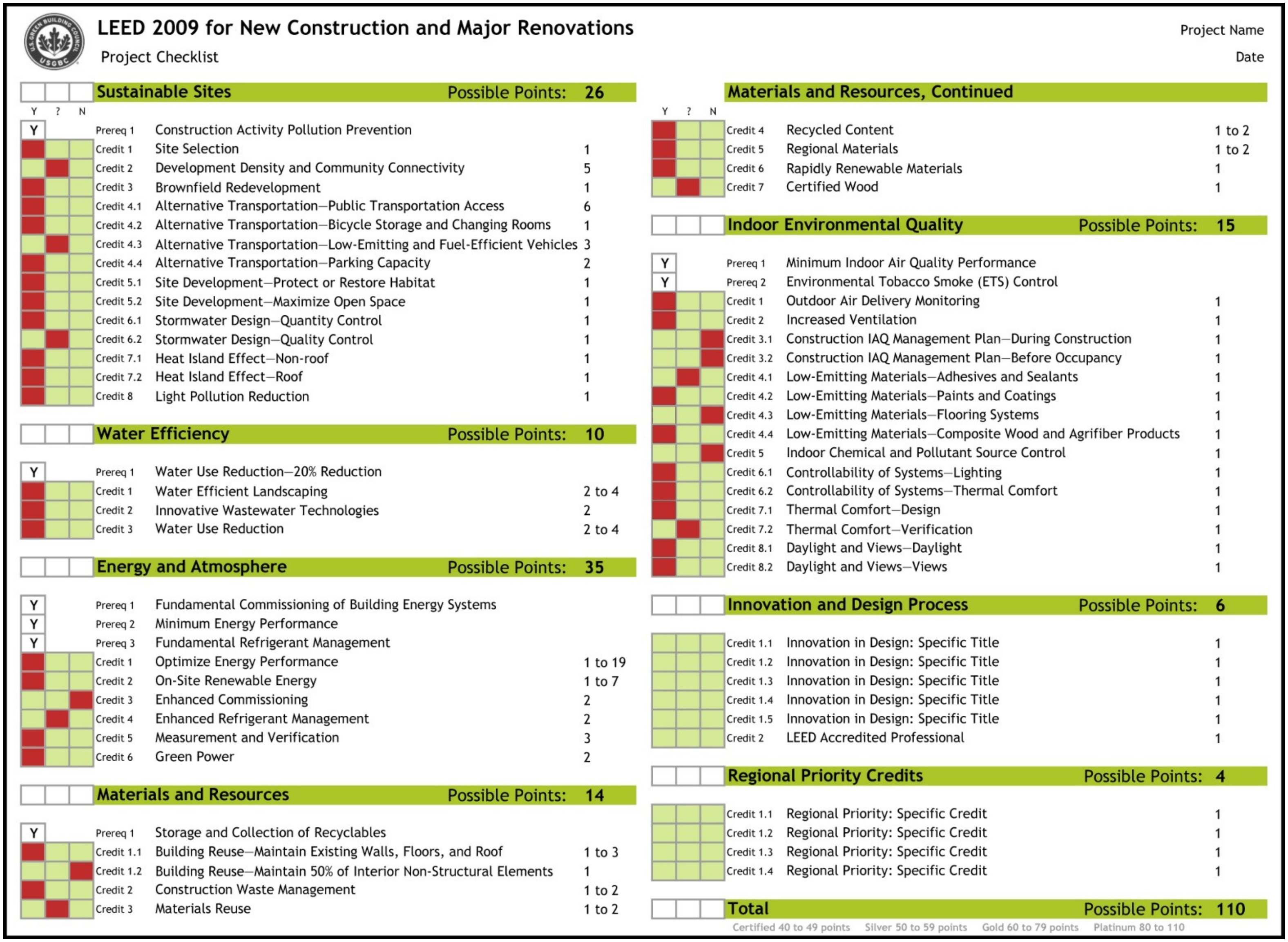
Project Name:
Date:

Yes	?	No			
0	0	0	**Smart Location and Linkage**		27 Points Possible
Y			Prereq 1	Smart Location	Required
Y			Prereq 2	Imperiled Species and Ecological Communities	Required
Y			Prereq 3	Wetland and Water Body Conservation	Required
Y			Prereq 4	Agricultural Land Conservation	Required
Y			Prereq 5	Floodplain Avoidance	Required
🟥	🟩	🟩	Credit 1	Preferred Locations	10
🟩	🟩	🟥	Credit 2	Brownfield Redevelopment	2
🟥	🟩	🟩	Credit 3	Locations with Reduced Automobile Dependence	7
🟥	🟩	🟩	Credit 4	Bicycle Network and Storage	1
🟩	🟥	🟩	Credit 5	Housing and Jobs Proximity	3
🟥	🟩	🟩	Credit 6	Steep Slope Protection	1
🟥	🟩	🟩	Credit 7	Site Design for Habitat or Wetland and Water Body Conservation	1
🟩	🟥	🟩	Credit 8	Restoration of Habitat or Wetlands and Water Bodies	1
🟩	🟥	🟩	Credit 9	Long-Term Conservation Management of Habitat or Wetlands and Water Bodies	1
Yes	**?**	**No**			
0	0	0	**Neighborhood Pattern and Design**		44 Points Possible
Y			Prereq 1	Walkable Streets	Required
Y			Prereq 2	Compact Development	Required
Y			Prereq 3	Connected and Open Community	Required
🟥	🟩	🟩	Credit 1	Walkable Streets	12
🟩	🟩	🟥	Credit 2	Compact Development	6
🟥	🟩	🟩	Credit 3	Mixed-Use Neighborhood Centers	4
🟩	🟥	🟩	Credit 4	Mixed-Income Diverse Communities	7
🟥	🟩	🟩	Credit 5	Reduced Parking Footprint	1
🟥	🟩	🟩	Credit 6	Street Network	2
🟥	🟩	🟩	Credit 7	Transit Facilities	1
🟩	🟥	🟩	Credit 8	Transportation Demand Management	2
🟥	🟩	🟩	Credit 9	Access to Civic and Public Spaces	1
🟥	🟩	🟩	Credit 10	Access to Recreation Facilities	1
🟩	🟩	🟥	Credit 11	Visitability and Universal Design	1
🟩	🟩	🟥	Credit 12	Community Outreach and Involvement	2
🟥	🟩	🟩	Credit 13	Local Food Production	1
🟥	🟩	🟩	Credit 14	Tree-Lined and Shaded Streets	2
🟩	🟩	🟥	Credit 15	Neighborhood Schools	1
Yes	**?**	**No**			
0	0	0	**Green Infrastructure and Buildings**		29 Points Possible
Y			Prereq 1	Certified Green Building	Required
Y			Prereq 2	Minimum Building Energy Efficiency	Required
Y			Prereq 3	Minimum Building Water Efficiency	Required
Y			Prereq 4	Construction Activity Pollution Prevention	Required

Yes	?	No			
			Green Infrastructure and Buildings, Continued		
🟩	🟥	🟩	Credit 1	Certified Green Buildings	5
🟩	🟥	🟩	Credit 2	Building Energy Efficiency	2
🟩	🟥	🟩	Credit 3	Building Water Efficiency	1
🟥	🟩	🟩	Credit 4	Water-Efficient Landscaping	1
🟥	🟩	🟩	Credit 5	Existing Building Use	1
🟥	🟩	🟩	Credit 6	Historic Resource Preservation and Adaptive Reuse	1
🟩	🟥	🟩	Credit 7	Minimized Site Disturbance in Design and Construction	1
🟥	🟩	🟩	Credit 8	Stormwater Management	4
🟥	🟩	🟩	Credit 9	Heat Island Reduction	1
🟥	🟩	🟩	Credit 10	Solar Orientation	1
🟥	🟩	🟩	Credit 11	On-Site Renewable Energy Sources	3
🟥	🟩	🟩	Credit 12	District Heating and Cooling	2
🟩	🟥	🟩	Credit 13	Infrastructure Energy Efficiency	1
🟥	🟩	🟩	Credit 14	Wastewater Management	2
🟥	🟩	🟩	Credit 15	Recycled Content in Infrastructure	1
🟥	🟩	🟩	Credit 16	Solid Waste Management Infrastructure	1
🟩	🟥	🟩	Credit 17	Light Pollution Reduction	1
0	0	0	**Innovation and Design Process**		6 Points
🟩	🟩	🟩	Credit 1.1	**Innovation and Exemplary Performance:** Provide Specific Title	1
🟩	🟩	🟩	Credit 1.2	**Innovation and Exemplary Performance:** Provide Specific Title	1
🟩	🟩	🟩	Credit 1.3	**Innovation and Exemplary Performance:** Provide Specific Title	1
🟩	🟩	🟩	Credit 1.4	**Innovation and Exemplary Performance:** Provide Specific Title	1
🟩	🟩	🟩	Credit 1.5	**Innovation and Exemplary Performance:** Provide Specific Title	1
🟩	🟩	🟩	Credit 2	LEED® Accredited Professional	1
Yes	**?**	**No**			
0	0	0	**Regional Priority Credit**		4 Points
🟩	🟩	🟩	Credit 1.1	**Regional Priority Credit:** Region Defined	1
🟩	🟩	🟩	Credit 1.2	**Regional Priority Credit:** Region Defined	1
🟩	🟩	🟩	Credit 1.3	**Regional Priority Credit:** Region Defined	1
🟩	🟩	🟩	Credit 1.4	**Regional Priority Credit:** Region Defined	1
Yes	**?**	**No**			
0	0	0	**Project Totals (Certification estimates)**		110 Points

Certified: 40-49 points, **Silver**: 50-59 points, **Gold**: 60-79 points, **Platinum**: 80+ points

Figure 329 LEED ND check list



LEED 2009 for New Construction and Major Renovations

Project Checklist

Project Name

Date

Y	?	N			
			Sustainable Sites	Possible Points:	**26**
Y			Prereq 1	Construction Activity Pollution Prevention	
🟥	🟩	🟩	Credit 1	Site Selection	1
🟩	🟥	🟩	Credit 2	Development Density and Community Connectivity	5
🟥	🟩	🟩	Credit 3	Brownfield Redevelopment	1
🟥	🟩	🟩	Credit 4.1	Alternative Transportation—Public Transportation Access	6
🟥	🟩	🟩	Credit 4.2	Alternative Transportation—Bicycle Storage and Changing Rooms	1
🟩	🟥	🟩	Credit 4.3	Alternative Transportation—Low-Emitting and Fuel-Efficient Vehicles	3
🟥	🟩	🟩	Credit 4.4	Alternative Transportation—Parking Capacity	2
🟥	🟩	🟩	Credit 5.1	Site Development—Protect or Restore Habitat	1
🟥	🟩	🟩	Credit 5.2	Site Development—Maximize Open Space	1
🟥	🟩	🟩	Credit 6.1	Stormwater Design—Quantity Control	1
🟩	🟥	🟩	Credit 6.2	Stormwater Design—Quality Control	1
🟥	🟩	🟩	Credit 7.1	Heat Island Effect—Non-roof	1
🟥	🟩	🟩	Credit 7.2	Heat Island Effect—Roof	1
🟥	🟩	🟩	Credit 8	Light Pollution Reduction	1
			Water Efficiency	Possible Points:	**10**
Y			Prereq 1	Water Use Reduction—20% Reduction	
🟥	🟩	🟩	Credit 1	Water Efficient Landscaping	2 to 4
🟥	🟩	🟩	Credit 2	Innovative Wastewater Technologies	2
🟥	🟩	🟩	Credit 3	Water Use Reduction	2 to 4
			Energy and Atmosphere	Possible Points:	**35**
Y			Prereq 1	Fundamental Commissioning of Building Energy Systems	
Y			Prereq 2	Minimum Energy Performance	
Y			Prereq 3	Fundamental Refrigerant Management	
🟥	🟩	🟩	Credit 1	Optimize Energy Performance	1 to 19
🟥	🟩	🟩	Credit 2	On-Site Renewable Energy	1 to 7
🟩	🟩	🟥	Credit 3	Enhanced Commissioning	2
🟩	🟥	🟩	Credit 4	Enhanced Refrigerant Management	2
🟥	🟩	🟩	Credit 5	Measurement and Verification	3
🟥	🟩	🟩	Credit 6	Green Power	2
			Materials and Resources	Possible Points:	**14**
Y			Prereq 1	Storage and Collection of Recyclables	
🟥	🟩	🟩	Credit 1.1	Building Reuse—Maintain Existing Walls, Floors, and Roof	1 to 3
🟩	🟩	🟥	Credit 1.2	Building Reuse—Maintain 50% of Interior Non-Structural Elements	1
🟥	🟩	🟩	Credit 2	Construction Waste Management	1 to 2
🟩	🟥	🟩	Credit 3	Materials Reuse	1 to 2

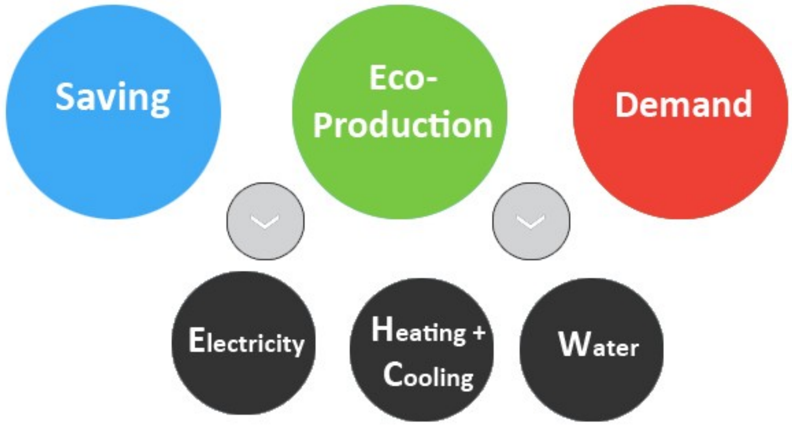
Y	?	N			
			Materials and Resources, Continued		
🟥	🟩	🟩	Credit 4	Recycled Content	1 to 2
🟥	🟩	🟩	Credit 5	Regional Materials	1 to 2
🟥	🟩	🟩	Credit 6	Rapidly Renewable Materials	1
🟩	🟥	🟩	Credit 7	Certified Wood	1
			Indoor Environmental Quality	Possible Points:	**15**
Y			Prereq 1	Minimum Indoor Air Quality Performance	
Y			Prereq 2	Environmental Tobacco Smoke (ETS) Control	
🟥	🟩	🟩	Credit 1	Outdoor Air Delivery Monitoring	1
🟥	🟩	🟩	Credit 2	Increased Ventilation	1
🟩	🟩	🟥	Credit 3.1	Construction IAQ Management Plan—During Construction	1
🟩	🟩	🟥	Credit 3.2	Construction IAQ Management Plan—Before Occupancy	1
🟩	🟥	🟩	Credit 4.1	Low-Emitting Materials—Adhesives and Sealants	1
🟥	🟩	🟩	Credit 4.2	Low-Emitting Materials—Paints and Coatings	1
🟩	🟩	🟥	Credit 4.3	Low-Emitting Materials—Flooring Systems	1
🟥	🟩	🟩	Credit 4.4	Low-Emitting Materials—Composite Wood and Agrifiber Products	1
🟩	🟩	🟥	Credit 5	Indoor Chemical and Pollutant Source Control	1
🟥	🟩	🟩	Credit 6.1	Controllability of Systems—Lighting	1
🟥	🟩	🟩	Credit 6.2	Controllability of Systems—Thermal Comfort	1
🟥	🟩	🟩	Credit 7.1	Thermal Comfort—Design	1
🟩	🟥	🟩	Credit 7.2	Thermal Comfort—Verification	1
🟥	🟩	🟩	Credit 8.1	Daylight and Views—Daylight	1
🟥	🟩	🟩	Credit 8.2	Daylight and Views—Views	1
			Innovation and Design Process	Possible Points:	**6**
🟩	🟩	🟩	Credit 1.1	Innovation in Design: Specific Title	1
🟩	🟩	🟩	Credit 1.2	Innovation in Design: Specific Title	1
🟩	🟩	🟩	Credit 1.3	Innovation in Design: Specific Title	1
🟩	🟩	🟩	Credit 1.4	Innovation in Design: Specific Title	1
🟩	🟩	🟩	Credit 1.5	Innovation in Design: Specific Title	1
🟩	🟩	🟩	Credit 2	LEED Accredited Professional	1
			Regional Priority Credits	Possible Points:	**4**
🟩	🟩	🟩	Credit 1.1	Regional Priority: Specific Credit	1
🟩	🟩	🟩	Credit 1.2	Regional Priority: Specific Credit	1
🟩	🟩	🟩	Credit 1.3	Regional Priority: Specific Credit	1
🟩	🟩	🟩	Credit 1.4	Regional Priority: Specific Credit	1
			Total	Possible Points:	**110**

Certified 40 to 49 points Silver 50 to 59 points Gold 60 to 79 points Platinum 80 to 110

Figure 330 LEED NC check list

2. Consumption vs production

With respect to the previously mentioned savings resulted from the followed sustainable architectural design and detailing techniques, the below roughly estimated schemes are presenting the advantages of using relevant integrated services technologies, as it is dramatically influencing the demand and the final needed energy bills, as per the below shown values:



	Demand	Saving	Production
Heating and cooling	100%	Labyrinth 28% saving	GHP + IHT using thermal banks 50% saving
		Heat recovery 25% saving	
		Radiant flooring 30% saving	
Electricity	47 W/m2	Daylight sensors 6W/m2	PV panels 150W/m2 for panel area
		Occupant sensors 10W/m2	
		BMS 10W/m2	Greenasium 30W/m2 for gym area only
water	5500 lit/day	Waste water management 90 lit/day saving	Storm water 280 lit/day production
		Efficient water fixtures 800 lit / day saving	

Figure 331 Comparison between the Demand, Conservation and Production of energy

3. Final statement

Using a unique solution a project of unique nature and scale, keeping in view the historical significance, industrial development, authenticity of the culture and society therein, a remarkable proposal awaits Valmadrera to be transformed into a city of future with futuristic vision of development in hand.

By developing the old factory building, of course exhibiting a vital character, we have focused on the heart of the city, carrying the opportunity and potential to become a catalyst in redefining not only the local and urban infrastructure of the city itself, but to influence on a larger scale surrounding interrelated financial and economical centers of the region.

Understanding the worthiness of the project, being optimistic in facing results and consequences, various goals and objectives were pen downed and utilized as a guideline throughout the development process of the project. These were not limited to the project site but cater a bigger scale of influence to the city of Valmadrera.

Among various objectives, the main points were related to creating a spinal link between the isolated railway station and the city enter, by involving the deserted industrial areas which were already in the development plan of the city. In addition, targeting social interaction of the citizens by creating supplementary, well-connected public places and facilities. Infrastructural development, interconnecting the city center, the new piazza, the lake and parks, through pedestrian, bicycle and other vehicular accesses.

Architectural Design

Apart from the usual architectural aspects, necessary to define a project, the main elements distinguishing our project from a traditional one is the effective use of the passive technologies well integrated with the architectural spaces.

The major mass of the building being below ground, the functions are defined accordingly. This was done deliberately to exploit the thermal mass surrounding the areas in assisting functions and comfort conditions. Other architectural aspects include but are not limited to, maintaining visual connectivity with the park and surrounding landmarks, focusing on transparent elements to have daylight and ventilation objectives, defining the flow of visitors and staff, merging the building with natural landscape around, etc.

Technological Design

Dealing with the technological advances in our project, covering from site to urban scale level, the energy and technological details suffice the needs and requirements. These include the implementation of state of the art techniques such as intersesonal heat transfer using the thermal banks, geothermal heat pumps, earth labyrinths heat recovery system, ventilated radiant raised floor, mainly for air and water conditioning alike.

The production of energy was also the point of importance, to have the minimum level of energy demand and achieving the desired energy rating for the project. This was accomplished through installation of photovoltaic panels and greenasium concept within the premises of the site and using the biomass energy on a larger scale from the established plant.

Natural means have been adopted wherever possible, to make the energy input as lesser as could be and making use of nature. For instance, using heliostat and mirrored tubing for daylight, storm water harvesting technology, waste water management, green roof and landscape involved therein.

Also artificial intelligence is used for exploiting certain means to make the building energy efficient, in the best manner. These involve BMS monitoring, occupancy, daylight and pollution sensors and the use of well insulated and exceptional thermal quality building elements.

Structural Design

The structural approach involved usage of material and structural system to focus on the sustainability and technology, e.g., using flyash concrete to help reduce the CO_2 emission and contributing in making the project sustainable. Meanwhile, bubbledeck slab technology is used to span the building by not only reducing the concrete/cement involved in the project but also the self weight reduction of the slab, rendering the building light weight comparatively.

In view of the foregoing, we can conclude that the project covers most of the criteria defined by the LEED NC and ND as mentioned above in the form of check list, was covered with proficiency. This and other techniques elaborated above helped to achieve a minimum level of thermal energy requirements, consequently making the project to qualify the building category - Class A in accordance with the European standards. This distinction is exclusively achieved through the usage of earth sheltering technology; as is also the title of the project.

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LIST OF FIGURES

LIST OF TABLES

LIST OF DRAWINGS

Chapter 02	U 01	Conceptual Mater plan
	U 02	Master plan
	U 03	Functional master plan
	U 04	Conceptual sections and sketches
	U 05	Conceptual sections and sketches
	U 06	Conceptual sections and sketches
	U 07	Spine mood board
Chapter 03	AR 01	Site plan
	AR 02	Basement floor plan
	AR 03	Ground floor plan
	AR 04	1st floor plan
	AR 05	Section 01
	AR 06	Section 02
	AR 07	Section 03
	AR 08	Section 04
	AR 09	Section 05
	AR 10	3D views 01
	AR 11	3D views 02
Chapter 04	STR 01	Basement plan
	STR 02	Ground floor plan
	STR 03	1st floor and Details
Chapter 05	T.S 01	Roofing
	T.S 02	Roofing
	T.S 03	Roofing
	T.S 04	Flooring
	T.S 05	Flooring
	T.S 06	Flooring
	T.S 07	Walls
	T.S 08	Walls
	T.S 09	Walls
	T.S 10	Meditation rooms skin scheme
	T.S 11	Walls section_Mediation room
Appendix	Ref 01	Façade Material survey
	Ref 02	Facade Damage survey
	Ref 03	Facade Intervention
	Ref 04	Retrofitting Walls section

Appendix A

Earth sheltering and underground spaces design

TABLE OF CONTENTS

1. Introduction

Earth has been used as a building material through the history. Natural cave, spaces carved out of rock or soil. And earth berming are examples of the indigenous to the need for shelter. Mankind and animals discovered the first earth shelter when they sought protection and safety in natural caves and rock formations of burrowed into the earth to keep out of the heat, shelters, however offered a number of advantages that are still valid up to this moment[1].

With the growing awareness of energy needs and shortage in the early seventies, and the increasing fears of the ozone layer depletion and the global worming phenomena as indicators of impending biological degradation ,earth sheltering rapidly gained interest both as a conservation method and as an alternative life style [2]. After the energy crisis in 1973, there has emerged a better understanding of the particular design issues and technical consideration all over the world, to develop environmental design and management criteria's, driven by the energy conservation approach.

From that, the growth of the earth sheltered facilities usage has been witnessed recently, as it gives the solution for the dilemma of providing long term humanity needs, along with responding to the recent shortage of capital energy resources.

2. Definitions

The expression earth-sheltering is a generic term, with the general meaning: building design in which soil plays an integral part.

From this research work point of view , **Earth sheltered** design is best defined as **the art and technology of building to fit the site rather than modeling and shaping the site to fit the structure** , and is currently described as the evolution of a sustainable design sensibility rooted in the 1960[3].

Also, **Earth sheltering** A building can be described as earth-sheltered if its external envelope is in contact with a thermally significant volume of soil or substrate (where “thermally significant” means making a functional contribution to the thermal effectiveness of the building in question.)[4]

An earth integrated structure may be designed to combine the below forms:

- An **earth-covered** building is one where the thermally effective element is placed solely on the roof, but is more usually a continuation of the earth-bunding at the unexposed elevations of the building.
- An **earth-bunded** building is one where the thermally significant element insulates one or more of the sheltered elevations of the building. The bunding can be partial or total.

---

[1] S.Sheta, Earth sheltered housing design Thesis ,Mansoura University,1998

[2] Randall Thomas, Environmental design: An introduction for architects and engineers ,London :E& FN Spon,1996

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[4] http://en.wikipedia.org/wiki/Earth_sheltering

- A **subterranean** building is one where the thermally significant element insulates all elevations of the building, leaving only the roof exposed; or, if the building is built into an incline, it may be that the roof is covered and only one elevation is left exposed[5]

3. Climatic suitability

Inhabitants of the earth shelters no longer feel that they are at the mercy of the nature’s climatic extremes, the mass and the of oil offered around the earth-sheltered design has a large heat storage capacity .therefore, earth sheltering is considered as the primary ingredient of conservation whereas thermal comfort is attained most economically through conservation with **passive heating and cooling**[6].in that manner , we can see that technique is not suitable for all climatic conditions and site conditions.

The use of subterranean construction can be most suitable if applied in regions with any of the following types of climate:

1. Very warm and dry climate, such as in the aried zones of most of north Africa.
2. Temperate zone climate cold and snowy in winter and rainy and warm in summer.
3. Very cold and dry climate , such as the aired zone of central Asia[7]

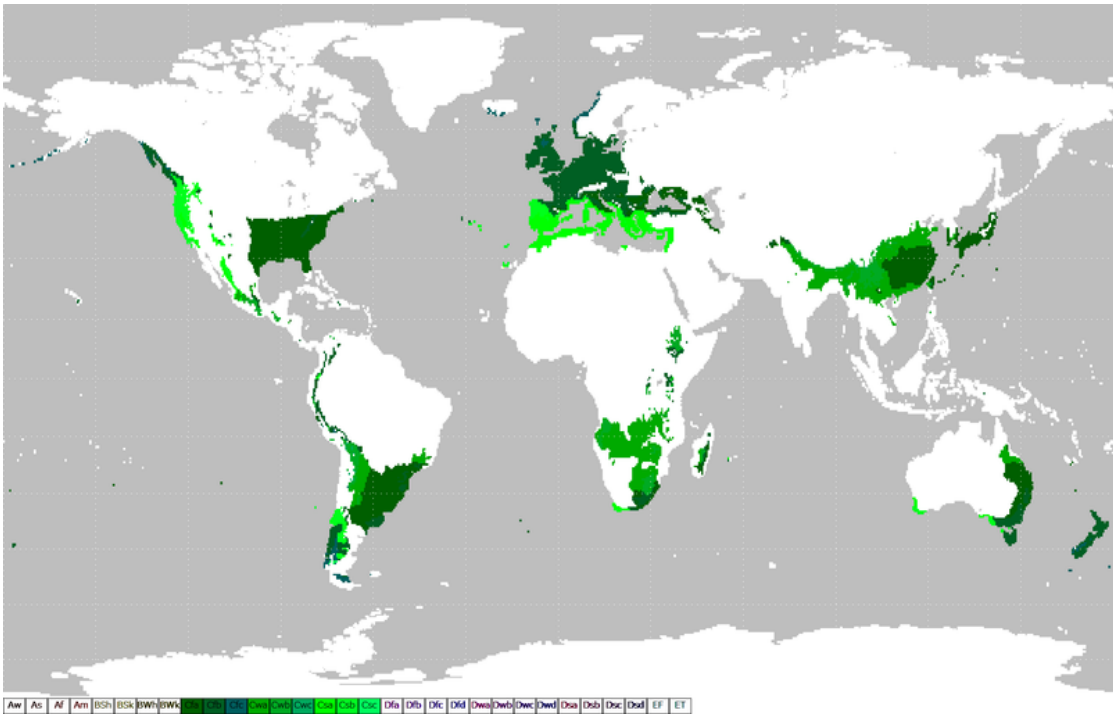

Figure 1 Temperate zone climate [8]

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[5] http://en.wikipedia.org/wiki/Earth_sheltering

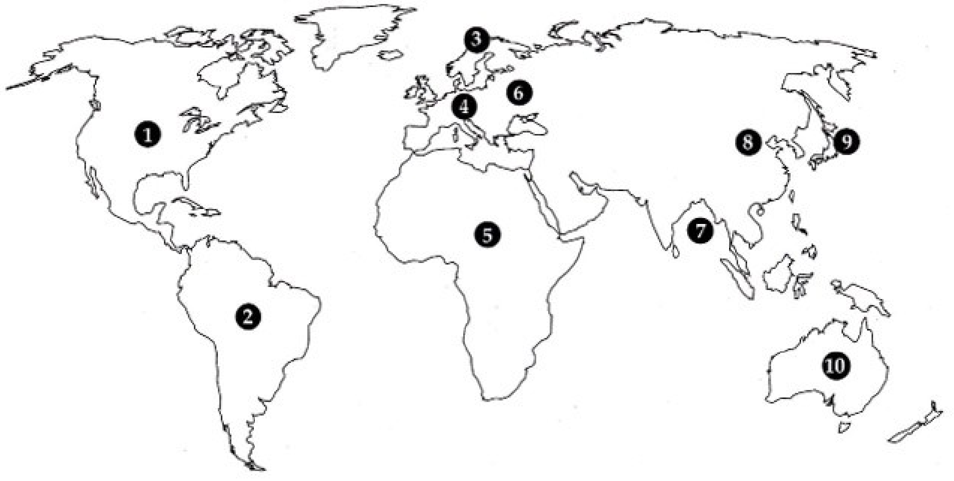
[6] Andrew Blowers, Planning for a sustainable environment ,London: Earthscan publications,1993

[7] Gideon Golany, Earth sheltered habitat ,new York :Van Nostrand Reinhold company,1983

[8] http://en.wikipedia.org/wiki/Temperate_climate

4. Lessons from the past

With the respect to the usage of the earth as the oldest building material used by humans, the stresses environment of 350,000 years ago led the early human to build shelters under limestone cliffs. Since then, the technology of building with earth has been developed by trial and error. This trend, however extreme, has its logical reasons to evolve.[9] Relevant current and historical usage of subterranean architecture can be shown as the below figure.



1. **NORTH AMERICA**
   - Indigenous housing utilized earth and rock structures. Examples include Indian cliffside dwellings.
   - Many examples of modern earth sheltered housing and nonresidential buildings such as libraries and museums.
   - Subway systems in some larger urban areas including some with related underground commercial development (Montreal and Toronto, Canada).
   - Scattered examples of mined space use. Examples include the limestone mines in Kansas City, USA.
2. **SOUTH AMERICA**
   - Limited number of uses outside of mining excavations.
   - Subway systems in some large cities.
   - Hydroelectric schemes under development in mountain areas.
   - Some experience with underground food storage.
3. **SCANDINAVIA**
   - Large variety of uses mostly in hard rock. Examples include churches, concert halls, sports facilities, and archives.
   - Many uses are dual-purpose civil defense/community facilities.
   - Large number of underground hydropower facilities.
   - Extensive oil storage caverns and other energy storage systems.
   - Subway systems in capital cities.
4. **OTHER WESTERN EUROPEAN COUNTRIES**
   - Variety of urban uses including multipurpose commercial centers, parking facilities.
   - Many interurban road and rail tunnels crossing natural barriers. Examples are the English Channel Tunnel, alpine tunnels, and German high speed rail network.
   - Many underground portions of transit systems in major cities.
   - Indigenous underground housing found in France, Spain, Italy and Greece.
5. **AFRICA**
   - Indigenous food storage in North Africa—notably Morocco.
   - Extensive mining activities and some hydropower.
   - Indigenous housing in North Africa (both current and historical). Examples include Matmata and Bulla Regia, Tunisia.
6. **EASTERN EUROPE AND WESTERN ASIA**
   - Extensive metro systems in major cities.
   - Use of utilidors for some urban utilities.
   - Civil defense facilities.
   - Indigenous housing and religious structures—mostly historical. Examples found in Cappadocia in central Turkey.
7. **SOUTHERN AND SOUTHEASTERN ASIA**
   - Cave temples such as Ajanta and Ellora in India.
   - A few urban underground facilities including pedestrian underpasses and short road tunnels.
   - Subway systems in some major cities including Calcutta and Hong Kong.
   - Hydropower facilities in mountainous regions.
8. **EASTERN ASIA**
   - Approximately 30 million people living in cave dwellings in north-central China.
   - Extensive civil defense works in cities in China.
   - Extensive interurban road and rail tunnels.
   - Metro systems in some cities such as Beijing, Novosibirsk.
9. **JAPAN**
   - Large metro systems in major cities.
   - Extensive underground shopping centers connected to transit facilities.
   - Urban uses for infrastructure purposes.
   - Extensive interurban road and rail tunnels.
   - Intense interest in a wide range of future uses.
10. **AUSTRALIA**
    - Housing and other building uses in outback mining communities.
    - Building applications for environmental preservation in sensitive areas.
    - Hydroelectric facilities in mountainous areas.
    - Limited underground urban road and rail facilities.

Figure 2 World map indicating notable patterns of underground utilization, Extracted from (Underground space design, by John Carmony)

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[9] S.Sheta, Earth sheltered housing design

4.1 Historical Examples

Figure 4 Subterranean dwellings at Siwa oasis, Egypt (www.minamar.com)

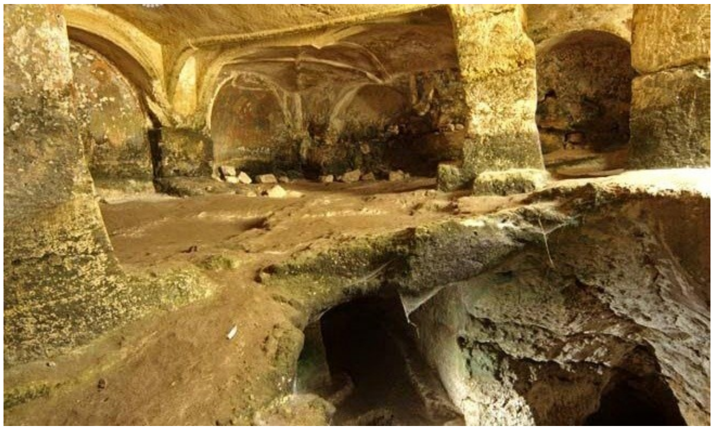


Figure 3 Cave homes and churches, Apulia Province, Italy (www.visualphotos.com)

Figure 5 Underground courtyard, China, Extracted from (Underground space design, by John Carmony)

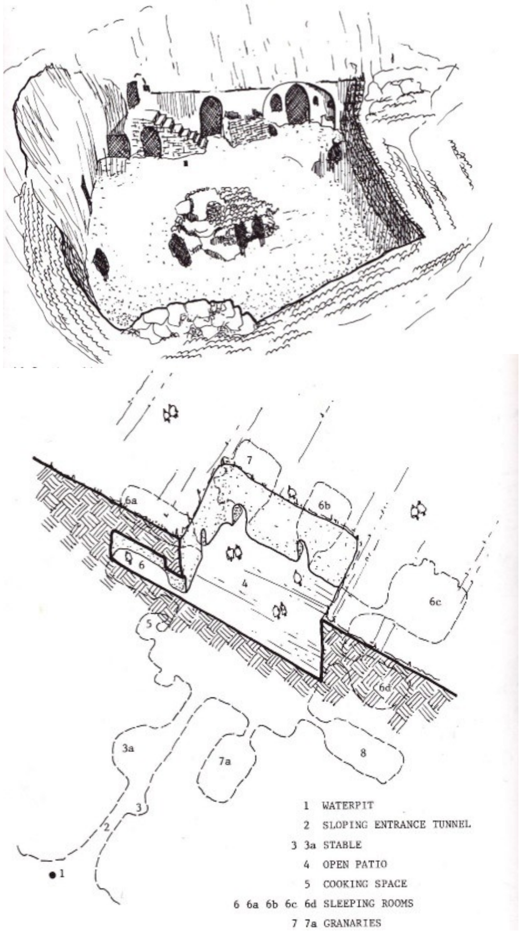


Figure 6 Underground House, Matmata, Tunisia, Extracted from (Earth sheltered habitat, Gideon Golany)

4.2 Examples by pioneers

The technology was experimented by pioneers and their structures, i.e., Frank Lioyd Right, Philip Hounson and Wiliam Morgan .

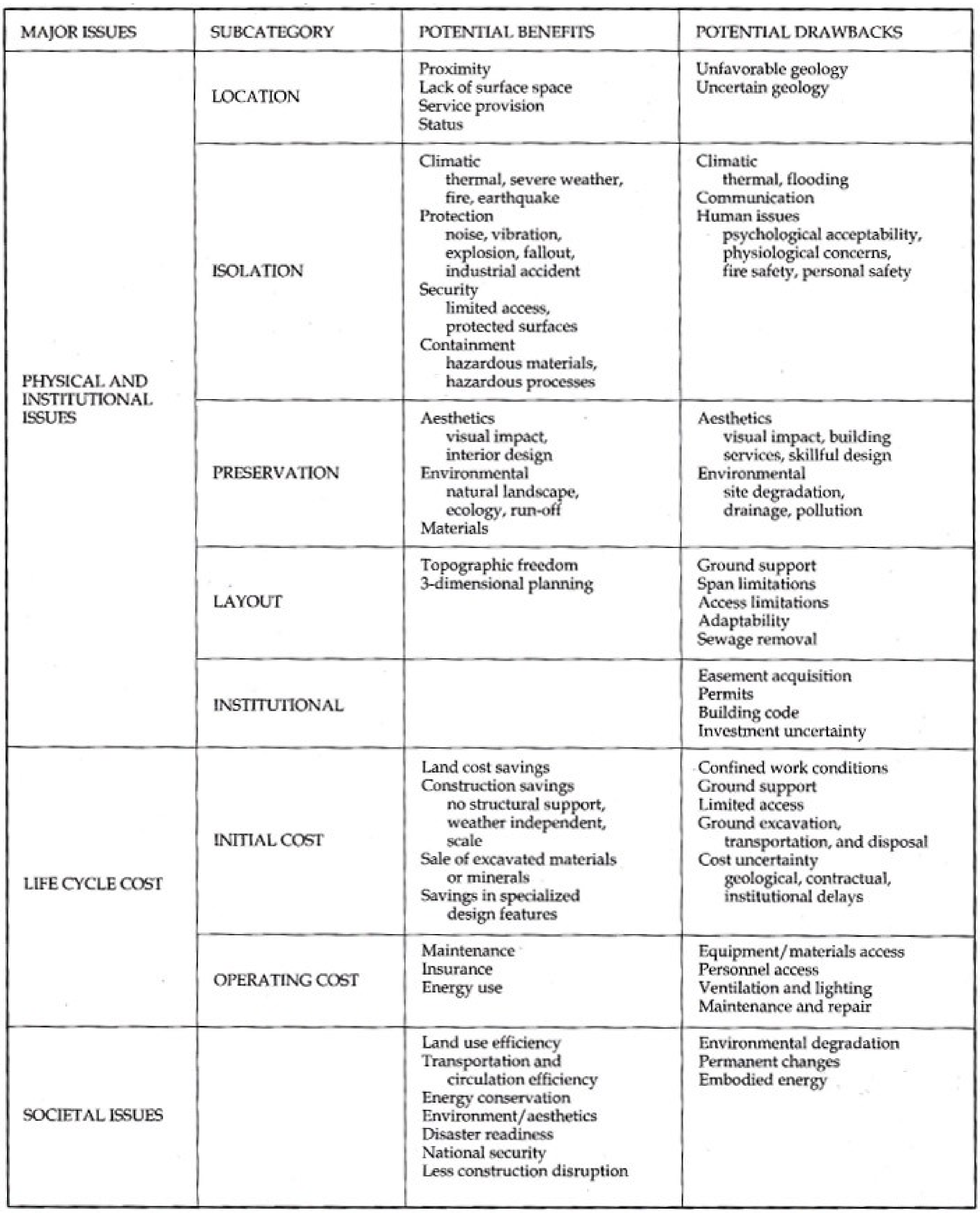
Figure 7 Geier House by Philip Johnson (www.mexsi.wordpress.com)

Figure 8 Dunehouse by Wiliam Morgan (www.forumishqiptar.net)

Figure 9 Hilltop Houseby William Morgan (www.trianglemodernisthouses.com)

5. Benefits and drawbacks of earth sheltering

A comparison between the potential advantages and negative effects of that technique have been considered, which can be summarized as per the schemes below.



MAJOR ISSUES	SUBCATEGORY	POTENTIAL BENEFITS	POTENTIAL DRAWBACKS
PHYSICAL AND INSTITUTIONAL ISSUES	LOCATION	Proximity Lack of surface space Service provision Status	Unfavorable geology Uncertain geology
	ISOLATION	Climatic thermal, severe weather, fire, earthquake Protection noise, vibration, explosion, fallout, industrial accident Security limited access, protected surfaces Containment hazardous materials, hazardous processes	Climatic thermal, flooding Communication Human issues psychological acceptability, physiological concerns, fire safety, personal safety
	PRESERVATION	Aesthetics visual impact, interior design Environmental natural landscape, ecology, run-off Materials	Aesthetics visual impact, building services, skillful design Environmental site degradation, drainage, pollution
	LAYOUT	Topographic freedom 3-dimensional planning	Ground support Span limitations Access limitations Adaptability Sewage removal
	INSTITUTIONAL		Easement acquisition Permits Building code Investment uncertainty
LIFE CYCLE COST	INITIAL COST	Land cost savings Construction savings no structural support, weather independent, scale Sale of excavated materials or minerals Savings in specialized design features	Confined work conditions Ground support Limited access Ground excavation, transportation, and disposal Cost uncertainty geological, contractual, institutional delays
	OPERATING COST	Maintenance Insurance Energy use	Equipment/materials access Personnel access Ventilation and lighting Maintenance and repair
SOCIETAL ISSUES		Land use efficiency Transportation and circulation efficiency Energy conservation Environment/aesthetics Disaster readiness National security Less construction disruption	Environmental degradation Permanent changes Embodied energy

Figure 10 Benefits and drawbacks, Extracted from (Underground space design, by John Carmony)

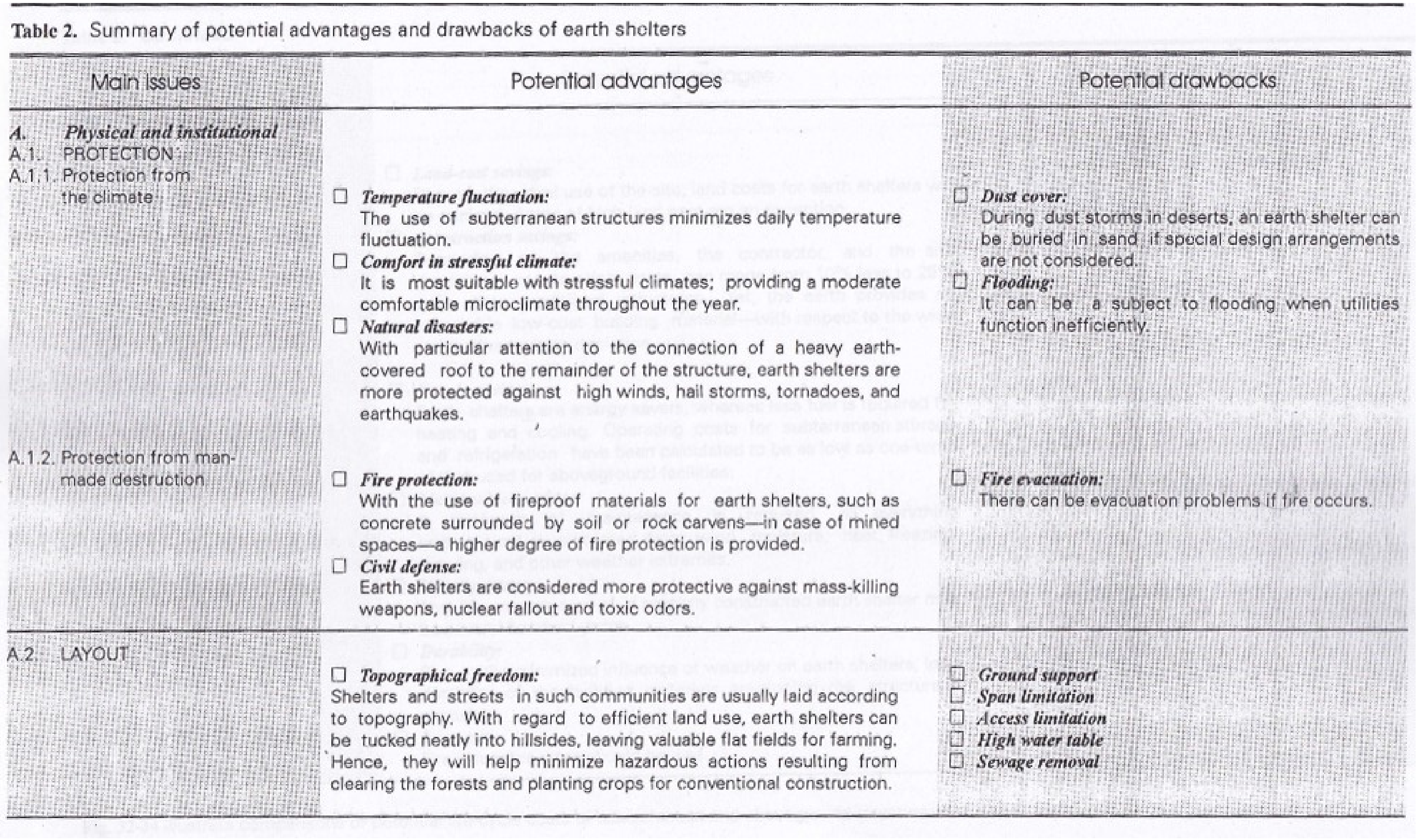


Table 2. Summary of potential advantages and drawbacks of earth shelters

Main issues	Potential advantages	Potential drawbacks
A. Physical and institutional A.1. PROTECTION A.1.1. Protection from the climate	☐ ***Temperature fluctuation:*** The use of subterranean structures minimizes daily temperature fluctuation. ☐ ***Comfort in stressful climate:*** It is most suitable with stressful climates; providing a moderate comfortable microclimate throughout the year. ☐ ***Natural disasters:*** With particular attention to the connection of a heavy earth-covered roof to the remainder of the structure, earth shelters are more protected against high winds, hail storms, tornadoes, and earthquakes.	☐ ***Dust cover:*** During dust storms in deserts, an earth shelter can be buried in sand if special design arrangements are not considered. ☐ ***Flooding:*** It can be a subject to flooding when utilities function inefficiently.
A.1.2. Protection from man-made destruction	☐ ***Fire protection:*** With the use of fireproof materials for earth shelters, such as concrete surrounded by soil or rock carvens—in case of mined spaces—a higher degree of fire protection is provided. ☐ ***Civil defense:*** Earth shelters are considered more protective against mass-killing weapons, nuclear fallout and toxic odors.	☐ ***Fire evacuation:*** There can be evacuation problems if fire occurs.
A.2. LAYOUT	☐ ***Topographical freedom:*** Shelters and streets in such communities are usually laid according to topography. With regard to efficient land use, earth shelters can be tucked neatly into hillsides, leaving valuable flat fields for farming. Hence, they will help minimize hazardous actions resulting from clearing the forests and planting crops for conventional construction.	☐ ***Ground support*** ☐ ***Span limitation*** ☐ ***Access limitation*** ☐ ***High water table*** ☐ ***Sewage removal***

Figure 11 Advantages and disadvantages, Extracted from (Earth sheltered housing design by S.Sheta)

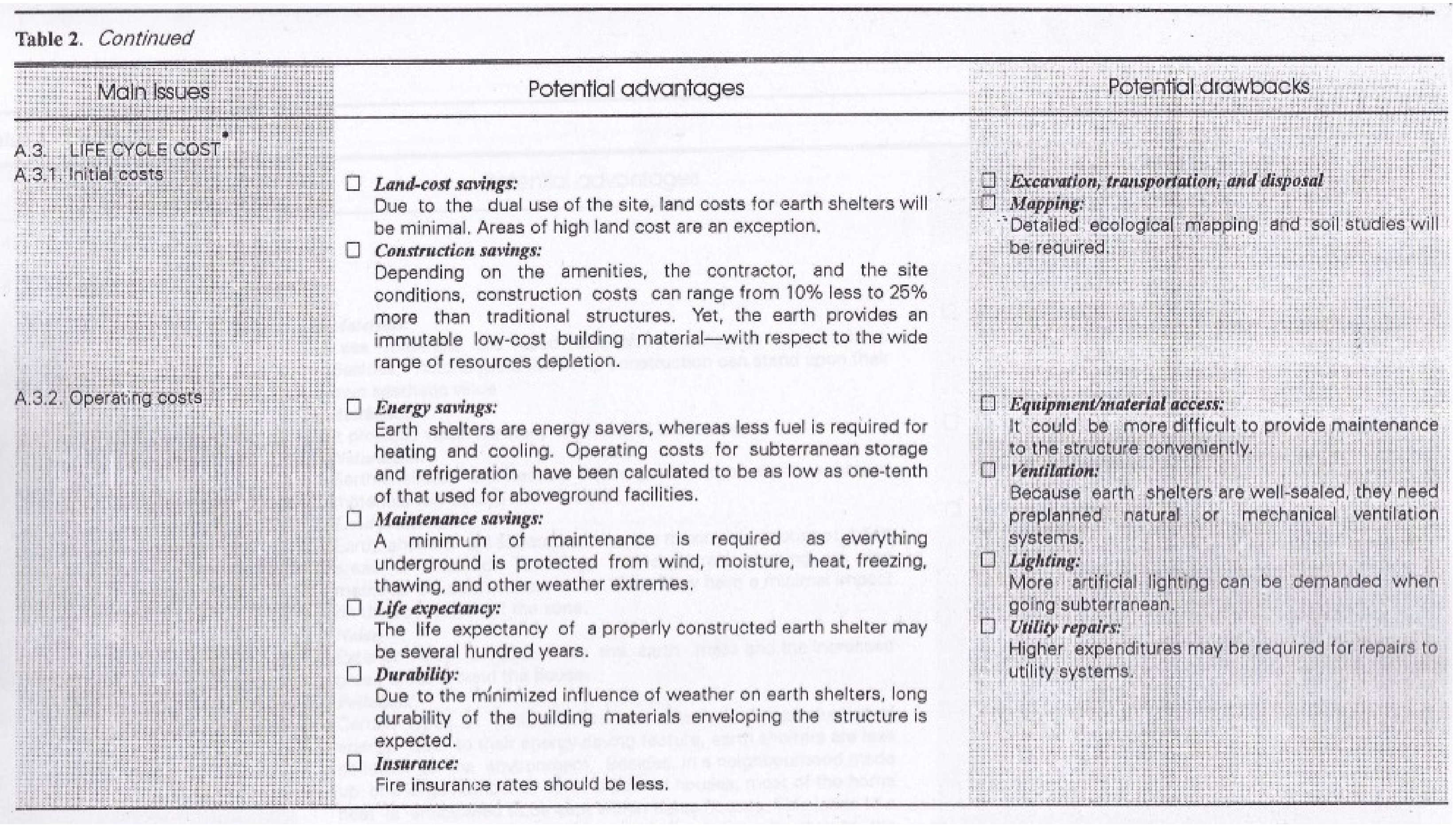


Table 2. *Continued*

Main Issues	Potential advantages	Potential drawbacks
A.3. LIFE CYCLE COST A.3.1. Initial costs	☐ ***Land-cost savings:*** Due to the dual use of the site, land costs for earth shelters will be minimal. Areas of high land cost are an exception. ☐ ***Construction savings:*** Depending on the amenities, the contractor, and the site conditions, construction costs can range from 10% less to 25% more than traditional structures. Yet, the earth provides an immutable low-cost building material—with respect to the wide range of resources depletion.	☐ ***Excavation, transportation, and disposal*** ☐ ***Mapping:*** Detailed ecological mapping and soil studies will be required.
A.3.2. Operating costs	☐ ***Energy savings:*** Earth shelters are energy savers, whereas less fuel is required for heating and cooling. Operating costs for subterranean storage and refrigeration have been calculated to be as low as one-tenth of that used for aboveground facilities. ☐ ***Maintenance savings:*** A minimum of maintenance is required as everything underground is protected from wind, moisture, heat, freezing, thawing, and other weather extremes. ☐ ***Life expectancy:*** The life expectancy of a properly constructed earth shelter may be several hundred years. ☐ ***Durability:*** Due to the minimized influence of weather on earth shelters, long durability of the building materials enveloping the structure is expected. ☐ ***Insurance:*** Fire insurance rates should be less.	☐ ***Equipment/material access:*** It could be more difficult to provide maintenance to the structure conveniently. ☐ ***Ventilation:*** Because earth shelters are well-sealed, they need preplanned natural or mechanical ventilation systems. ☐ ***Lighting:*** More artificial lighting can be demanded when going subterranean. ☐ ***Utility repairs:*** Higher expenditures may be required for repairs to utility systems.

Figure 12 Advantages and disadvantages, Extracted from (Earth sheltered housing design by S.Sheta)

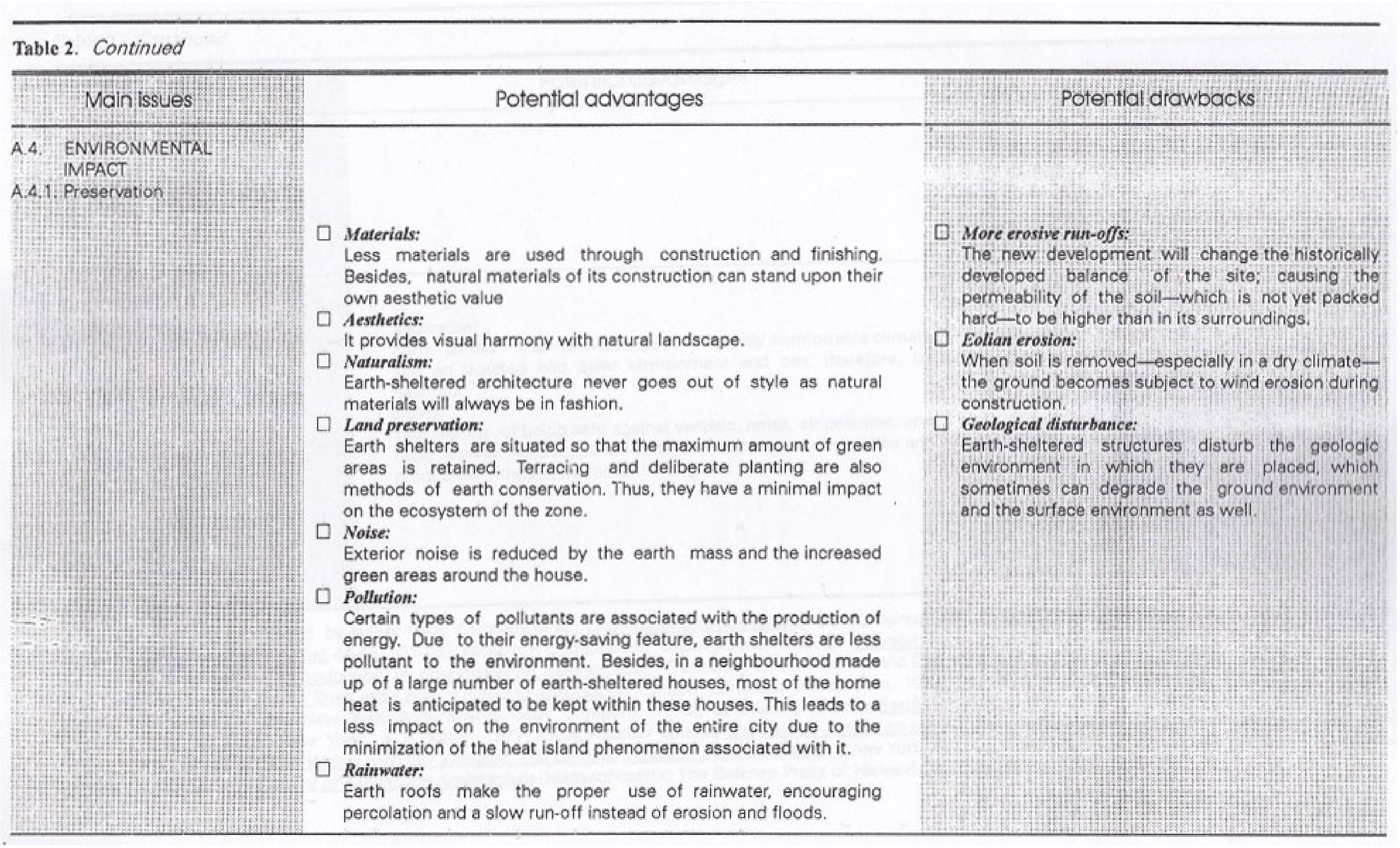


Table 2. *Continued*

Main issues	Potential advantages	Potential drawbacks
A.4. ENVIRONMENTAL IMPACT A.4.1. Preservation	☐ ***Materials:*** Less materials are used through construction and finishing. Besides, natural materials of its construction can stand upon their own aesthetic value ☐ ***Aesthetics:*** It provides visual harmony with natural landscape. ☐ ***Naturalism:*** Earth-sheltered architecture never goes out of style as natural materials will always be in fashion. ☐ ***Land preservation:*** Earth shelters are situated so that the maximum amount of green areas is retained. Terracing and deliberate planting are also methods of earth conservation. Thus, they have a minimal impact on the ecosystem of the zone. ☐ ***Noise:*** Exterior noise is reduced by the earth mass and the increased green areas around the house. ☐ ***Pollution:*** Certain types of pollutants are associated with the production of energy. Due to their energy-saving feature, earth shelters are less pollutant to the environment. Besides, in a neighbourhood made up of a large number of earth-sheltered houses, most of the home heat is anticipated to be kept within these houses. This leads to a less impact on the environment of the entire city due to the minimization of the heat island phenomenon associated with it. ☐ ***Rainwater:*** Earth roofs make the proper use of rainwater, encouraging percolation and a slow run-off instead of erosion and floods.	☐ ***More erosive run-offs:*** The new development will change the historically developed balance of the site; causing the permeability of the soil—which is not yet packed hard—to be higher than in its surroundings. ☐ ***Eolian erosion:*** When soil is removed—especially in a dry climate—the ground becomes subject to wind erosion during construction. ☐ ***Geological disturbance:*** Earth-sheltered structures disturb the geologic environment in which they are placed, which sometimes can degrade the ground environment and the surface environment as well.

Figure 13 Advantages and disadvantages, Extracted from (Earth sheltered housing design by S.Sheta)

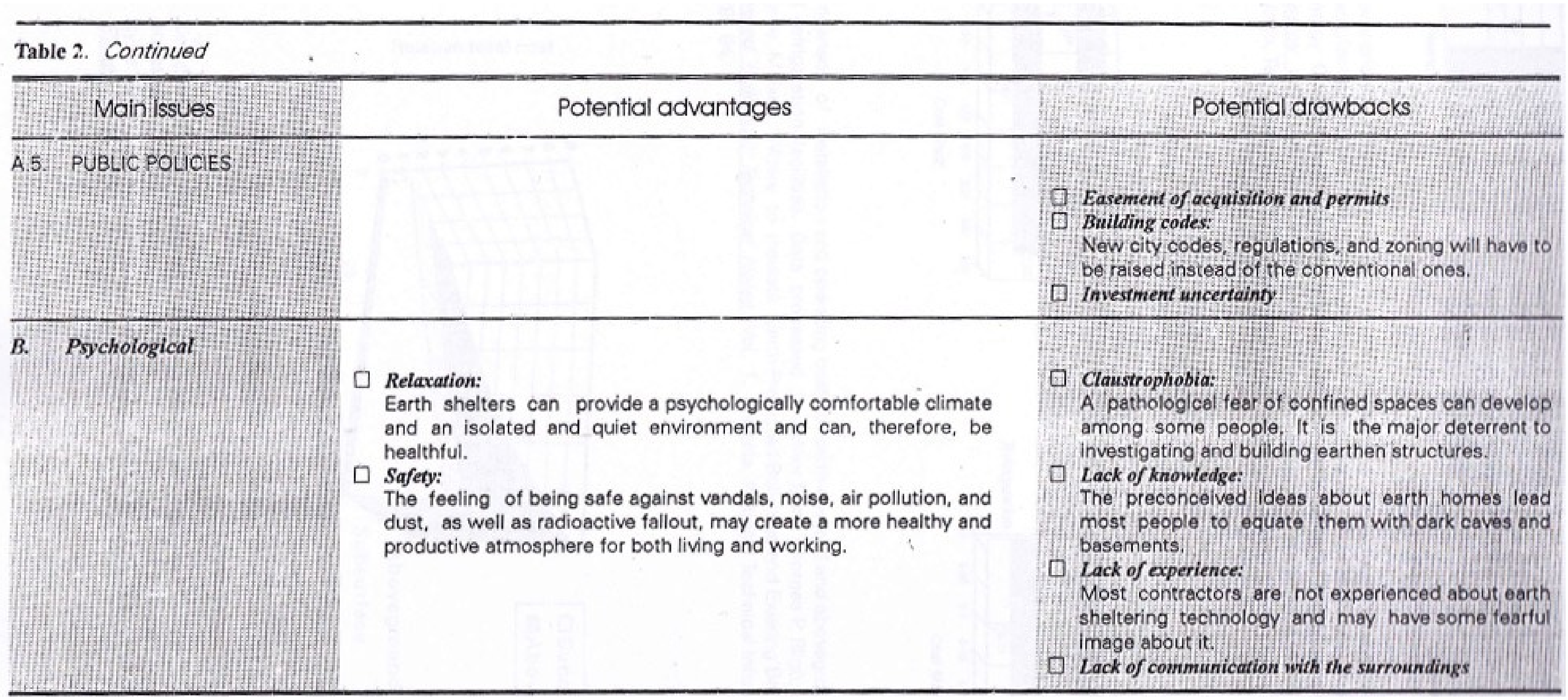


Table 2. *Continued*

Main Issues	Potential advantages	Potential drawbacks
A.5. PUBLIC POLICIES		☐ ***Easement of acquisition and permits*** ☐ ***Building codes:*** New city codes, regulations, and zoning will have to be raised instead of the conventional ones. ☐ ***Investment uncertainty***
B. ***Psychological***	☐ ***Relaxation:*** Earth shelters can provide a psychologically comfortable climate and an isolated and quiet environment and can, therefore, be healthful. ☐ ***Safety:*** The feeling of being safe against vandals, noise, air pollution, and dust, as well as radioactive fallout, may create a more healthy and productive atmosphere for both living and working.	☐ ***Claustrophobia:*** A pathological fear of confined spaces can develop among some people. It is the major deterrent to investigating and building earthen structures. ☐ ***Lack of knowledge:*** The preconceived ideas about earth homes lead most people to equate them with dark caves and basements. ☐ ***Lack of experience:*** Most contractors are not experienced about earth sheltering technology and may have some fearful image about it. ☐ ***Lack of communication with the surroundings***

Figure 14 Advantages and disadvantages, Extracted from (Earth sheltered housing design by S.Sheta)

6. Site adequacy for the technique

Each site has its own unique characteristics resulting from the nature of its configurations, the relation of one to the other, and the combination of all factors together, from this perspective , the site and its components can be considered as a tool to reduce thermal energy consumption and maintain efficiency. For example, the site can easily define the preliminary design inputs according to its foam, as if the closed site will result as totally different output than the open one[10].The scheme below is summarizing relevant guidelines and relations.

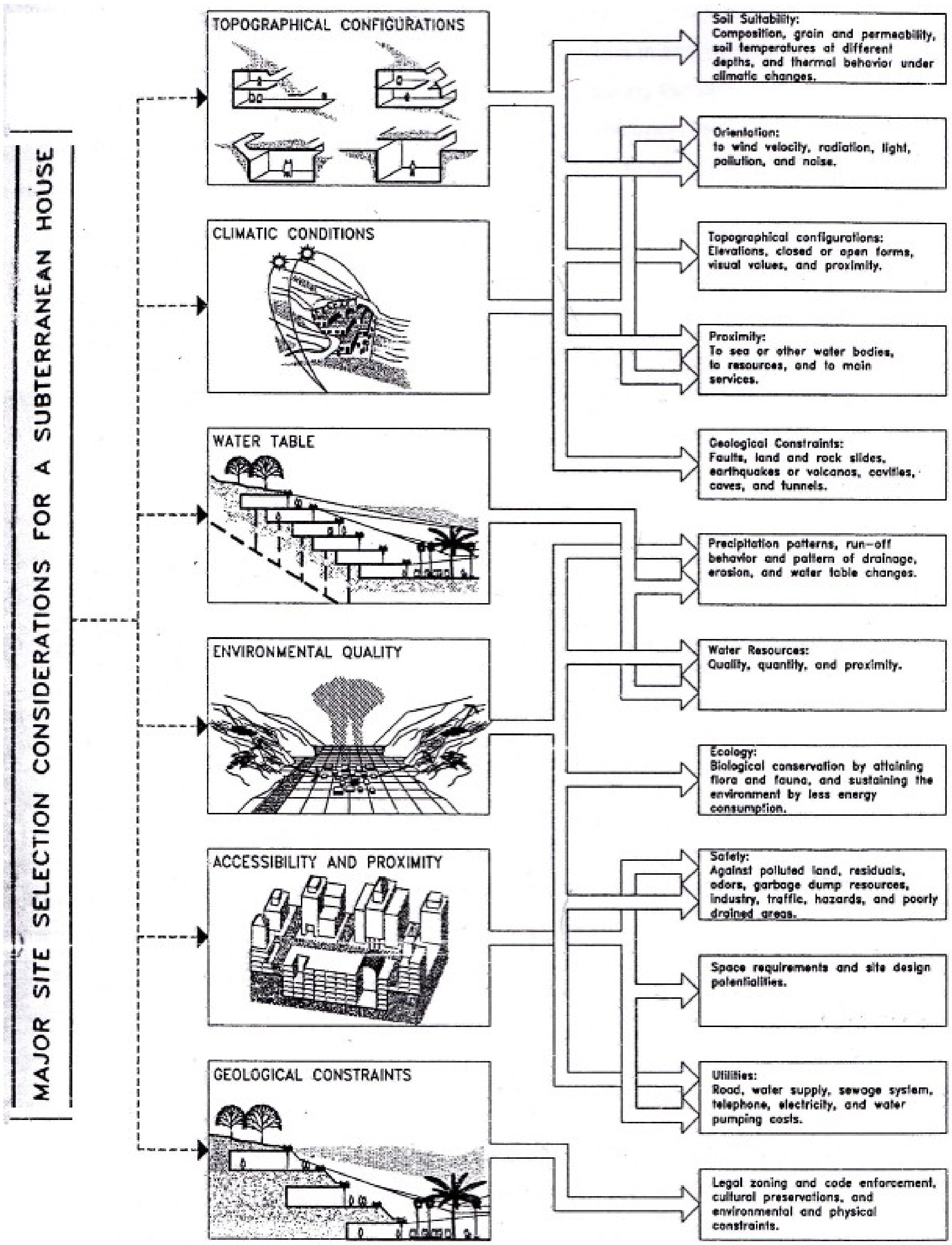


Figure 15 Site Conditions classification, Extracted from (Earth sheltered housing design by

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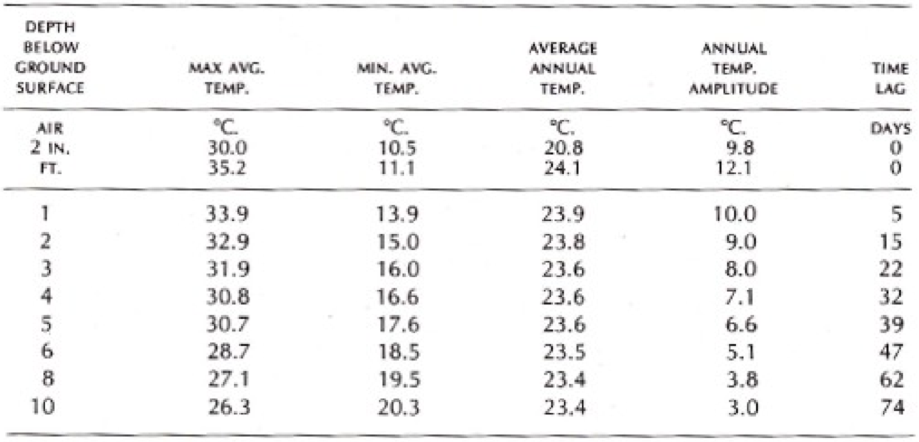
[10] Gideon Golany, Earth sheltered habitat

7. Soil Thermal mass

Soil is the dominate factor in the development of earth shelters in stressed climates as it represents the main thermal mass[11].thermal mass is a term used to describe the ability of ordinary building materials to store heat in theory, the earth can store the summer heat and release it in the cold winter through the walls of the subterranean structure, so less heating will be required for comfort. Likewise, the earth will store the winter cold; the same process occurs on a smaller scale within the day as the earth stores the sun's heat and releases it in the cold night, when it is needed[12].

With careful analysis of the thermal soil behavior, the appropriate depth of the earth sheltered structure with the desired thermal comfort could be stated .The following issues highlights the basic principles of such aspects:

- Seasonal temperature of the soil fluctuates to the depth of 8 to 10 meters. below this level, the temperature becomes stable .As the depth reaches 3 meters , the temperature becomes similar to the above ground yearly average .fluctuation of soil temperature follows the seasonal above ground changes.



DEPTH BELOW GROUND SURFACE	MAX AVG. TEMP.	MIN. AVG. TEMP.	AVERAGE ANNUAL TEMP.	ANNUAL TEMP. AMPLITUDE	TIME LAG
AIR	°C.	°C.	°C.	°C.	DAYS
2 IN.	30.0	10.5	20.8	9.8	0
FT.	35.2	11.1	24.1	12.1	0
1	33.9	13.9	23.9	10.0	5
2	32.9	15.0	23.8	9.0	15
3	31.9	16.0	23.6	8.0	22
4	30.8	16.6	23.6	7.1	32
5	30.7	17.6	23.6	6.6	39
6	28.7	18.5	23.5	5.1	47
8	27.1	19.5	23.4	3.8	62
10	26.3	20.3	23.4	3.0	74

Figure 16 Average minimum and maximum temperatures, USA. Extracted from (Earth sheltered habitat, Gideon Golany)

- The material and thickness of the overlying earth are responsible for damping down the seasonal changes. Thus, the stability of the subsurface temperature will be the result.
- The greater the depth in the soil, the more the temperature stability, and the longer the lag in time for soil temperature to reach air temperature. This time-lag can be calculated to determine the necessary depth for placement of the earth-integrated house regarding the desired temperature for proper thermal comfort. Diurnal temperature fluctuation within the soil is limited, extending to the depth of 10-30 cm[13].

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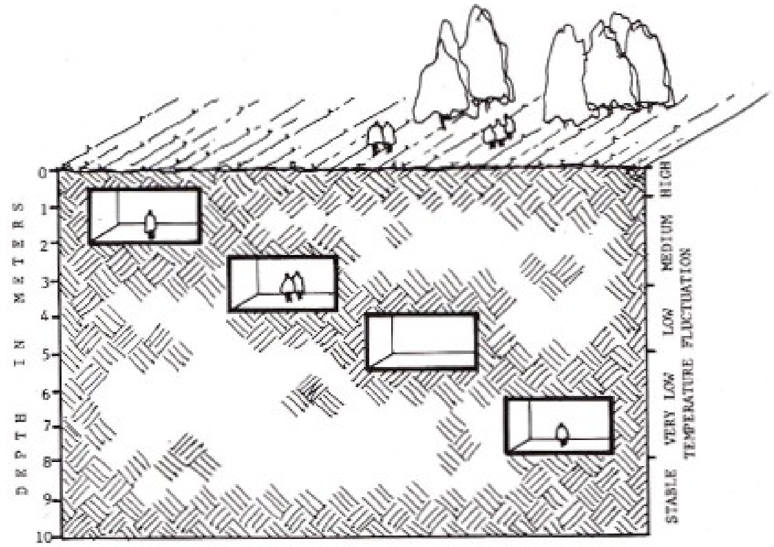
[11] Goudie, the human impact on the natural environment
[12] S.Sheta, Earth sheltered housing design
[13] Gideon Golany, Earth sheltered habitat



GENERAL DEPTH	DEPTH OF CEILING IN M.	TEMPERATURE FLUCTUATION °C	°F
VERY SHALLOW	0 - 0.80	-7 - 24 (31)	28 - 74 (46)
SHALLOW	1.60 - 3.20	2 - 18 (16)	35 - 65 (30)
MID-DEEP	3.20 - 4.80	5 - 14 (9)	41 - 58 (17)
DEEP	4.80 - 8.00	7 - 12 (5)	43 - 53 (10)
VERY DEEP	8.00 -10.00	9 - 10 (1)	48 - 50 (2)

Figure 17 Soil heat gain fluctuation. Extracted from (Earth sheltered habitat, Gideon Golany)

Principally, earth shelter has more than enough thermal mass area, and with careful design, they can provide moderate stable temperatures in stressful climates through the year.

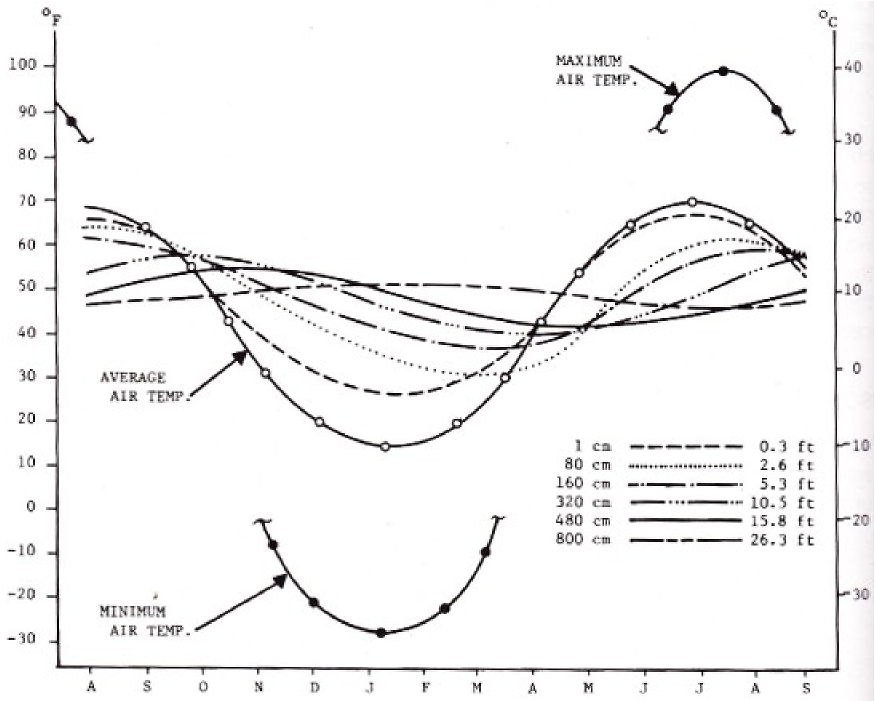


Figure 18 Average monthly soil temperature changes at different depths. Extracted from (Earth sheltered habitat, Gideon Golany)

8. Classifications and configuration

Rather than being limited by their subsurface location, earth sheltered buildings have exhibited a diverse range of design approaches .these types of subterranean space with widely varying characteristics may be grouped according to classes in order to make easier to identify each.

8.1 Classification by fenestration

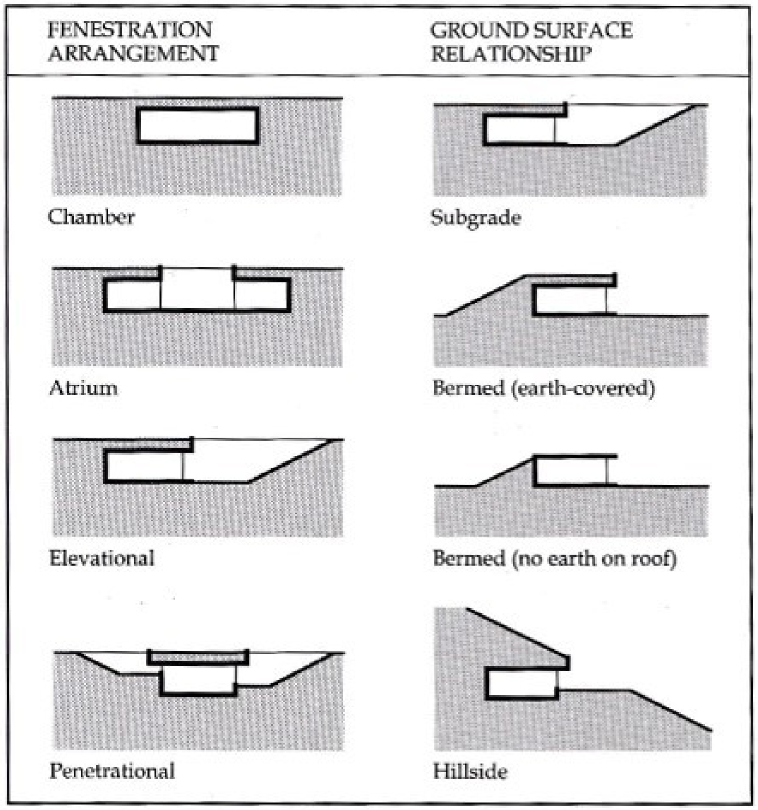
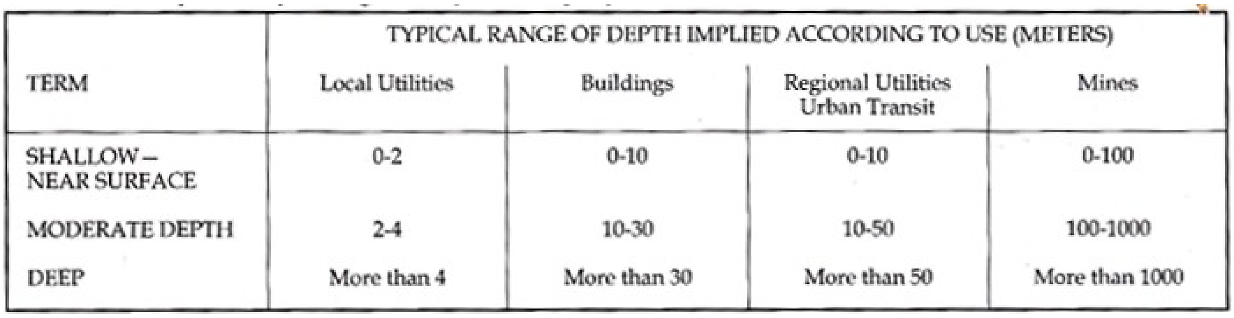


Figure 19 Classification by fenestration, Extracted from (Underground space design, by John Carmony)

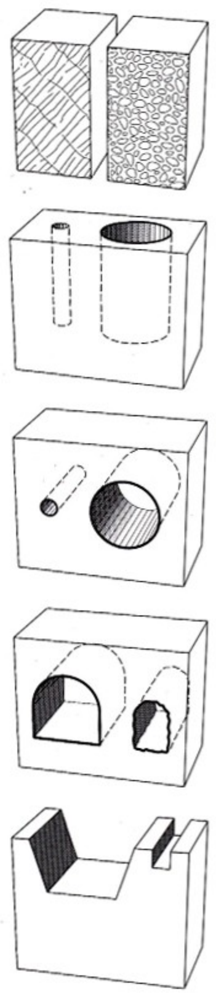
8.2 Classification by depth



TERM	TYPICAL RANGE OF DEPTH IMPLIED ACCORDING TO USE (METERS)			
	Local Utilities	Buildings	Regional Utilities Urban Transit	Mines
SHALLOW – NEAR SURFACE	0-2	0-10	0-10	0-100
MODERATE DEPTH	2-4	10-30	10-50	100-1000
DEEP	More than 4	More than 30	More than 50	More than 1000

Figure 20 Classification by depth, Extracted from (Underground space design, by John Carmony)

8.3 Classification by geometric type of space



BASIC TYPE	REASON FOR OCCURRENCE	ORIENTATION OPTIONS
Pore Space Fissure	Natural Backfilled Fractured	
Borehole Shaft	Excavated	Vertical Inclined
Tunnel Microtunnel	Natural Excavated	Horizontal Inclined Spiral
Cave Cavern	Natural Excavated	
Trench Open Pit	Excavated	

Figure 21 Classification by Geometry, Extracted from (Underground space design, by John Carmony)

9. Psychological and physiological effects in underground spaces

By its very nature, an earth shelter provides quietness, peace, security, privacy, and uniqueness; some of which are the psychological bases of any successful architecture .confirming these desired feelings, human prefer to be in a space that enclose them[14].On the other hand, Psychological and physiological barriers are crucial to earth sheltered design, as they can be categorized as follows:

- Personal bias against living in an earth covered building because of its connotations off living in caves, confinement, seclusion and primitiveness, associated feelings that it may be

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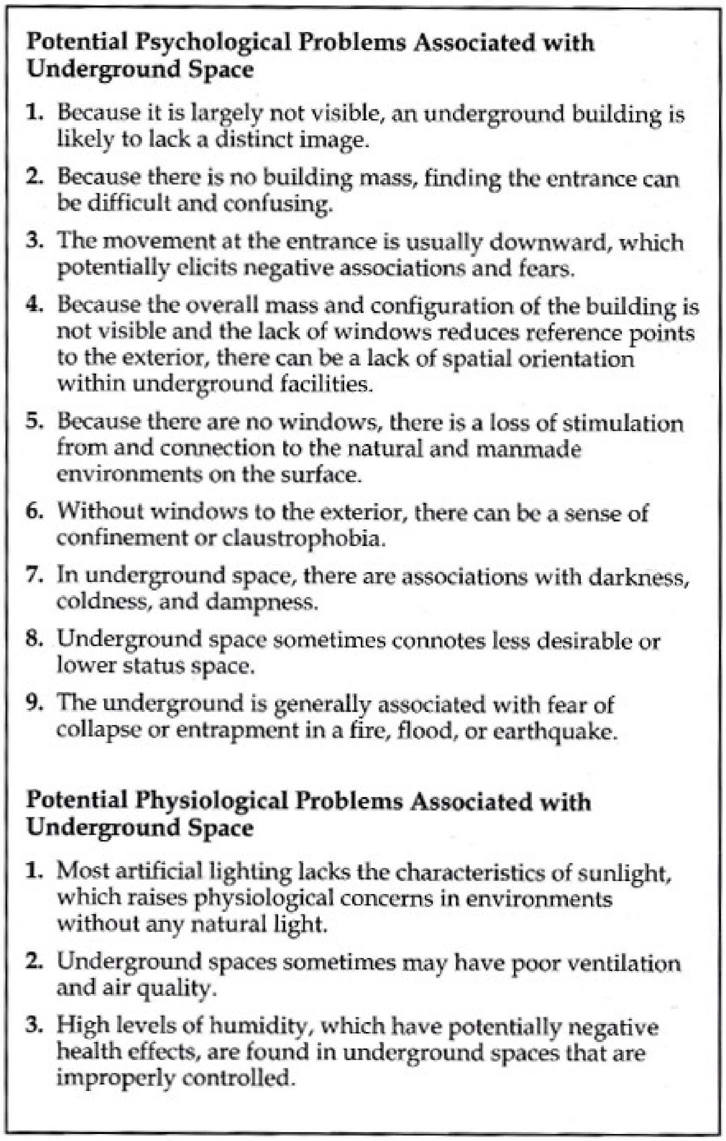
[14] James Howard Kunstler, Homes from nowhere, New York : Simon & schusdter,1996

damp, unhealthy, unventilated, and unsafe; or any previous experience of badly designed subterranean space or from an association with old basement or cellars, usually unhealthy for living conditions[15].

- Claustrophobia among some people who may have some fearful images of being trapped underground, or may also be afraid of being in a confined, closed form[16].

From that, more effort should be paid to the Contact with outdoors, Noise, Day lighting, Interior design and Entrances design, as will be explained in the next topic.



Potential Psychological Problems Associated with Underground Space

1. Because it is largely not visible, an underground building is likely to lack a distinct image.
2. Because there is no building mass, finding the entrance can be difficult and confusing.
3. The movement at the entrance is usually downward, which potentially elicits negative associations and fears.
4. Because the overall mass and configuration of the building is not visible and the lack of windows reduces reference points to the exterior, there can be a lack of spatial orientation within underground facilities.
5. Because there are no windows, there is a loss of stimulation from and connection to the natural and manmade environments on the surface.
6. Without windows to the exterior, there can be a sense of confinement or claustrophobia.
7. In underground space, there are associations with darkness, coldness, and dampness.
8. Underground space sometimes connotes less desirable or lower status space.
9. The underground is generally associated with fear of collapse or entrapment in a fire, flood, or earthquake.

Potential Physiological Problems Associated with Underground Space

1. Most artificial lighting lacks the characteristics of sunlight, which raises physiological concerns in environments without any natural light.
2. Underground spaces sometimes may have poor ventilation and air quality.
3. High levels of humidity, which have potentially negative health effects, are found in underground spaces that are improperly controlled.

Figure 22 Potential Psychological problems, Extracted from (Underground space design, by John Carmony)

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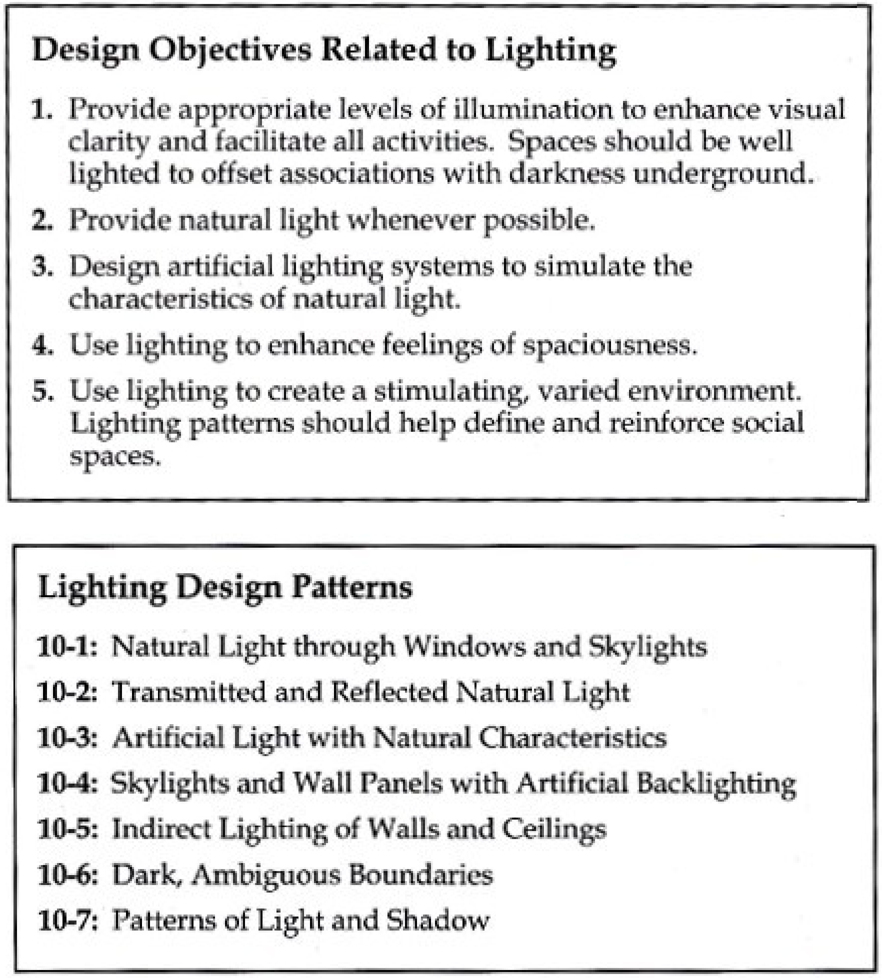
[15] Robert Bechtel, Earth covered buildings: technical notes, Vol.1 _Virginia: National technical information services,1979

[16] S.Sheta, Earth sheltered housing design

10. Architectural design guidelines for underground spaces

The previous topic demonstrates that placing people in underground environments can result in a number of potential psychological and physiological problems .these problems either are documented from actual experiences in underground or analogous environments, or they are reflected in general attitudes based on associations with general image of underground[17] .From that appropriate solutions were proposed to alleviate these problems, some of those will be summarized in the schemes of the main **design objective** and its proposed alternatives or **solution pattern**.

10.1 Lighting Design



Design Objectives Related to Lighting

1. Provide appropriate levels of illumination to enhance visual clarity and facilitate all activities. Spaces should be well lighted to offset associations with darkness underground.
2. Provide natural light whenever possible.
3. Design artificial lighting systems to simulate the characteristics of natural light.
4. Use lighting to enhance feelings of spaciousness.
5. Use lighting to create a stimulating, varied environment. Lighting patterns should help define and reinforce social spaces.

Lighting Design Patterns

10-1: Natural Light through Windows and Skylights
10-2: Transmitted and Reflected Natural Light
10-3: Artificial Light with Natural Characteristics
10-4: Skylights and Wall Panels with Artificial Backlighting
10-5: Indirect Lighting of Walls and Ceilings
10-6: Dark, Ambiguous Boundaries
10-7: Patterns of Light and Shadow

Figure 23 Lighting related objectives and design patterns , Extracted from (Underground space design, by John Carmony)

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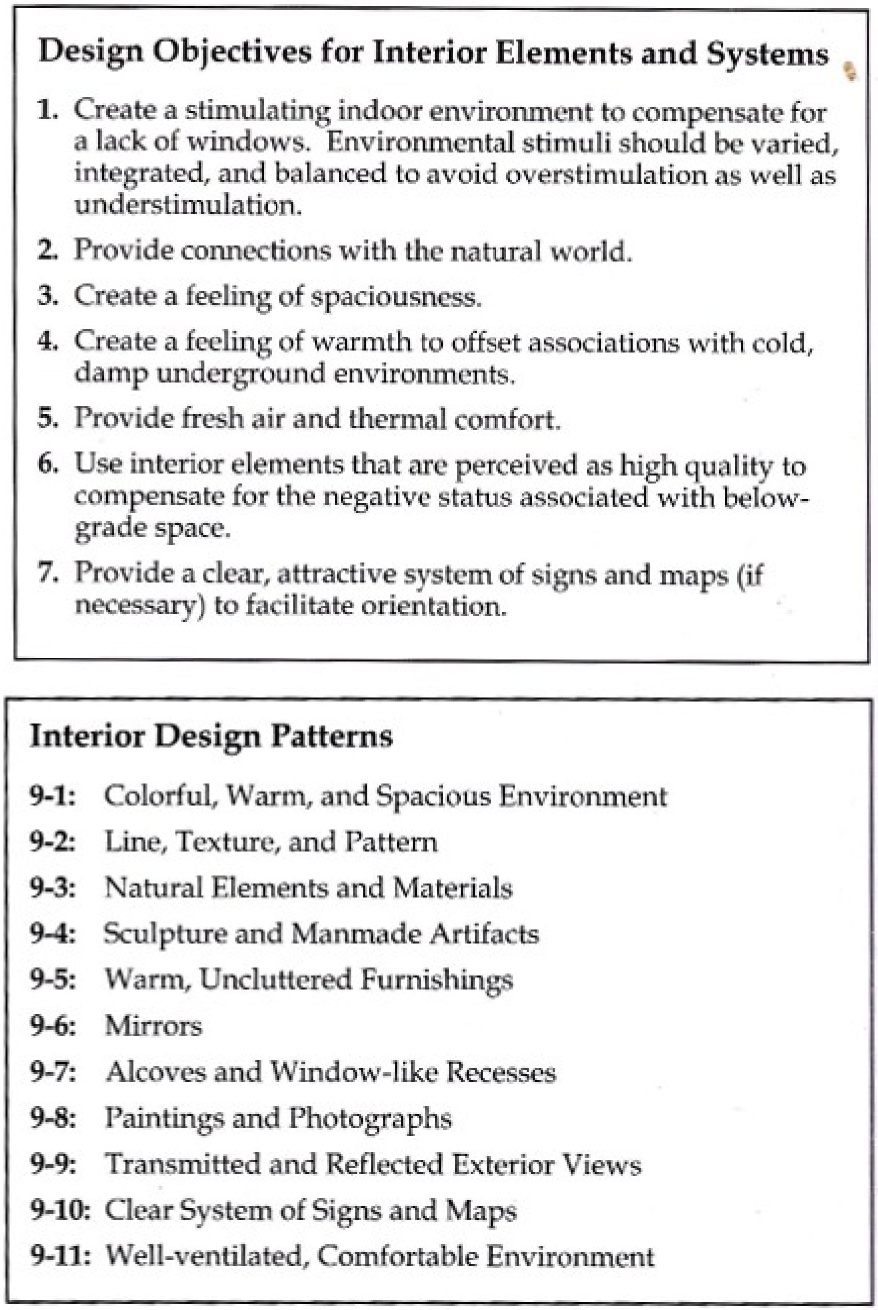
[17] John Carmony & Raymond Sterling, Underground space design , New York: Van Nostrand Reinhold,1993

10.2 Interior design



Design Objectives for Interior Elements and Systems

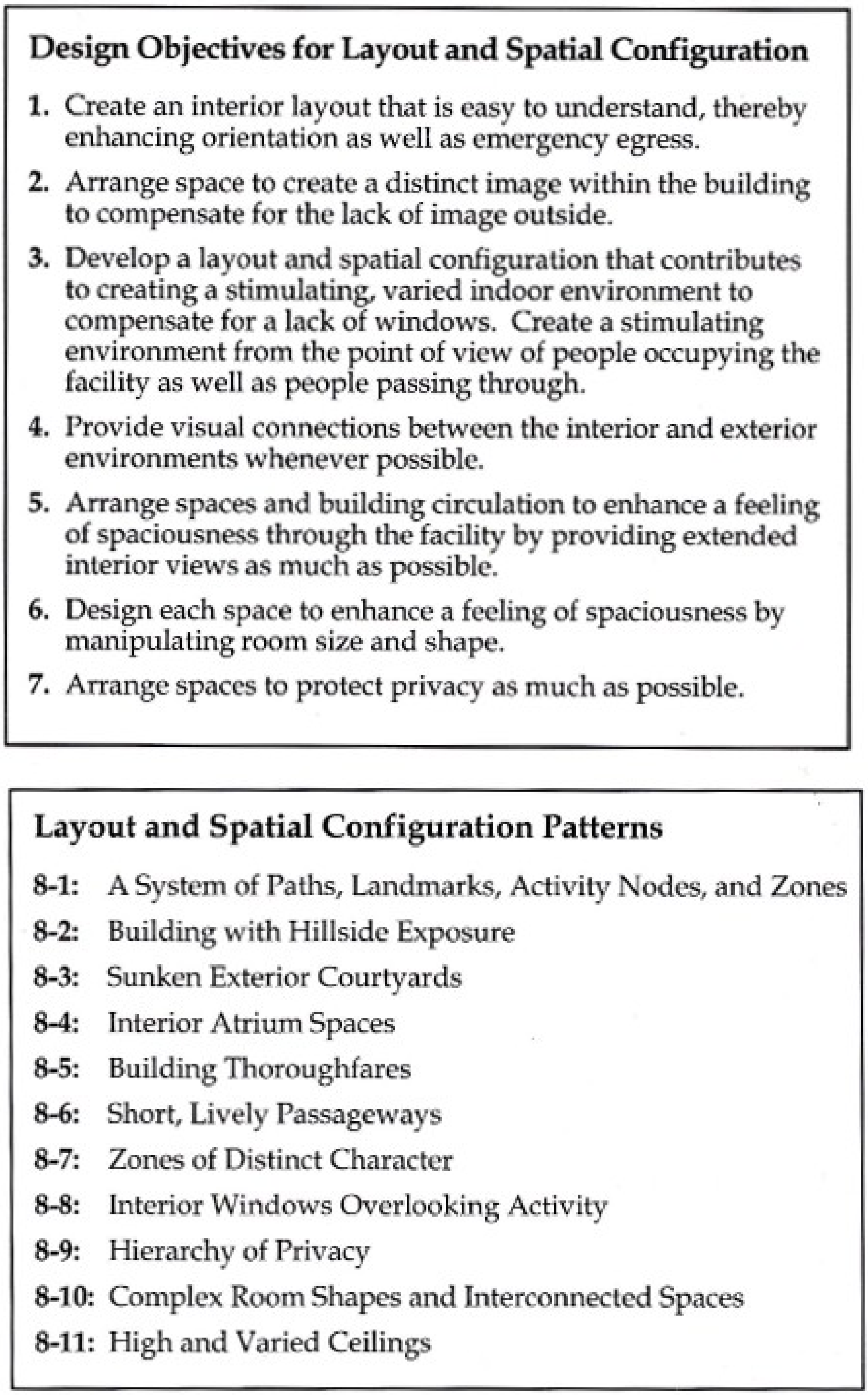
1. Create a stimulating indoor environment to compensate for a lack of windows. Environmental stimuli should be varied, integrated, and balanced to avoid overstimulation as well as understimulation.
2. Provide connections with the natural world.
3. Create a feeling of spaciousness.
4. Create a feeling of warmth to offset associations with cold, damp underground environments.
5. Provide fresh air and thermal comfort.
6. Use interior elements that are perceived as high quality to compensate for the negative status associated with below-grade space.
7. Provide a clear, attractive system of signs and maps (if necessary) to facilitate orientation.

Interior Design Patterns

9-1: Colorful, Warm, and Spacious Environment
9-2: Line, Texture, and Pattern
9-3: Natural Elements and Materials
9-4: Sculpture and Manmade Artifacts
9-5: Warm, Uncluttered Furnishings
9-6: Mirrors
9-7: Alcoves and Window-like Recesses
9-8: Paintings and Photographs
9-9: Transmitted and Reflected Exterior Views
9-10: Clear System of Signs and Maps
9-11: Well-ventilated, Comfortable Environment

Figure 24 Interior design related objectives and design patterns, Extracted from (Underground space design, by John Carmony)

10.3 Spatial configuration



Design Objectives for Layout and Spatial Configuration

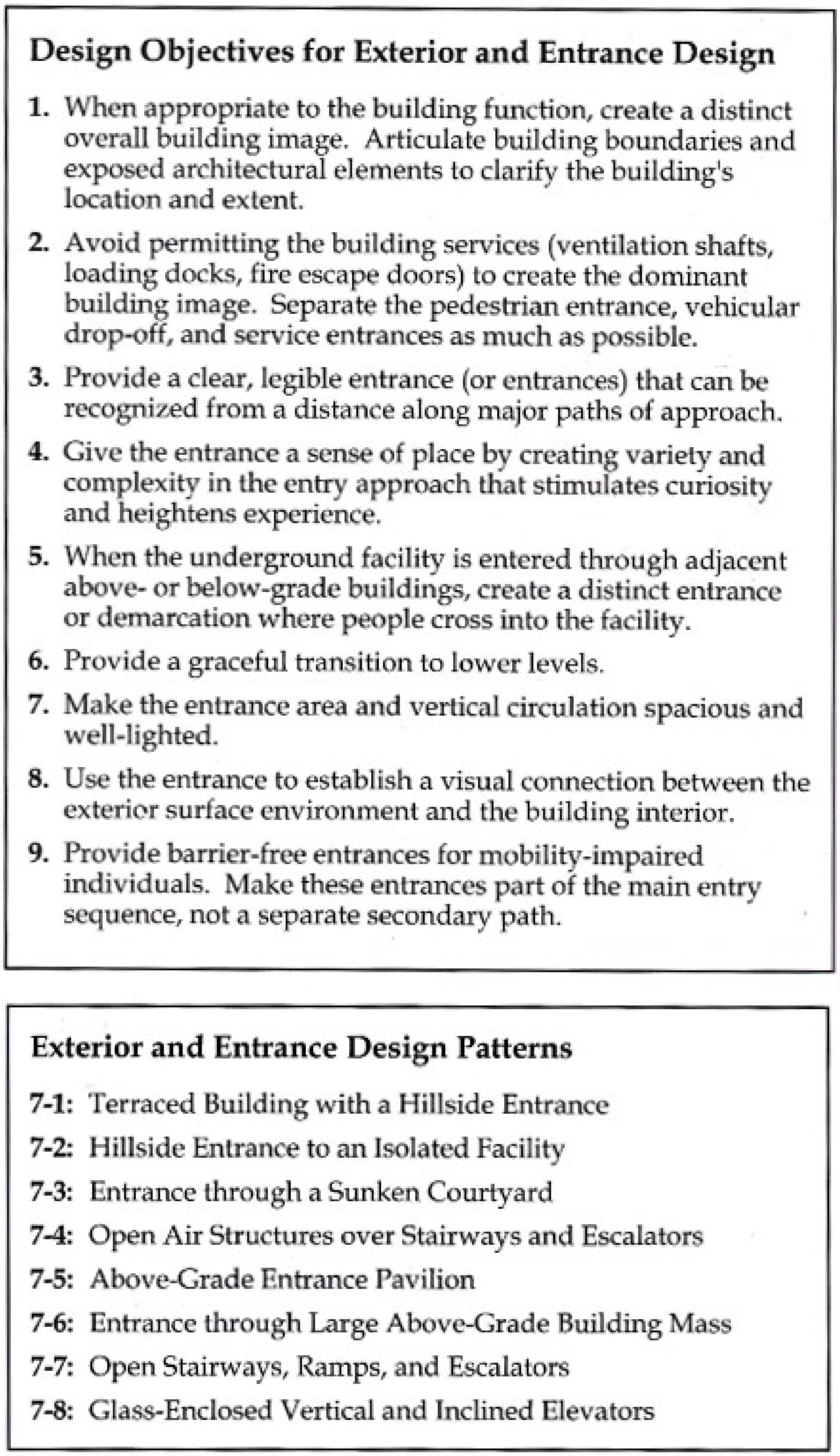
1. Create an interior layout that is easy to understand, thereby enhancing orientation as well as emergency egress.
2. Arrange space to create a distinct image within the building to compensate for the lack of image outside.
3. Develop a layout and spatial configuration that contributes to creating a stimulating, varied indoor environment to compensate for a lack of windows. Create a stimulating environment from the point of view of people occupying the facility as well as people passing through.
4. Provide visual connections between the interior and exterior environments whenever possible.
5. Arrange spaces and building circulation to enhance a feeling of spaciousness through the facility by providing extended interior views as much as possible.
6. Design each space to enhance a feeling of spaciousness by manipulating room size and shape.
7. Arrange spaces to protect privacy as much as possible.

Layout and Spatial Configuration Patterns

8-1: A System of Paths, Landmarks, Activity Nodes, and Zones
8-2: Building with Hillside Exposure
8-3: Sunken Exterior Courtyards
8-4: Interior Atrium Spaces
8-5: Building Thoroughfares
8-6: Short, Lively Passageways
8-7: Zones of Distinct Character
8-8: Interior Windows Overlooking Activity
8-9: Hierarchy of Privacy
8-10: Complex Room Shapes and Interconnected Spaces
8-11: High and Varied Ceilings

Figure 25 Layout and spatial configuration related objectives and design patterns, Extracted from (Underground space design, by John Carmony)

10.4 Exterior and entrance design



Design Objectives for Exterior and Entrance Design

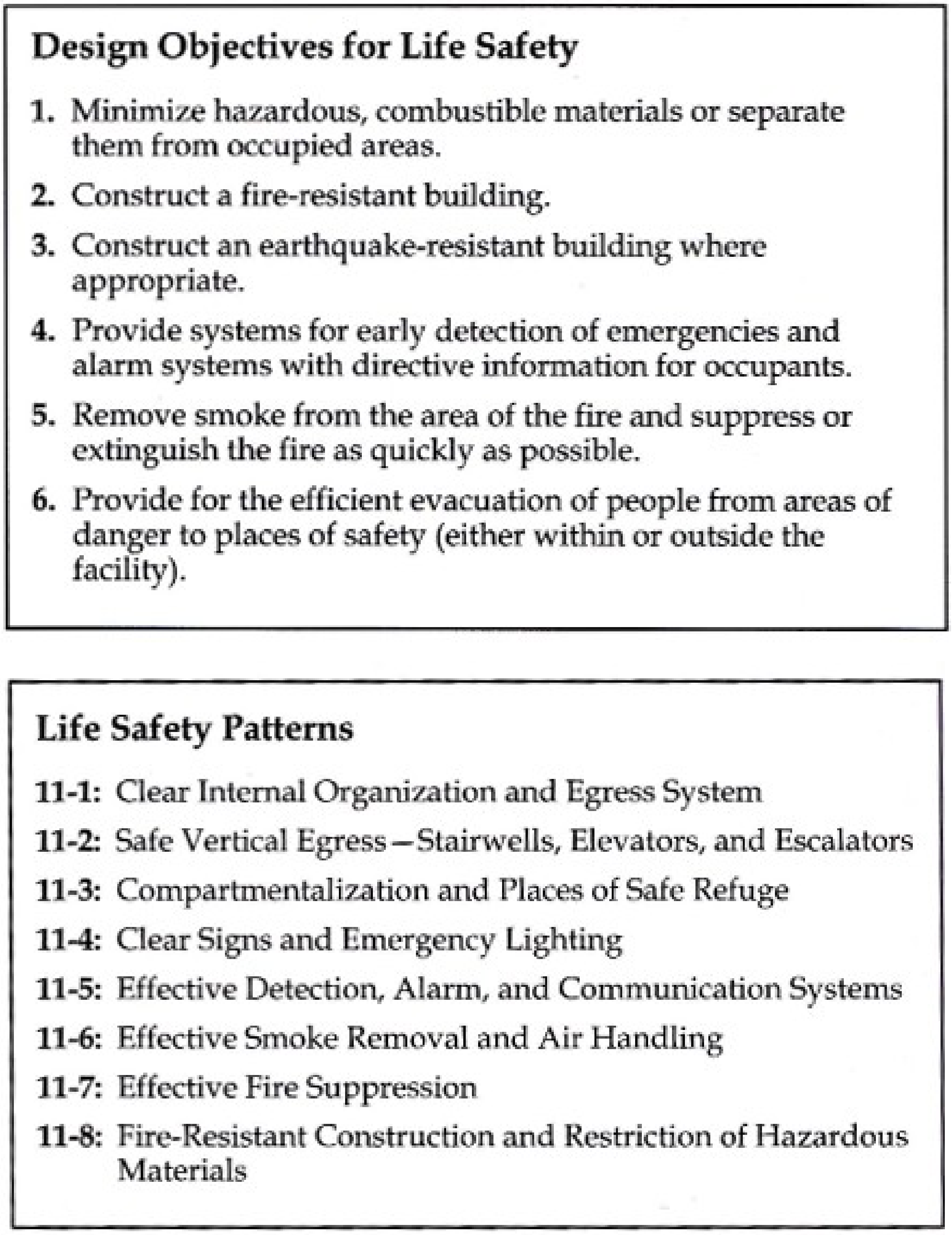
1. When appropriate to the building function, create a distinct overall building image. Articulate building boundaries and exposed architectural elements to clarify the building's location and extent.
2. Avoid permitting the building services (ventilation shafts, loading docks, fire escape doors) to create the dominant building image. Separate the pedestrian entrance, vehicular drop-off, and service entrances as much as possible.
3. Provide a clear, legible entrance (or entrances) that can be recognized from a distance along major paths of approach.
4. Give the entrance a sense of place by creating variety and complexity in the entry approach that stimulates curiosity and heightens experience.
5. When the underground facility is entered through adjacent above- or below-grade buildings, create a distinct entrance or demarcation where people cross into the facility.
6. Provide a graceful transition to lower levels.
7. Make the entrance area and vertical circulation spacious and well-lighted.
8. Use the entrance to establish a visual connection between the exterior surface environment and the building interior.
9. Provide barrier-free entrances for mobility-impaired individuals. Make these entrances part of the main entry sequence, not a separate secondary path.

Exterior and Entrance Design Patterns

7-1: Terraced Building with a Hillside Entrance
7-2: Hillside Entrance to an Isolated Facility
7-3: Entrance through a Sunken Courtyard
7-4: Open Air Structures over Stairways and Escalators
7-5: Above-Grade Entrance Pavilion
7-6: Entrance through Large Above-Grade Building Mass
7-7: Open Stairways, Ramps, and Escalators
7-8: Glass-Enclosed Vertical and Inclined Elevators

Figure 26 Entrance and Exterior design patterns, Extracted from (Underground space design, by John Carmony)

10.5 Life safety



Design Objectives for Life Safety

1. Minimize hazardous, combustible materials or separate them from occupied areas.
2. Construct a fire-resistant building.
3. Construct an earthquake-resistant building where appropriate.
4. Provide systems for early detection of emergencies and alarm systems with directive information for occupants.
5. Remove smoke from the area of the fire and suppress or extinguish the fire as quickly as possible.
6. Provide for the efficient evacuation of people from areas of danger to places of safety (either within or outside the facility).

Life Safety Patterns

11-1: Clear Internal Organization and Egress System
11-2: Safe Vertical Egress—Stairwells, Elevators, and Escalators
11-3: Compartmentalization and Places of Safe Refuge
11-4: Clear Signs and Emergency Lighting
11-5: Effective Detection, Alarm, and Communication Systems
11-6: Effective Smoke Removal and Air Handling
11-7: Effective Fire Suppression
11-8: Fire-Resistant Construction and Restriction of Hazardous Materials

Figure 27 Objectives and design patterns related to life safety, Extracted from (Underground space design, by John Carmony)

11. Recent examples

Project: Städel Museum
Location: Frankfurt, Germany
Architects: Schneider + Schumacher

Figure 28 Internal and External views, Extracted from (www.archdaily.com)

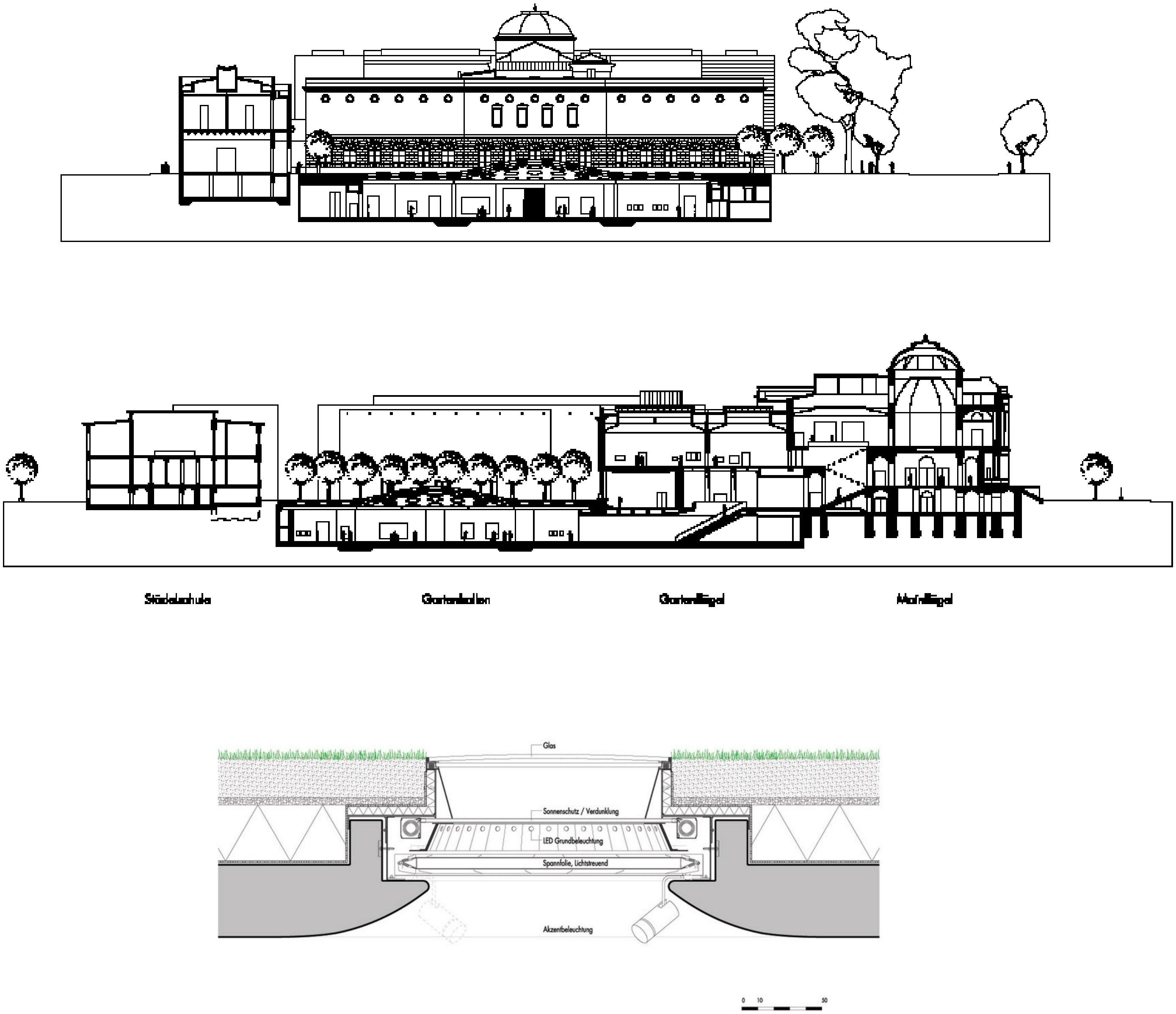


Figure 29 Drawings and Skylight detail, , Extracted from (www.archdaily.com)

Project: Antinori Winery
Location: Bargino, San Casciano in Val di Pesa, Firenze, Italy
Architects: Archea Associati

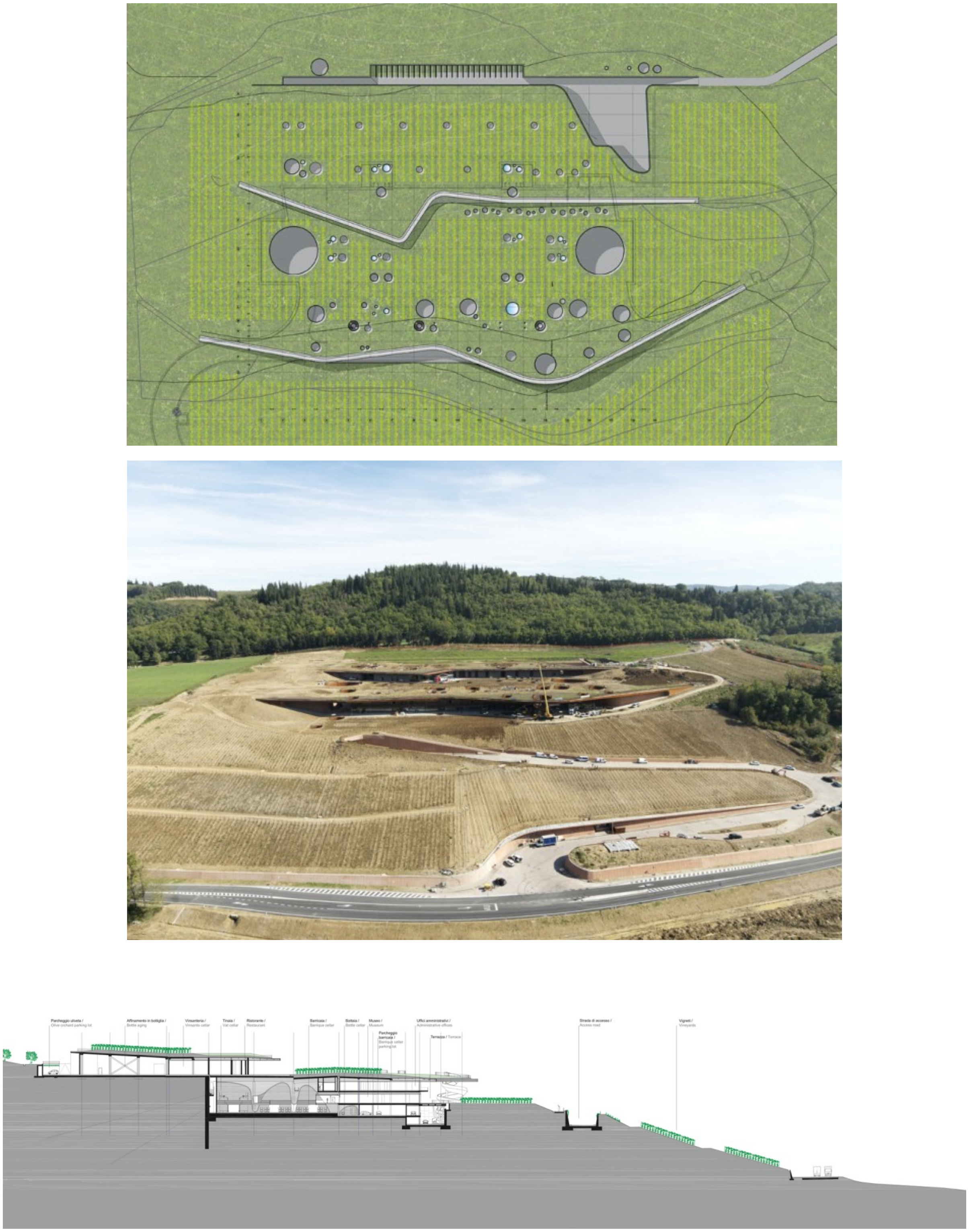
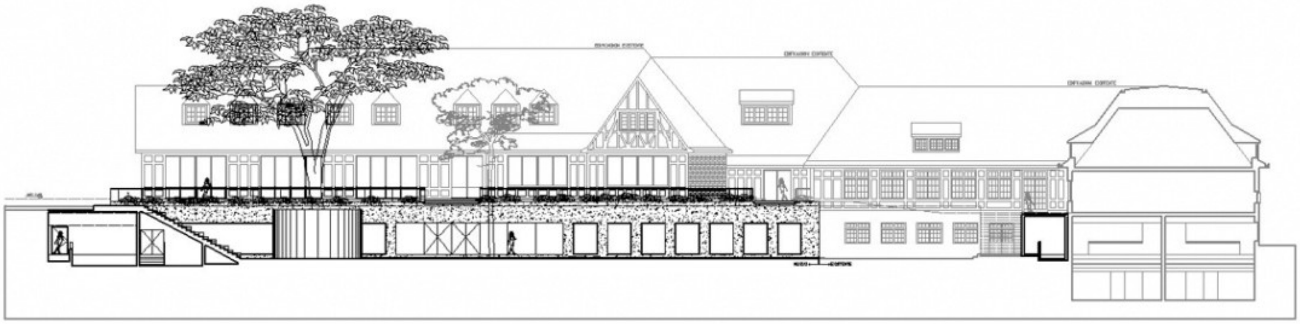
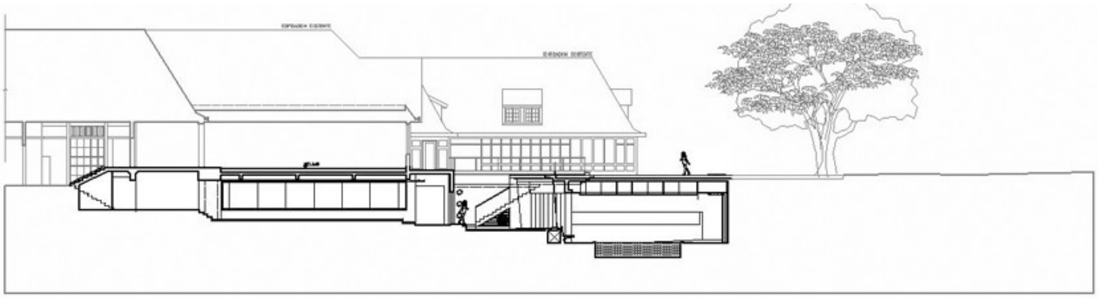


Figure 30 Views and Drawings, Extracted from (www.archdaily.com)

Project: P.W.C.C. Spa & Fitness Center
Location: Santiago, Chile
Architects: PLAN Arquitectos **+** Loroworks architects



LONGITUDINAL SECTION



CROSS SECTION

Figure 31 Views and drawings, Extracted from (www.archdaily.com)

Project: Castellaneta all Mare

Location: Puglia, Italy

Architects: Emilio Ambasz

Figure 32 Arial views, extracted from (www.emilioambaszandassociates.com)

Appendix B

LEED rating system

TABLE OF CONTENTS

12. What is LEED ?

Leadership in Energy and Environmental Design (LEED) consists of a suite of rating systems for the design, construction and operation of high performance green buildings, homes and neighborhoods. Developed by the U.S. Green Building Council (USGBC), LEED is intended to provide building owners and operators a concise framework for identifying and implementing practical and measurable green building design, construction, operations and maintenance solutions[18].

Since its inception in 1993, the U.S. Green Building Council [19] has grown to encompass more than 7,000 projects in the United States and 30 countries, covering over 1.501 billion square feet (140 km²) of development area[20]. The hallmark of LEED is that it is an open and transparent process where the technical criteria proposed by USGBC members are publicly reviewed for approval by the almost 20,000 member organizations that currently constitute the USGBC.

13. LEED Rating Systems

Rating systems are groups of requirements for projects that want to achieve LEED certification. Each group is geared towards the unique needs of a project or building type.

LEED is flexible enough to apply to all project types including healthcare facilities, schools, homes and even entire neighborhoods[21]. Projects earn points by satisfying green building requirements, within each of the LEED credit categories, projects must satisfy prerequisites and earn points. The number of points the project earns determines its level of LEED certification.

Figure 33 Rating system as per project types, Extracted from (www.usgbc.org)

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[18] http://en.wikipedia.org/wiki/Leadership_in_Energy_and_Environmental_Design#cite_note-7

[19] LEED for existing buildings v2.0 reference guide

[20] http://www.usgbc.org/

[21] http://www.usgbc.org/leed/rating-systems

14. Why LEED

Due to its Proven performance in saving money, conserving energy, reducing water consumption, improving indoor air quality, making better building material choices, and driving innovation , it helps to deliver energy and water efficient, healthy, environmentally-friendly cost saving buildings, homes and communities.

15. Credits classification[22]

15.1 Main credit categories

- **Sustainable sites credits** encourage strategies that minimize the impact on ecosystems and water resources.
- **Water efficiency credits** promote smarter use of water, inside and out, to reduce potable water consumption.
- **Energy & atmosphere credits** promote better building energy performance through innovative strategies.
- **Materials & resources credits** encourage using sustainable building materials and reducing waste.
- **Indoor environmental quality credits** promote better indoor air quality and access to daylight and views.

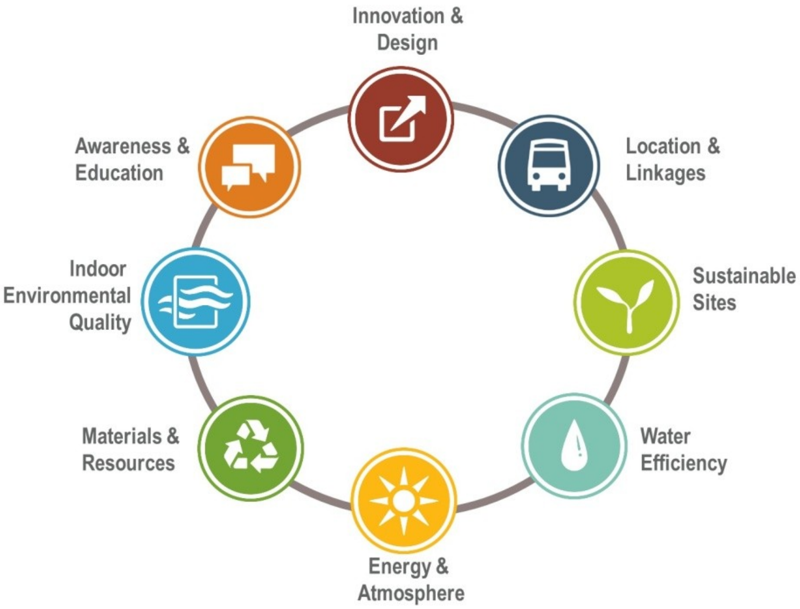

Figure 34 Main credits scheme, Extracted from (www.southface.org)

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[22] http://www.usgbc.org/leed/rating-systems

15.2 Additional LEED for Neighborhood Development credit categories

- **Smart location & linkage credits** promote walkable neighborhoods with efficient transportation options and open space.
- **Neighborhood pattern & design credits** emphasize compact, walkable, vibrant, mixed-use neighborhoods with good connections to nearby communities.
- **Green infrastructure & buildings credits** reduce the environmental consequences of the construction and operation of buildings and infrastructure.

15.3 Additional LEED for Homes credit categories

- **Location & linkage credits** encourage construction on previously developed or infill sites and promotes walkable neighborhoods with access to efficient transportation options and open space.
- **Awareness & education credits** encourage home builders and real estate professionals to provide homeowners, tenants and building managers with the education and tools they need to understand and make the most of the green building features of their home.

15.4 Two bonus credit categories

- **Innovation in design or innovation in operations credits** address sustainable building expertise as well as design measures not covered under the five LEED credit categories. Six bonus points are available in this category.
- **Regional priority credits** address regional environmental priorities for buildings in different geographic regions. Four bonus points are available in this category.

16. Green building council Italia[23]

The LEED New Construction and Restoration 2009 Italy is the result of a transposition that led not only to the introduction of Italian and European reference standards but also to adapt to the needs of the domestic construction market. The LEED 2009 Italy is closely linked to the reality of construction, standards and production Italian and is recognized in the global market.

LEED standards, processed by USGBC and also present in Italy thanks to the work of GBC Italy which has created a local version, indicate the requirements for building environmentally sustainable buildings, both from the energy point of view and from the point of view of the consumption of all environmental resources involved in the process of realization.

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[23] http://www.gbcitalia.org/page/show/leed-italia--3

LEED is also a flexible and articulated that provides differentiated formulations for new buildings (Building Design & Construction - Schools - Core & Shell), existing buildings (EBOM - Existing Buildings Operations & Maintenance), small houses (GBC Home Italy), for urban areas (ND - Neighborhood) while maintaining a basic approach consistent between different areas.

This certification is a third party verification, independent of the performance of a whole building (or part thereof) and / or urban areas. LEED certification, an internationally recognized, states that a building is environmentally friendly and is a healthy place to live and work.

17. LEED 2009 Certificates

Figure 35 Certificates and Points accreditation, Extracted from (www.erketasarim.com)

In LEED 2009 there are 100 possible base points distributed across five major credit categories: Sustainable Sites, Water Efficiency, Energy and Atmosphere, Materials and Resources, Indoor Environmental Quality, plus an additional 6 points for Innovation in Design and an additional 4 points for Regional Priority. Buildings can qualify for four levels of certification[24]:

- **Certified:** 40–49 points
- **Silver:** 50–59 points
- **Gold:** 60–79 points
- **Platinum:** 80 points and above

17.1 Points and Prerequisites

For this thesis study case, the LEED for New Construction and Neighborhood design will be considered as a frame work and evaluation methodology, these 2 schemes perquisites checklist can be concluded as extracted from the (LEED ND 2009 - Manual Guide) and (LEED NC 2009 New Constructions-Reference Guide), as follows:

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[24] http://en.wikipedia.org/wiki/Leadership_in_Energy_and_Environmental_Design

LEED 2009 FOR NEIGHBORHOOD DEVELOPMENT PROJECT CHECKLIST

Smart Location and Linkage 27 possible points

☑	Prerequisite 1	Smart Location	Required
☑	Prerequisite 2	Imperiled Species and Ecological Communities	Required
☑	Prerequisite 3	Wetland and Water Body Conservation	Required
☑	Prerequisite 4	Agricultural Land Conservation	Required
☑	Prerequisite 5	Floodplain Avoidance	Required
☐	Credit 1	Preferred Locations	10
☐	Credit 2	Brownfield Redevelopment	2
☐	Credit 3	Locations with Reduced Automobile Dependence	7
☐	Credit 4	Bicycle Network and Storage	1
☐	Credit 5	Housing and Jobs Proximity	3
☐	Credit 6	Steep Slope Protection	1
☐	Credit 7	Site Design for Habitat or Wetland and Water Body Conservation	1
☐	Credit 8	Restoration of Habitat or Wetlands and Water Bodies	1
☐	Credit 9	Long-Term Conservation Management of Habitat or Wetlands and Water Bodies	1

Neighborhood Pattern and Design 44 possible points

☑	Prerequisite 1	Walkable Streets	Required
☑	Prerequisite 2	Compact Development	Required
☑	Prerequisite 3	Connected and Open Community	Required
☐	Credit 1	Walkable Streets	12
☐	Credit 2	Compact Development	6
☐	Credit 3	Mixed-Use Neighborhood Centers	4
☐	Credit 4	Mixed-Income Diverse Communities	7
☐	Credit 5	Reduced Parking Footprint	1
☐	Credit 6	Street Network	2
☐	Credit 7	Transit Facilities	1
☐	Credit 8	Transportation Demand Management	2
☐	Credit 9	Access to Civic and Public Spaces	1
☐	Credit 10	Access to Recreation Facilities	1
☐	Credit 11	Visitability and Universal Design	1
☐	Credit 12	Community Outreach and Involvement	2
☐	Credit 13	Local Food Production	1
☐	Credit 14	Tree-Lined and Shaded Streets	2
☐	Credit 15	Neighborhood Schools	1

Green Infrastructure and Buildings 29 possible points

☑	Prerequisite 1	Certified Green Building	Required
☑	Prerequisite 2	Minimum Building Energy Efficiency	Required
☑	Prerequisite 3	Minimum Building Water Efficiency	Required
☑	Prerequisite 4	Construction Activity Pollution Prevention	Required

☐ Credit 1	Certified Green Buildings	5
☐ Credit 2	Building Energy Efficiency	2
☐ Credit 3	Building Water Efficiency	1
☐ Credit 4	Water-Efficient Landscaping	1
☐ Credit 5	Existing Building Reuse	1
☐ Credit 6	Historic Resource Preservation and Adaptive Use	1
☐ Credit 7	Minimized Site Disturbance in Design and Construction	1
☐ Credit 8	Stormwater Management	4
☐ Credit 9	Heat Island Reduction	1
☐ Credit 10	Solar Orientation	1
☐ Credit 11	On-Site Renewable Energy Sources	3
☐ Credit 12	District Heating and Cooling	2
☐ Credit 13	Infrastructure Energy Efficiency	1
☐ Credit 14	Wastewater Management	2
☐ Credit 15	Recycled Content in Infrastructure	1
☐ Credit 16	Solid Waste Management Infrastructure	1
☐ Credit 17	Light Pollution Reduction	1

Innovation and Design Process		**6 possible points**
☐ Credit 1	Innovation and Exemplary Performance	1–5
☐ Credit 2	LEED® Accredited Professional	1

Regional Priority Credit		**4 possible points**
☐ Credit 1	Regional Priority	1–4

LEED 2009 for Neighborhood Development Certification Levels

100 base points plus 6 possible Innovation and Design Process and 4 possible Regional Priority Credit points

Certified	40–49 points
Silver	50–59 points
Gold	60–79 points
Platinum	80 points and above

LEED 2009 FOR NEW CONSTRUCTION AND MAJOR RENOVATIONS PROJECT CHECKLIST

Sustainable Sites		**26 Possible Points**
☑ Prerequisite 1	Construction Activity Pollution Prevention	Required
☐ Credit 1	Site Selection	1
☐ Credit 2	Development Density and Community Connectivity	5
☐ Credit 3	Brownfield Redevelopment	1
☐ Credit 4.1	Alternative Transportation—Public Transportation Access	6
☐ Credit 4.2	Alternative Transportation—Bicycle Storage and Changing Rooms	1
☐ Credit 4.3	Alternative Transportation—Low-Emitting and Fuel-Efficient Vehicles	3
☐ Credit 4.4	Alternative Transportation—Parking Capacity	2
☐ Credit 5.1	Site Development—Protect or Restore Habitat	1
☐ Credit 5.2	Site Development—Maximize Open Space	1
☐ Credit 6.1	Stormwater Design—Quantity Control	1
☐ Credit 6.2	Stormwater Design—Quality Control	1
☐ Credit 7.1	Heat Island Effect—Nonroof	1
☐ Credit 7.2	Heat Island Effect—Roof	1
☐ Credit 8	Light Pollution Reduction	1

Water Efficiency		**10 Possible Points**
☑ Prerequisite 1	Water Use Reduction	Required
☐ Credit 1	Water Efficient Landscaping	2-4
☐ Credit 2	Innovative Wastewater Technologies	2
☐ Credit 3	Water Use Reduction	2-4

Energy and Atmosphere		**35 Possible Points**
☑ Prerequisite 1	Fundamental Commissioning of Building Energy Systems	Required
☑ Prerequisite 2	Minimum Energy Performance	Required
☑ Prerequisite 3	Fundamental Refrigerant Management	Required
☐ Credit 1	Optimize Energy Performance	1–19
☐ Credit 2	On-site Renewable Energy	1–7
☐ Credit 3	Enhanced Commissioning	2
☐ Credit 4	Enhanced Refrigerant Management	2
☐ Credit 5	Measurement and Verification	3
☐ Credit 6	Green Power	2

Materials and Resources		**14 Possible Points**
☑ Prerequisite 1	Storage and Collection of Recyclables	Required
☐ Credit 1.1	Building Reuse—Maintain Existing Walls, Floors and Roof	1-3
☐ Credit 1.2	Building Reuse—Maintain Existing Interior Nonstructural Elements	1
☐ Credit 2	Construction Waste Management	1-2
☐ Credit 3	Materials Reuse	1-2
☐ Credit 4	Recycled Content	1-2

☐ Credit 5	Regional Materials	1-2
☐ Credit 6	Rapidly Renewable Materials	1
☐ Credit 7	Certified Wood	1

Indoor Environmental Quality		**15 Possible Points**
☑ Prerequisite 1	Minimum Indoor Air Quality Performance	Required
☑ Prerequisite 2	Environmental Tobacco Smoke (ETS) Control	Required
☐ Credit 1	Outdoor Air Delivery Monitoring	1
☐ Credit 2	Increased Ventilation	1
☐ Credit 3.1	Construction Indoor Air Quality Management Plan—During Construction	1
☐ Credit 3.2	Construction Indoor Air Quality Management Plan—Before Occupancy	1
☐ Credit 4.1	Low-Emitting Materials—Adhesives and Sealants	1
☐ Credit 4.2	Low-Emitting Materials—Paints and Coatings	1
☐ Credit 4.3	Low-Emitting Materials—Flooring Systems	1
☐ Credit 4.4	Low-Emitting Materials—Composite Wood and Agrifiber Products	1
☐ Credit 5	Indoor Chemical and Pollutant Source Control	1
☐ Credit 6.1	Controllability of Systems—Lighting	1
☐ Credit 6.2	Controllability of Systems—Thermal Comfort	1
☐ Credit 7.1	Thermal Comfort—Design	1
☐ Credit 7.2	Thermal Comfort—Verification	1
☐ Credit 8.1	Daylight and Views—Daylight	1
☐ Credit 8.2	Daylight and Views—Views	1

Innovation in Design		**6 Possible Points**
☐ Credit 1	Innovation in Design	1-5
☐ Credit 2	LEED Accredited Professional	1

Regional Priority		**4 Possible Points**
☐ Credit 1	Regional Priority	1-4

LEED 2009 for New Construction and Major Renovations

100 base points; 6 possible Innovation in Design and 4 Regional Priority points

Certified	40–49 points
Silver	50–59 points
Gold	60–79 points
Platinum	80 points and above

Appendix C

Existing Mill survey and intervention drawings sample

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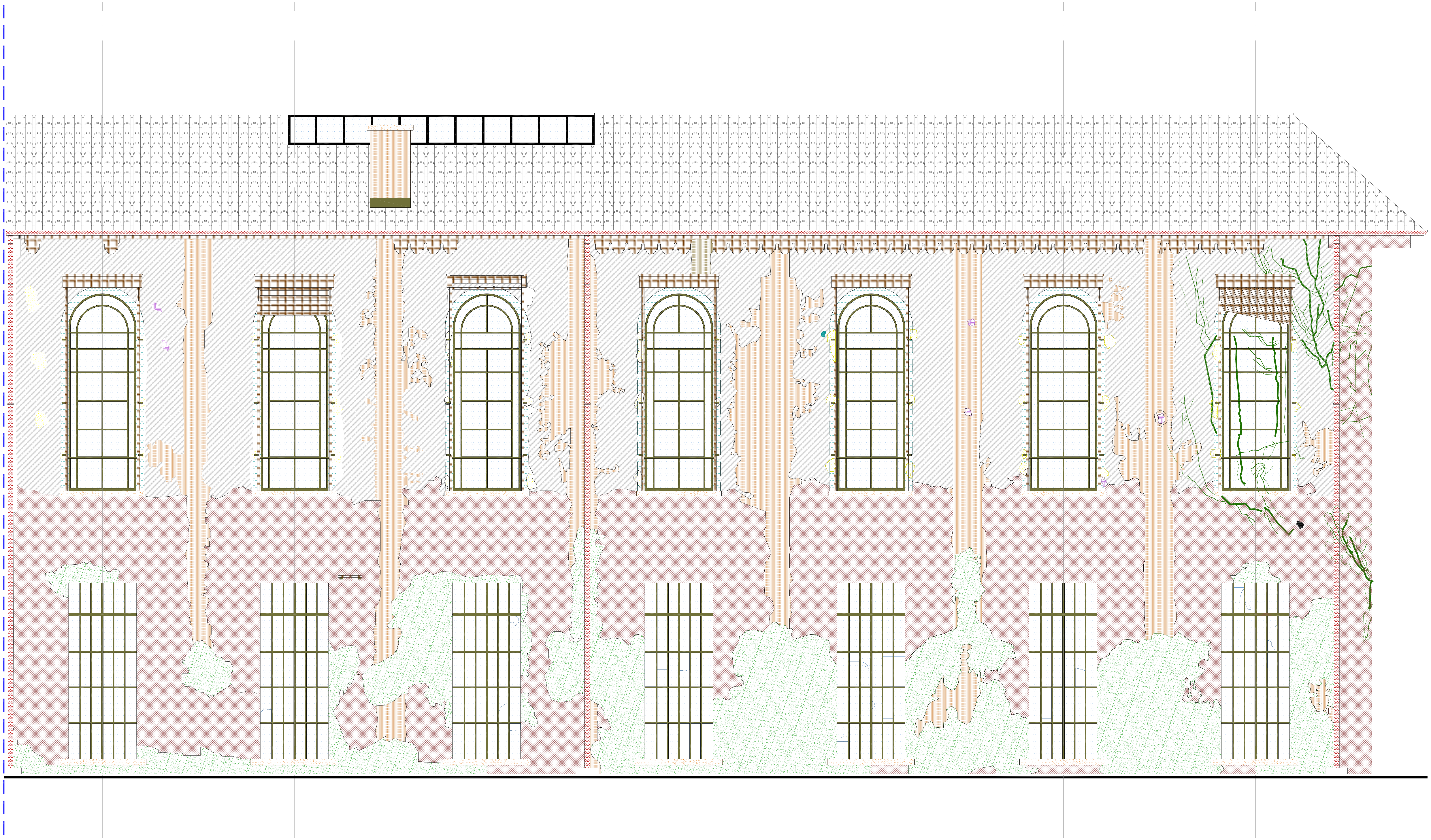
■ METAL DRAINAGE FIXTURE
▨ CLAY TILES
■ STONES
■ WOOD
■ METAL FRAMING/FLASHING
□ GLAZING
■ PLASTER 01
▨ PLASTER 02
▨ PLASTER 03
■ PLASTER 04
■ PLASTER 05
■ PLASTER 06
■ PLASTER 07
▨ PLASTER 08
■ VEGETAION



Map Surfacing _ Materials

POLITECNICO DI MILANO
VI FACOLTA' DI INGEGNERIA
MASTER OF BUILDING ENGINEERING

The Earth sheltered Body Factory | VALMADRERA-LECCO

A.Y. 2012/2013

SCALE
1:20

Ref 01

- ▩ Alga - Biological Colonization
- ▩ Missing Part
- ▩ Corrosion/Rust
- ▩ Scratching
- ◩ Impact Damage
- ▩ Delamination
- ▩ Cracking
- ▩ Pitting
- ▩ Plaster Detachment
- ▩ Moist Area
- ▩ Staining
- ▨ Efflorescence
- ▩ Iron rich Patina - Didscoloration & Deposit
- ▩ Peeling
- ◩ Plant
- ▩ Coloration

Map Surfacing Damages

POLITECNICO DI MILANO
VI FACOLTA' DI INGEGNERIA
MASTER OF BUILDING ENGINEERING

The Earth sheltered Body Factory | VALMADRERA-LECCO

A.Y. 2012/2013

SCALE
1:20

Ref 02

Facade Intervention

▨ Alga - Biological Colonization
▨ Missing Part
▨ Corrosion/Rust
▨ Scratching
▨ Impact Damage
▨ Delamination
▨ Cracking
▨ Pitting
▨ Plaster Detachment
▨ Moist Area
▨ Staining
▨ Efflorescence
▨ Iron rich Patina - Didscoloration & Deposit
▨ Peeling
▨ Plant
▨ Coloration

General Note:
As have been investigated, many Destructive/ unprofessional actions took place for the original Façade plaster fixation, using different colors, materials, techniques, etc,. Thus, our main preserving action is to try to reset the time line towards the original Historical image by removing the destructive grey plaster on the lower part of the facade and replace it with lime mortar, check all the additions above the old incomplete original plaster and fix the damages of added ones, to provide a clean bedding layer for the new added Eco-Logical solution. The facade will be painted altogether with a Mineral Silicate paint that is more durable then the limewash and maintains the necessary breathability of the facade.

CLEANING OPERATION	
1	Compressed air at low pressure
2	Deionized water
3	Deionized water at low pressure
4	Pack with cellulose
5	Automatic suction
6	Manual sanding
7	Chemical formulation
8	Manual cleaning with brush
9	Deteriorated product/item removal
10	Micro sandblasting
11	Duster/rag
12	Stiff brush
13	Small tools usage
CONSOLIDATION OPERATION	
A	Chemical primer
B	Injection of fluid mortar (hydraulic lime)
C	Smoothing
D	New implants
E	Patch with lime mortar
F	New plaster
G	Grouting and/or beading
H	Sealing/filling with lime + mortar
I	Consolidating treatment with body wraps
J	Consolidating treatment with a brush
K	Dehumidification
PROTECTION OPERATION	
I	Application of aluminium
II	Application of oil
III	Anti-rusting
IV	New glazing
V	Application/preparation of wax
VI	Airless protective treatment
VII	Protective treatment with a brush
VIII	Cover of coloured lime
IX	Synthetic paint / coating
OTHER OPERATIONS	
a	Excavation
b	Trenches
R1	Replacement with the exact material
R2	Replacement material with same physical properties and appearance

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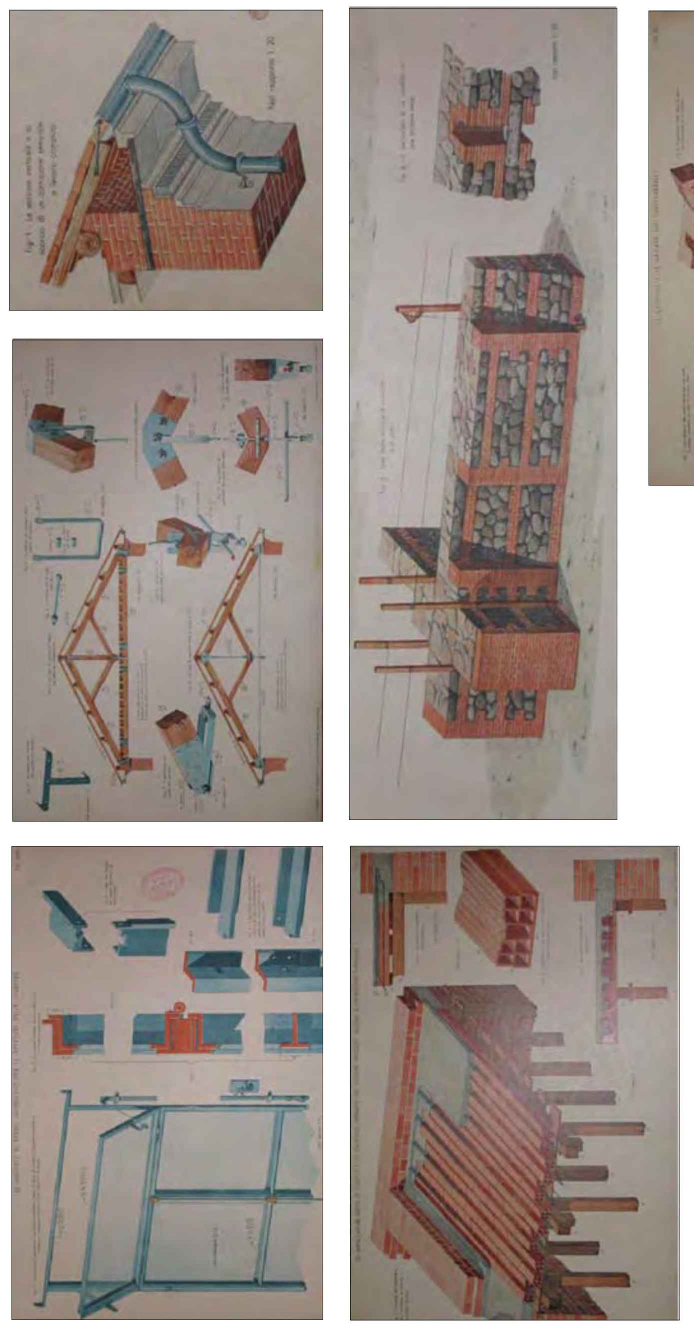
MASTER OF BUILDING ENGINEERING

The Earth sheltered Body Factory | VALMADRERA-LECCO

A.Y. 2012/2013

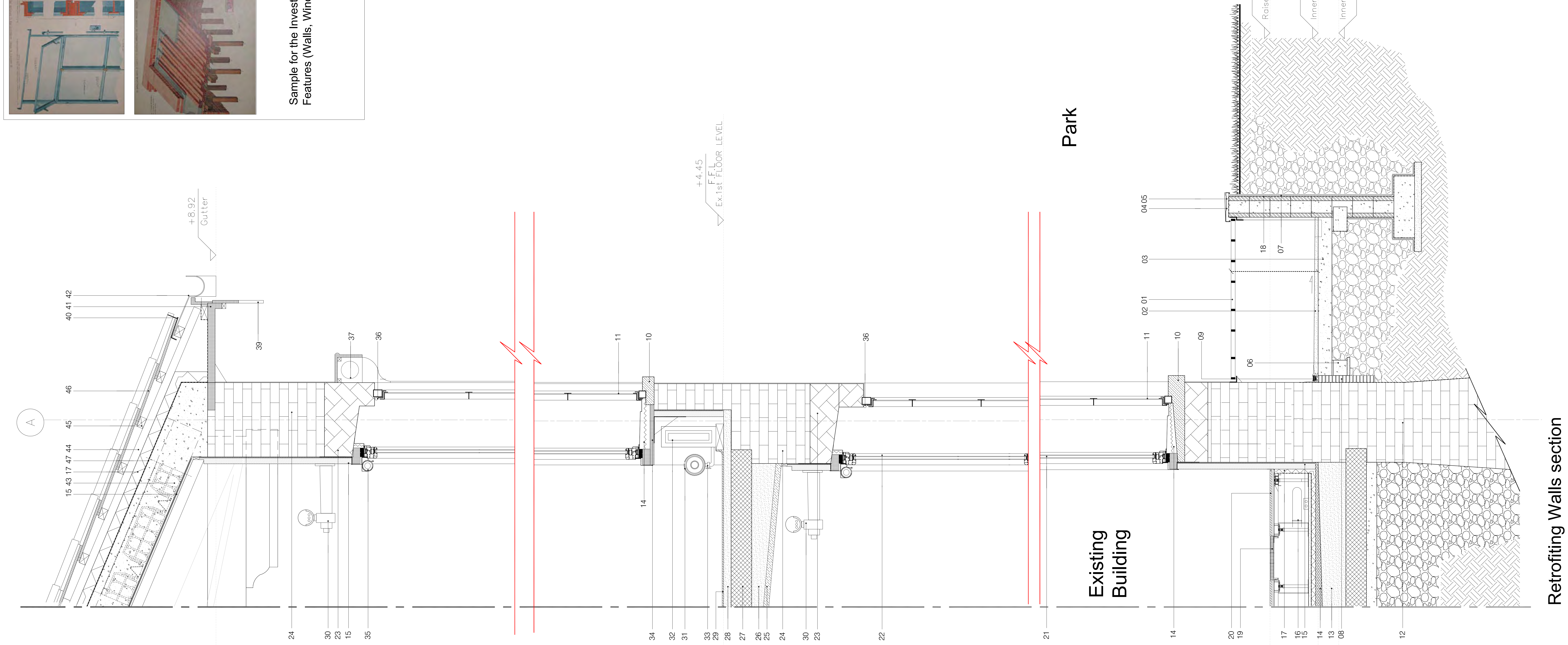
SCALE
1:20

Ref 03



Sample for the Investigated Existing Building Construction Features (Walls, Window Frames, Openings, Slabs , etc.,)

1-Aluminum Grill
2-Slope Cement Screed
3-Precasted Conc. Slab
4-Metal Flashing
5-Grouted Cement Block
6-Precasted Conc. curb
07-Convex Earth Shield
08-Compressible Foam Filler
09-Expansion joint_Floor to wall
10-Existing Window Sill
11-Existing Window(Refer to Report)
12-Existing Masonary&Stone Foundation
13-Existing L.W conc.
14-Demountable Cellular Glass Sloping Board(Foam glass)
15-Earth plaster with renforced mesh (Refer to Report)
16-Air Plenum
17-Rigid XPS Insulation
18-WP membrane
19-Floor Grill
20-Resistive Raised Floor system_Tate
21-Automated Operable Clear Glazed panel with Sensor and Timer Connected to BMS
22- Double Glazzing with Low E Coating (Refer to report)
23-Existing Brick Arch
24-Existing Masonry & Stone Wall
25-Existing Clay Celing tiles
26-Existing L.W Conc. Filler
27-Existing Concrete Slab
28-Leveling Screed
29-Gym rubber mat flooring
30-Exisitng Holder Feature , to be used as Electrical Trunk
31-Existing Radiator (Refer to report)
32-Night thermal storage (Refer to Report)
33-Valve with timer
34-Existing Wooden sill
35-Automated Curtain
36-Weather Sealing+Backer rod
37-Existing Wooden Canopy(Refer to Intervention Drawing)
38-Paint (Refer to Intervention Drawing)
39-Existing Wooden Cornice
40-Bird Mesh
41-Existing Wooden Shelf
42-Bronze Drain Gutter
43-Rib and Block Renforced Concrete Slab
44-Wooden Purlins for ventilated roof
45-Wooden Studs for Clay Tiles fixation
46-Original Clay Tiles to be Conserved/Reused
47-W.P and V.B Polymer Bitoumin



Retrofiting Walls section

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MASTER OF BUILDING ENGINEERING

The Earth sheltered Body Factory | VALMADRERA-LECCO

A.Y. 2012/2013

SCALE
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Ref 04

Appendix D

Spas and wellness centers Examples

Project: Bagni di bormio Wellness and Spa Resort, Italy

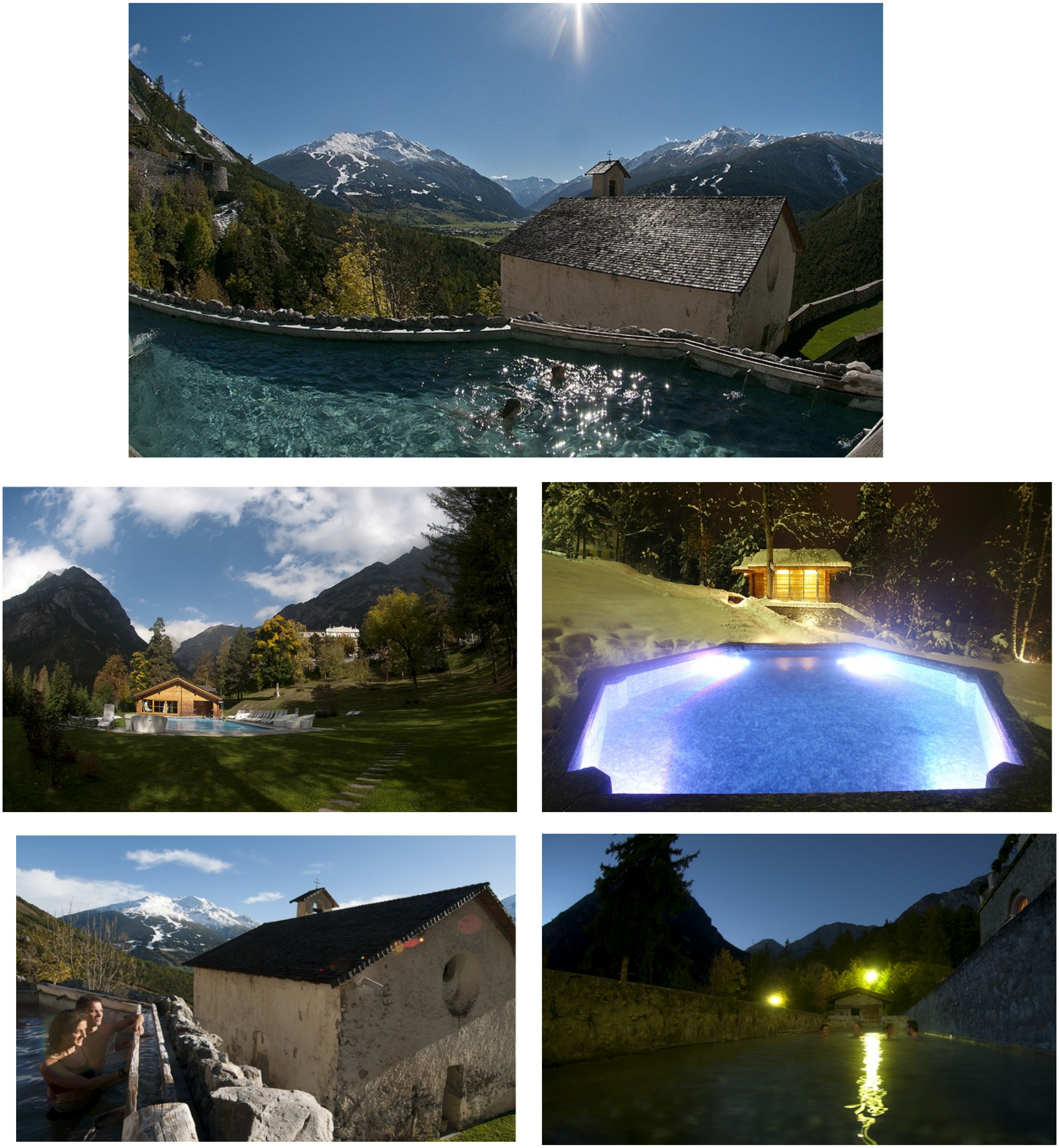

Figure 36 External Views, Extracted from (www.bagnidibormio.it)

Project: Orhidelia Wellness center, Slovenia

Architect: Enota

Figure 37 Internal and External views (www.archdaily.com)

Project: The Therme Vals Spa, Swizland

Architect: Peter Zumthor

Figure 38 Internal and external views (www.archdaily.com)

Appendix E

Psychometric Chart

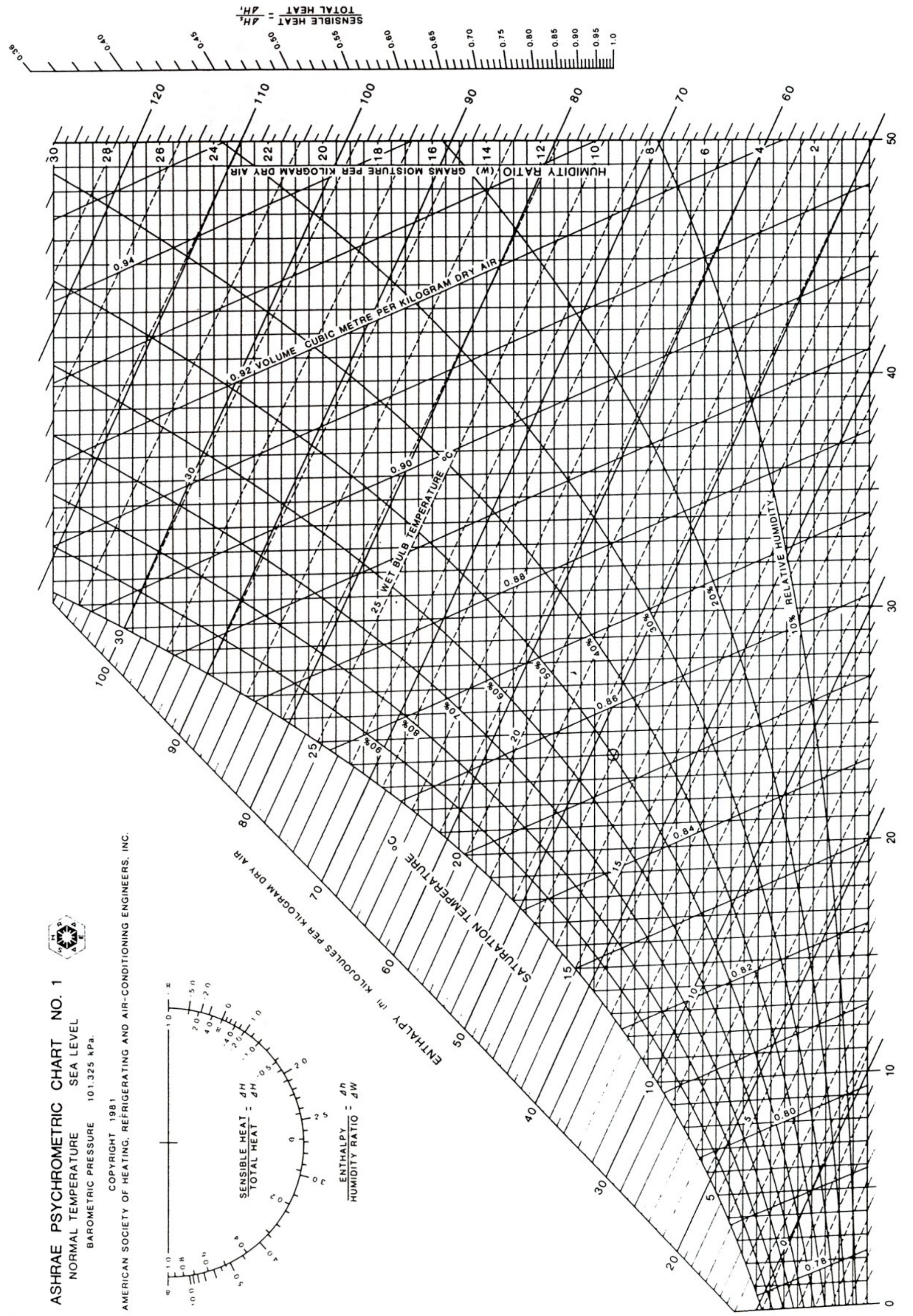

Fig. 2-10 SI ASHRAE Psychrometric Chart

Figure 39 Psychometric Chart, Extracted from (www.mie.uth.gr)