TECH + AND BUILDING SERVICES DESIGN

CHAPTER V: *TECHNOLOGICAL AND BUILDING SERVICES DESIGN*

1. INTRODUCTION

1.1 PROJECT LOCALIZATION

The main facilities considered for this project are located at an average altitude of 286 m.a.s.l. and coordinates 45°43'32"25 N, 09°24'42"28 E.

1.2 ENVIRONMENTAL CONDITIONS

The data hereafter presented is extracted from the analysis of the data available in the zone in the last 5 year of operations of the meteorological stations respectively underlined: Station No. 22a - I90580765 located in the city of Merate (LC) 240 m.a.s.l, and coordinates 45°41'59" N, 09°25'23" E. [77]The calculation of the average temperature, precipitation rates, and wind data is hence presented:

	Spr	Sum	Aut	Win	AVERAGE
Max T (°C)	37.8	36.4	31.4	21.2	37.8
Min T (°C)	-3.4	10.5	-2.5	-9.8	-9.8
Average T (°C)	13.8	25.2	13.4	4.1	14.1
Average Humidity (%)	54.4	51.6	67.2	72.5	61.4
Average Wind speed (km/h)	2.8	2.1	1.6	1.4	2.0
Average wind direction (-)	SE-SW	SW	SW	SW	SW
Precipitation (mm)	280.7	391.0	366.7	260.3	1298.7
% precipitation (mm)	21.6	30.1	28.2	20.0	

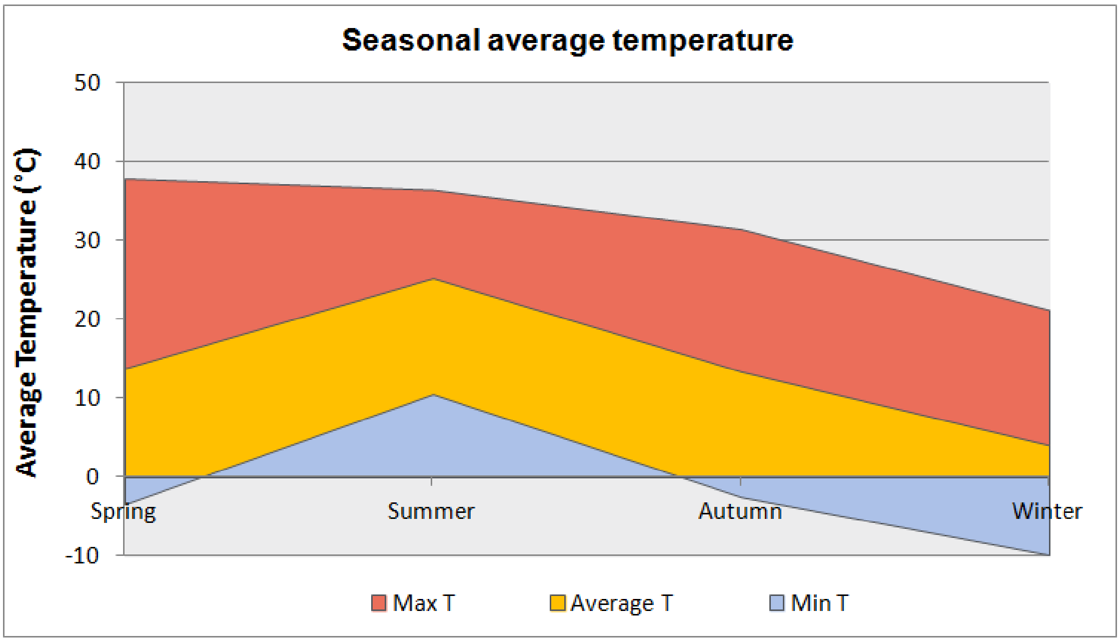
Table 10. Average environmental conditions per seasonal year.

1.2.1 Temperature and climate

The city of Calco presents an average temperature throughout the year of approximate 14 °C and an average relative humidity of 60%. The location of the city is characterized by a temperate climate characteristic of the Brianza

[77] WEATHER UNDERGROUND. Storic data private personal meteorological station No. I90580765. (Online web content). http://www.wunderground.com/weatherstation/WXDailyHistory.asp?ID= I90580765

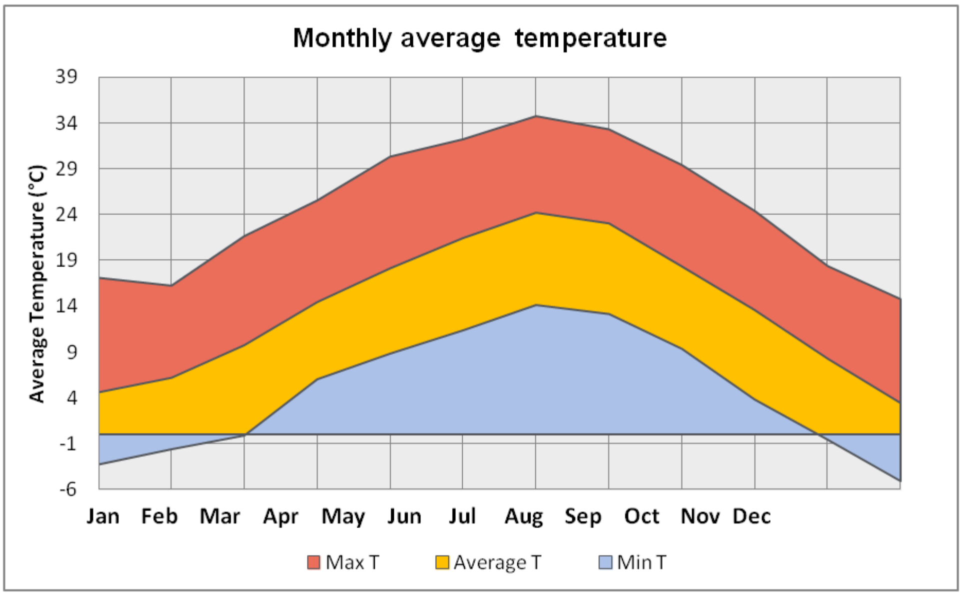
Lecchese, where winters trend to be rainy and to hold a temperature down to -5°C. Mid-seasons are wet (50% of year's precipitation occurrence) and mild. In the last years during these seasons, the weather has been relatively temperate presenting average temperatures of 13°C as it can be seen in the table 0.2 During summer, day time is in average warm-hot with temperatures oscillating among 20°C and 25°C, however nights are particularly fresh-cold presenting temperatures close to 10°C. summers are particularly also wet, presenting in average 30% of the total yearly precipitation.



Graphic 63. Maximum, minimum and average temperature.

	Spr	Sum	Aut	Win	AVERAGE
Max T (°C)	37.8	36.4	31.4	21.2	37.8
Min T (°C)	-3.4	10.5	-2.5	-9.8	-9.8
Average T (°C)	13.8	25.2	13.4	4.1	14.1
Average Humidity (%)	54.4	51.6	67.2	72.5	61.4

Table 11. Seasonal and average yearly temperature and humidity conditions.



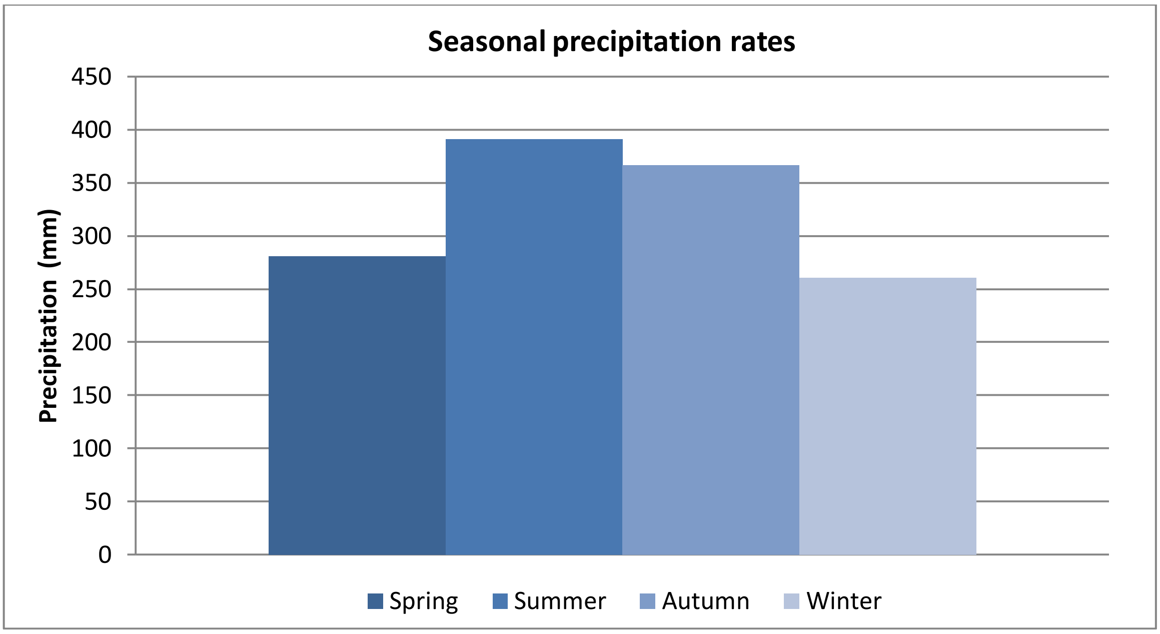
Graphic 64. Maximum, minimum and average temperature.

	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb
Max T (°C)	24.3	27.8	37.8	33.4	35.8	36.4	31.4	25.3	20.6	16	21.2	17.1
Min T (°C)	-3.4	2.6	7	10.9	13	10.5	8.1	2	-2.5	-9.8	-5.1	-4.5
Average T (°C)	9.5	13.8	18.0	21.3	31.2	23.1	18.4	13.5	8.3	3.2	4.4	4.8
Average Humidity (%)	55.3	55.3	52.6	55.6	46.3	53.0	58.3	65.9	77.3	71.8	75.2	70.4

Table 12. Temperature and humidity conditions per month.

1.2.2 Precipitation rates

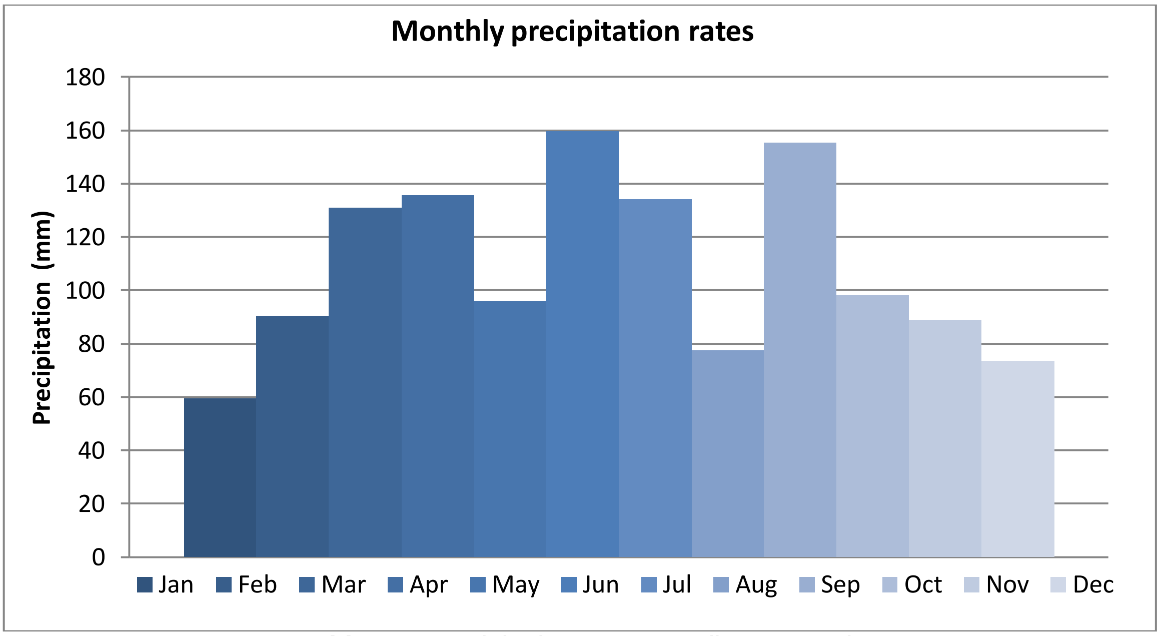
The wide extension of open fields and nature along the region together with the precipitation rate presented during the average year (>=1000mm) represent suitable conditions that facilitate the extraction and circulation of subterranean water, which is a main benefit for the agricultural activities and environmental development of the territory. On the other hand, the showers expected during all seasonal stages during the year generate an outstanding possibility of using this renewable source for rainwater harvesting purposes, as it can be seen in the next table.



Graphic 65. Precipitation rate according to season.

	Spr	Sum	Aut	Win	TOTAL
Precipitation (mm)	280.7	391.0	366.7	260.3	1298.7
% precipitation (mm)	21.6	30.1	28.2	20.0	

Table 13. Seasonal and total precipitation rates.



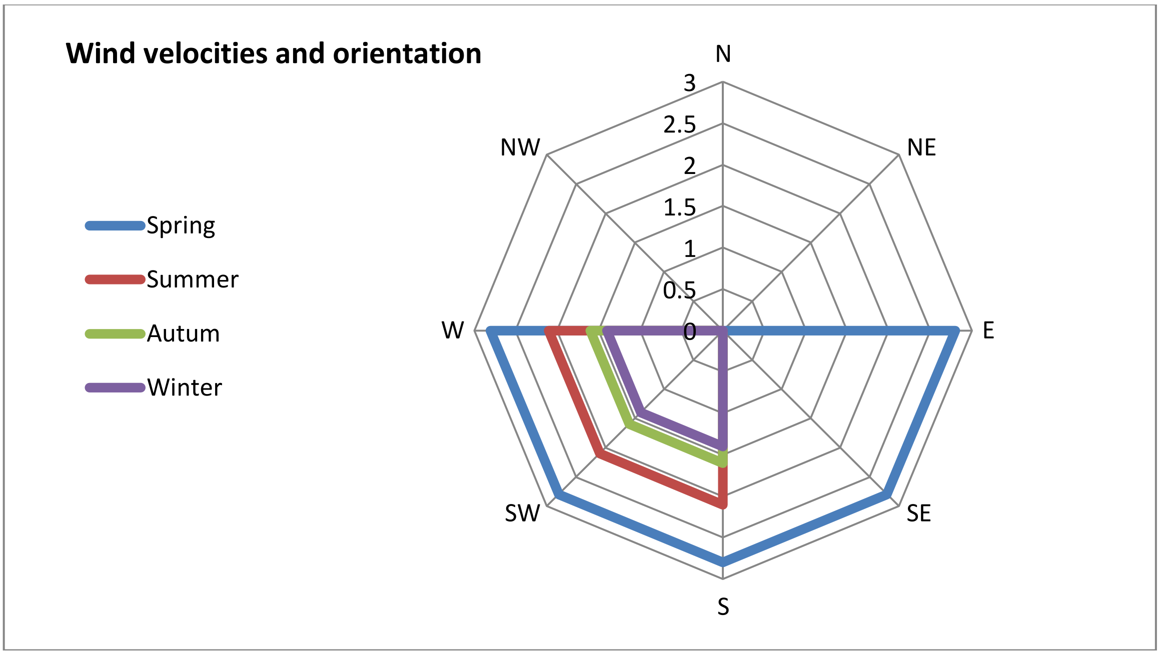
Graphic 66. Precipitation rate according to month.

	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb
Precipitation (mm)	59.4	90.4	131.0	135.6	96.0	159.5	134.0	77.5	155.3	98.1	88.7	73.6
% precipitation (mm)	4.6	7.0	10.1	10.4	7.4	12.3	10.3	6.0	12.0	7.6	6.8	5.7

Table 14. Monthly precipitation rates.

1.2.3 Wind characteristics

According to the data available, the region is characterized by the presence of “light winds or calm wind condition” [78] (Beaufort scale) having an average velocity of 2.0 kmh and an orientation mainly towards South (S).



Graphic 67. Wind rose per season.

In the next list of tables and graphics it is represented the wind average velocities measured in the region at 25 and 50 m.a.t.l. [79]

	Spr	Sum	Aut	Win	AVERAGE
Average Wind speed (km/h)	2.8	2.1	1.6	1.4	2.0
Average wind direction (-)	SE-SW	SW	SW	SW	SW

Table 15. Seasonal and year average wind velocities and orientation.

	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb
Average Wind speed (km/h)	3.0	2.8	2.6	2.2	2.5	1.7	1.9	1.4	1.6	1.2	1.7	1.3
Average wind direction (-)	S	SSE	SE	SW	SW	SW	SW	SW	SE	SE	SW	SW

Table 16. Monthly wind velocities and orientation

1.2.4 Solar radiation

The monthly solar radiation parameters disposed for the area of the project are calculated from the data base SAF-PVGIS of the European Joint Research

[78] YEANG, Ken. Eco design: a manual for economical design. 2006. p. 213.
[79] RICERCA SISTEMA ENERGETICFO. Atlante Eolico Italiano. 2011. (Online web content). http://atlanteeolico.rse-web.it/viewer.htm

centre JRC[80]. The data is calculated towards its application for photovoltaic solar electricity potential for the defined site coordinates, following the methodology implemented by this institute. [81] The following compound of tables and graphics show the monthly radiation parameters and characteristics for the location of the project.

Month	Hh (Wh/m2/day)	Hopt (Wh/m2/day)	H(90) (Wh/m2/day)	Iopt °	TL (-)	D/G (-)	T24h (°C)	NDD (-)
Jan	1460	2760	2890	67	3.7	0.48	1.8	479
Feb	2410	3940	3700	60	4.2	0.42	3.9	379
Mar	3700	4970	3920	48	4	0.41	8.1	252
Apr	4560	5100	3200	32	4.4	0.43	11.7	117
May	5710	5700	2970	19	5.3	0.44	17.1	22
Jun	6760	6440	2980	13	5.8	0.4	21	8
Jul	6840	6670	3150	16	5.2	0.34	22.8	2
Aug	5660	6090	3480	27	4.4	0.37	22.3	10
Sep	4180	5240	3800	42	4.1	0.41	17.9	57
Oct	2510	3610	3130	54	4.1	0.49	13.3	225
Nov	1620	3000	3070	66	3.4	0.42	7	404
Dec	1170	2290	2450	69	3.2	0.52	2.9	497
Year	3890	4650	3220	38	4.3	0.41	12.5	2452

Where:

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

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

H(90): Irradiation on plane at angle: 90deg. (Wh/m^2/day)

I_{opt}: Optimal inclination (deg.)

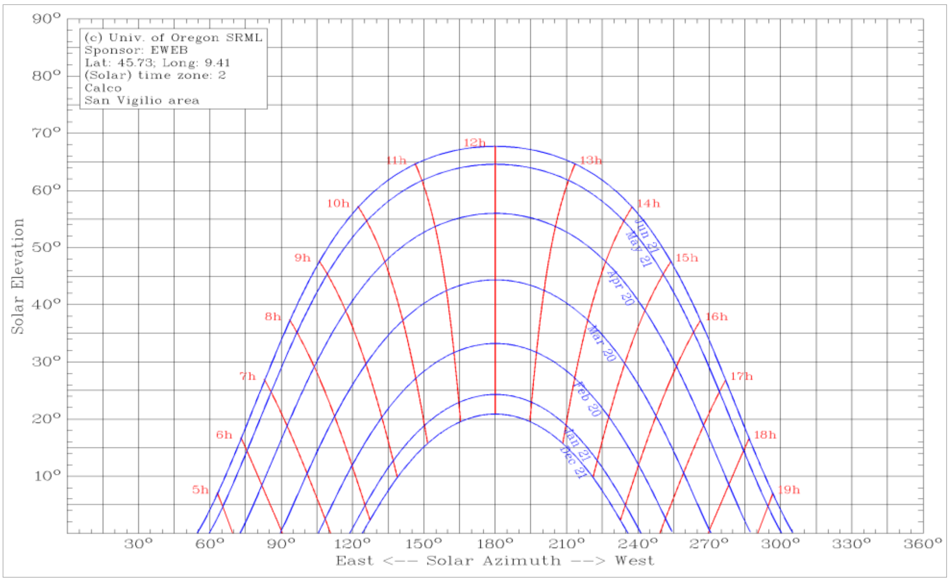
D/G: Ratio of diffuse to global irradiation (-)

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

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

T_L: Linke turbidity (-)

Table 17. Results Monthly radiation parameters for project's site.



Graphic 68. Annual Solar path at Calco- San Vigilio area. [82]

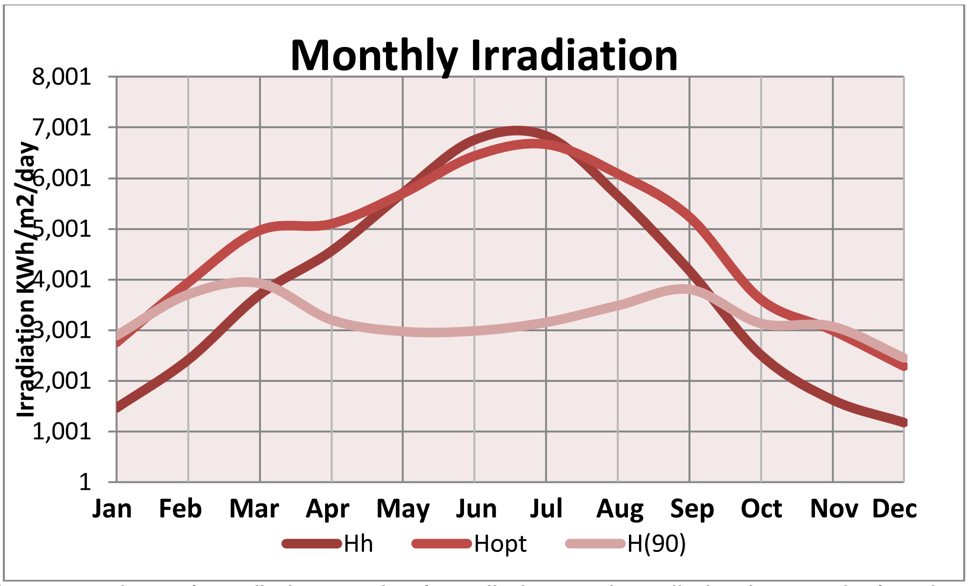
[80] JOINT RESEARCH CENTRE. Photovoltaic geographical information system, interactive maps. (Online web content). http://re.jrc.ec. europa.eu/pvgis/ apps4/ pvest.php

[81] Ibid. Methodology of calculation, interactive maps. (Online web content). http://re.jrc.ec.europa.eu/pvgis /solres/solrespvgis.htm

[82] UNIVERSITY OF OREGON. Solar radiation monitoring laboratory. (Online web content). http://solardat.uoregon.edu /SunChartProgram.html

1.2.4.1 Irradiation on horizontal plane:

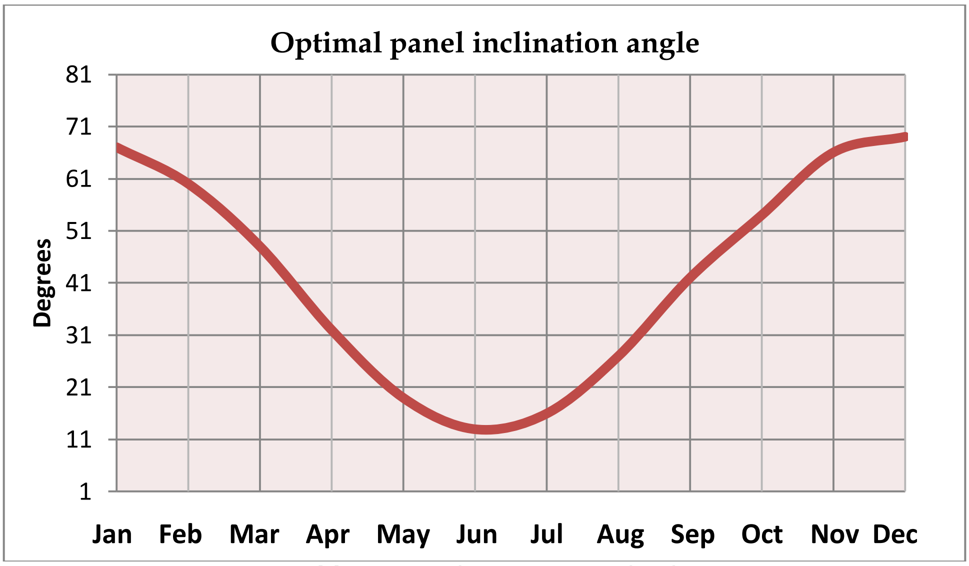
This value is the monthly/yearly average of the sum of the solar radiation energy that hits one square meter in a horizontal plane in one day. This is measured in kWh/m2/day.



Graphic 69. Horizontal Irradiation, Optimal Irradiation, and Irradiation in a vertical surface

1.2.4.2 Optimal inclination angle:

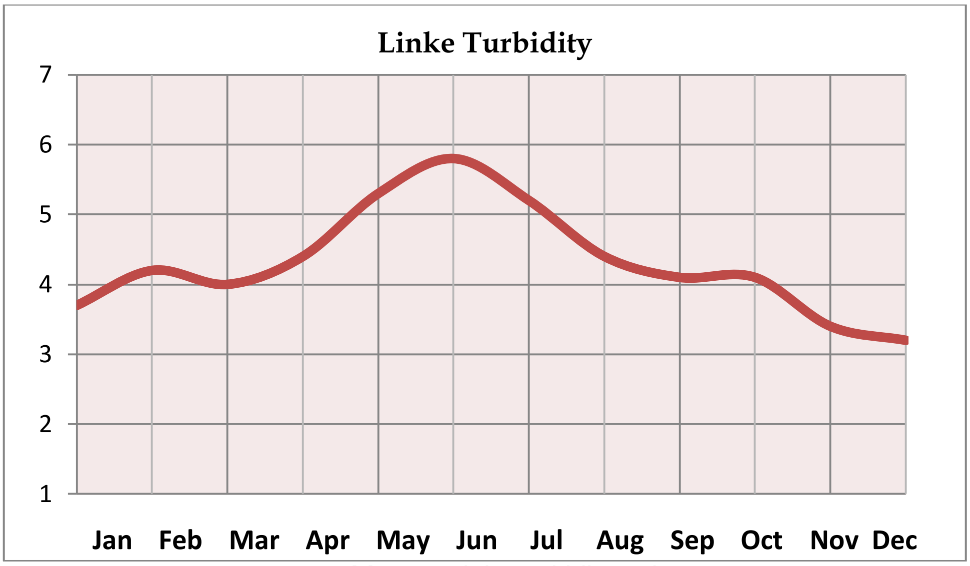
It is the angle, in order to receive the maximum amount of solar energy on a flat plate facing south (I.e Solar panels). For this case the calculated optimal angle is **38°** for all the year, if the flat plate remains still along the year; however, this surface can be oriented month by month to the optimum angles described below.



Graphic 70. Optimal panel Inclination.

1.2.4.3 Linke turbidity:

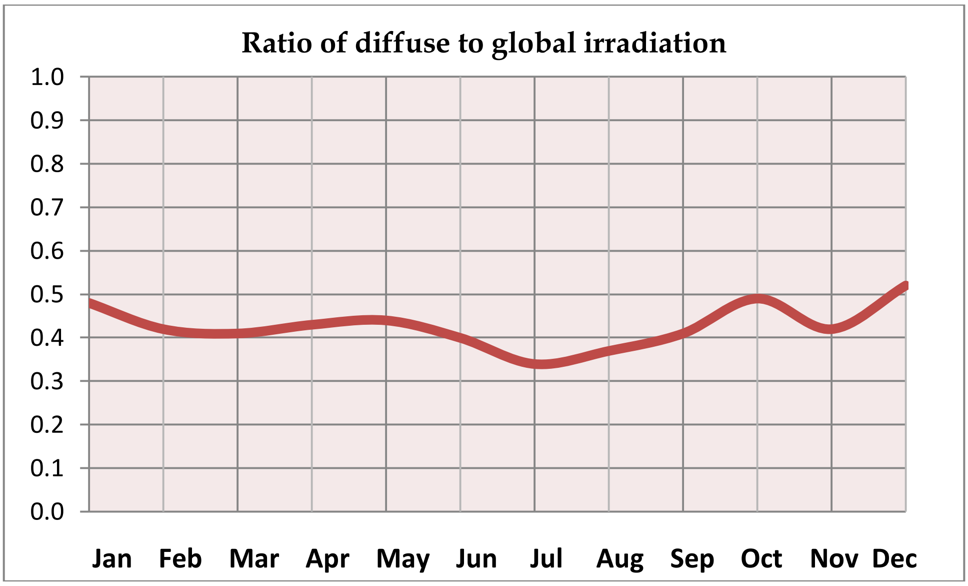
It is a measure of how much solar radiation is attenuated by aerosols. It indicates the optical density of hazy and humid atmosphere in relation to a clean and dry atmosphere. It is dimensionless.



Graphic 71. Linke turbidity ratio.

1.2.4.4 Ratio of diffuse to global irradiation:

This relation gives the fraction of the total radiation arriving at the ground which is due to diffuse radiation. As it can be seen **50%** of the total radiation along the year in Calco is due to diffuse radiation.



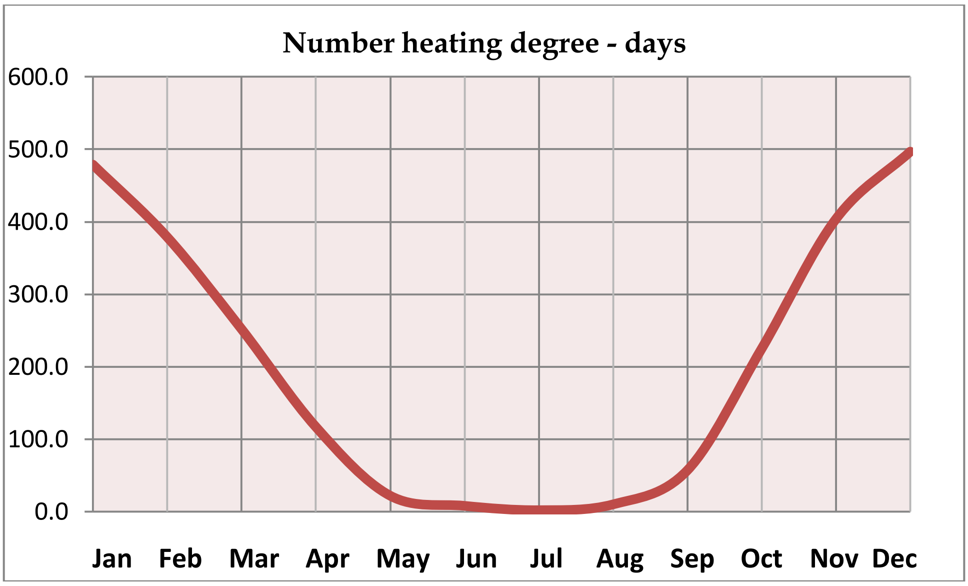
Graphic 72. Ratio of diffuse to global irradiation

1.2.4.5 Number of heating degree-days:

Considering an average comfort temperature of 18°C for buildings, the heating degree-days are a measurement that reflects the demand of heat needed to satisfy this comfort temperature; besides, it can describe how cold the climate is. These values are calculated from daily average values of temperature reported in the table 3.

As an example, if the average outside temperature for a day is 1 degree less than the inside base temperature (18°C), then it will be accumulated 1 degree day on that day and so on. The higher the number of degree days for the climate, the colder the climate it is., the ranges vary from 140 HDD per year (warm hot climate) up to 14000 per year (Cold climate) [83]. Calco accumulates around **2500** heating days throughout the year.

[83] NOAA satellite and information site. HDD locations united states. (Online web content). http://www.ncdc.noaa.gov/oa/climate/online/ccd/nrmhdd.txt



Graphic 73. Number of heating degree-days per month.

1.3 POLICIES AND GUIDELINES

The Energy plan of the Lecco province promotes the execution of projects and initiatives related to the use of new forms of energy in the province, but also directed to the general enhancement of the energy network in the territory. Following, there are listed the most important projects that directly or indirectly concern Calco's territory and this thesis proposal.

- Promotion of wind farms of small size (maximum 20 kW) in areas of Alto Lario and Valsassina.
- Construction of small hydroelectric water systems for a power generation of not less than 0.5 MW. Saving between 3.500 and 4.500 MWh per year.
- Explore the possibility of use of biomass energy from forests existent along the territory.
- Use of solar energy to produce hot water for public buildings or of public use.
- Use of the governmental economical support system "Conto energia" for the implementation of photovoltaic panels, Expected future application of the expired regulation.

2 INFORMATION ANALYSIS

2.1 SWOT ANALYSIS

STRENGHTS

- Allowance to provide free orientation of the main building and facilities.
- Temperate climate, does not present extreme temperatures variations among seasons.
- Precipitation rates suitable for rainwater harvesting purposes.

WEAKNESSES

- 90% of the territory uses nowadays metanol gas, 6% regular fuel vs. 1% coming from renewable sources for mainly heating purposes. [84]
- Main current electrical consumption in residential buildings due to illumination (15%), refrigeration systems (19%) and use of Audio/video devices (17%).[85]
- Main current electrical consumption in public buildings due to illumination (35%), AHVC (18%) and use of Audio/video devices (12%).[86]
- Average Low annual wind velocities (<3m/s) measured at 25m a.t.l and 50m a.t.l, make unpractical the use of wind power.

OPPORTUNITIES

- Promotion to construct small hydroelectric water systems applied to existing network of water supply.
- 30% of Calco's area is composed by forest[87], the policies regarding exploration of use of Biomass from these areas is considered an opportunity to apply this renewable source of energy in the project.
- Governmental economical support for the implementation of Photovoltaic panels.

[84] PROVINCIA DI LECCO. Piano Energetico Territoriale Provinciale(PETP): VolIIscenari. 2008. p. 33.
[85] PROVINCIA DI LECCO. Piano Energetico Territoriale Provinciale(PETP): VolIIscenari. 2008. p. 62.
[86] PROVINCIA DI LECCO. Piano Energetico Territoriale Provinciale(PETP): VolIIscenari. 2008. p. 64.
[87] PROVINCIA DI LECCO. Piano Energetico Territoriale Provinciale(PETP): VolIIscenari. 2008. p. 92.

THREATS

- The not inclusion of Calco's territory inside the plan of wind Energy promotion.
- Goal to guarantee 50% coverage of the total consumption due to water heating in all the year using solar heating systems.

3 STRATEGY

3.1 RENEWABLE-ENERGY TECHNOLOGIES AND ENERGY EFFICIENCY MEASURES

3.1.1 Small Hydropower generation:

A new application in recent times of hydroelectric energy production has been focused to provide hydropower appliances to be installed in the main input of the potable water supply network. In this case, small power turbines are set in the city's aqueduct intake in order to exploit the potential energy inherent in the intake network uneven levels, allowing the recovery of a certain amount of energy that commonly is dissipated while reducing the water pressure coming from the main reservoir.

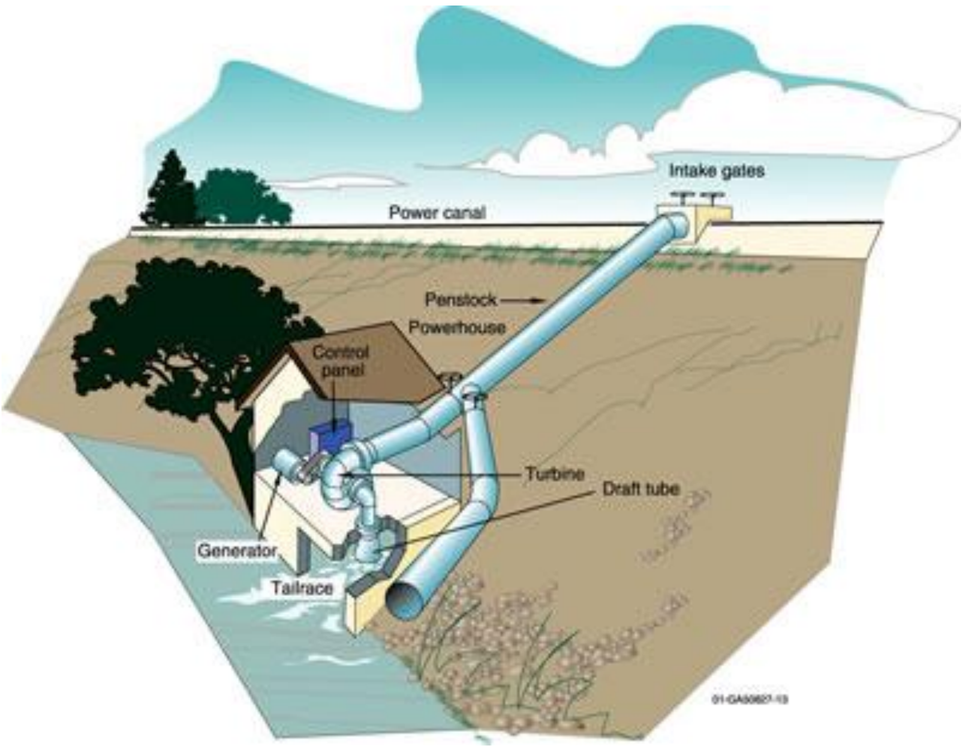


Illustration 128 Small Hydroelectric power scheme (extracted from US department of energy.[88])

The PEPT has established studies in order to prove the feasibility of this kind of infrastructure in the water network of main cities around the Lecco's province, with a minimum energy production of 15 kW and a maximum of 74 kW, the payback time for these installations is estimated to be from 7 to 10 years[89]

[88] US Department of energy, Types of hydropower plants. (Online web content). http://www1.eere.energy.gov/windandhydro/hydro_plant_types.html. 2011

[89] H.M Ramos Et al. Clean power in water supply systems as a sustainable solution: from planning to practical implementation. 2010 pag 47.

depending on the estimated production of energy which ranges from 127 to 637 MWh/year in individual cities. [90]

If we consider a mean value (360 MW/year) for Calco's energy production from this energy source, but also mean values of projected electric consumption 0.9MW/inhb[91] and population growth of 5132 inhb[92] by the year 2020, it can be calculated in average the percentage of energy that a hydropower plant located in the municipality would be able to meet with respect to the consumption in the residential sector of the town itself.

As a result a possible small hydropower plant located in Calco can satisfy the **8%** of the electric demand of the resident population by 2020, when the total investment payback will be generated already. This value is given only for projection matters, and it does not demonstrate a real quantity of the energy intake to be generated from Calco's possible potable water network system.

3.1.2 Biomass production

The implementation of Biomass use in the zone of Calco, lies in the idea of recollection, processing (chipping/pelleting) and supply of residues derivative of forests and agricultural fields, such as fallen leafs, cut down stems due to coppicing[93] and natural tree life cycle, dried tree branches etc… residues which are considered not only to be a potential source of energy, but also to be responsible of a probable risk of fire.

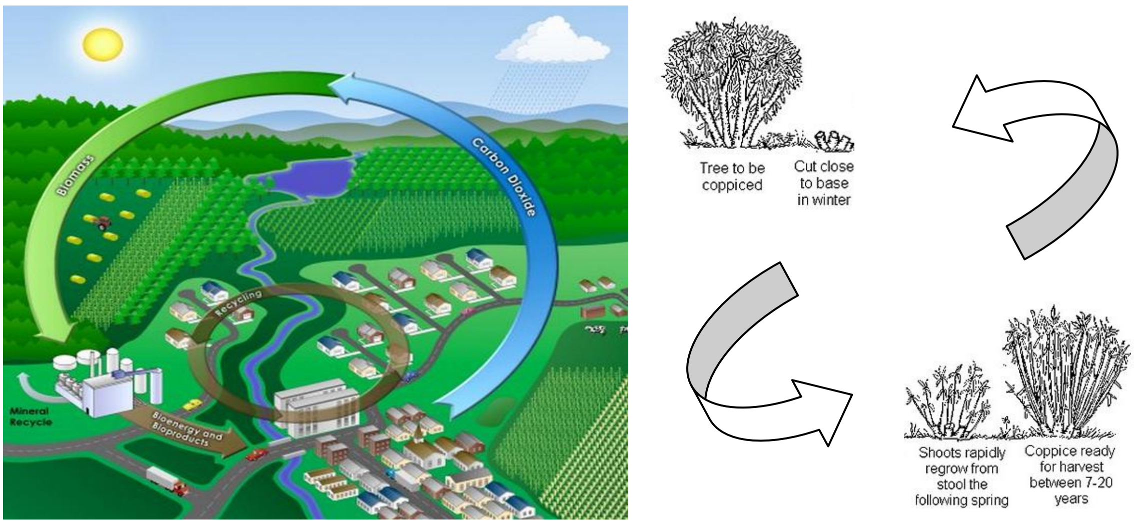


Illustration 129 Biomass power generation and coppicing schemes (extracted from ISIS[94])

The wide extension of agricultural and forest areas disposed inside and at the vicinity of the city as it is presented in the ANNEX 1 PTCP brief, makes Calco a

[90] PROVINCIA DI LECCO. Piano Energetico Territoriale Provinciale(PETP): VolIIscenari. 2008. p. 120-121
[91] Ibid. Piano Energetico Territoriale Provinciale(PETP): VolIIscenari. 2008. p. 120-121
[92] ISAT. Calco 2020 demographic measurement http://demo.istat.it/bil2010/index02_e.html
[93] Copicing: is a traditional method of woodland management which takes advantage of the fact that many trees make new growth from the stump or roots if cut down.
[94] ISIS Arturo Malignani Udine. Alternative power sources at different latitudes in Europe (Online web content). http://www.malignani.ud.it/webenis/northwind-southsun/power/Biomass.htm

suitable place for the implementation of action plans that lead in the future, to the use of Biomass as a main source of energy for combined heat and power applications *CHP* (other outcomes such as fertilizers, concrete fillers, electrical energy can be considered), as well as an alternative for economical growth in the region.

The province of Lecco establishes that around 80%[95] of the area of the forests in the region is constituted by shoots or suckers (kind of tree capable to be specially subjected to Coppicing).

Due to the aspects before presented, the Lecco province promotes redundantly the inclusion on local systems of supply and consumption of residual Biomass aimed to the production of small-medium size heat network for public & private facilities, and small industries.

However systems for direct supply of chipping/pelleting for domestic internal heating purposes should be considered as part of the general approach of this source of energy. It has to be taken into consideration that the province of Lecco has supported feasibility studies (€ 50.000 for each potential locality) of this kind of projects in the region.[96]

Illustration 130. Calco's north-oriental forest and agricultural fields

3.1.3 Solar photovoltaic energy

Solar energy can be converted into electric energy by the use of photovoltaic cells' systems. These systems can be designed and developed to satisfy the needs and requirements of the operations given by the building or facility. The power generated from this type of energy can be used to satisfy internal demand as well as external demand (See scheme below).

[95] PROVINCIA DI LECCO. Piano Energetico Territoriale Provinciale(PETP): VolII scenari. 2008. p. 94
[96] Ibid. Piano Energetico Territoriale Provinciale(PETP): VolII scenari. 2008. p. 89

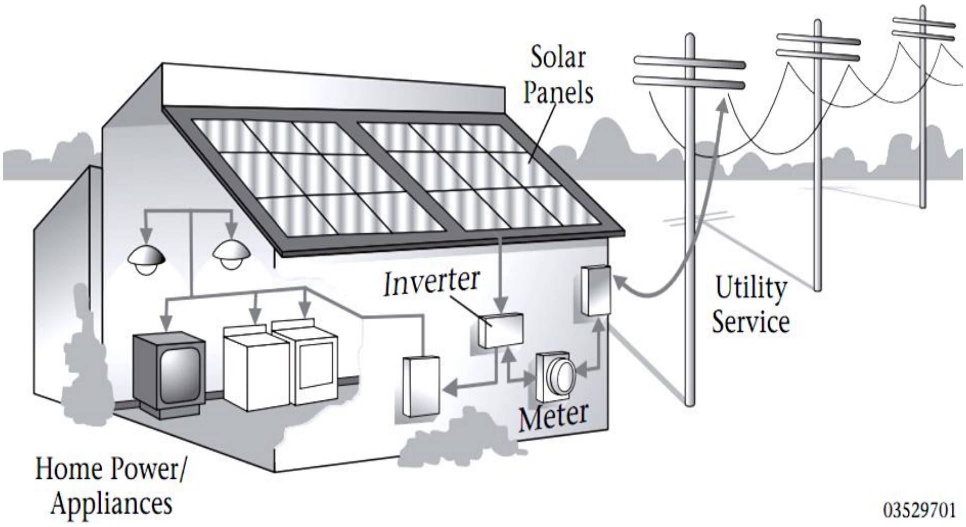


Illustration 131. Hybrid Solar photovoltaic energy power scheme (extracted from US. Department of Energy[97])

Photovoltaic appliances have no moving parts, are modular, easily expandable and even transportable in some cases, but also can provide thermal insulation due to its main composition of low emissivity glass; however, the most considered added value of this technology is the use of solar energy as a renewable source of energy, which limits effectively the emissions of CO2 released in the atmosphere, caused by the use of other non renewable sources of energy. In the same way, the initial high-cost can be easily repaid according to the economical contribution of the Italian government and financial opportunities as it was explained in the first chapter. On the other hand, it can be considered a mean time of investment-payback of 12 years. [98]

The main types of solar photovoltaic systems are grid-connected and off-grid. [99] In Grid-connected systems the solar panels are connected also to the local electricity network allowing any excess of solar electricity produced to be sold to the utility, electricity is taken back from the network outside daylight hours, an inverter is used to convert the DC power produced by the solar system to AC power needed to run normal electrical equipment. In off-grid systems, the solar energy is directly connected to a battery which stores the electricity generated and it works as the main power supply. An inverter can be used to transform the DC power into AC power, allowing the use of normal appliances without main power supply; however, both systems can be implemented in a hybrid system, as it is shown in the illustration 4.

[97]U.S department of energy: Consumer Guide, get your power from the sun, 2010 p. 5
[98]MY ENERGY, Calcolo simulazione impianto fotovoltaici per casa di famiglia, media provincial di lecco. (on-line website content).http://www.myenergy.it/conto-energia/simula-impianto/simula-impianto.aspx
[99]GREENSPEC, Photovoltaic PV-cells. (on-line website content). http://greenspec.co.uk/pv-cells.php

3.1.4 Geothermal energy systems

The Ground Source Heat Pump (GSHP) systems work by extracting heat from de ground during winter seasons, and reciprocally, by releasing heat during summer into the ground, taking advantage of the almost constant temperature of the soil during the year (12°C for Milan - Italy)[100].

One type of systems is the closed Loop systems: These systems circulate a mixture of water and antifreeze liquid throughout a loop of pipe buried in the ground; the loop absorbs heat from the soil and transports it to a heat exchanger powered by an electric pump and compressor.

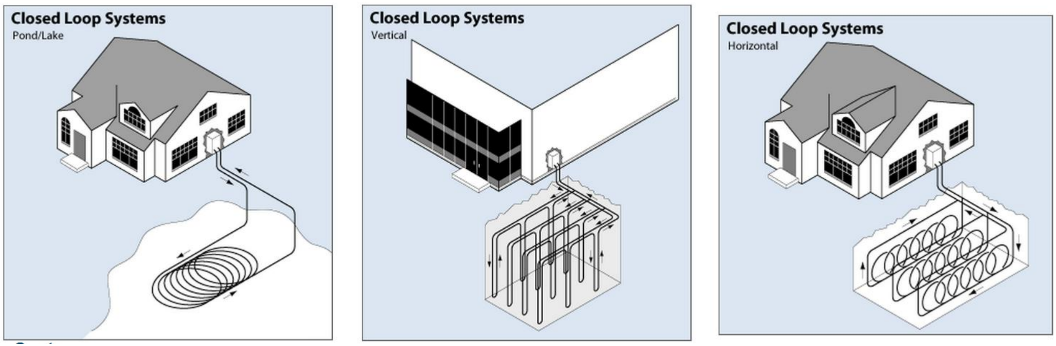


Illustration 132. GSHP closed loop systems scheme (extracted from US department of energy [101])

The other main category of ground source heating pump systems is the so called open loop system. It uses well or surface body water as the heat exchange fluid that circulates directly through the GHP system. Once it has circulated through the system, the water returns to the ground through the well, a recharge well, or surface discharge. This option is obviously practical only where there is an adequate supply of relatively clean water[102], which is assumed to be the San Vigilio area in Calco (project area).

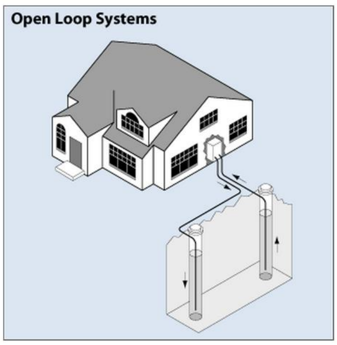


Illustration 133. GSHP Open loop systems scheme (extracted from US department of energy[103])

[100] U.S department of energy: Consumer Guide, get your energy from the sun, 2001, p. 4,
[101] US. DEPARTMENT OF ENERGY. Types of geothermal Heat pump system. (on-line website content). http://www.energysavers.gov/your_home/space_heating_cooling/index.cfm/mytopic=12650.2011
[102] Ibid, Types of geothermal Heat pump system. (on-line website content). http://www.energysavers.gov/your_home/space_heating_cooling/index.cfm/mytopic=12650.2011
[103] Ibid, Types of geothermal Heat pump system. (on-line website content). http://www.energysavers.gov/your_home/space_heating_cooling/index.cfm/mytopic=12650.2011

Although there is no geothermal energy plan contemplated in the PETP, the use of this technology can be a complementary source of energy to the solar water heating systems, in the production of hot water and cold water for the air conditioning units to be supplied into the project.

On the other hand the sources of energy needed to activate the pumping systems can be extracted from solar photovoltaic energy; by combining this approach it can be achieved a 400% of efficiency of the GSHP, generating 0.00 CO_2 emissions.[104]

3.1.5 Rain water recollection and application to services.

Rainwater has been during centuries one of the most common sources of water needed to meet agricultural requirements, and in some case, potable water as well. Most rainwater collection systems are designed to capture rainwater from the roofs of buildings; however systems of recollection of rainwater once it has been drained through natural surfaces are considered also. The water is then transported through gutters and other pipes into cisterns or tanks, where it is stored until needed.

The water collected can be used for irrigation, laundry, hygiene, or even potable water, depending upon the materials used and the treatments undertaken. In most cases when the water is not treated, the rain water is used for irrigation, toilets, flushing water, and in some limited cases for laundry.

The recollected water can supply different fixtures in the building in two ways. A passive way can take advantage of gravity and head of pressure obtained by locating the storage tank in a higher level from the fixtures to be used; this system has as main disadvantage the need of continuous and elevated collocation of the storage tanks, which can be constrained according to the general aspect, space conditions, configuration of the building, and main water supply network level (which provides a backup for the water supply).

The other type of systems store collected water in a ground tank, from which it is pumped back to the fixtures for its later use. The main disadvantages of this systems is the need of electricity for pumping (which can be satisfied by PV solar panels) and the need of a second storage tank in each fixture (specially toilets) that can maintain the needed flux of water.

[104] GREEN SPEC, Ground source heating pumps. (on-line website content). http://greenspec.co.uk /ground-source-heat-pumps.php

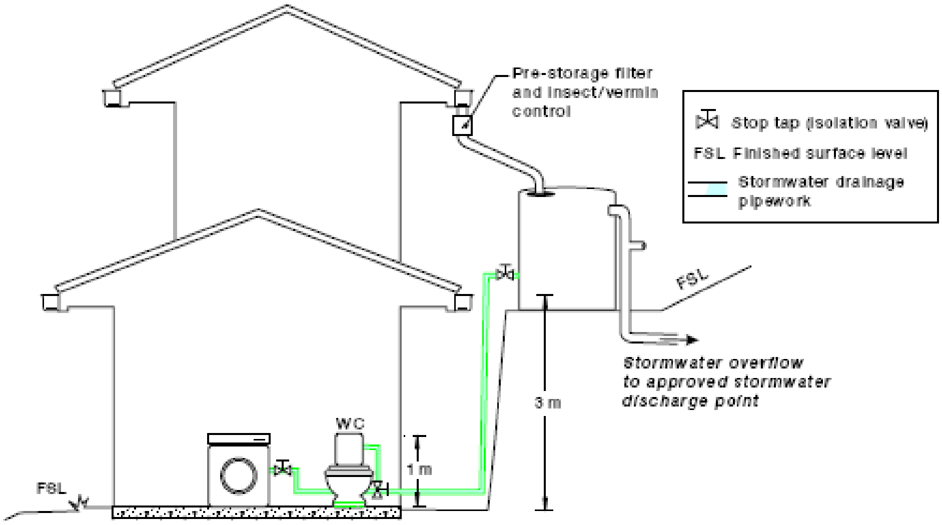


Illustration 134. Passive-Gravity rainwater recollection system scheme (extracted from AUSgov[105])

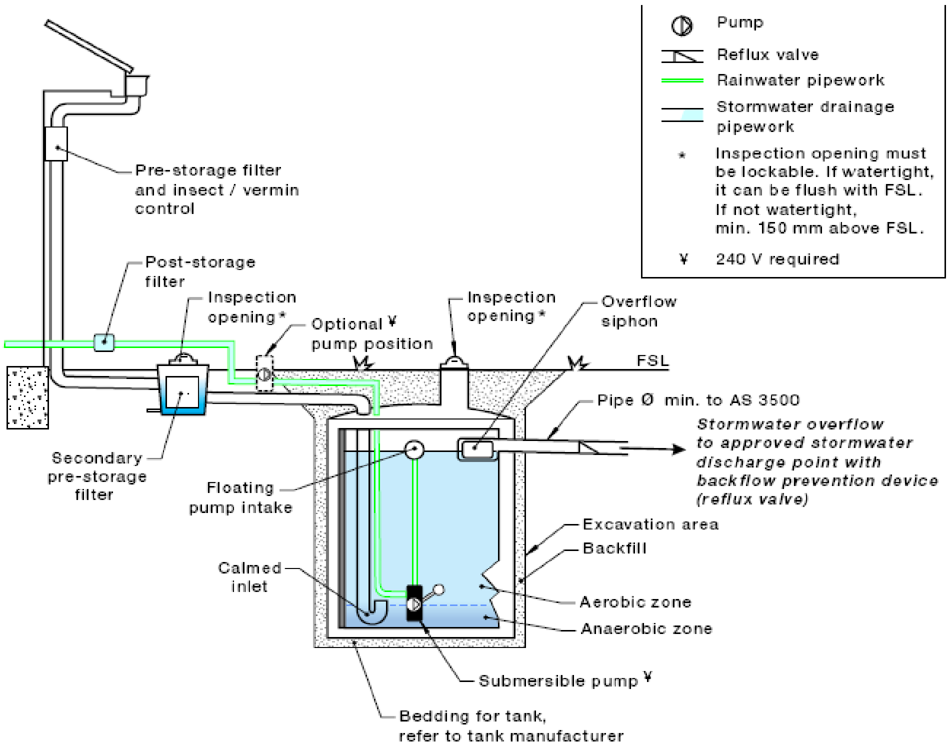


Illustration 135 Active rainwater recollection system scheme (extracted from AUSgov[106])

[105]AUSTRALIAN GOVERNMENT- National water commission. Rain water tank design and installation Hand-book. 2008. P21
[106]Ibid Rain water tank design and installation Hand-book. 2008. P47

3.1.6 Appliances for electrical consumption reduction.

The use of energy efficient appliances can reduce the consumption of energy related to illumination. Fluorescence bulbs with electronic reactor provide 50% more efficiency that a normal incandescent bulb, Payback time 5-6 years.

The use of natural diffusion illumination making use of tubular skylights can be another energy saving application, for zones that cannot be illuminated directly by windows; this strategy avoids the use of artificial illumination in those spaces during day. These systems consist on tubular shaped foils of reflective material (satisfy around 98% of light transmission efficiency) that conduct the sunlight previously absorbed by a dome above the tube. The dome has the function to block out +- 99% of the harmful UV rays.[107] At the bottom, a diffuser foil lets the light to be transferred to all the space.

Main advantages are that these systems can provide daylight at any required space in nearly any climate, but also can provide competitive prices and thermal efficiency according to other appliances for solar illumination such as skylights and even windows.

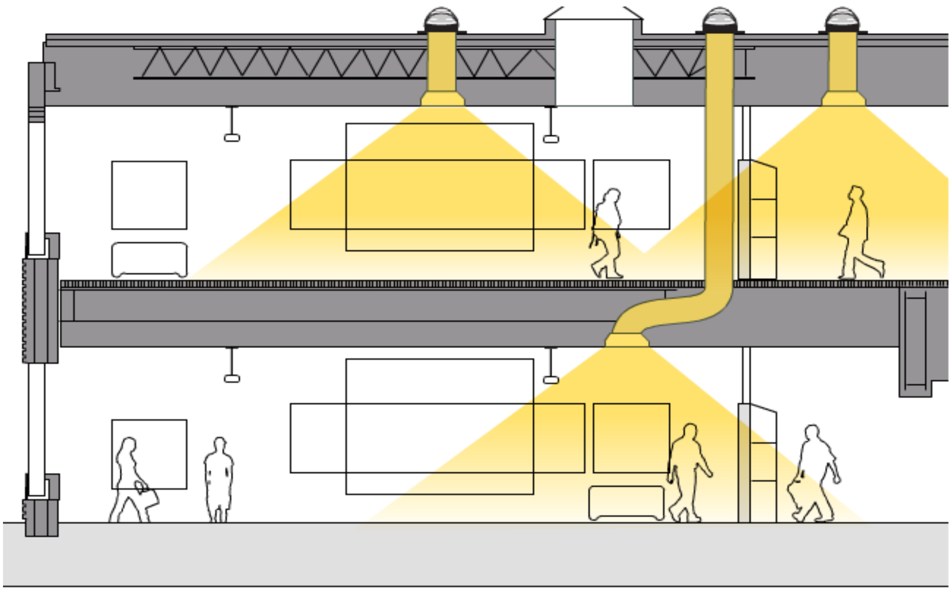


Illustration 136 Sun tunnel scheme (extracted from SOLATUBE[108])

3.2 ENERGY EFFICIENT BUILDING ENVELOPE

3.2.1 Passive solar heating systems- ETFE sunspace & shading

ETFE foil technology consists on lightweight (1% weight compared to glass) cushions kept continually pressurised by a small inflation unit which maintains

[107]REUK Uk. Ligh tubes for interior lighting article 2007 (Online web content). http://www.reuk.co.uk/Light-Tubes-for-Interior-Lighting.htm
[108]SOLATUBE. Side lighting vs. top lighting (Online web content). http://www.solatube.com /commercial/daylighting/top-lighting-vs-side-lighting.php

the pressure at approx. 220 Pa and gives the compound of two or more foils inside the cushions a structural stability while providing also high efficient insulation performance (3 foils, U = 1.96 W*m2/°K)[109]

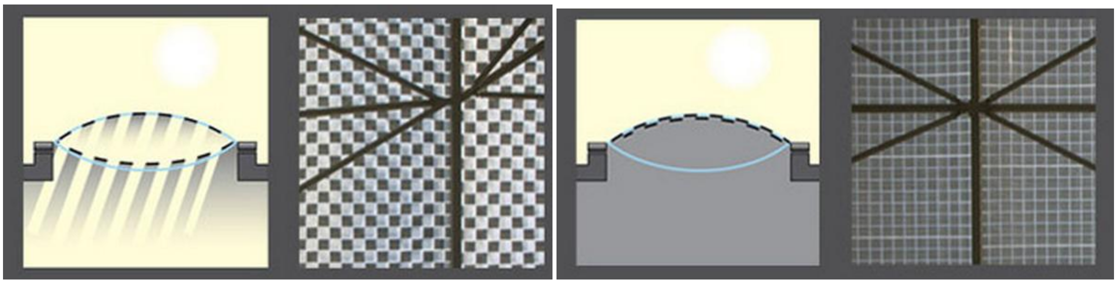


Illustration 137. sun shading system system. Open and closed configuration (extracted from VECTORFOILTEC[110])

High technological advanced systems can provide full controlled shading by means of alteration between the pressure of the foils and the pattern of them, as it can be shown in the next figure. Basically a foil in between the two chambers can be blown to the top of the surface, creating an enclosed penetration of sun rays, according by the pattern inked into its surface; in order to let the light go in, the foil is unpressurised.

Illustration 138 Configuration of three foils with sun shading system foil (extracted from VECTORFOILTEC[111])

A classical system is composed of a series of pneumatic cushions made up of between two and five layers of a modified copolymer called Ethylene Tetra

[109]VECTORFOILTEC. Texlon technical specifications. http://www.vector-foiltec.com/cms /gb/ technical/ randd.php. 2011.
[110]VECTORFOILTEC. Variable skins. http://www.vector-foiltec.com/cms/gb/technical /variableskins.php
[111]VECTORFOILTEC. Texlon technical specifications. http://www.vector-foiltec.com/cms /gb/ technical/ randd.php. 2011.

Flouro Ethylene (ETFE), is supported by basic circular or extruded aluminum profiles that can be connected to any common structural system made out of cables or steel profiles.

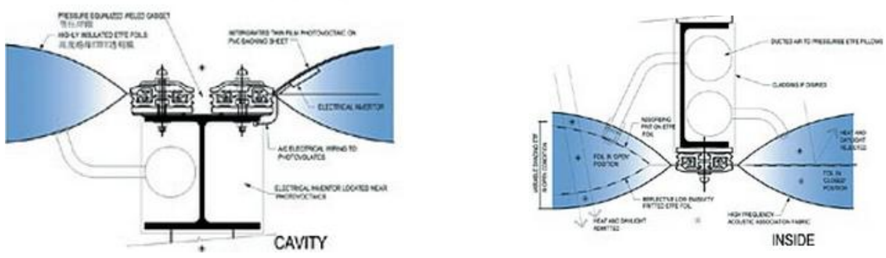


Illustration 139 Typical structural system and connections of the system (extracted from ARCHITEN[112])

The use of a secondary ETFE skin will generate a controlled green-house effect on winter, while a free release of internal loads on summer, when this secondary façade can be wide open. (Indirect diffusion gain) or some openings can generate the natural ventilation required.

Illustration 140 Ventilation systems for ETFE pneumatic cushions (extracted from VECTORFOILTEC[113])

By effectively adding another layer to the building envelope, the sunspace becomes a thermal buffer of air within a cavity wall. A further effect of the sunspace is to shelter the envelope from wind chill and rain which are factors that affect the area of the project precisely in North-south direction where wind permanently blows.

[112]ARCHITEN. ETFE foil: A guide to design. 2011 p 14.
[113]VECTORFOILTEC. Ventilation systems. http://www.vector-foiltec.com/cms/gb /technical/ ventilation.php

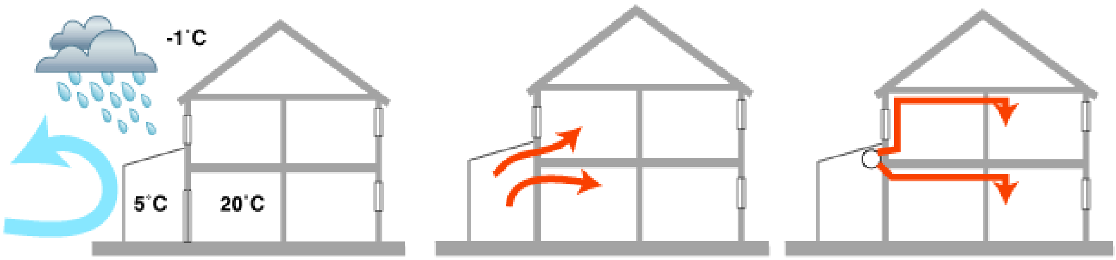


Illustration 141. Buffer effect of sunspace, natural and mechanical ventilation advantages scheme. (extracted from GREENSPEC[114])

The scheme given above, describes some advantages in terms of natural ventilation, where warm air can flow into adjoining spaces via operable vents located in the common wall at the top of the sunspace. Cool air is returned from the living spaces through lower vents to be again heated.

On another hand, Mechanical ventilation can extend the penetration of pre-heated air, but also provide extra conditioning and reduce possible noise effects. For the project considered in this work, Mechanical ventilation of the theater can have intake of warm air in the sunspace colliding the corridor and lobby of the theater.

3.2.2 Maximum solar gain in winter

A strategy regarding the main orientation of the building is suggested to be east-west ensuring a long side of the building to face the sun, in order to minimize east and west facing walls and windows, and reduce excessive heat gain in summer. Also, South oriented ETFE façade, will provide maximum solar radiation absorption in winter, while in summer being clustered by one of its layered systems, as explained above, will provide shading requirements.

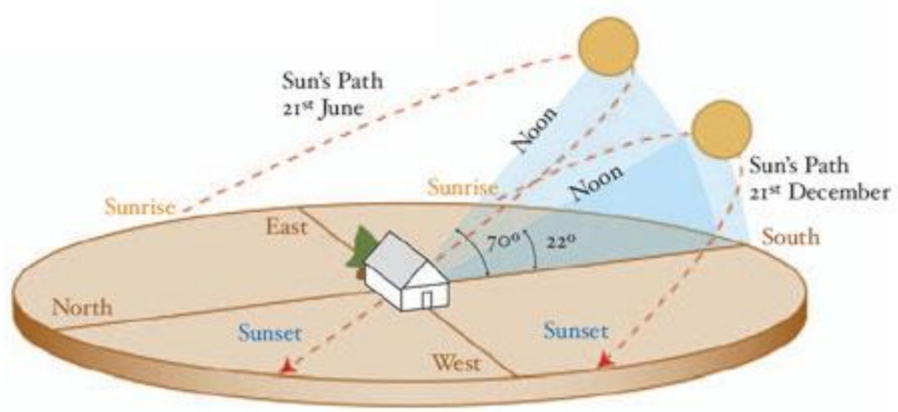


Illustration 142 Building orientation scheme towards south. (Extracted from CANOSOLAIR[115])

[114]GREENSPEC. Passive solar design: sun spaces. (Online web content). http://greenspec.co.uk /passive-solar-sunspaces.php
[115]CANOSOLAIR. Site orientation scheme (Online web content). http://www.cansolair. com/ features.php. 2011

3.2.3 Efficient ventilation

Efficient ventilation in the building can be provided by using the advantages of both natural and mechanical ventilation. Due to the need of regulation of air quality, sound quality and possible draughts in the theater/auditorium, the best solution is to provide mechanical ventilation with heat-recovery systems, and probable air tightness; in the same way, the mechanical system to be proposed, can take advantage of solar air heating collectors and/or ground water pump, technology that has been newly implemented in commercial and industrial uses as it was described before.

Natural ventilation is generally suitable only for selective areas such as lobbies, staircases and toilets, which can have operable windows or air gaps to the exterior. Due to the one-floor configuration and its height, it becomes not useful the use of stack effect, which can generate thermal bridges with low effect in ventilation performance, as a result its application is limited to bathrooms and restaurant kitchens.

However a crucial strategy has been chosen in order to provide the best performance of the building in terms of HAVC system efficiency, points that will be further discussed in the chapter 6. HVAC SYSTEMS.

3.2.4 Air tightness

Building an airtight thermal consists on arranging the structure of the building in order to avoid infiltration or too high losses of latent heat during winter. Satisfying air tightness ensures the efficacy of the mechanical ventilation system chosen for the project to control the humidity in the environment and satisfy easily the needs of thermal comfort while the moisture is kept away of causing deterioration of the structure.

3.2.5 Super Insulation

In zones with relative low temperatures such as the north of Italy and central Europe, the R-Values set on external walls, slab foundation and roofs ranges among 38 and 52 reduces the heating losses and gains throughout the seasons, keeping the house at a balanced temperature and humidity level with a lower use of energy.

3.2.6 Thermal Bridging Reduction

In addition to the use of high insulation levels, the removal of thermal bridges from inside to the outside of the house would avoid the heat flow through the least resistance paths (wool, metal, etc.), empowering the insulation effect. This thermal bridging reduction is avoided by considering a total a construction detailing in which the insulation path can enclose entirely all the building envelope avoiding insulation offsets in joints and connections.

3.3 ACUSTICAL SUITABLE PERFORMANCE

Another topic that the theater/auditorium in concern should satisfy is level of acoustical performance that can be acquired by following simple but effective strategies in terms of internal shape, materials, and distribution. [116] The quality of sound for a theater can be given by three main aspects, sonority, reflection and reverberation time.

3.3.1 Criteria for direct sound generation

It is suitable to have any receptor to a distance no more than 20 m from the source in order to avoid a misinterpretation of the message, however, this fact depends on the attenuation given by the room or the amplification of the source.

3.3.2 Criteria for first reflection generation

Even when there was made a careful choice of the materials in order to obtain the recommended values of reverberation time for any space, it does not guarantee the complete the recognition of the message and an optimum sonority in all the points of the place. It s needed to avoid certain phenomena such as echo, flutter echo and focalization with the implementation of practical shapes.

In terms of shape, the sonority and a graceful first reflection should be satisfied in order to avoid certain phenomena to be discussed here after;

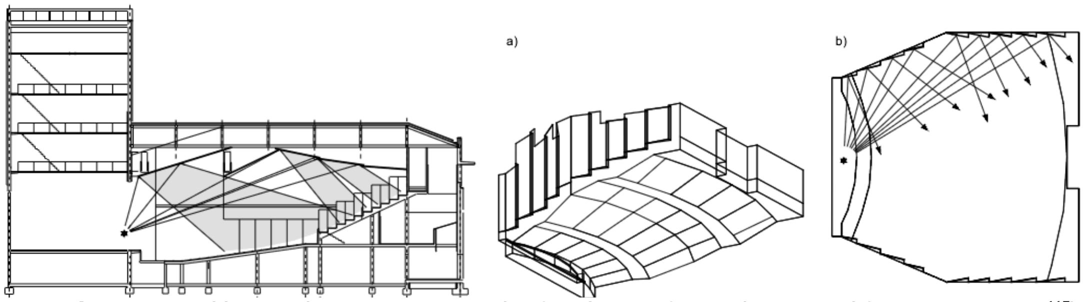


Illustration 143 Ceiling and wall convex and reflective surfaces (extracted from CARRION[117])

3.3.3 Echo reduction

Every sound reflection that arrives to a receptor in between the first 50 ms after the arrival of the direct sound is recognized by the human ear as a single sound. When the sound is emitted from any oral source the existence of those reflections help to improve the comprehension of the sound; on the other hand, the appearance of certain reflections of sound with a delay higher than 50ms,

[116]CARRION Antoni. Diseño acústico de espacios architectonicos. 1998. P. 137
[117]Ibid. Diseño acústico de espacios architectonicos. 1998. p. 198-201

recreates a repetition of the first sound emitted called echo. Two main solutions can be given to avoid echo.

a. Use absorption material or Helmotz selective absorption type in the surfaces with a proportion of not more than 10% of the total area covered. Further absorption material could affect the reverberation time of the room.
b. Use convex surfaces.
c. Use of tilted surfaces.

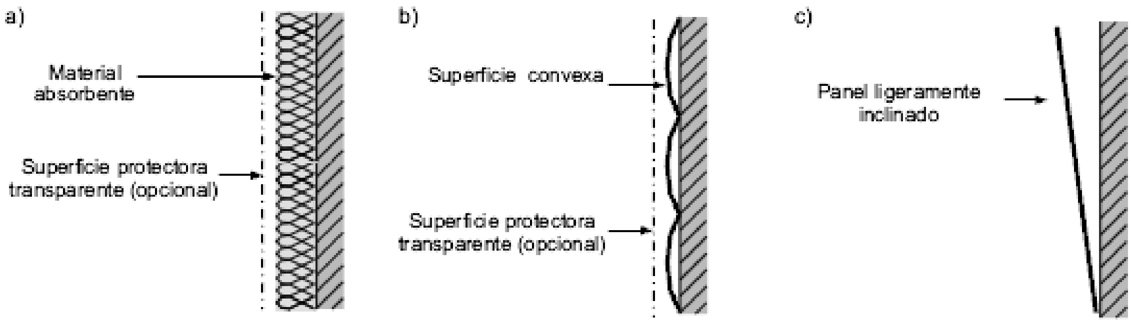


Illustration 144 Solutions to avoid echo (extracted from CARRION[118])

3.3.4 Flutter Echo reduction

The flutter echo consists on the multiple repetitions in a small period of time of a sound generated by any source in an space enclosed by mainly highly reflective and smooth. This phenomenon can be prevented by avoiding de use of large reflecting parallel walls; a reflective wall is composed mainly by sound reflective material such as wood.

The solution relies on either incline one of the walls at least 5° inclined, or a less effective alternative, absorption material.

3.3.5 Focalization

In cases when the surfaces are concave such as domes or circular plans, the energy emitted by a source will be focalized into a single point, forming unbalance in the level of sound reception between different points with of the room. The solution is to avoid these circular shapes in walls and ceilings.

[118]Ibid. Diseño acústico de espacios architectonicos. 1998. p. 209

4 THERMAL DESIGN OF BUILDING ENVELOPE

4.1 TECHNICAL ENVIRONMENTAL DATA

The present environmental data is analyzed in order to obtain the conditions at which the system will run during the average summer and winter season.

Location	Calco	
Altitude	284	m.o.s.l
Latitude	45°94'	Nord
Longitude	9°24'	Est

Heating Design Data:		
Heating internal design temperature	20	°C
Heating internal design humidity	0.5	-
Heating external design temperat.	-5	°C
Heating external design humidity	0.9	-
Degree Days	2617	°C
Heating daily time period	24	h

Surface and ground Conditions		
Internal surface emminsivity	9.09	W/mK
External Surface Emminsivity	16.67	W/mK
Thermal conductivity of the ground	3	W/m2K
Thermal conductance of the soil	2	W/m2K

Cooling internal design temperature	26	°C
Cooling internal design humidity.	0.5	-
Max external temperature	31.9	°C
DT ext (daily temp. swing)	11	°C
Cooling daily time period		h
Cooling external design humidity	0.5	-

Table 18. Technical environmental data Calco –Lecco province (extracted from UNI13049)

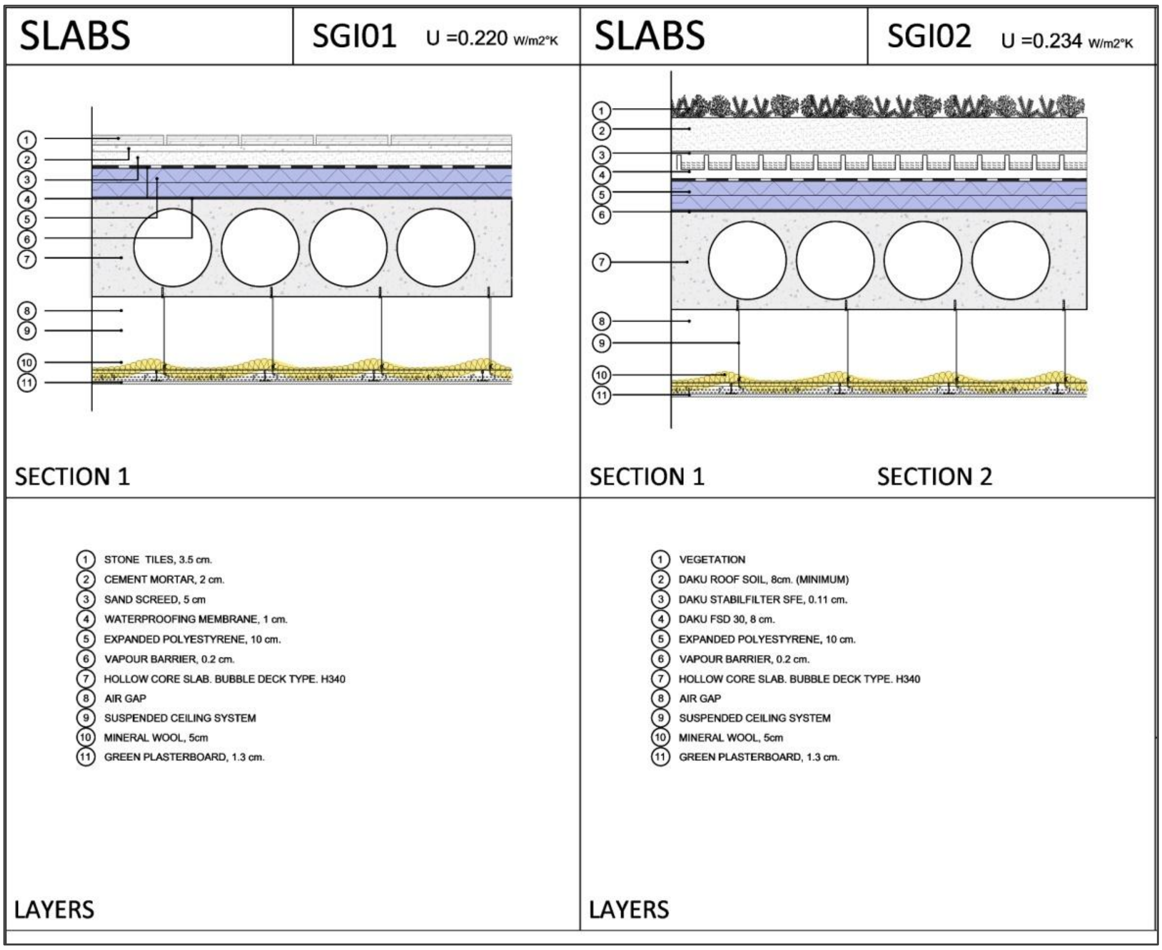
MATERIAL PROPERTIES ISO 10351-1994		
Name	Conductance/conductivity (W/m2K)	Vapour Permeability (Kg/msPa)
Airgap HFup > 2cm	7	1.93E+14
Airgap HL > 2cm	5.2	1.93E+14
Airgap VL > 2cm	6.4	1.93E+14
Mineral wool	0.038	6.30E+13
Expanded polystyrene	0.038	6.30E+24
Extruded polystyrene	0.038	6.30E+12
Polyurethane	0.033	3.90E+12
Cement wood	0.078	4.50E+12
Concrete	1.7	1.95E+12
lightweight Concrete	0.4	1.95E+12
Cement Mortar	1.73	7.00E+12
Plasterboard (gypsum)	0.17	2.30E+13
Cellular glass	0.048	1.50E+14
Ceramic tiles	0.02	2.00E+13
Parquet (wood)	0.078	4.50E+12
Marble	2.51	2.00E+13
Stainless steel	16	1.90E+14
Wooden Plancks/panels	0.078	4.50E+12
Actis panel x 3cm super 10	0.0054	9.00E+12
waterproofing membrane	0.27	10000000000
Green Plasterboard	0.17	2.30E+13
Stone Tiles	1.33	1.95E+12
Sand screed	1.7	1.95E+12
Hollow core Slab H230	1.49	2.50E+12
Hollow core Slab H340	1.62	2.50E+12
ETFE tripple foil panels		1.20E+12
Plywood acoustical panels	0.078	4.50E+12

Table 19. Materials thermal and permeability properties

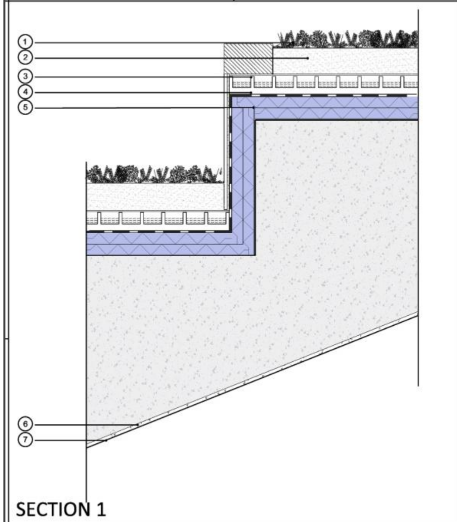
4.2 TECHNOLOGICAL CHOICES

A detail abacus was created compiling all the different material solutions and layers for the range of walls and slabs proposed as technological solution in our project, taking into account into the design of the thermal efficient envelope. Based on these we started the calculations of the U values for each one of the elements and its components.

4.2.1 Slabs



SLABS | SGI03 U =0.236 W/m2°K

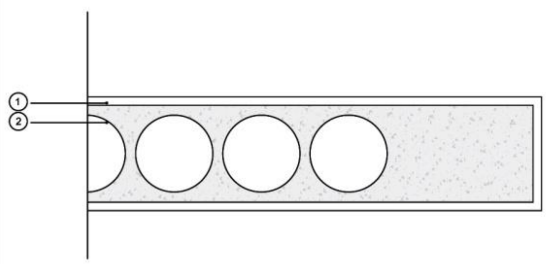


SECTION 1

1. VEGETATION
2. DAKU ROOF SOIL, 8cm. (MINIMUM)
3. DAKU STABILFILTER SFE, 0.11 cm.
4. DAKU FSD 30, 8 cm.
5. EXPANDED POLYESTYRENE, 5 cm.
   EXPANDED POLYESTYRENE, 5 cm.
6. PLASTER, 1.5 cm.
7. PAINT

LAYERS

SLABS | SG04



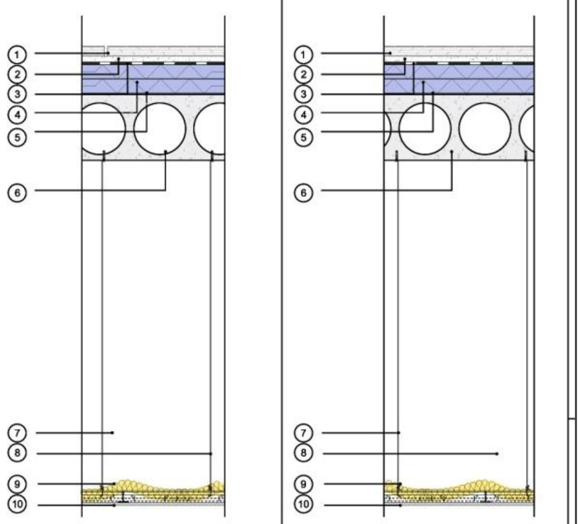
SECTION 1

SECTION 2

1. CEMENT RENDER, 3.0 cm.
2. HOLLOW CORE SLAB. BUBBLE DECK TYPE. H340

LAYERS

SLABS | SGI05 U =0.205 W/m2°K



SECTION 1

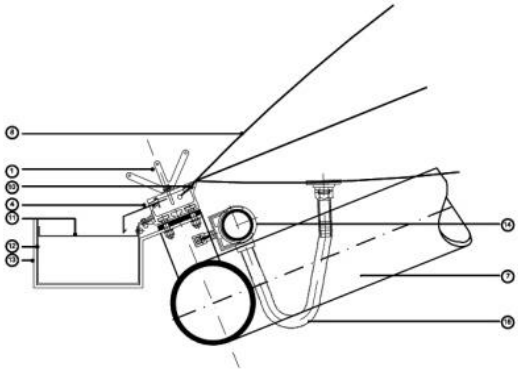
SECTION 2

1. CONCRETE TILES, 3.5 cm.
2. CONCRETE MORTAR, 2cm.
3. WATERPROOFING MEMBRANE, 1 cm.
4. EXPANDED POLYESTYRENE, 5 cm.
   EXPANDED POLYESTYRENE, 5 cm.
5. VAPOUR BARRIER, 0.5 cm.
6. HOLLOW CORE SLAB. BUBBLE DECK TYPE. H230
7. AIR GAP
8. SUSPENDED CEILING SYSTEM
9. MINERAL WOOL, 5cm
10. GREEN PLASTERBOARD, 1.3 cm.

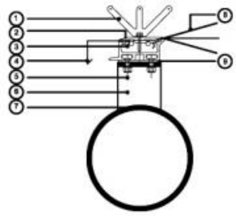
LAYERS

SLABS

SGI06 U = 1.470 W/m2°K



SECTION 1



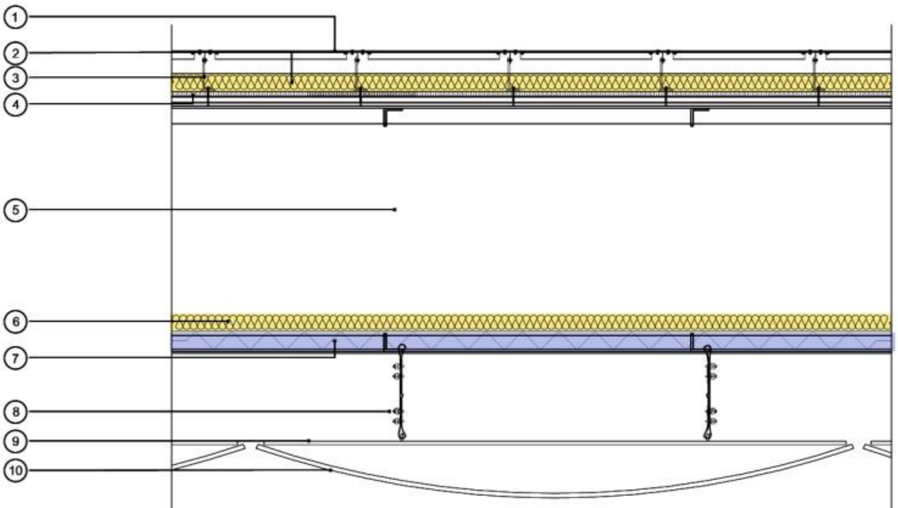
SECTION 2

1. BIRD WIRE GUARDING & FIXING TO VF EXTRUSION
2. VF?DS F16 EXTRUSION ASSEMBLY LOCATED & FIXED CENTRALLY ON t SADDLES BELOW THROUGH SEPARATING SEALANT TYPE 2/4 nO. HAMMERGHEAD BOLT FIXINGS @200-200 C/S
3. LOCATION OF NEW KEDER WHEN INSTALLED
4. VERGE FLASHING
5. 4 NO. HAMMERHEAD BOLTS FIXING EXTRUSION TO T-SADLEES AT EXTRUSION JOINTS 2 NO. HAMMERHEAD BOLTS BETWEEN JOINTS
6. TEE SADDLE SUPPORTS
7. PRIMARY STEEL WORK
8. OUTER, MIDDLE & INNER LAYERS OF ETFE CUSHIONS
9. MASTIC SEALANT TYPE: SYKAFLEX -11FC (POLYURETHENE BASED
10. TYPICAL F16_SS EXTRUSION SUPPLIED AND FIXED BY VECTORFLEX (VF)
11. GUTTER STRAPS @ reg c/s
12. ALUMINUM GUTTER 0.25X0.25
13. GUTTER BRACKET SUPPORT
14. AIR FEED PLENUM PIPE
15. 25 mm FLEXI PLENUM AIR PIPE FEED TO ETFE CUSHION

LAYERS

SLABS

SGI07 U = 0.323 W/m2°K

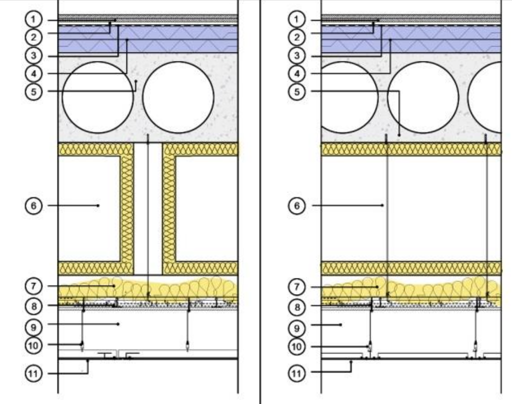


SECTION 1

1. COR-TEN STEEL, 0.2 cm.
2. MINERAL WOOL, 5cm
3. ALUCOBOND SYSTEM
4. FIBERCEMENT BOARD, 1.3 cm.
5. TRUSS
6. MINERAL WOOL, 5cm
7. EXPANDED POLYESTYRENE, 5 cm.
8. COMMERCIAL GRADE AIRCRAFT CABLE. 2mm diameter.
9. ALL THREAD-ROD. 1 cm. diameter.
10. OVATION REFLECTOR PANEL. DECORTECH.

LAYERS

SLABS — SGI08 U = 0.162 W/m2°K

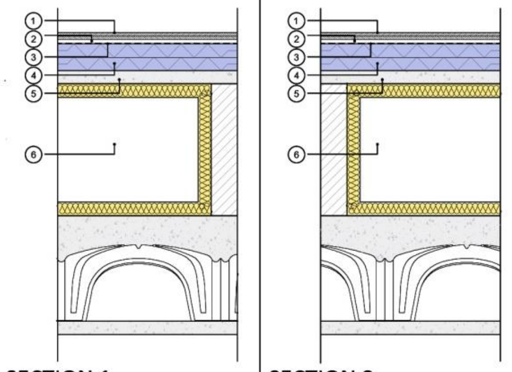


SECTION 1 SECTION 2

1. PAQUET FINISHING AND ADHESIVE LAYER, 1 cm.
2. PAVILASTRA F145, 1.25cm.
3. WATERPROOFING MEMBRANE, 0.5 cm.
4. EXPANDED POLYSTYRENE, 10cm.
5. HOLLOW CORE SLAB. BUBBLE DECK TYPE. H340
6. AIR DIFFUSER
7. MINERAL WOOL, 10 cm.
8. SUSPENDED CEILING SYSTEM
9. ALUCOBOND SYSTEM
10. ALUCOBOND SYSTEM
11. COR-TEN STEEL, 0.2 cm.

LAYERS

SLABS — SGI09 U = 0.287 W/m2°K

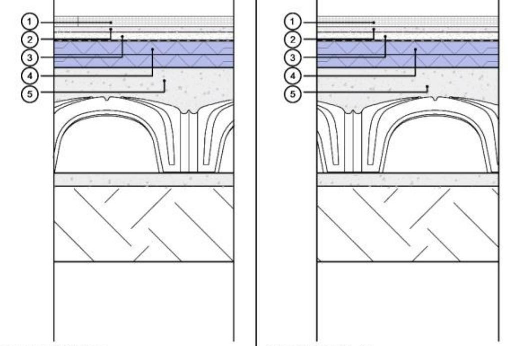


SECTION 1 SECTION 2

1. PAQUET FINISHING AND ADHESIVE LAYER, 1 cm.
2. PAVILASTRA F145, 1.25cm.
3. EXPANDED POLYSTYRENE, 5 cm.
4. EXPANDED POLYSTYRENE, 5 cm.
5. CONVRETE SLAB. 10 cm.
6. AIR DIFFUSER

LAYERS

SLABS — SGI10 U = 0.307 W/m2°K

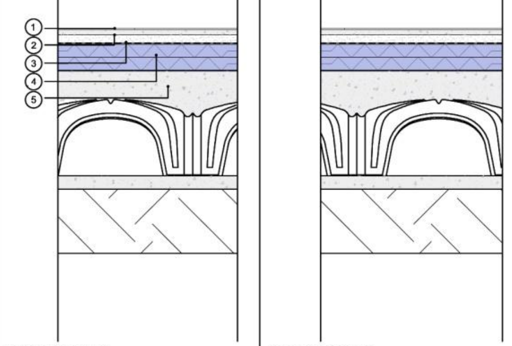


SECTION 1 SECTION 2

1. MARBEL TILES, 80x80x4 cm.
2. MORTAR, 2cm/
3. SANDSCREED, 3cm.
4. EXPANDED POLYSTYRENE, 5 cm.
   EXPANDED POLYSTYRENE, 5 cm.
5. CONCRETE SLAB. 10 cm.

LAYERS

SLABS — SGI11 U = 0.287 W/m2°K



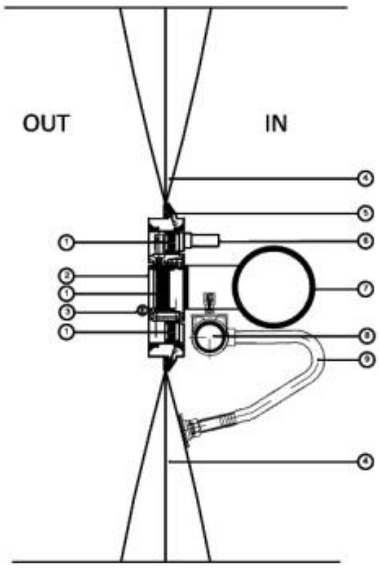
SECTION 1 SECTION 2

1. CERAMIC TILES, 60 x 60 x 0.5 cm.
2. MORTAR, 2cm
3. SANDSCREED, 3cm.
4. EXPANDED POLYSTYRENE, 5 cm.
   EXPANDED POLYSTYRENE, 5 cm.
5. CONCRETE SLAB. 10 cm.

STONE TILES, 3.5 cm.

LAYERS

SLABS	SGI12 U = 1.7 W/m2°K



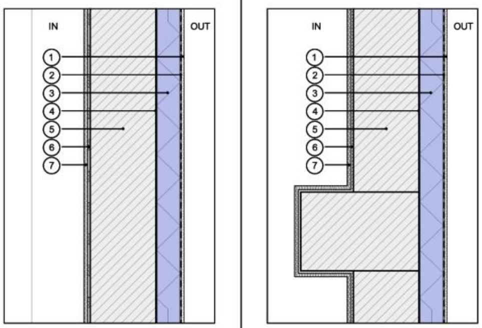
PLAN

1. Internal Foam Insulation
2. ALUMINUM PROFILE DOOR TYPE 75HD.SL (Schueco)
3. ALUMINUM BUUT HINGE DOOR TYPE 75HD.SL (Schueco)
4. OUTER, MIDDLE & INNER LAYERS OF ETFE CUSHIONS
5. TYPICAL F16_SS EXTRUSION SUPPLIED AND FIXED BY VECTORFLEX (VF)
6. ALUMINUM HANDLE
7. PRIMARY STEEL WORK
8. PLENUM PIPE BUTT HINGE
9. AIR FEED PLENUM PIPE

LAYERS

4.2.2 Walls

WALLS | **AGI01** U = 0.299 W/m2°K

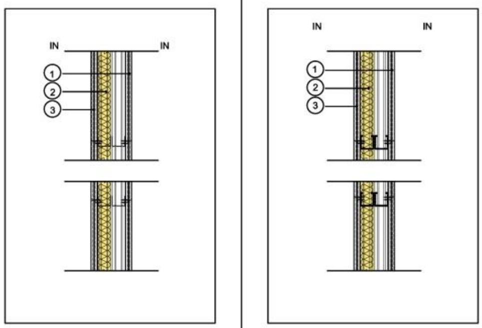


SECTION | PLAN

1. EXTRUDED POLYSTYRENE, 1cm.
2. WATERPROOFING MEMBRANE, 0.5 cm.
3. EXPANDED POLYSTYRENE, 10cm.
4. VAPOUR BARRIER, 0.02 cm.
5. CONCRETE WALL, 25 cm.
6. PLASTERBOARD ADHESIVE, T 1cm.
7. PLASTERBOARD, 1.3 cm.

LAYERS

WALLS | **AG02** U = 0.553 W/m2°K

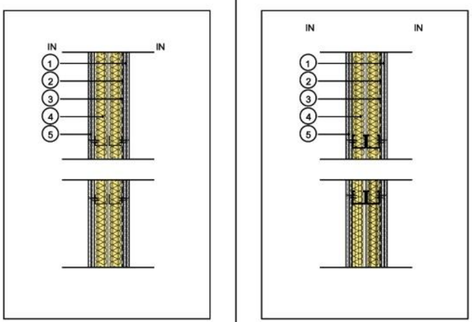


SECTION | PLAN

1. DOUBLE PLASTERBOARD, 2.6 cm.
2. MINERAL WOOL, 5 cm.
3. DOUBLE PLASTERBOARD, 2.6 cm.

LAYERS

WALLS | **AGI02A** U = 0.299 W/m2°K

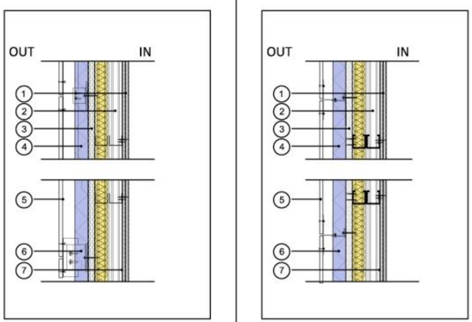


SECTION | PLAN

1. DOUBLE PLASTERBOARD, 2.6 cm.
2. WATERPROOFING MEMBRANE, 0.5 cm.
3. VAPOUR BARRIER, 0.02 cm.
4. MINERAL WOOL, 5 cm.
   MINERAL WOOL, 5 cm.
5. DOUBLE PLASTERBOARD, 2.6 cm.

LAYERS

WALLS | **AGI04A** U =0.298 W/m2°K

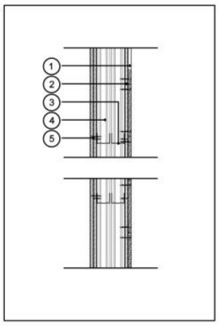


SECTION | PLAN

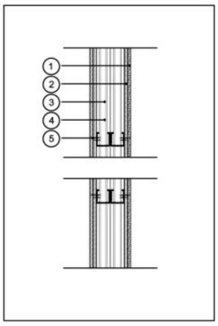
1. DOUBLE PLASTERBOARD, 2.6cm.
2. MINERAL WOOL, 5 cm.
3. LAMINATED TIMBER, 2.5 cm.
4. EXTRUDED POLYSTYRENE, 5 cm.
5. RIEDER FIBREC GLASSFIBRE CONCRETE SLAB, (120cm, x 360 x 1.3 cm)
6. ALUCOBOND SYSTEM
7. VAPOUR BARRIER, 0.02 cm.

LAYERS

WALLS — AG03 — U =1.022 W/m2°K



SECTION

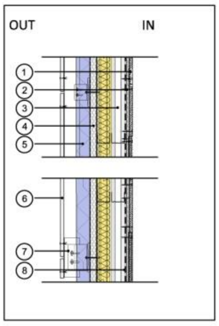


PLAN

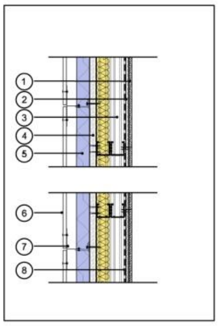
LAYERS

1. INNER WOOD PANNELS, 1.2 cm.
2. SINGLE PLASTERBOARD, 1.3 cm.
3. HORIZONTAL C SECTION
4. VERTICAL C SECTION
5. DOUBLE PLASTERBOARD, 2.6 cm.

WALLS — AGI04 — U =0.292 W/m2°K



SECTION

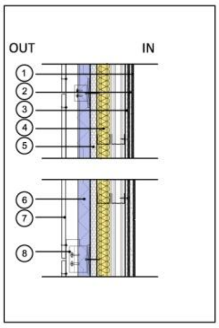


PLAN

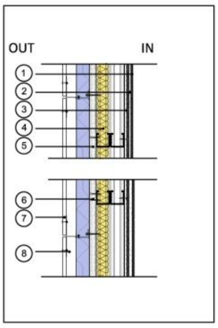
LAYERS

1. INNER WOOD PANNELS, 1.2 cm.
2. SINGLE PLASTERBOARD, 1.3 cm.
3. MINERAL WOOL, 5 cm.
4. LAMINATED TIMBER, 2.5 cm.
5. EXTRUDED POLYSTYRENE, 5 cm.
6. RIEDER FIBREC GLASSFIBRE CONCRETE SLAB, (120cm, x 360 x 1.3 cm)
7. ALUCOBOND SYSTEM
8. VAPOUR BARRIER, 0.02 cm.

WALLS — AGI05 — U =0.263 W/m2°K



SECTION

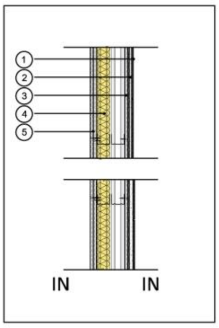


PLAN

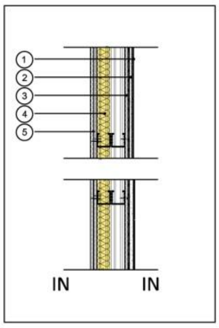
LAYERS

1. CERAMIC TILES, 0.5 cm.
2. CEMENT MORTAR, 1 cm.
3. SINGLE PLASTERBOARD, 1.3 cm.
4. MINERAL WOOL, 5 cm.
5. LAMINATED TIMBER, 2.5 cm.
6. EXTRUDED POLYSTYRENE, 5 cm.
7. RIEDER FIBREC GLASSFIBRE CONCRETE SLAB, (120cm, x 360 x 1.3 cm)
8. ALUCOBOND SYSTEM

WALLS — AG06 — U =0.498 W/m2°K



SECTION

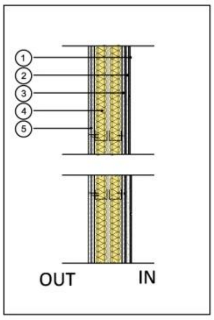


PLAN

LAYERS

1. CERAMIC TILES, 0.5 cm.
2. CEMENT MORTAR, 1 cm.
3. SINGLE PLASTERBOARD, 1.3 cm.
4. MINERAL WOOL, 5 cm.
5. DOUBLE PLASTERBOARD, 2.6 cm.
6. DOUBLE PLASTERBOARD, 2.6 cm.

WALLS — AGI06A U =0.279 W/m2°K



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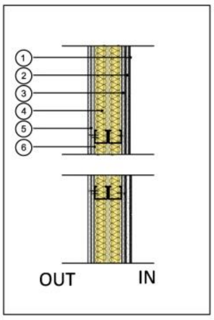
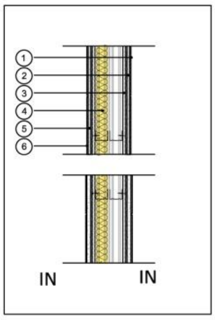


PLAN

1. CERAMIC TILES, 0.5 cm.
2. CEMENT MORTAR, 1 cm.
3. SINGLE PLASTERBOARD, 1.3 cm.
4. MINERAL WOOL, 5 cm.
   MINERAL WOOL, 5 cm.
5. DOUBLE PLASTERBOARD, 2.6 cm.

LAYERS

WALLS — AG07 U =0.333 W/m2°K



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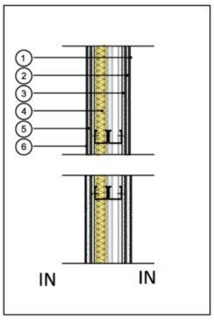
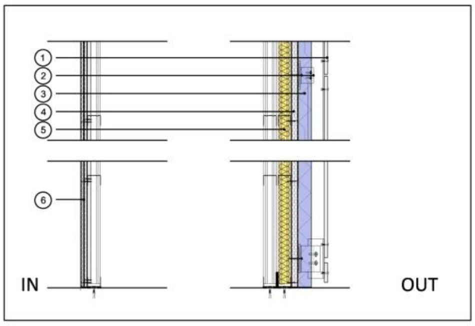


PLAN

1. CERAMIC TILES, 0.5 cm.
2. CEMENT MORTAR, 1 cm.
3. SINGLE PLASTERBOARD, 1.3 cm.
4. MINERAL WOOL, 5 cm.
5. CEMENT MORTAR, 1 cm.
6. CERAMIC TILES, 0.5 cm.

LAYERS

WALLS — AGI08/AGI08A U =0.296W/m2°K



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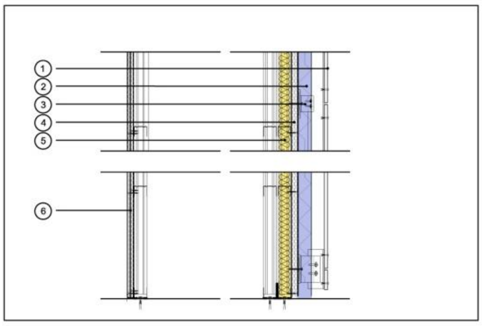
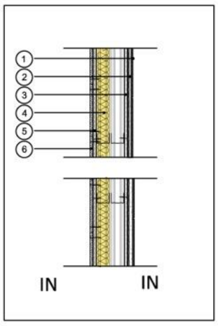


PLAN

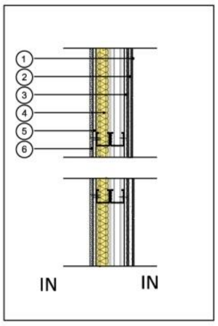
1. COR-TEN STEEL, 0.2 cm.
2. ALUCOBOND SYSTEM
3. EXTRUDED POLYSTYRENE, 4 cm.
4. FIBERCEMENT BOARD, 2 cm.
5. MINERAL WOOL, 5 cm.
6. DOUBLE PLASTERBOARD, 2.6 cm.

LAYERS

WALLS — AG09 U =0.403 W/m2°K



SECTION

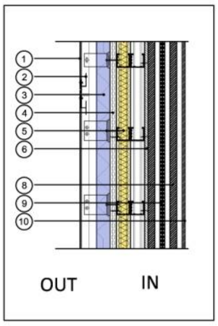


PLAN

1. CERAMIC TILES, 0.5 cm.
2. CEMENT MORTAR, 1 cm.
3. SINGLE PLASTERBOARD, 1.3 cm.
4. MINERAL WOOL, 5 cm.
5. SINGLE PLASTERBOARD, 1.3 cm.
6. INNER WOOD PANNELS, 1.2 cm.

LAYERS

WALLS — AGI10 U =0.248 W/m2°K



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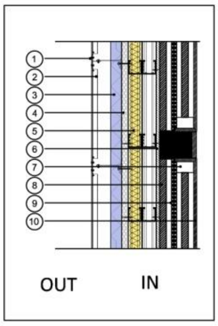
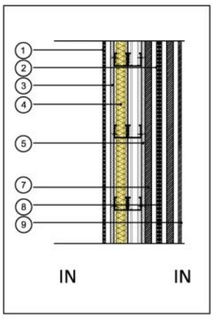


PLAN

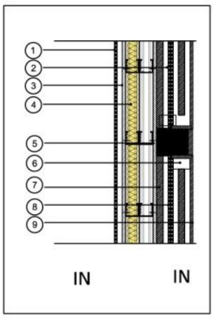
1. COR-TEN STEEL, 0.2 cm.
2. ALUCOBOND SYSTEM
3. EXTRUDED POLYSTYRENE, 5 cm.
4. FIBERCEMENT BOARD, 2 cm.
5. MINERAL WOOL, 5 cm.
6. SINGLE PLASTERBOARD, 1.3 cm.
7. OPERABLE WOOD FRAME ACOUSTIC PANELS
8. FIBERGLASS BOARD, 2.5 cm.
9. PERFORATED PLYWOOD PANEL DECORTECH HI 513
10. REFELCTIVE PLYWOOD PANEL, 1.27 cm.

LAYERS

WALLS — AGI11 U =0.382 W/m2°K



SECTION

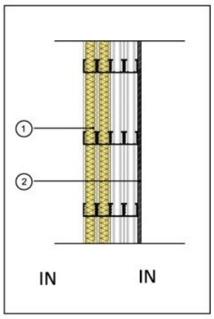


PLAN

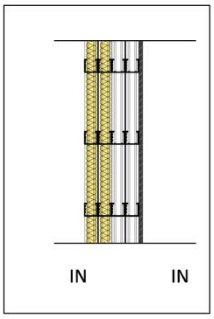
1. PERFORATED PLYWOOD PANEL DECORTECH HI 513
2. FIBERGLASS BOARD, 2.5 cm.
3. SINGLE PLASTERBOARD, 1.3 cm.
4. MINERAL WOOL, 5 cm.
5. SINGLE PLASTERBOARD, 1.3 cm.
6. OPERABLE WOOD FRAME ACOUSTIC PANELS
7. FIBERGLASS BOARD, 2.5 cm.
8. PERFORATED PLYWOOD PANEL DECORTECH HI 513
9. REFELCTIVE PLYWOOD PANEL, 1.27 cm.

LAYERS

WALLS — AGI14 U =0.297 W/m2°K



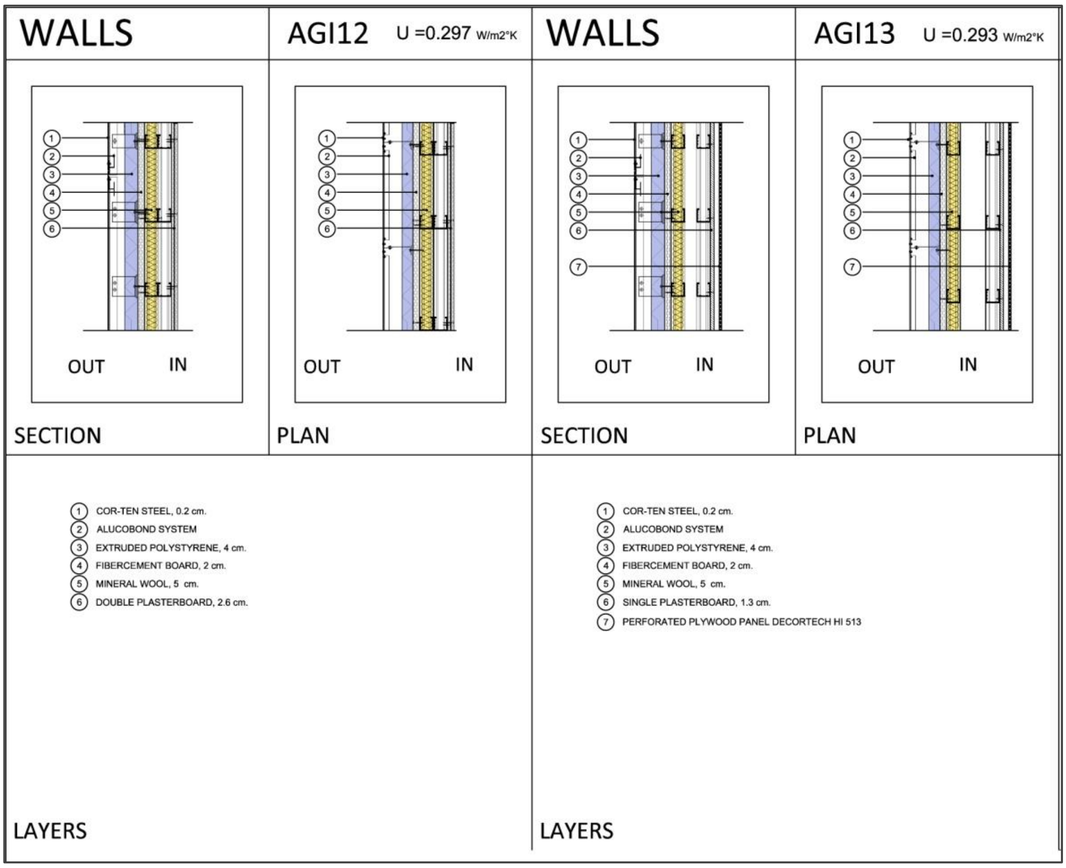
SECTION



PLAN

1. MINERAL WOOL, 5 cm.
   MINERAL WOOL, 5 cm.
2. PERFORATED PLYWOOD PANEL DECORTECH HI 513

LAYERS



4.3 METHODOLOGY

The methodology for the analysis of the building envelope is done by assessing the performance of the building during winter and summer in terms of energy needs for heating or cooling. The boundary of the building has been designed in order to offer the energy efficiency needed to satisfy the requirements of a zero foot print building, (less energy consumption, higher the possibilities to obtain the highest part of the energy from renewable sources exclusively).

In order to assess numerically the performance of the building envelope, the considerations and guidelines of the standard UNI 10351 – and ISO 1007-1:2007 are carried out as follows:

4.4 CONDENSATION RISK: U-VALUES AND GLAZER DIAGRAM.

The condensation risk measures numerically the direct probability in which a multilayered system can suffer from interstitial condensation, phenomena that leads commonly to accumulation of high amounts of water carried by the air. The phenomenon has to be avoided in order to guarantee the reliability of the components used during the entire service life of the structure, which can be compromised by biological growth, efflorescence and general deterioration of the layer or compound of layers in which this phenomenon can happen.

When condensation occurs the only possibility to avoid it (other than changing the composition of the multilayered component) is to employ a Vapor barrier in the layer where condensation is more likely to occur. As a result, the next calculation for each type of wall, and slab is generated aiming to know if the inclusion of a vapor barrier is needed or not.

In numerical terms, the need of vapor barrier can be obtained by making a comparison between the diagram of saturation pressure and vapor pressure (Glaser diagram) at every intersection between parallel layers for a flux of thermal energy, both during winter and during summer.

Steps:

1. The temperatures at each interface of the wall can be calculated using the next formula:

$$T_i = T_{i-1} - (T_{in} - T_{out}) * \frac{R_i}{R_T}$$

Where:

Ti = Temperature of the interface i. °C
Ti-1 = Temperature of the precedent interface in the flux direction.
Tin = Temperature inside.
Tout = Temperature Outside.
Ri = Thermal resistance of the interface i
RT = Total thermal resistance of the component

2. By knowing the temperatures through each wall, saturation pressure can be approximated to:

$$Ps_i = e^{26.23 - \frac{5416}{Ti+273}}$$

3. The vapor pressure at each interface can be calculated from the next formula:

$$Pv_i = Pv_{i-1} - (Pv_{in} - Pv_{out}) * \frac{Rv_i}{RV_T}$$

Where:

Ti = Vapor pressure at the interface i
Ti-1 = Vapor pressure of the precedent interface in the flux direction.
Tin = Vapor pressure inside.
Tout = Vapor pressure Outside.
Ri = Vapor flow resistance of the interface i
RT = Vapor flow resistance of the component

The ANNEX 2 shows the calculation and results of the condensation risk for each type of wall and then the inclusion of a water vapor barrier according to the outcome of the analysis can be seen in the list of abacus presented above. However an example of the analysis developed is hereafter presented:

DATA					
$\Delta T_{winter}(C^0)$=	25.000	$\Delta P_{winter}(Pa)$=	958.044	U_0 (W/m2*K)=	0.364
$\Delta T_{summer}(C^0)$=	5.900	$\Delta P_{summer}(Pa)$=	2626.823	U' (W/m2*K)=	2.630
$RH_{in\ WINTER}$=	0.500	$RH_{in\ SUMMER}$=	0.500	s (m)≥	0.090
$RH_{out\ WINTER}$=	0.500	$RH_{out\ SUMMER}$=	0.900		

LEVEL:	ROOF
CODE:	SG-02
U (W/m2*K)=	***0.234***

STRATIFICATION AND PROPERTIES							Water vapour barrier verification						
							Winter				Summer		
layer name	x	S_i	λ_i or C_i	S_i/λ_i or 1/C or $1/h_i$	δ_i	S_i/δ_i	T	P_v	P_{sat}	Pv'	T	P_v	P_{sat}
(unit)	(m)	(m)	(W/m*K)	(m^2*K/W)	(Kg/msPa)	(Ns/Kg)	(C°)	(Pa)	(Pa)	(Pa)	(C°)	(Pa)	(Pa)
out	0.833			0.060			-5.000	208.346	416.693	208.346	31.900	4316.383	4795.981
waterproofing membrane	0.783	0.010	0.270	0.037	1.E+10	0.000	-4.649	208.346	427.856	208.346	31.817	2052.345	4772.878
Extruded polystyrene	0.773	0.050	0.038	1.333	6.E+12	0.000	-4.432	1034.077	434.883	403.596	31.766	2034.376	4758.663
Extruded polystyrene	0.723	0.090	0.038	2.400	6.E+12	0.000	3.380	1040.631	768.500	405.146	29.922	2002.033	4271.302
Hollow core Slab H340	0.633	0.340	1.618	0.210	3.E+12	0.000	17.442	1052.427	1982.582	1139.443	26.604	1694.124	3504.624
Airgap HFup > 2cm	0.293	0.280	7.000	0.040	2.E+14	0.000	18.673	1164.726	2144.817	1165.997	26.313	1690.839	3443.703
Plasterboard (gypsum)	0.013	0.013	0.170	0.076	2.E+13	0.000	18.907	1165.924	2176.998	1166.280	26.258	1689.559	3432.217
	0.000			0.110			19.355	1166.391	2239.720	1166.391	26.152	1689.559	3410.354
in	-0.050	0.783				0.000	20.000	1166.391	2332.782	1166.391	26.000	1689.559	3379.119

Vapor barrier nedeed		ΔP' (Pa)	731.508
R bv (m2*s*Pa/Kg	0.000	f bv (m2*s*Pa	0.764

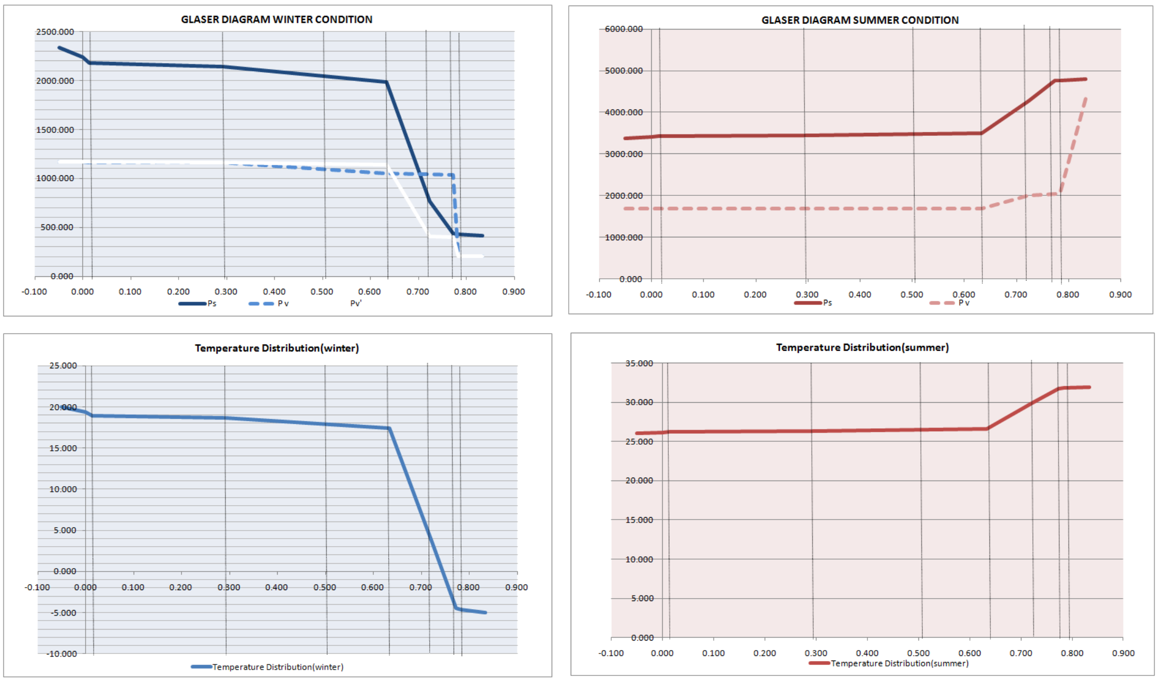


Illustration 145 Slab SG-02 Condensation risk analysis

4.5 THERMAL COMFORT ASSESSMENT

In order to understand the comfort levels that could be achieved at our spaces we analyzed the mean radiant temperatures for 5 of the main spaces in our project with the aim of understanding what the overall thermal sensation in our building would be considering the different layers of the envelope. We also considered calculating the buffer area in the entrance of the theater to understand the effect the radiation of the different surfaces affecting the space even though we understand the comfort levels for this kind of spaces are more flexible due to the fact that it is a transition zone. The results and process of these calculations are plotted in the tables following, which give as a result acceptable comfort levels in all the spaces except, of course for the buffer area.

The main 5 Spaces studied were: The Bar and its Kitchen, the restaurant, the exposition gallery and the theater, each for a different specific location and situation (sitting or standing).

The process we followed to assess the effects of radiation in terms of the mean radiant temperature for each space were as follows: In every room of the building studied we calculated:

$$MRT = \sum_i (Ti\, Fvi)$$

Where Ti is the surface indoor temperatures of the enclosure surfaces and Fvi are the shape factors of the surfaces with respect to a specific point within the space. The calculation of the shape factors are done considering the division of the surfaces with respect to the subject inside the space. Depending of different cases (whether the user is standing or sitting different tables are available for the calculations of these factors through the formula:

$$F\,pi = F * \left\{1 - \exp\left[-\frac{b}{c}/\tau\right]\right\}\left\{1 - exp\left[-\frac{b}{c}/\gamma\right]\right\}$$

Considering the values $\tau\,\gamma$ are taken from the relationship with the reference table where they can be calculated as:

$$\tau = A + B(a/c)$$
$$\gamma = C + D(b/c) + E(a/c)$$

The view factors can then be summed up to obtain the total Mean radiant temperature. After this we can calculate the operating temperature which will indicate us the thermal comfort level in the space. Operative temperature is approximated as the average of the dry bulb temperature and the mean radiant temperature. If the operative temperature is greater than 19 degrees there is an acceptable thermal comfort level.[119]

For the sake of simplicity it has been studied particular spaces that are assumed to drive the comfort conditions in all the building area. The results of the analysis and zones are here presented:

[119] MASERA GABRIELE. Thermal Comfort Presentation. (Available online) http://corsi.metid.polimi.it/col/data/contenuti/base_gruppi/078263_5597/allegati/LS01c%20TD%20-%20thermal%20comfort.pdf. 2010

	MRT(°C)	Top (°C)
Kitchen bar – viewer in the middle and standing	19.93	19.97
Bar – viewer in the middle	20.52	20.26
Restaurant – viewer in the middle, sitting	20.61	20.31
Gallery – viewer 1.6 meters form corner, standing	21.07	20.53
Theater – viewer in the middle, 6.7 m. from stage	20.77	20.38
Transition space – viewer in the middle standing	9.32	14.66

Table 20 summary of results of comfort assessment

The next illustration shows the results of the analysis for one particular case as an example of the process realized; however the ANNEX 4 shows the entire calculation tables and results for all the cases analyzed.

Surface

tab	F*	A	B	C	D	E
fig. 4a	0.120	1.24186	0.16730	0.61648	0.08165	0.05128
fig. 4b	0.116	1.59512	0.12788	1.22643	0.04621	0.04434

north	a	b	c	$F_{p,i}$	$A(m^2)$	U	$T_{s,i}$	τ	γ
	2.66	3.4	3.41	**0.04305**	9.044	0.279	20	1.24186	0.68017
	2.66	1	3.41	**0.01960**	2.66	0.279	20	1.24186	0.68017
	2.66	3.4	3.41	**0.04305**	9.044	0.279	20	1.24186	0.68017
	2.66	1	3.41	**0.01960**	2.66	0.279	20	1.24186	0.68017
				2.50604					
east	**a**	**b**	**c**	$F_{p,i}$	$A(m^2)$	**U**	$T_{s,i}$	τ	γ
	3.41	3.4	2.66	**0.05641**	11.594	0.299	19.178	1.45633105	0.78658
	3.41	1	2.66	**0.02879**	3.41	0.299	19.178	1.45633105	0.71291
	3.41	3.4	2.66	**0.05641**	11.594	0.299	19.178	1.45633105	0.78658
	3.41	1	2.66	**0.02879**	3.41	0.299	19.178	1.45633105	0.71291
				3.26763					
south	**a**	**b**	**c**	$F_{p,i}$	$A(m^2)$	**U**	$T_{s,i}$	τ	γ
	2.66	3.4	3.41	**0.03856**	8.144	0.498	20	1.37236381	0.73789
	2.66	1	3.41	**0.01822**	1.91	0.498	20	1.37236381	0.68043
	2.66	3.4	3.41	**0.03856**	9.044	0.498	20	1.37236381	0.73789
	2.66	1	3.41	**0.01822**	2.66	0.498	20	1.37236381	0.68043
				2.27097				τ	γ
door	0.75	1.2	3.41	0.00787	0.9	1.4	20	1.27865619	0.65649
	0.75	1	3.41	0.00687	0.75	1.4	20	1.27865619	0.65170
				0.29481					
west	**a**	**b**	**c**	$F_{p,i}$	$A(m^2)$	**U**	$T_{s,i}$	τ	γ
	3.4	3.4	2.66	**0.05633**	10.66	0.498	20	1.45570211	0.78639
	3.4	1	2.66	**0.02875**	2.65	0.498	20	1.45570211	0.71272
	3.4	3.4	2.66	**0.05633**	11.56	0.498	20	1.45570211	0.78639
	3.4	1	2.66	**0.02875**	3.4	0.498	20	1.45570211	0.71272
				3.40288				τ	γ

door	0.75	1.2	2.66	**0.01158**	0.9	1.4	20	1.28903105	0.66777
	0.75	1	2.66	**0.01022**	0.75	1.4	20	1.28903105	0.66163
				0.43596					
ceiling	a	b	c	$F_{p,i}$	A(m²)	U	$T_{s,i}$	τ	γ
	2.66	3.41	3.4	**0.02297**	9.0706	0.22	19.395	1.69516729	1.30747
	2.66	3.41	3.4	**0.02297**	9.0706	0.22	19.395	1.69516729	1.30747
	2.66	3.41	3.4	**0.02297**	9.0706	0.22	19.395	1.69516729	1.30747
	2.66	3.41	3.4	**0.02297**	9.0706	0.22	19.395	1.69516729	1.30747
				1.78196					
slab	a	b	c	$F_{p,i}$	A(m²)	U	$T_{s,i}$	τ	γ
	2.66	3.41	1	**0.07771**	9.0706	0.287	19.211	1.9352808	1.50195
	2.66	3.41	1	**0.07771**	9.0706	0.287	19.211	1.9352808	1.50195
	2.66	3.41	1	**0.07771**	9.0706	0.287	19.211	1.9352808	1.50195
	2.66	3.41	1	**0.07771**	9.0706	0.287	19.211	1.9352808	1.50195
				5.97115					

Results

MRT=	19.93		
T op=	19.96	>19	OK!!

Illustration 146 Kitchen Bar – Viewer in the Middle and Standing – thermal comfort analysis

5 LIGHTING DESIGN

5.1 INTRODUCTION:

> *"The objective of architectural lighting design is to obtain sufficient light for the purposes of the building, balancing factors of initial and operating cost, appearance, and energy efficiency"*[120]

Lighting design is an important aspect in the technological characteristics of a building. It requires consideration of the amount of functional light provided, the energy consumed, as well as the aesthetic impact supplied by the lighting system. Some buildings are primarily concerned with providing the appropriate amount of light for the associated task (such as sports facilities). Some buildings are primarily concerned with saving money through the energy efficiency of the lighting system (office and commercial buildings). Other buildings are primarily concerned with enhancing the appearance and emotional impact of architecture through lighting systems (theatres). Therefore, it is important that the lighting design process to be balanced with both, the artistic application of light as a medium in our built environment, as well as the impacts of day-lighting systems and be integrated with them in order to reach a holistic design/energy conservation approach.

This methodology of analysis employed in this chapter aims to simulate the sun path in the most important days in the four seasons of the year and its effect in terms of shading on the project building masses and their surroundings. This allows the understanding of the level of sunlight accessibility throughout the whole project and whether the orientation is well fixed or not.

5.2 SOLAR LOCAL PATH:

By using the environmental and geo-reference data of the Wheater station Bergamo-orio al serio, the program Ecotect generates the following sun-paths around the project masses during winter and during summer.

[120] GARY R. Steffy Architectural lighting design. 2002. p 24.

WINTER SOLSTICE: DECEMBER 21
Local Correction: -19.1 mins **Equation of Time:** 2.1 mins
Sunrise: 08:04 **Sunset:** 16:33 **Declination:** -23.5°

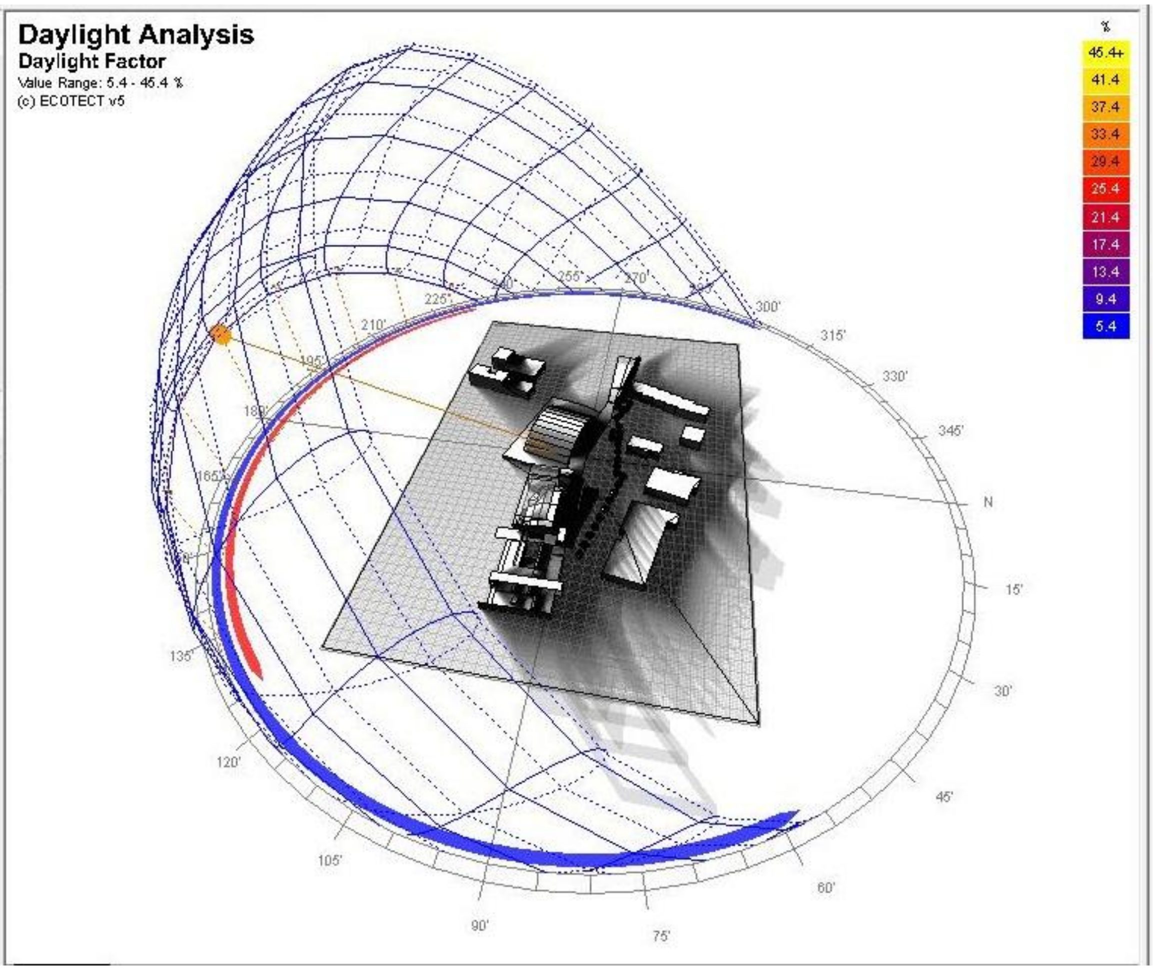


Illustration 147 Graphical representation of the solar path in winter

TIME		AZIMUTH	ALTITUDE	TIME		AZIMUTH	ALTITUDE
LOCAL	SOLAR			LOCAL	SOLAR		
08:30	08:10	129.4°	3.5°	**13:00**	12:40	-170.0°	20.2°
09:00	08:40	135.1°	7.4°	**13:30**	13:10	-162.8°	19.0°
09:30	09:10	141.1°	10.9°	**14:00**	13:40	-155.9°	17.1°
10:00	09:40	147.4°	14.0°	**14:30**	14:10	-149.2°	14.7°
10:30	10:10	154.0°	16.5°	**15:00**	14:40	-142.8°	11.8°
11:00	10:40	160.9°	18.5°	**15:30**	15:10	-136.7°	8.4°
11:30	11:10	168.0°	19.9°	**16:00**	15:40	-130.9°	4.6°
12:00	11:40	175.3°	20.7°	**16:30**	16:10	-125.4°	0.5°
12:30	12:10	-177.3°	20.8°				

Table 21 Winter Solar path and time

Summer looks like the usual days, but rather short in terms of time. The day with the lowest sun altitude is the same as that of the whole year; this corresponds to 20.8° at 12:30p.m.

INVERNAL EQUINOX: March 21
Local Correction: -28.4 mins **Equation of Time:** -7.2 mins
Sunrise: 06:29 **Sunset:** 18:27 **Declination:** -0.3°

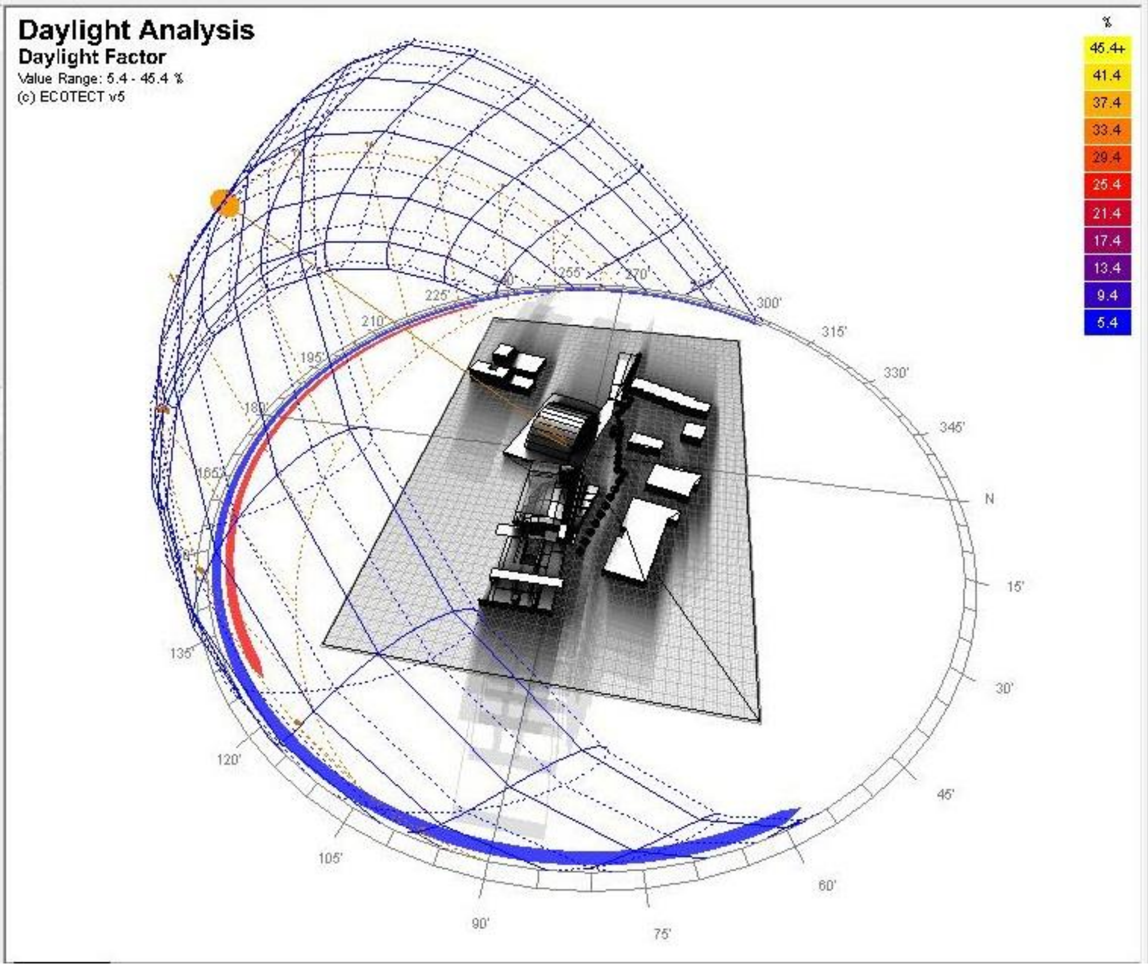


Illustration 148 Graphical Representation of the Solar Path in spring

TIME		AZIMUTH	ALTITUDE	TIME		AZIMUTH	ALTITUDE
LOCAL	SOLAR			LOCAL	SOLAR		
06:30	06:01	90.5°	0.1°	**12:30**	12:01	-179.4°	44.0°
07:00	06:31	95.9°	5.3°	**13:00**	12:31	-169.1°	43.5°
07:30	07:01	101.3°	10.5°	**13:30**	13:01	-159.0°	42.1°
08:00	07:31	107.0°	15.6°	**14:00**	13:31	-149.6°	39.8°
08:30	08:01	113.0°	20.5°	**14:30**	14:01	-140.8°	36.8°
09:00	08:31	119.3°	25.2°	**15:00**	14:31	-132.8°	33.2°
09:30	09:01	126.1°	29.6°	**15:30**	15:01	-125.4°	29.2°
10:00	09:31	133.6°	33.6°	**16:00**	15:31	-118.6°	24.7°
10:30	10:01	141.7°	37.2°	**16:30**	16:01	-112.3°	20.0°
11:00	10:31	150.5°	40.1°	**17:00**	16:31	-106.4°	15.0°
11:30	11:01	160.1°	42.3°	**17:30**	17:01	-100.7°	10.0°
12:00	11:31	170.2°	43.6°	**18:00**	17:31	-95.3°	4.8°

Table 22 Spring Solar path and time

The spring equinox works as a transitional period between winter and summer. In this regard it is noted that the highest point of the sun in the sky is: 44.0 °; at 12:30p.m.

SUMMER SOLSTICE: JUNE 21

Local Correction: -22.8 mins **Equation of Time:** -1.6 mins

Sunrise: 04:37 **Sunset:** 20:08 **Declination:** 23.4°

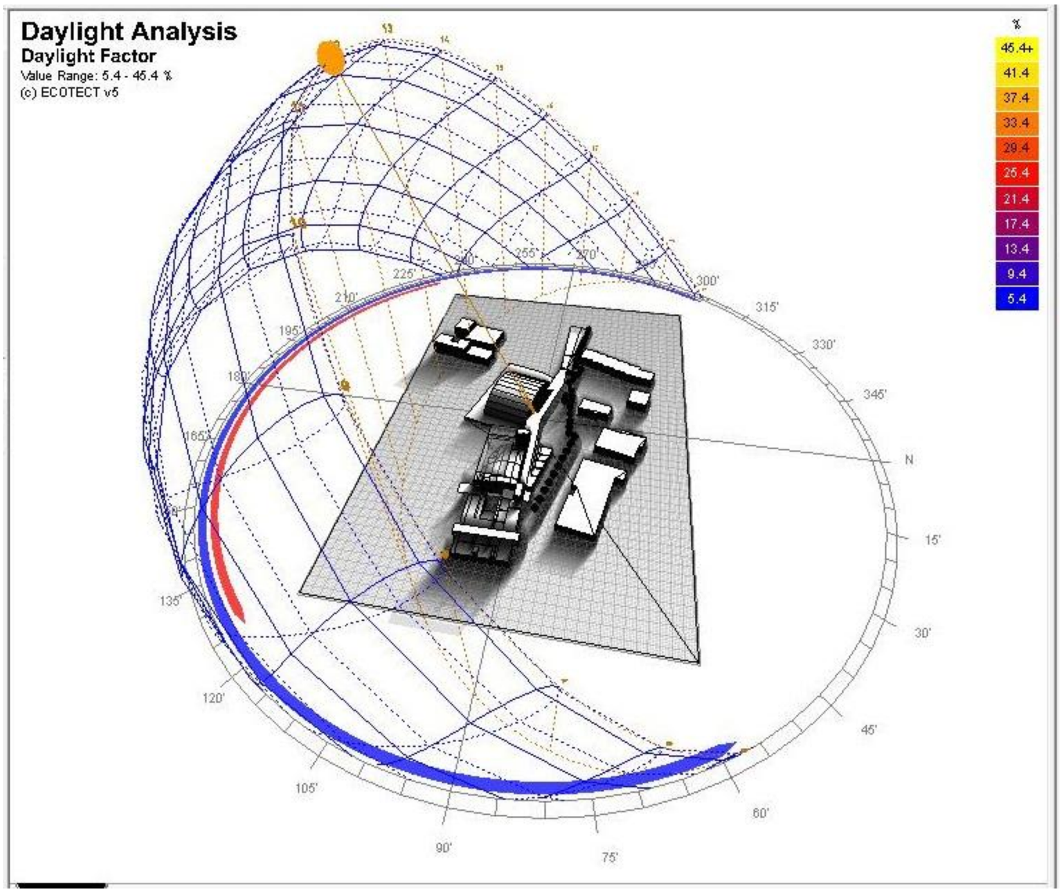


Illustration 149 Graphical Representation of the Solar Path in summer

TIME		AZIMUTH	ALTITUDE	TIME		AZIMUTH	ALTITUDE
LOCAL	SOLAR			LOCAL	SOLAR		
05:00	04:37	59.3°	3.3°	**13:00**	12:37	-158.2°	66.5°
05:30	05:07	64.4°	8.0°	**13:30**	13:07	-142.9°	63.9°
06:00	05:37	69.4°	12.8°	**14:00**	13:37	-130.3°	60.3°
06:30	06:07	74.3°	17.7°	**14:30**	14:07	-120.1°	56.0°
07:00	06:37	79.3°	22.8°	**15:00**	14:37	-111.6°	51.3°
07:30	07:07	84.3°	28.0°	**15:30**	15:07	-104.4°	46.3°
08:00	07:37	89.5°	33.3°	**16:00**	15:37	-98.0z	41.2°
08:30	08:07	95.0°	38.5°	**16:30**	16:07	-92.3°	36.0°
09:00	08:37	101.0°	43.7°	**17:00**	16:37	-87.0°	30.7°
09:30	09:07	107.7°	48.7°	**17:30**	17:07	-81.9°	25.5°
10:00	09:37	115.5°	53.6°	**18:00**	17:37	-76.9°	20.4°
10:30	10:07	124.8°	58.1°	**18:30**	18:07	-72.0°	15.3°
11:00	10:37	136.1°	62.1°	**19:00**	18:37	-67.0°	10.4°
11:30	11:07	149.9°	65.3°	**19:30**	19:07	-62.0°	5.7°
12:00	11:37	166.4°	67.3°	**20:00**	19:37	-56.8°	1.2°
12:30	12:07	-175.6°	67.7°				

Table 23 Summer Solar Path and time

Summer looks like the usual days, but rather long in terms of time. The day with the highest sun altitude is the same as that of the whole year; this corresponds to 67.7° at 12:30p.m.

AUTUMNAL EQUINOX: SEPTEMBER 21
Local Correction: -14.3 mins **Equation of Time:** 6.9 mins
Sunrise: 06:10 **Sunset:** 18:18 **Declination:** 1.0°

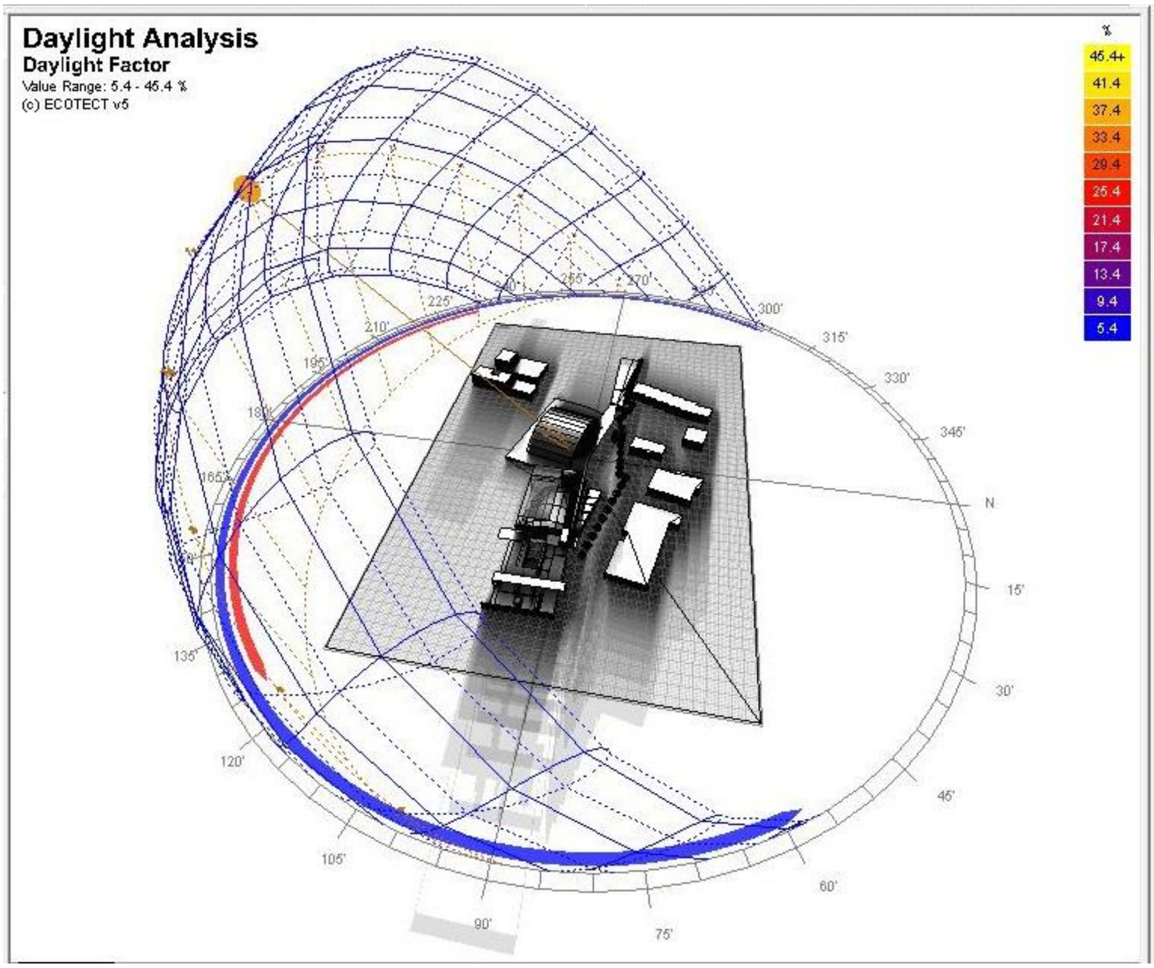


Illustration 150 Graphical Representation of the Solar Path in autumn

TIME		AZIMUTH	ALTITUDE	TIME		AZIMUTH	ALTITUDE
LOCAL	SOLAR			LOCAL	SOLAR		
06:30	06:15	92.1°	3.5°	**12:30**	12:15	-174.4°	45.2°
07:00	06:45	97.5°	8.7°	**13:00**	12:45	-164.0°	44.2°
07:30	07:15	103.1°	13.8°	**13:30**	13:15	-154.0°	42.3°
08:00	07:45	108.9°	18.9°	**14:00**	13:45	-144.7°	39.6°
08:30	08:15	115.0°	23.7°	**14:30**	14:15	-136.2°	36.3°
09:00	08:45	121.6°	28.3°	**15:00**	14:45	-128.4°	32.4°
09:30	09:15	128.8°	32.6°	**15:30**	15:15	-121.3°	28.1°
10:00	09:45	136.6°	36.5°	**16:00**	15:45	-114.7°	23.5°
10:30	10:15	145.1°	39.8°	**16:30**	16:15	-108.6°	18.6°
11:00	10:45	154.5°	42.4°	**17:00**	16:45	-102.8°	13.6°
11:30	11:15	164.5°	44.2°	**17:30**	17:15	-97.3°	8.4°
12:00	11:45	174.9°	45.2°	**18:00**	17:45	-91.9°	3.2°

Table 24 Autumn Solar Path and time

The autumnal equinox has values substantially equal to those of spring days. The discrepancies between the two days are somehow little. The altitude of the Day is: 45.2° at 12:00 & 12:30.

CONCLUSION (NOTE):

From the lighting simulation of the project area and the context around it, it's notable that the building has good access to sunlight in each of the cases seen.

Also, the orientation of the main openings (glazed areas) is well positioned (towards the south). However, spaces such as the bars and restaurants depths could lead to problems in the lighting levels within the spaces. The daylight factor analysis will host different alternatives for solving such a potential issue in the next part of this chapter.

The shadows reach the context in later times of the day. The shape of the building and its inclusion in the site identifies two main fronts; South and Western facades. The eastern part is covered with earth, since the mass is emerging from it due to the difference in levels between the San Vigilio church and the park level; the same goes for the North façade.

Another fact to consider is the analysis of local weather conditions that define the average situation of the local cloud. In this case, we used the data for the city of Milano, since the data for Calco or Bergamo wasn't available, and the differences in the results are not expected to be of major significance. All the other results are based on the weather data of the city of Bergamo.

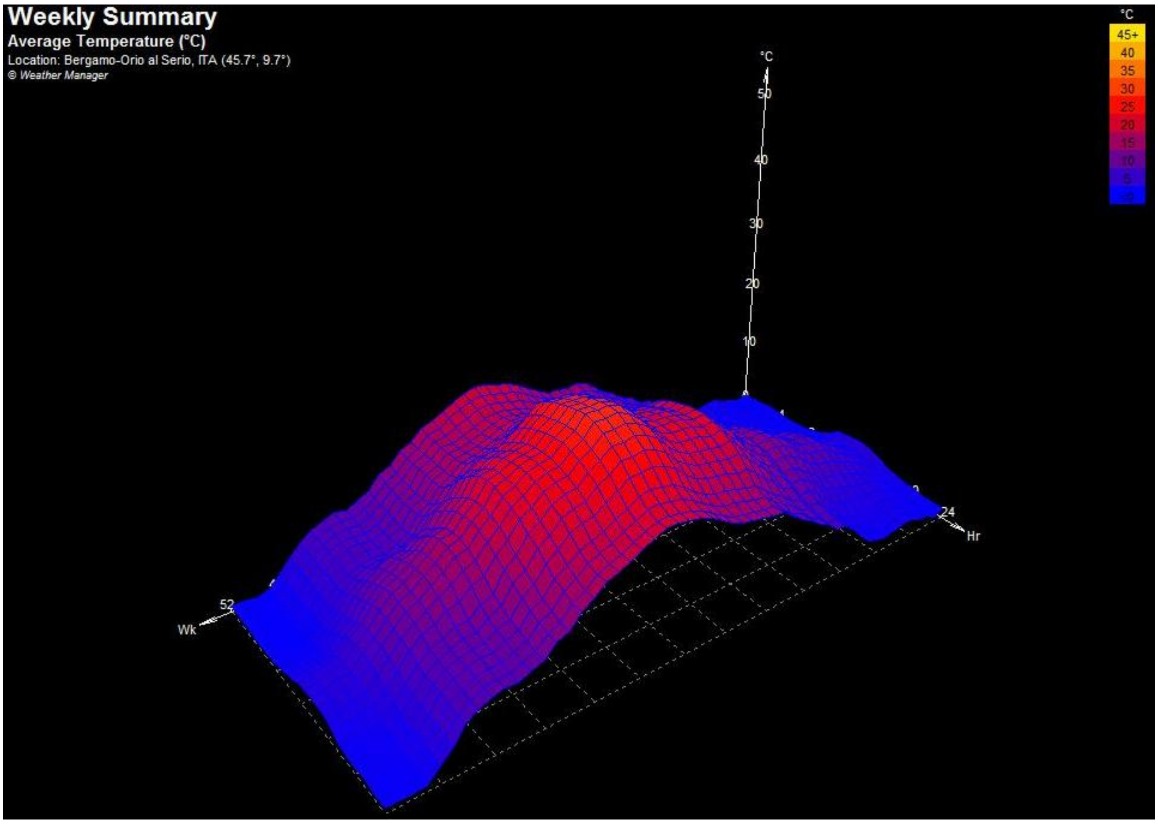


Illustration 151 Graphical Representation of the average Temperature for the city of Bergamo

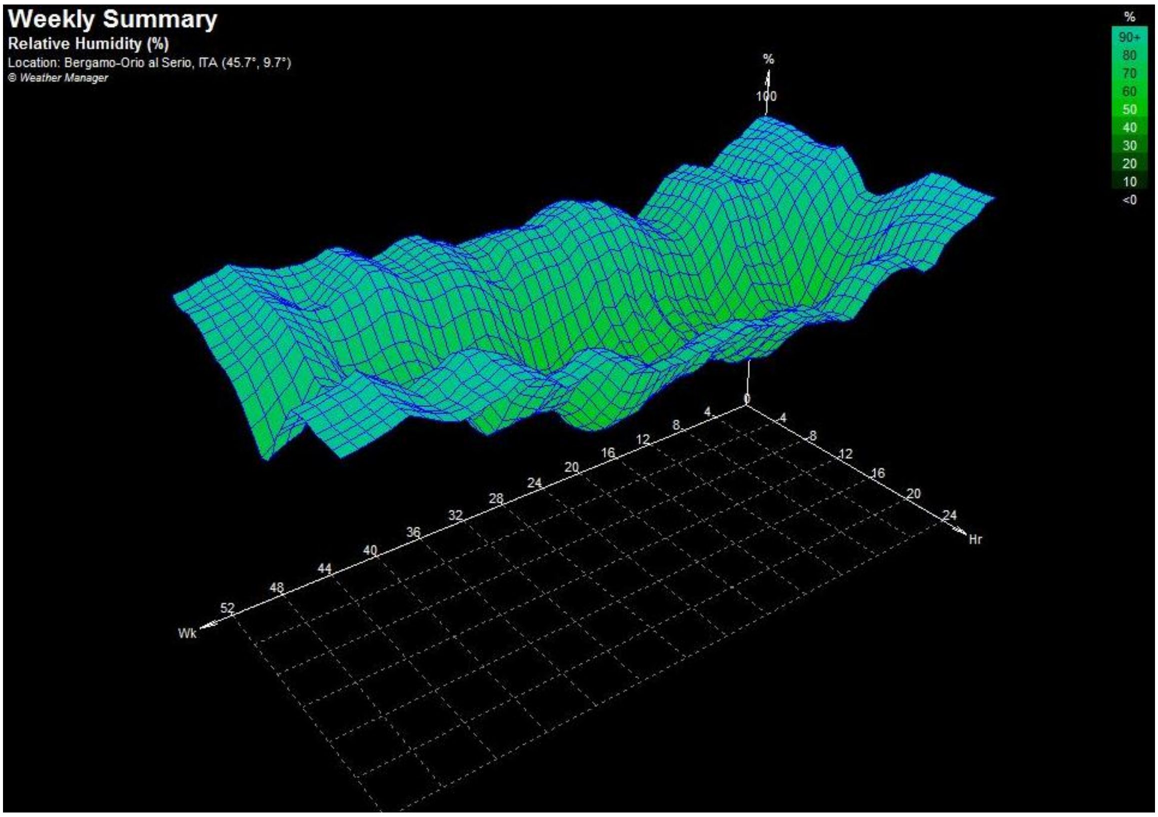


Illustration 152 Graphical Representation of the Relative Humidity for the city of Bergamo

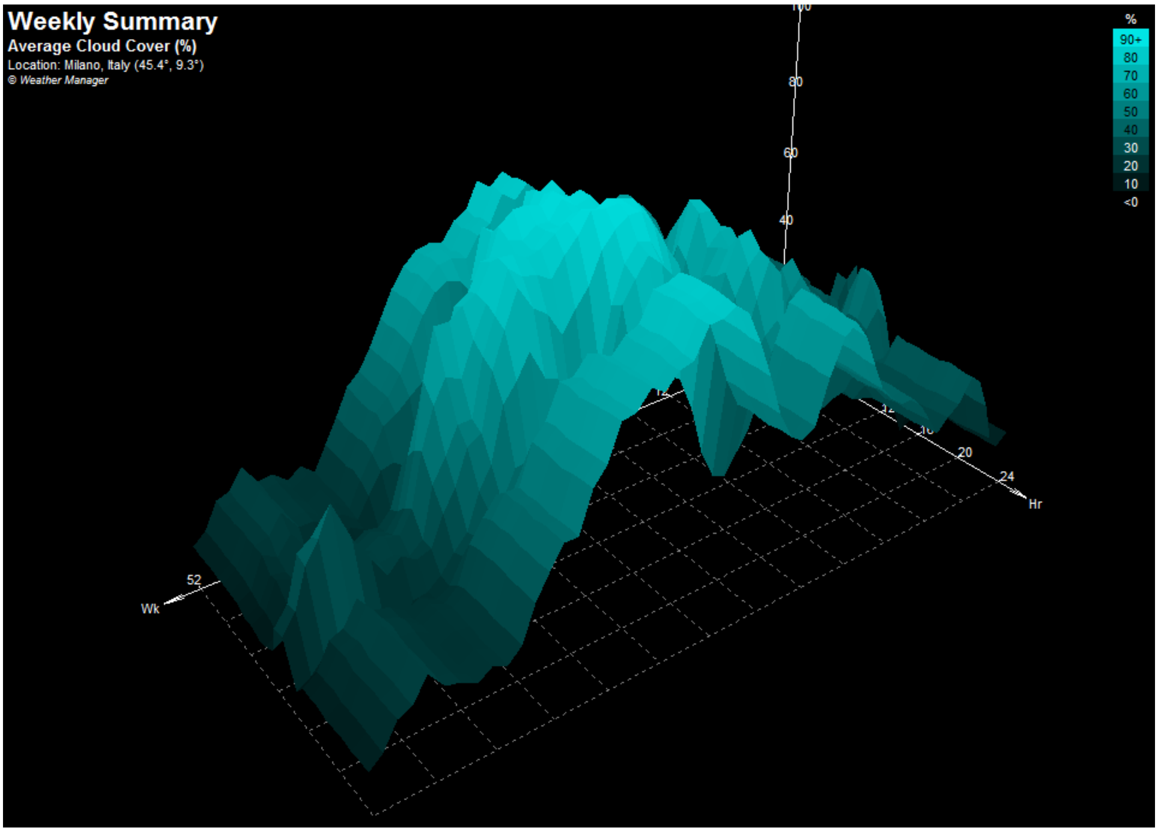


Illustration 153 Graphical Representation of the average Cloud Cover for the city of Milano

It is obvious that a clear day is not on the agenda and that the average trend of the weather, settles down on a condition of partial cloudiness.

5.3 NATURAL LIGHTING ANALYSIS

The management of the natural light is designed to optimize its use to obtain better living conditions inside the environment. In addition to its use may reduce the artificial light in terms of quantity and time to obtain the benefits of economic power consumption.

In our case, due to the size of the south windows, and in order to obtain the maximum glass area clean, we tried the horizontal development in accordance with the will to give to the prospectus in horizontal planes integrated within the window (Okalux glazing systems) above the base on the south, west and east façade; some parts of the south and west façade are made of ETFE, which is difficult to model with their characteristics in terms of shading, in this case recommendations from the manufacturers have been taken as the determining factor.

The solution to optimize for the wide clear south windows will be addressed in the thermal analysis part in terms of discomfort degree hours and heating/cooling loads; and that is in order to have optimal behavior in both fields.In order to obtain a good natural lighting design, two requirements need to be taken into consideration:

a) Provide enough light to satisfy a visual task (Social activity, eating, drinking). For daylight, this means tuning the aperture designs to minimize solar heat gain while achieving the illumination levels required.
b) The contrast and brightness of the other objects within the field of vision must not be excessive in order to minimize the glare effect.

As mentioned earlier, in order to provide daylight in the deep parts of the leisure spaces located far from any window, we designed different shapes of skylights. The shape is rectangular, with the glazed part sometimes facing south, and in one case is located on the top of the geometry. In this case, this could lead to overheating in the below area, that's why a diffusing translucent fiber glass will be mounted at the bottom of this specific skylight.

Following are the analysis grids showing the amount of daylight factor and daylight autonomy for the spaces dedicated to leisure and social activities, the calculations have been performed using the software Ecotect.

The daylight factor is used to calculate the illuminance level at each analysis point at any time of the day, for any day of the year. Thus it is clearly important to determine how often the illuminance at each point will be above a certain value; this is determined by calculating the daylight autonomy, which is given as the percentage of time throughout the year that each point will need no additional light to maintain the selected level.

The vernacular approach for the solution of the windows mentioned above has been optimized by introducing the appropriate shading devices, and control of incoming light. The use of sun protection has been explored through a series of tests which prove their effectiveness.

5.3.1 ZONE*:* BAR

The comparable situation in the simulation is as follows:

- Case (A): Double glazing window system without shading.
- Case (B): Double glazing window system with a type of screening; which includes a shading plane on top of the window with a depth of 2m, and Okalux glazing system which incorporates aluminum blades within the double glazing, these blades have been chosen with a spacing of 30cm. The horizontal type of sunscreen is best for meeting needs of natural lighting along the southern side as the sun when it occurs at its maximum efficiency is high in the sky during the summer.

The simulation regarding the lighting survey determines that the daylight factor is performed on the bar space with dimensions of 7m x 19.6m, with a clear height of 5.4 m located precisely on the south facade. The reflection coefficients of the walls are 0.753 as well as 0.749 for the ceiling and 0.4 for floors. The glazed area covers an area of 32.64 m^2 for a total height of 5.1m. The glass has a light transmission factor equal to 0.61. The reference planes to read these values are placed lighting at a height of 0.8m covering the whole area of the. The following reduction is assumed that band-pass and turned into space for circulation in depth confining work space.

5.3.1.1 Daylight Factor Case A.

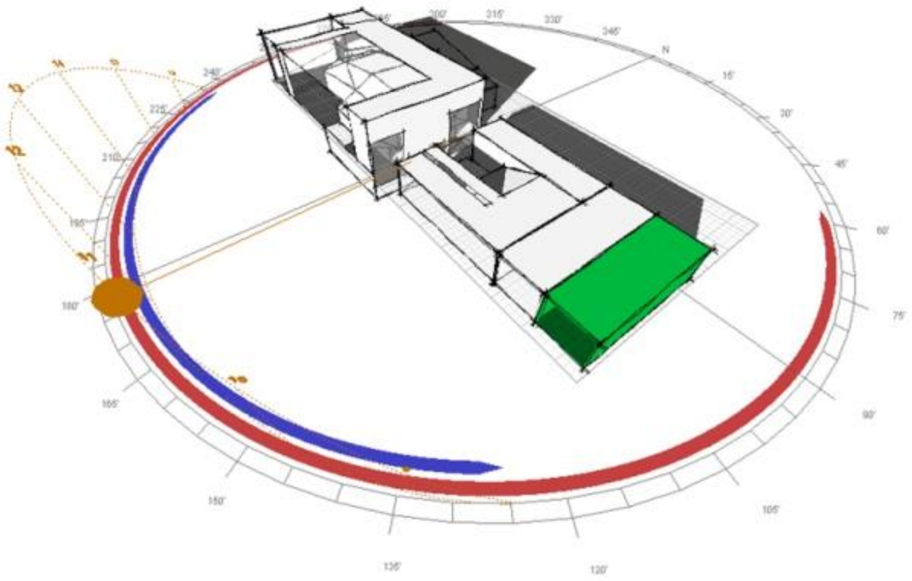


Illustration 154 Highlighted zone (Bar) in Case A

ANALYSIS CONDITION: No Skylights, No Shading
Total Area: 561.680 m2 **Floor Area:** 137.200 m2 **Volume:** 740.878 m3
Sky Conditions: CIE Overcast Sky **DF** = 8500 Lux

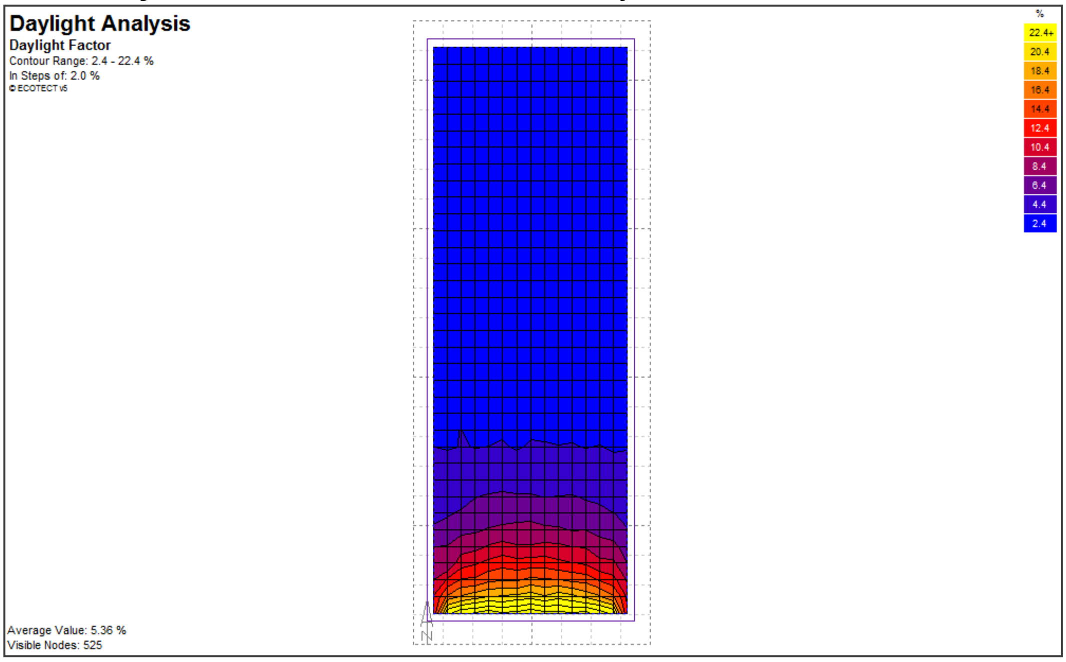


Illustration 155 Daylight Factor in Plan (Bar) – Without Okalux or Shed

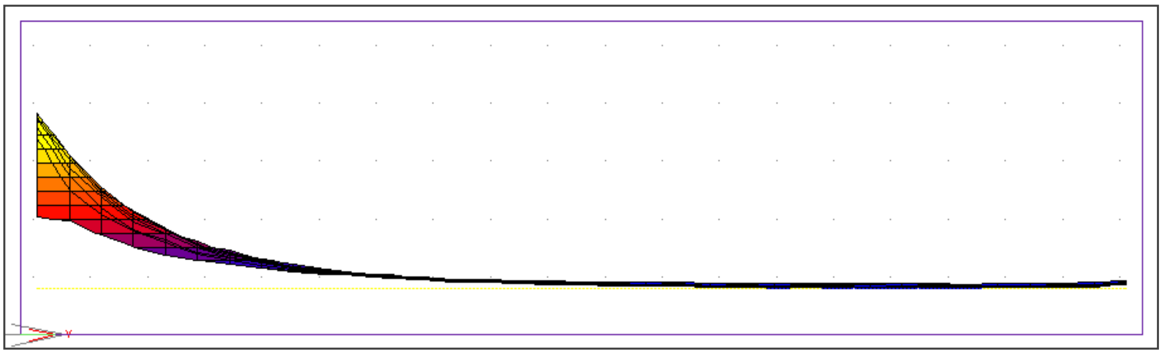


Illustration 156 Daylight Factor in Section (Bar) – Without Okalux or Shed

AVERAGE VALUE: 5.36%
VALUES RANGE: 2.4% (Top Half of Plan) **- 22.4%** (Attached to Window)

5.3.1.2 Daylight Autonomy Case A.

ANALYSIS CONDTION: No Skylights, No Shading
Total Area: 561.680 m2 **Floor Area:** 137.200 m2 **Volume:**740.878 m3
Sky Conditions: CIE Overcast Sky **Calculation Value:** 500Lux

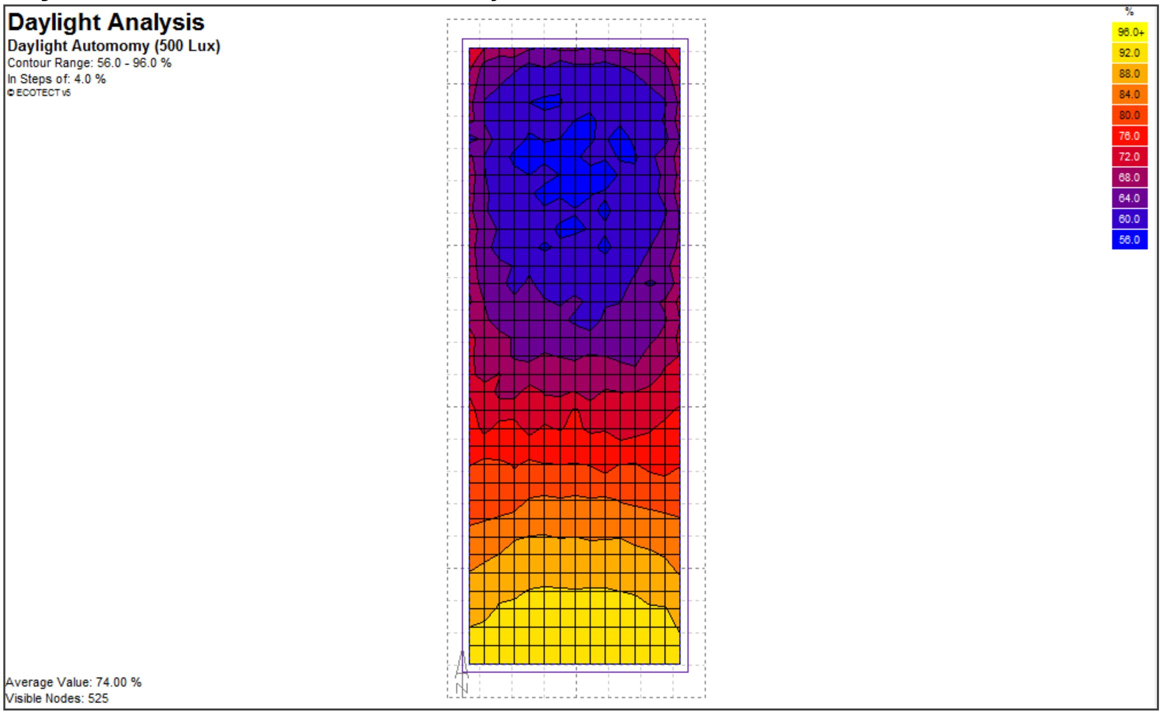


Illustration 157 Daylight Autonomy in Plan (Bar) – Without Okalux or Shed

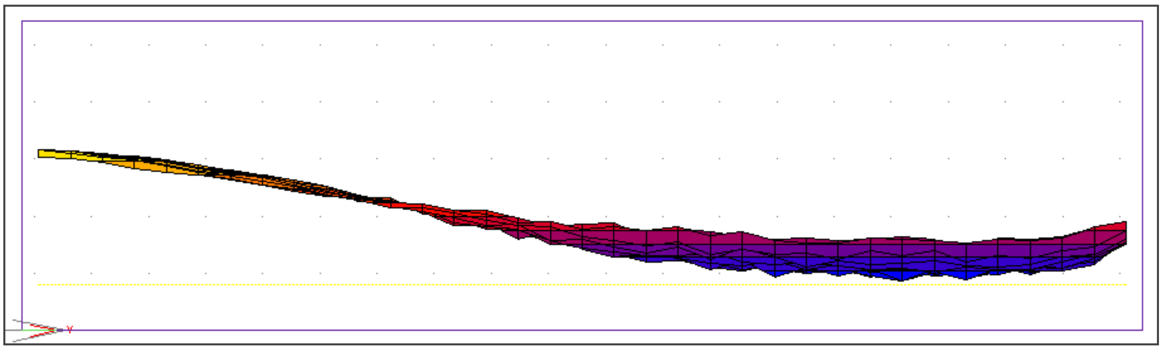


Illustration 158 Daylight Autonomy in Plan (Bar) – Without Okalux or Shed

AVERAGE VALUE: 74%
VALUES RANGE: 56% (Middle of the Top Half of Plan) **– 96%** (Attached to Window)
Notices:

Having a minimum Daylight Factor of 2.4% is rather low for such a space usage; as well as the light distribution is characterized by major differences in the values, which leads to high levels of glare. Daylight Autonomy is almost 74%, which is a good indicator; however, the minimum value is rather low.

5.3.1.3 Daylight Factor Case B.

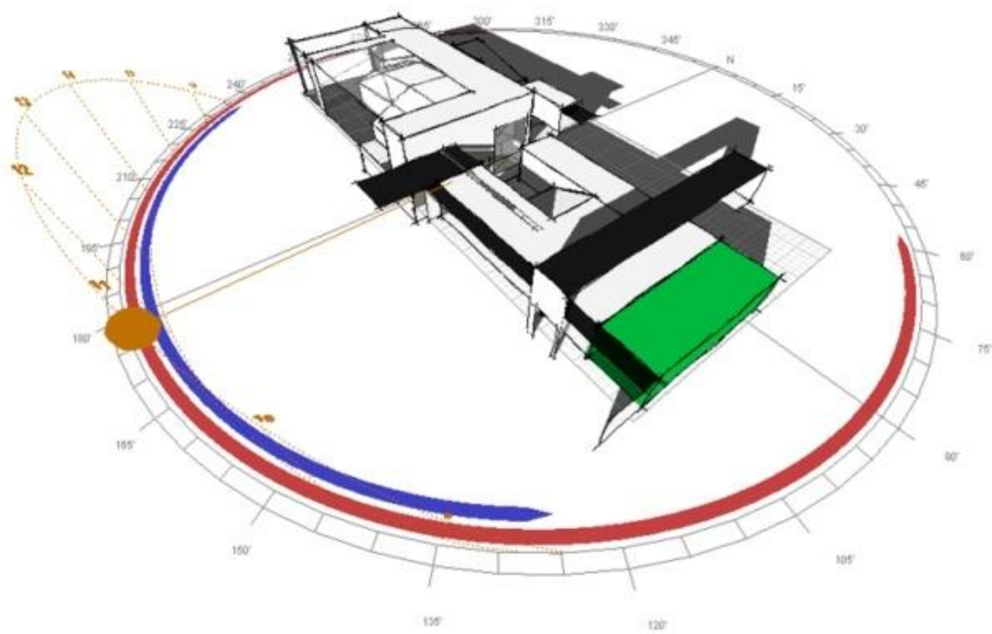


Illustration 159 Highlighted zone (Bar) in Case B

ANALYSIS CONDTION: With Skylights and Shading
Total Area: 561.680 m2 **Floor Area:** 137.200 m2 **Volume:** 740.878 m3
Sky Conditions: CIE Overcast Sky 8500 Lux

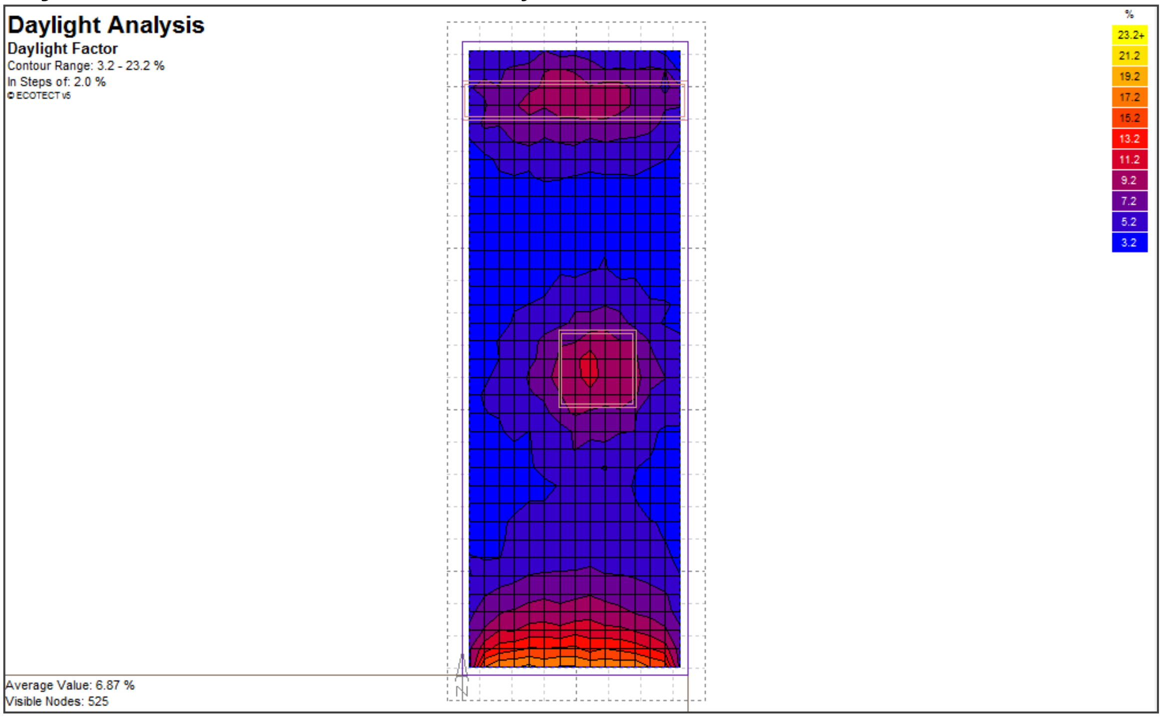


Illustration 160 Daylight Factor in Plan (Bar) – With Okalux and Shed

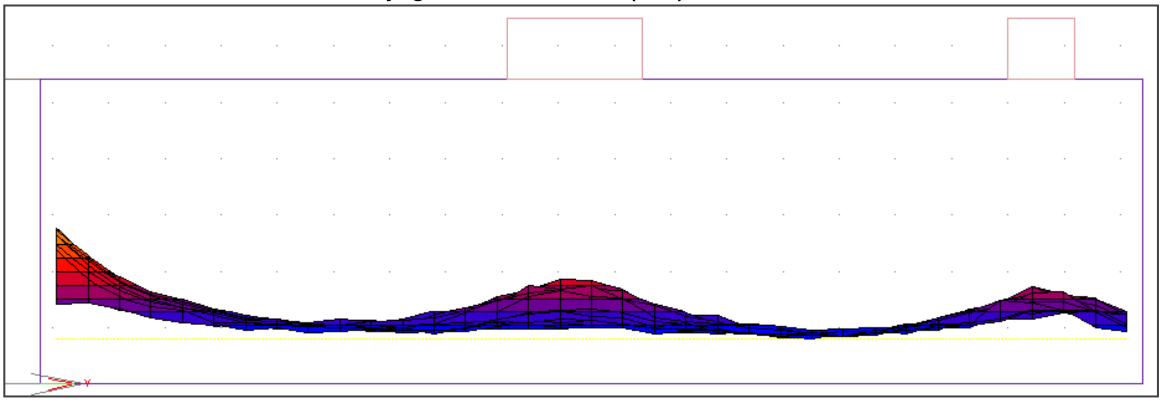


Illustration 161 Daylight Factor in Section (Bar) – With Okalux and Shed

AVERAGE VALUE: **6.87%**
VALUES RANGE: **4.2%** (Below the first skylight to the right in Plan) **– 23.2%** (Attached to Window)

5.3.1.4 Daylight Autonomy Case B.

ANALYSIS CONDTION: With Skylights and Shading
Total Area: 561.680 m2 **Floor Area:** 137.200 m2 **Volume:** 740.878 m3
Sky Conditions: CIE Overcast Sky **CalculationValue:** 500Lux

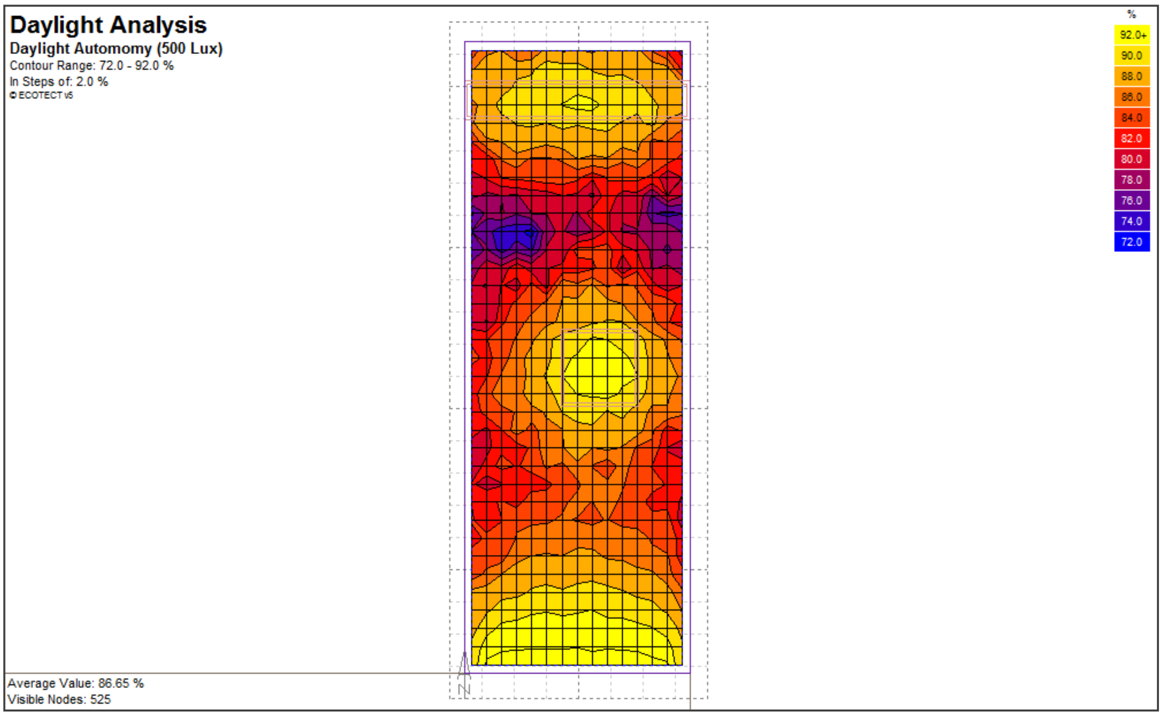


Illustration 162 Daylight Autonomy in Plan (Bar) – With Okalux and Shed

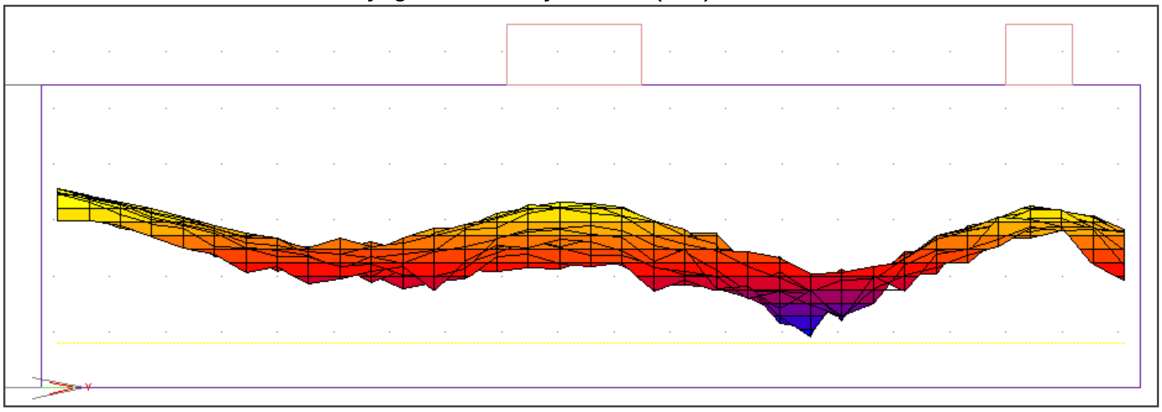


Illustration 163 Daylight Autonomy in Section (Bar) – With Okalux and Shed

AVERAGE VALUE: **86.65%**
VALUES RANGE: 72% (Below the first skylight to the left in Plan) **– 92%** (Attached to Window)

Notices:

The minimum value is higher than that of the alternative without Shed or Okalux system. 4.2% is regarded as the minimum for a good visibility in the space with this specific use. Other than that fact, the lighting levels distribution is obviously more coherent. Daylight Autonomy has a higher value as well (87%), which is a good indicator.

5.3.2 ZONE: GALLERY/STORE

The use of sun protection has been explored through a series of tests which prove their effectiveness. The comparable situation in the simulation is performed as follows:

- Case (A): Double glazing window system without shielding.
- Case (B): Double glazing window system with a type of screening; which includes a shading plane on top of the window with a depth of 2m, and Okalux glazing system which incorporates aluminum blades within the double glazing, these blades have been chosen with a spacing of 30cm. The horizontal type of sunscreen is best for meeting needs of natural lighting along the southern side as the sun when it occurs at its maximum efficiency is high in the sky during the summer.

The simulation regarding the lighting survey determines the daylight factor is performed on the gallery space with dimensions of 7m x 19.6m, with a clear height of 5.4me located precisely on the south elevation. The reflection coefficients of the walls are 0.753 as well as 0.749 for the ceiling and 0.4 for floors. The glazed area covers an area of 32.64 m^2 for a total height of 5.1m. The glass has a light transmission factor equal to 0.61. The reference planes to read these values are placed lighting at a height of 0.8m covering the whole area of the. The following reduction is assumed that band-pass and turned into space for circulation in depth confining work space.

5.3.2.1 Daylight Factor Case A.

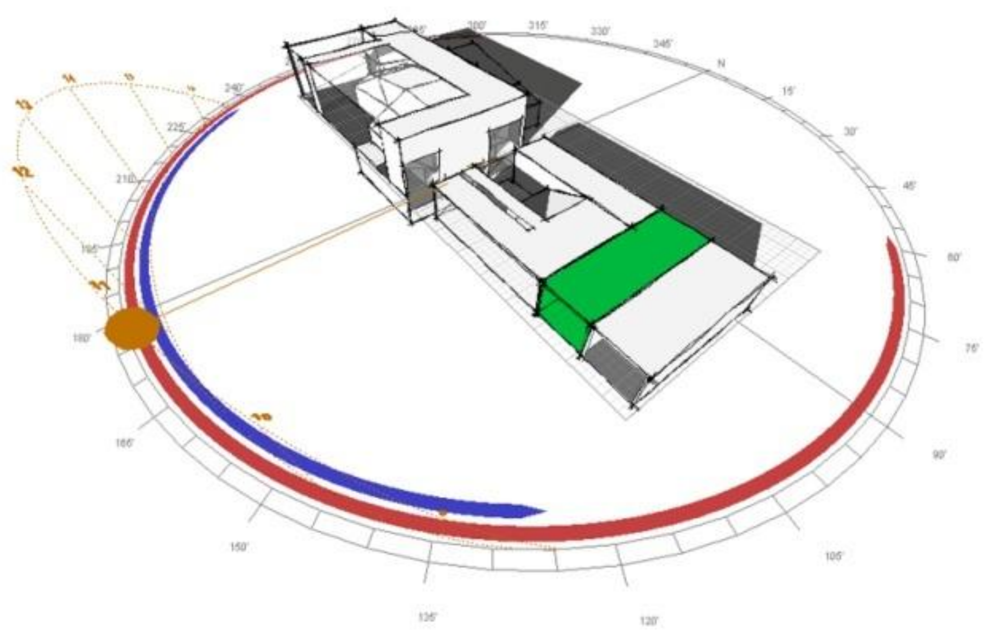


Illustration 164 Highlighted zone (Gallery/Store) in Case A

ANALYSIS CONDTION: No Skylights, No Shading

Total Area: 561.680 m2 **Floor Area:** 137.200 m2 **Volume:** 740.878 m3

Sky Conditions: CIE Overcast Sky 8500 Lux

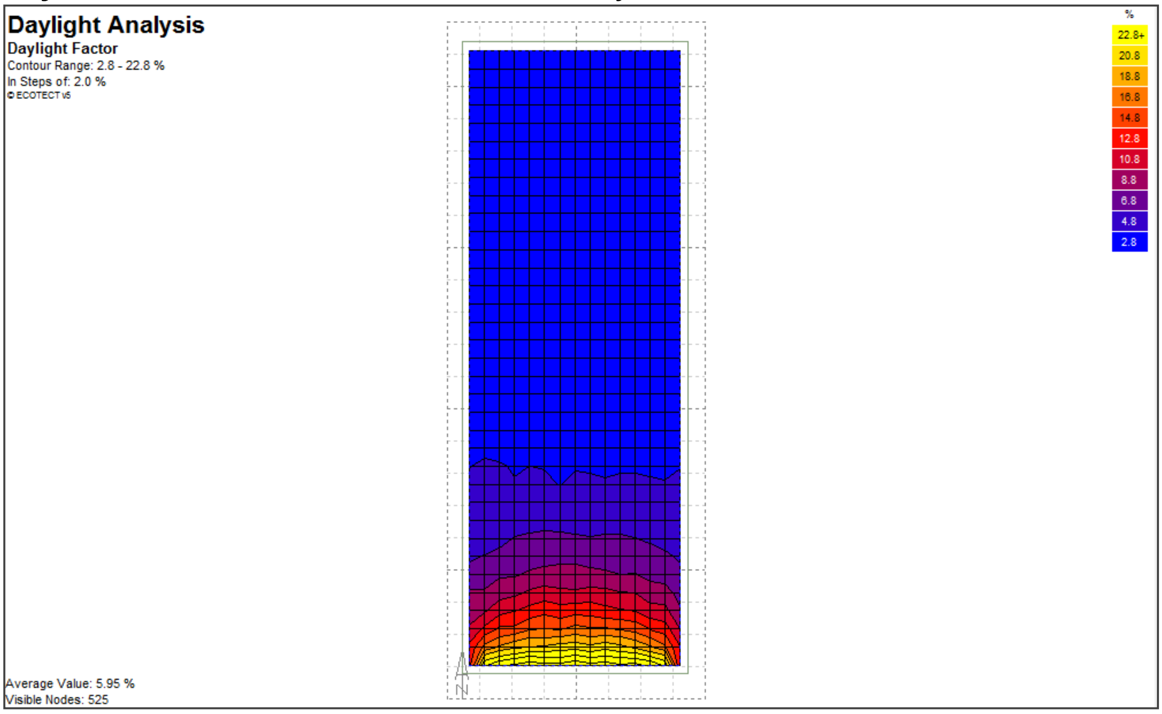


Illustration 165 Daylight Factor in Plan (Gallery/Store) – Without Okalux or Shed

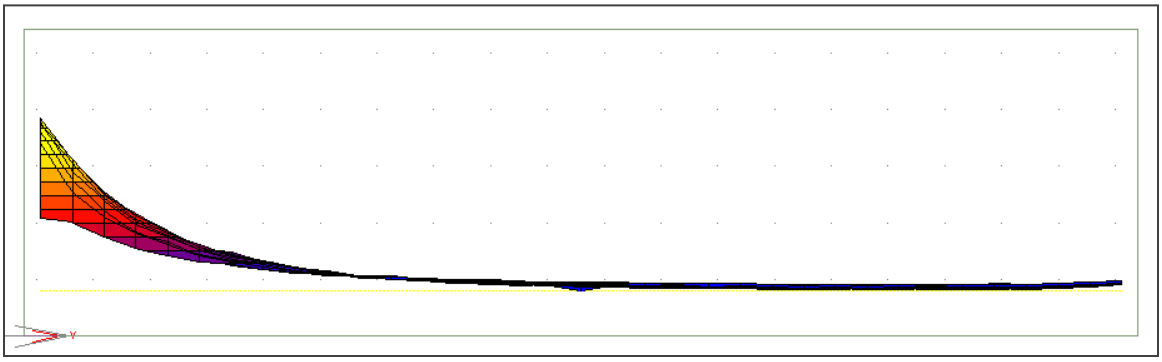


Illustration 166 Daylight Factor in Section (Gallery/Store) – Without Okalux or Shed

AVERAGE VALUE: **5.95%**

VALUES RANGE: **2.8%** (Top Half of Plan) **- 22.8%** (Attached to Window)

5.3.2.2 Daylight Autonomy Case A.

ANALYSIS CONDTION: No Skylights, No Shading
Total Area: 561.680 m2 **Floor Area:** 137.200 m2 **Volume:** 740.878 m3
Sky Conditions: CIE Overcast Sky 8500 Lux
Calculation Value: 500Lux

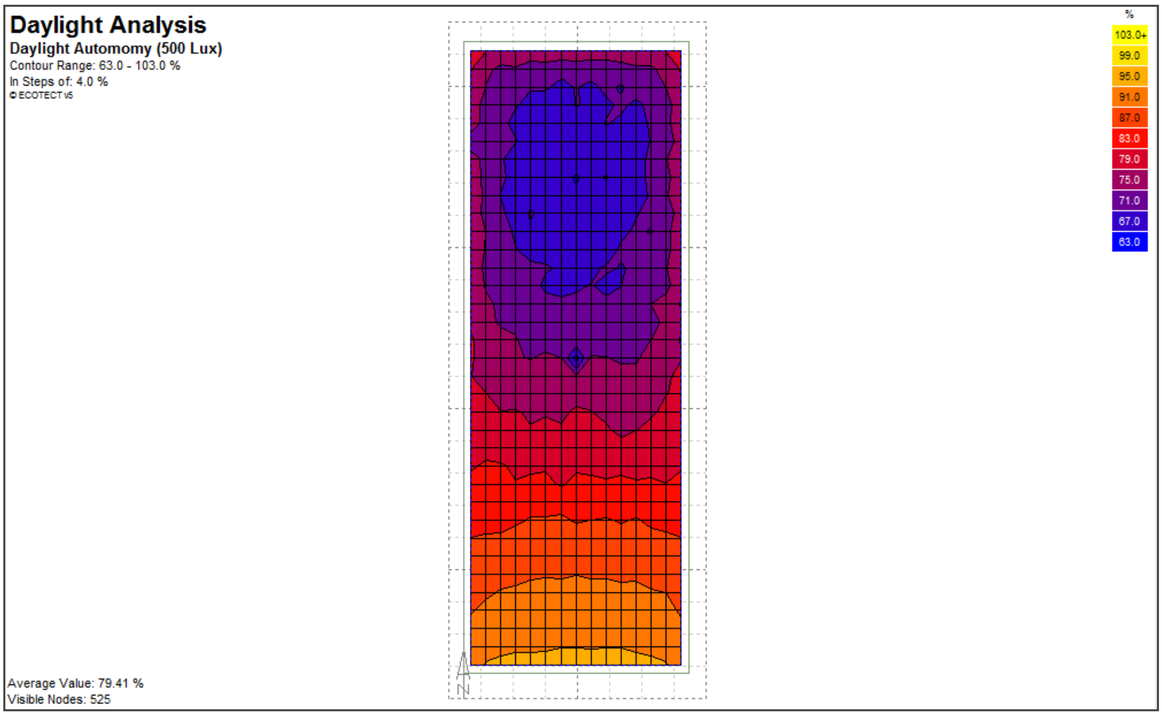


Illustration 167 Daylight Autonomy in Plan (Gallery/Store) – Without Okalux or Shed

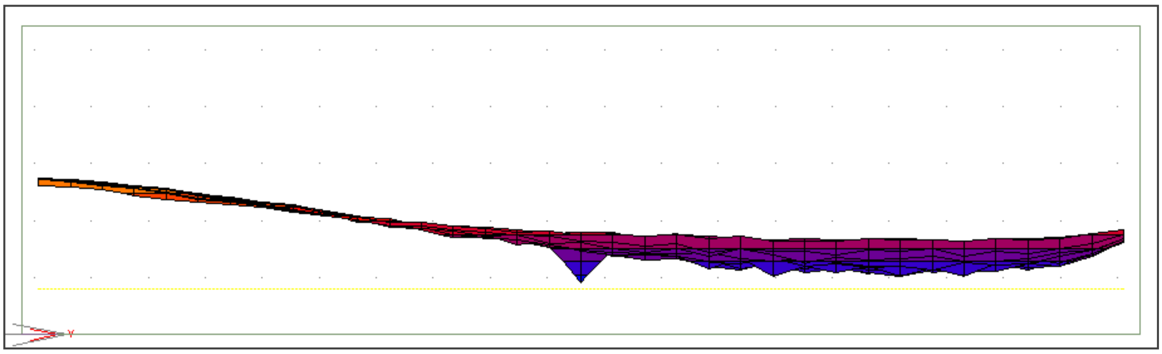


Illustration 168 Daylight Autonomy in Plan (Gallery/Store) – Without Okalux or Shed

AVERAGE VALUE: 79.41%
VALUES RANGE: 63% (Middle of the Top Half) **– 103%** (Attached to Window)

Notices: Having a minimum Daylight Factor of 2.8% is rather low for such a space usage; as well as the light distribution is characterized by major differences in the values, which leads to high levels of glare. Daylight Autonomy is almost 80%, which is a good indicator; however, the minimum value is rather low.

5.3.2.3 Daylight Factor Case B.

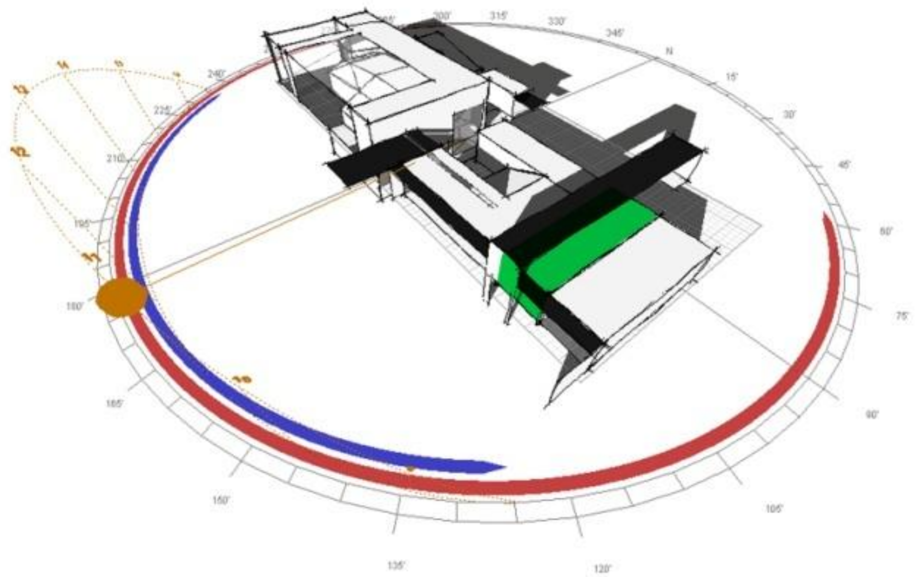


Illustration 169 Highlighted zone (Gallery/Store) in Case B

ANALYSIS CONDTION: With Skylights and Shading
Total Area: 561.680 m2 **Floor Area:** 137.200 m2 **Volume:** 740.878 m3
Sky Conditions: CIE Overcast Sky 8500 Lux

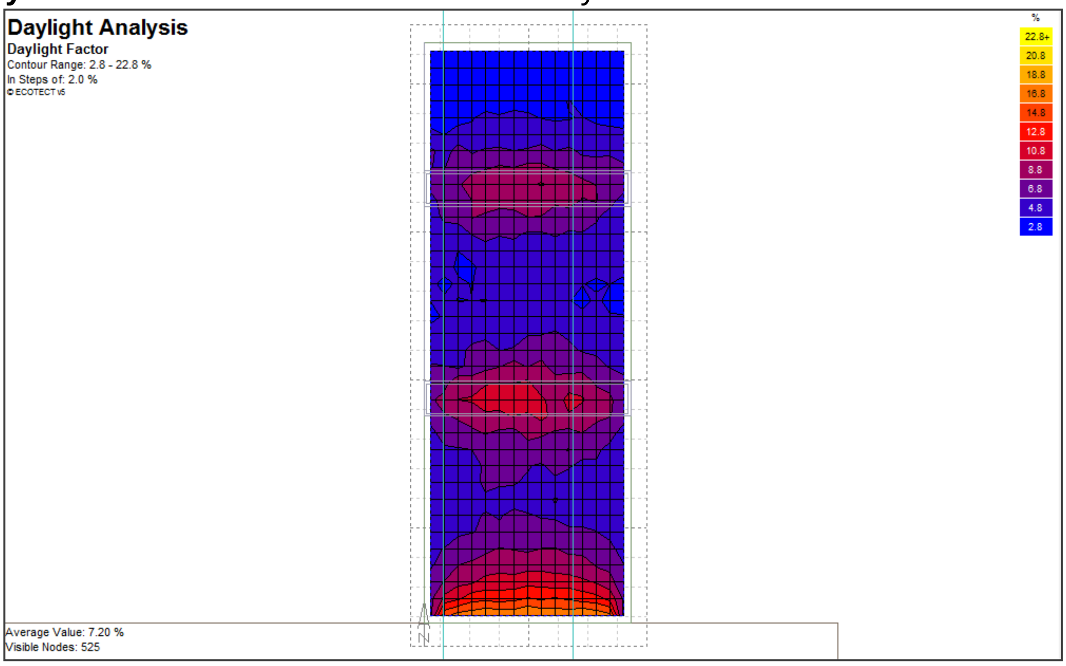


Illustration 170 Daylight Factor in Plan (Gallery/Store) – With Okalux and Shed

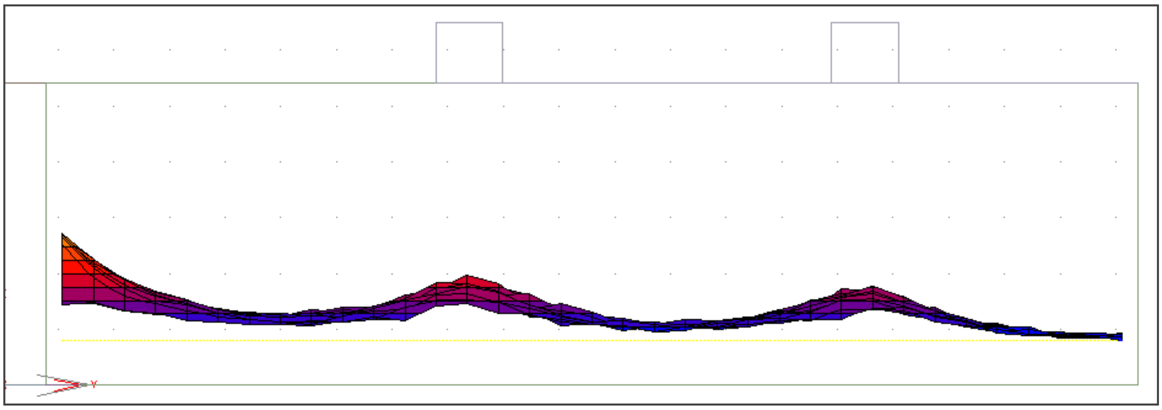


Illustration 171 Daylight Factor in Section (Gallery/Store) – With Okalux and Shed

AVERAGE VALUE: **7.20%**
VALUES RANGE: 3.8% (Above the first skylight) **– 22.8%** (Attached to Window)

5.3.2.4 Daylight Autonomy Case B.

ANALYSIS CONDTION: With Skylights and Shading
Total Area: 561.680 m2 **Floor Area:** 137.200 m2 **Volume:** 740.878 m3
Sky Conditions: CIE Overcast Sky 8500 Lux
Calculation Value: 500Lux

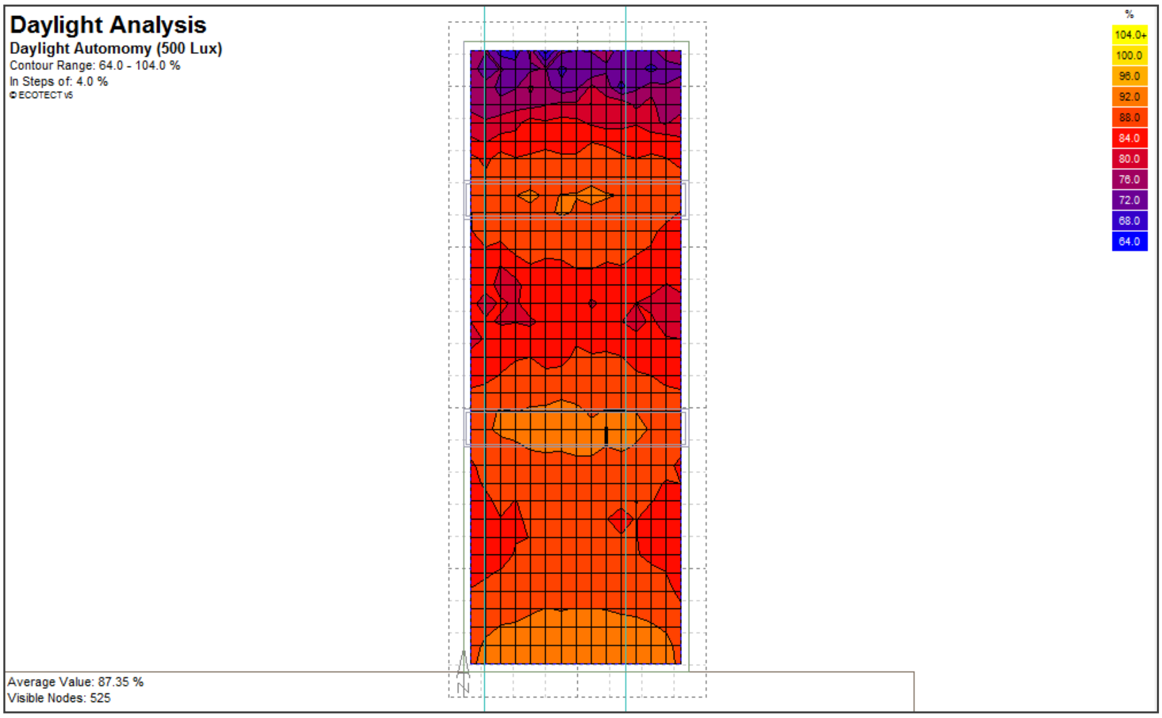


Illustration 172 Daylight Autonomy in Plan (Gallery/Store) – With Okalux and Shed

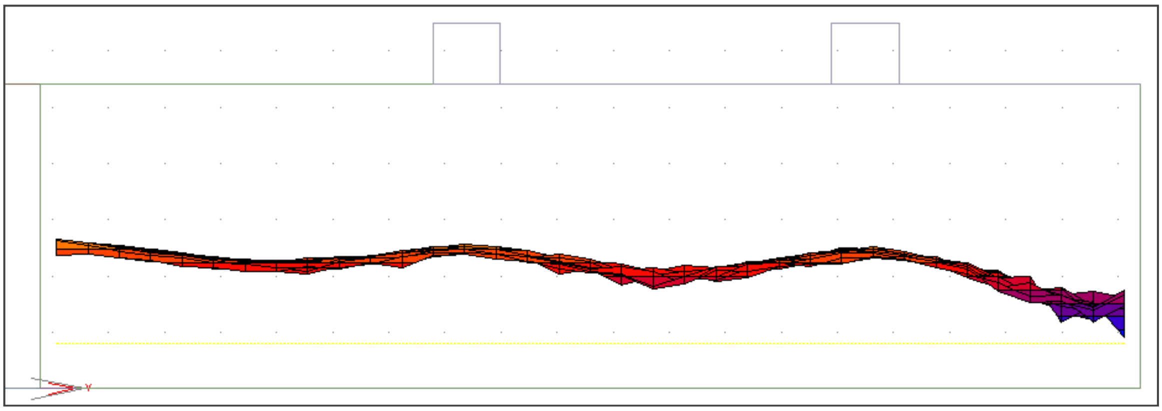


Illustration 173 Daylight Autonomy in Section (Gallery/Store) – With Okalux and Shed

AVERAGE VALUE: 87.35%
VALUES RANGE: 64% (Top of the first skylight) **– 97%** (Attached to Window)

Notices:

The minimum value is higher than that of the alternative with Shed or Okalux system, 3.8% is regarded a bit less than the minimum for a good visibility in this space, however, the average value is quite good. the increase in lighting due to the skylights contributes much in saving energy within the space. Other than that fact, the lighting levels distribution is obviously more coherent. Daylight Autonomy is 87%, which is a good indicator.

5.3.3 ZONE*:* Restaurant

The use of sun protection has been explored through a series of tests which prove their effectiveness. The comparable situation in the simulations is as follows:

- Case (A): Double glazing window system without shielding.
- Case (B): Double glazing window system with a type of screening; which includes a shading plane on top of the window with a depth of 2m, and Okalux glazing system which incorporates aluminum blades within the double glazing, these blades have been chosen with a spacing of 30cm. however, on the western façade, a normal glazing system has been used, since it already incorporates a big shading that covers the whole area (see incident radiation in the next division). The horizontal type of sunscreen is best for meeting needs of natural lighting along the southern side as the sun when it occurs at its maximum efficiency is high in the sky during the summer.

The simulation regarding the lighting survey determines the daylight factor are performed on the restaurant space with a floor area of 245.700 m^2, with a clear height of 5.4me located precisely on the south and west elevation. The reflection coefficients of the walls are 0.753 as well as 0.749 for the ceiling and 0.4 for floors. The glazed area covers an area of 104.04 m^2 for a total height of 5.1m. The glass has a light transmission factor equal to 0.61. The reference planes to read these values are placed lighting at a height of 0.8m covering the whole area of the. The following reduction is assumed that band-pass and turned into space for circulation in depth confining work space.

5.3.3.1 Daylight Factor Case A.

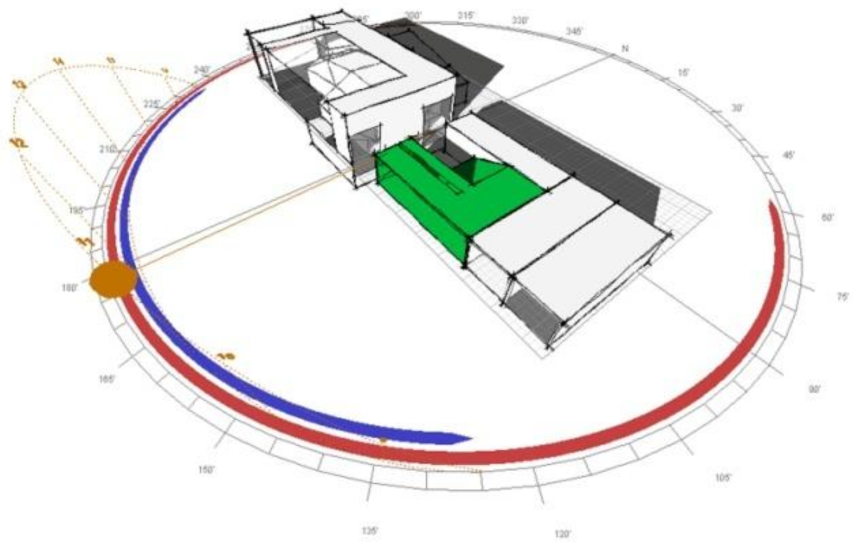


Illustration 174 Highlighted zone (Restaurant) in Case A

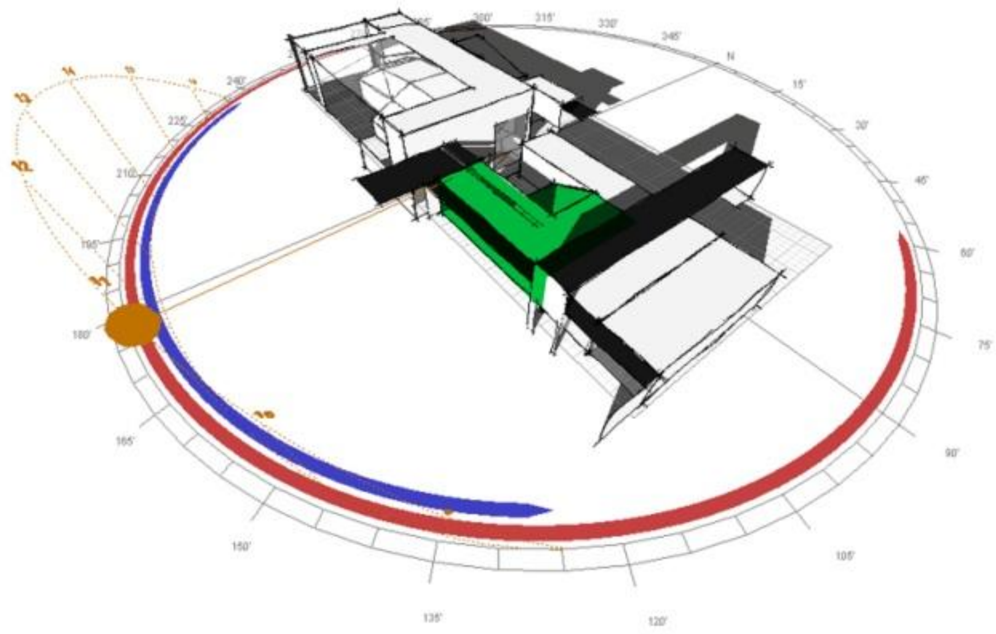


Illustration 175 Highlighted zone (Restaurant) in Case B

ANALYSIS CONDTION: No Skylights, No Shading
Total Area: 712.369 m2 **Floor Area:** 245.700 m2 **Volume:** 1256.346 m3
Sky Conditions: CIE Overcast Sky 8500 Lux

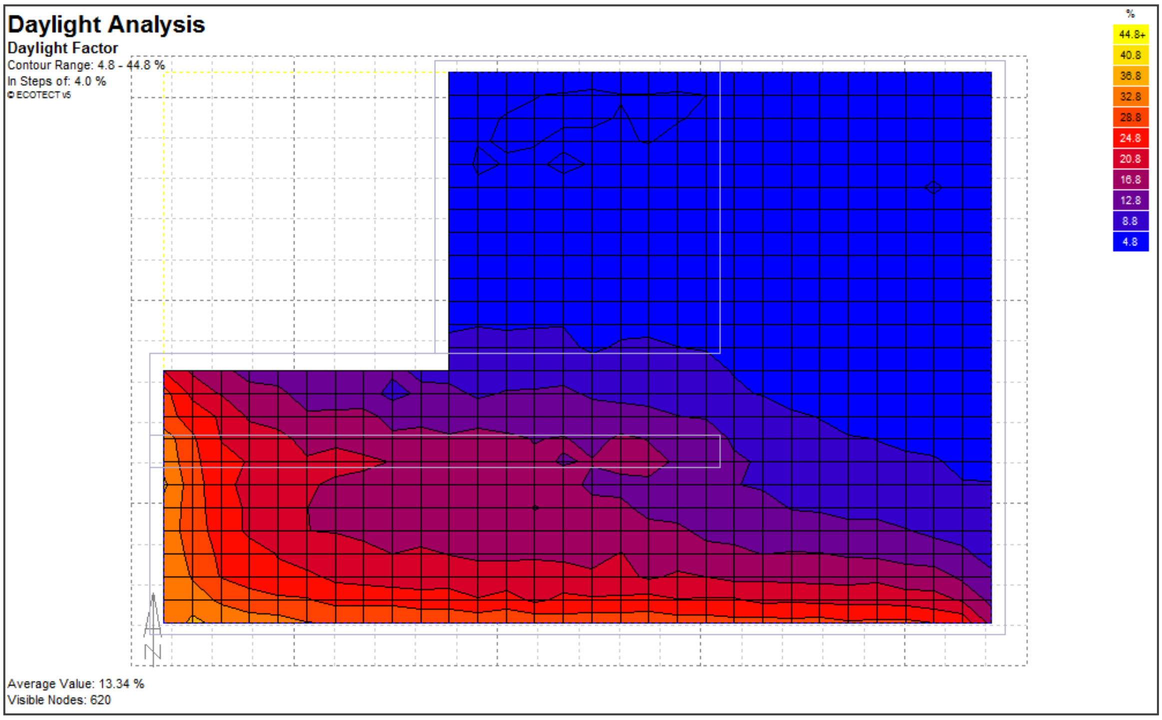


Illustration 176 Daylight Factor in Plan (Restaurant) – Without Okalux or Shed

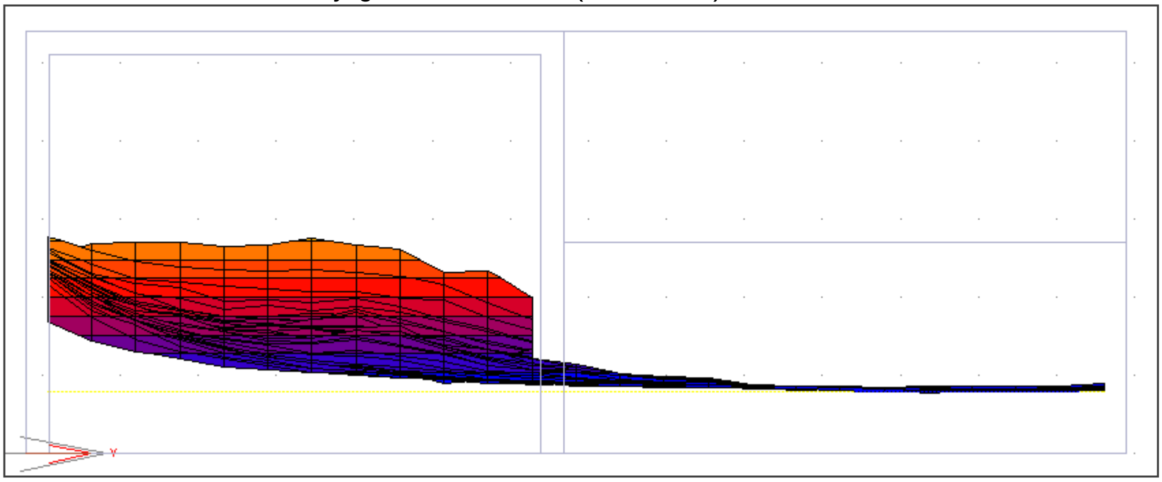


Illustration 177 Daylight Factor in Section (Restaurant) – Without Okalux or Shed

AVERAGE VALUE: 13.34%
VALUES RANGE: 4.8% (Top Right part of Plan) **- 44.8%** (Attached to Windows)

5.3.3.2 Daylight Autonomy Case A.

ANALYSIS CONDTION: No Skylights, No Shading
Total Area: 712.369 m2 **Floor Area:** 245.700 m2 **Volume:** 1256.346 m3
Sky Conditions: CIE Overcast Sky 8500 Lux
Calculation Value: 500Lux

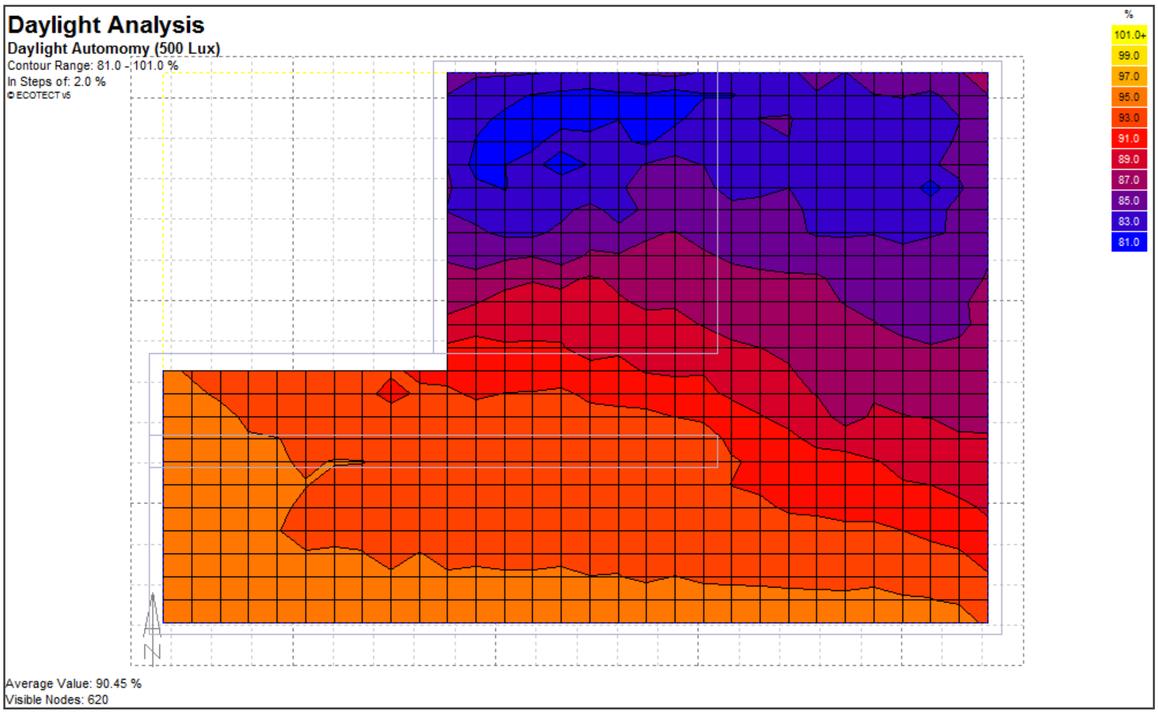


Illustration 178 Daylight Autonomy in Plan (Restaurant) – Without Okalux or Shed

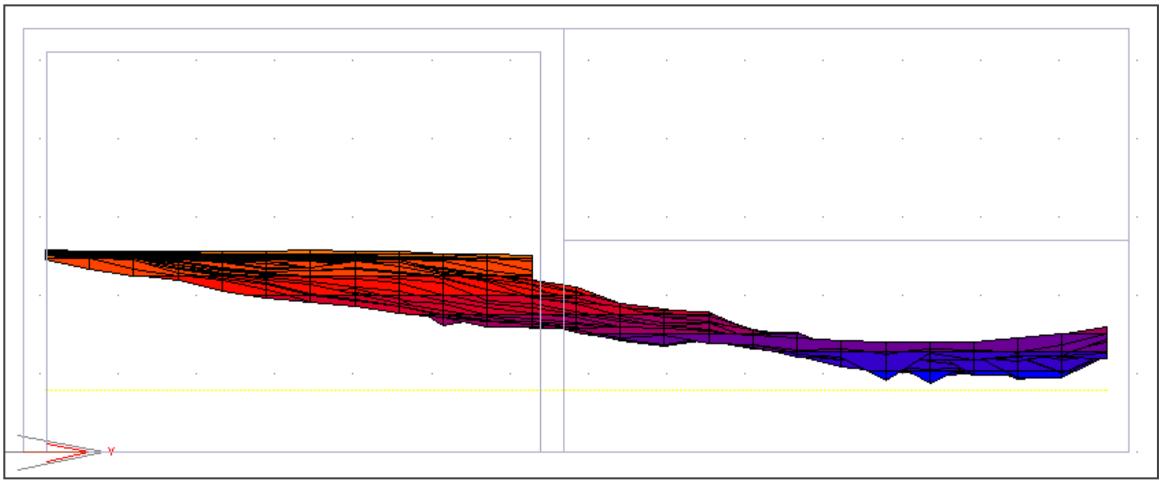


Illustration 179 Daylight Autonomy in Plan (Restaurant) – Without Okalux or Shed

AVERAGE VALUE: 90.45%
VALUES RANGE: 81% (Top Right part of Plan) **– 97%** (Attached to Window)

Notices: Having a minimum Daylight Factor of 4.8% is quite good for such a space usage; as for the light distribution, it is characterized by major differences in the values, which leads to high levels of glare. Daylight Autonomy is almost 90%, which is a good indicator.

5.3.3.3 Daylight Factor Case B.

ANALYSIS CONDTION: With Skylights and Shading
Total Area: 712.369 m2 **Floor Area:** 245.700 m2 **Volume:** 1256.346 m3
Sky Conditions: CIE Overcast Sky 8500 Lux

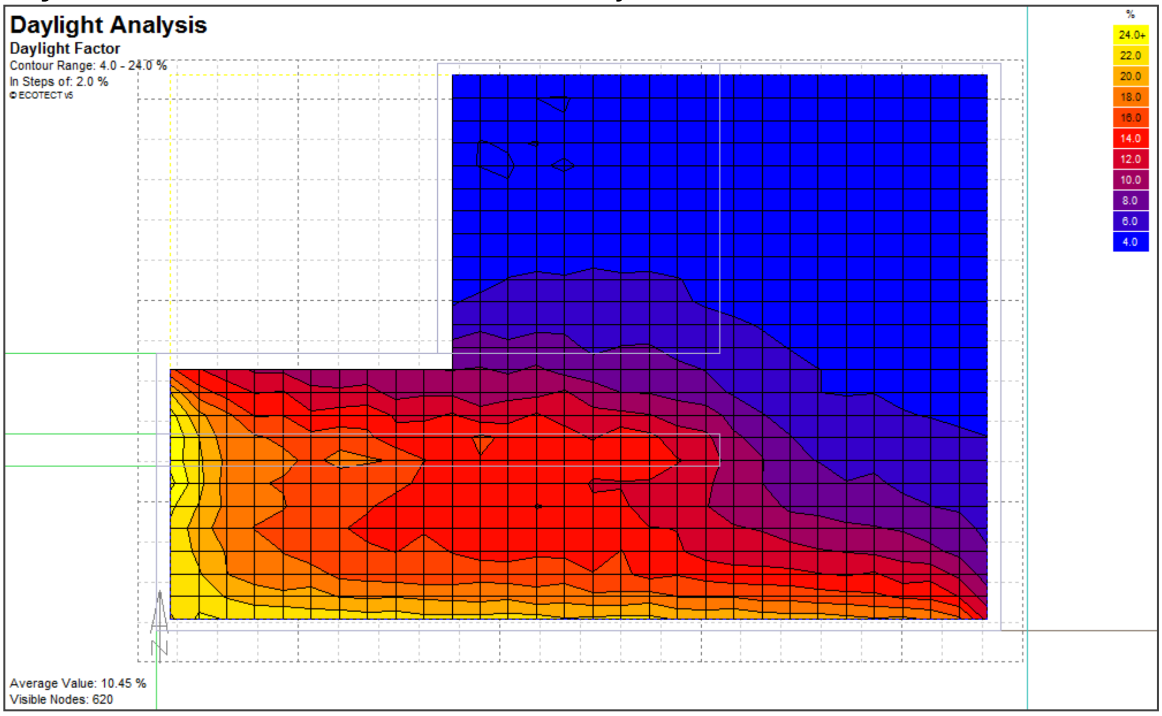


Illustration 180 Daylight Factor in Plan (Restaurant) – With Okalux and Shed

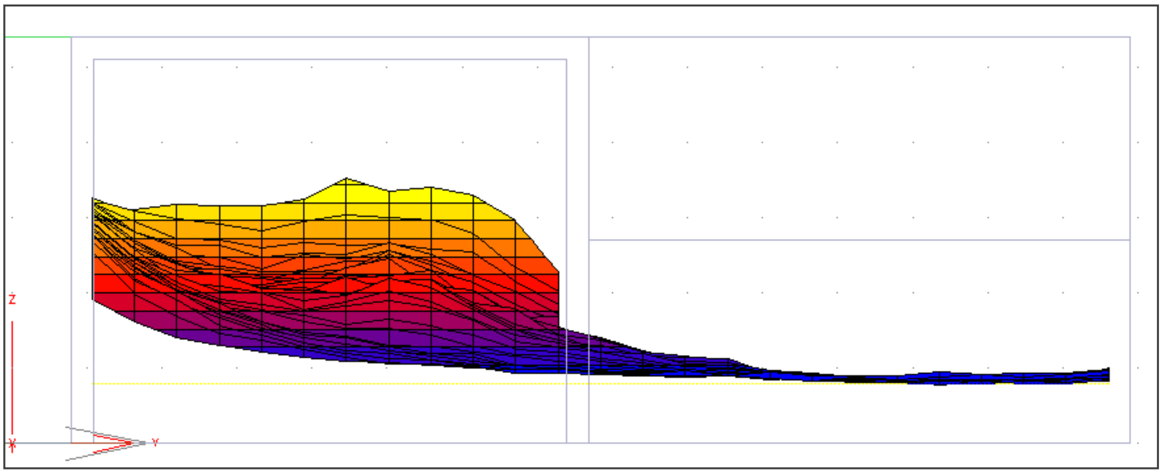


Illustration 181 Daylight Factor in Section (Restaurant) – With Okalux and Shed

AVERAGE VALUE: 10.45%
VALUES RANGE: 4% (Top Right part of Plan) **– 24%** (Attached to Windows)

5.3.3.4 Daylight Autonomy Case B.

ANALYSIS CONDTION: With Skylights and Shading
Total Area: 712.369 m2 **Floor Area:** 245.700 m2 **Volume:** 1256.346 m3
Sky Conditions: CIE Overcast Sky 8500 Lux **Calculation**
Calculation Value: 500Lux

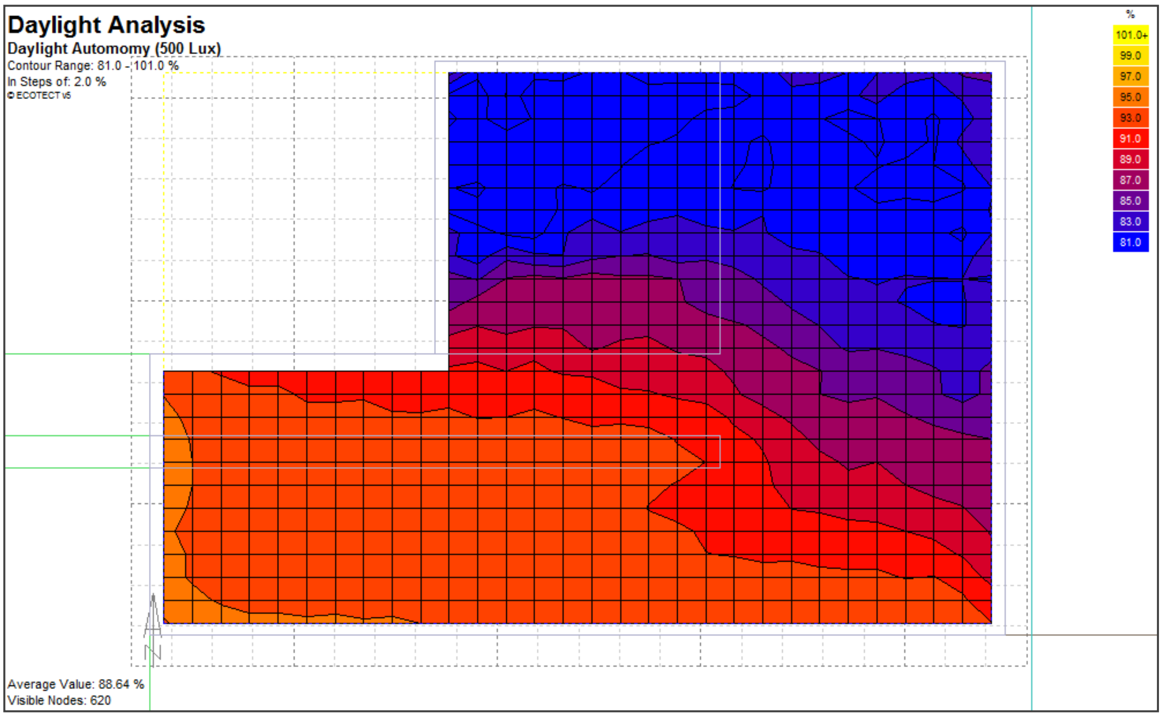


Illustration 182 Daylight Autonomy in Plan (Restaurant) – With Okalux and Shed

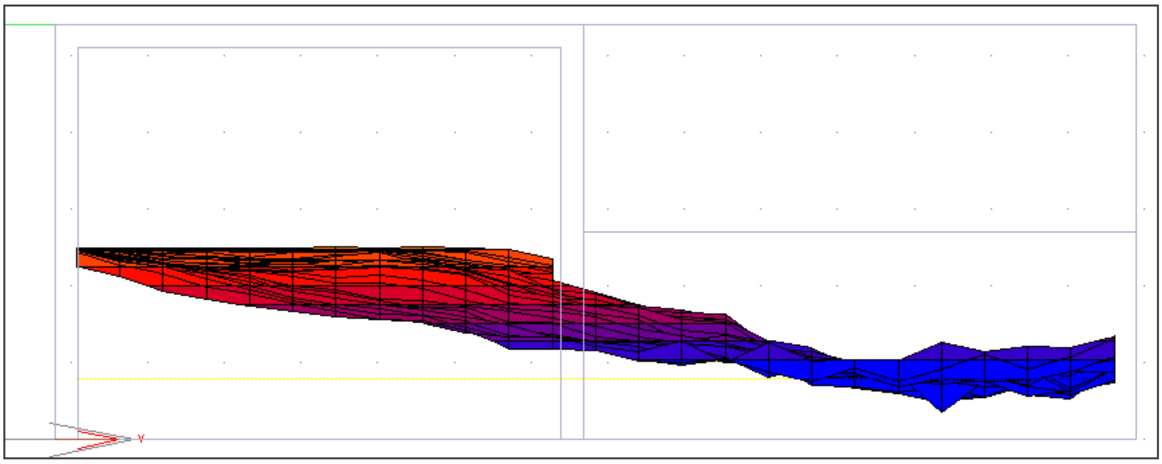


Illustration 183 Daylight Autonomy in Section (Restaurant) – With Okalux and Shed

AVERAGE VALUE: 88.64%
VALUES RANGE: 78% (Top Right part of Plan) **– 97%** (Attached to Windows)

Notices:

The minimum is higher than that of this alternative 4% is regarded the minimum for a good visibility in this space, however, the average DF value is quite good. The lighting levels distribution is obviously more coherent. Daylight Autonomy is 89%, which is a good indicator.

5.3.4 ZONE: TRANSITIONAL ZONE

The values used in the test are extracted from the manufacturers' information. The situation in the simulations is as follows:

- Case (A): 3-layer ETFE cushions. The system allows for a change in the shading due to the air pressure. This can be useful to acquire more shade in the summer to reduce the heat gains, and vice versa in the winter.

The ETFE system include panels with dimensions of 3mx25m, 3mx9m, and 3mx6m… the fixed 3m width of the panels is intentionally the same in order to have an effective depth to thermal behavior ratio.

The simulation regarding the lighting survey determines the daylight factor are performed on the transitional zone with a floor area of 61.346 m^2, with a clear height of 9m from zero level, and 14m from basement, located precisely on the south and west elevation. The reflection coefficients of the walls are 0.753 as well as 0.749 for the ceiling and 0.4 for floors. The glazed area covers an area of 891.945 m^2 for a total height of 8.7m from zero level. The glass has a light transmission factor equal to 0.8. The reference planes to read these values are placed lighting at a height of 0.8m covering the whole area of the. The following reduction is assumed that band-pass and turned into space for circulation in depth confining work space.

5.3.4.1 Daylight Factor Case A

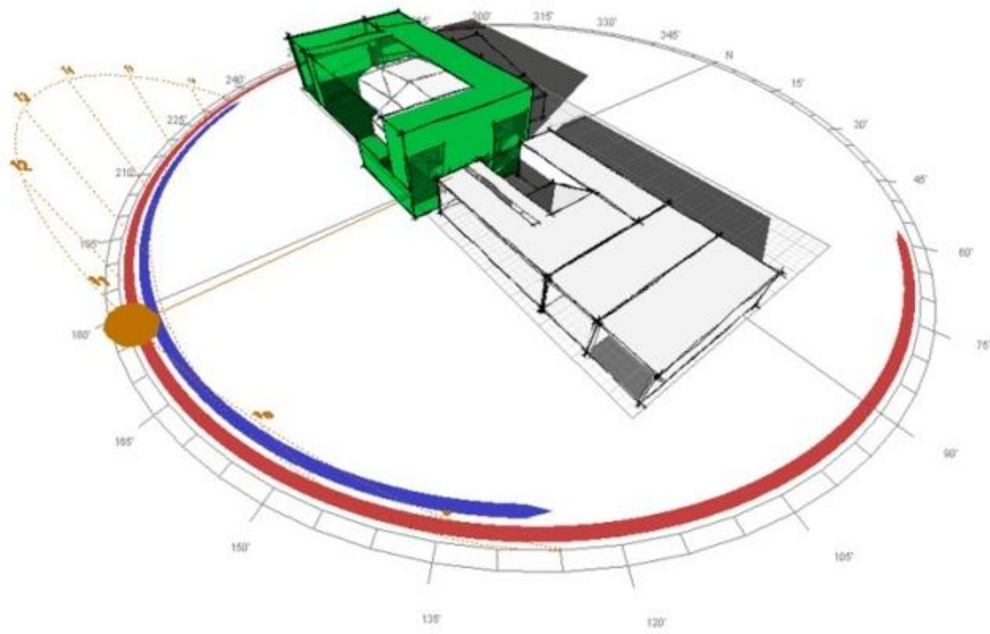


Illustration 184 Highlighted zone (Transitional zone) in Case A

ANALYSIS CONDTION: With Skylights and Shading
Total Area: 3023.601 m2 **Floor Area:** 633.412 m2 **Volume:** 9110.485 m3
Sky Conditions: CIE Overcast Sky 8500 Lux

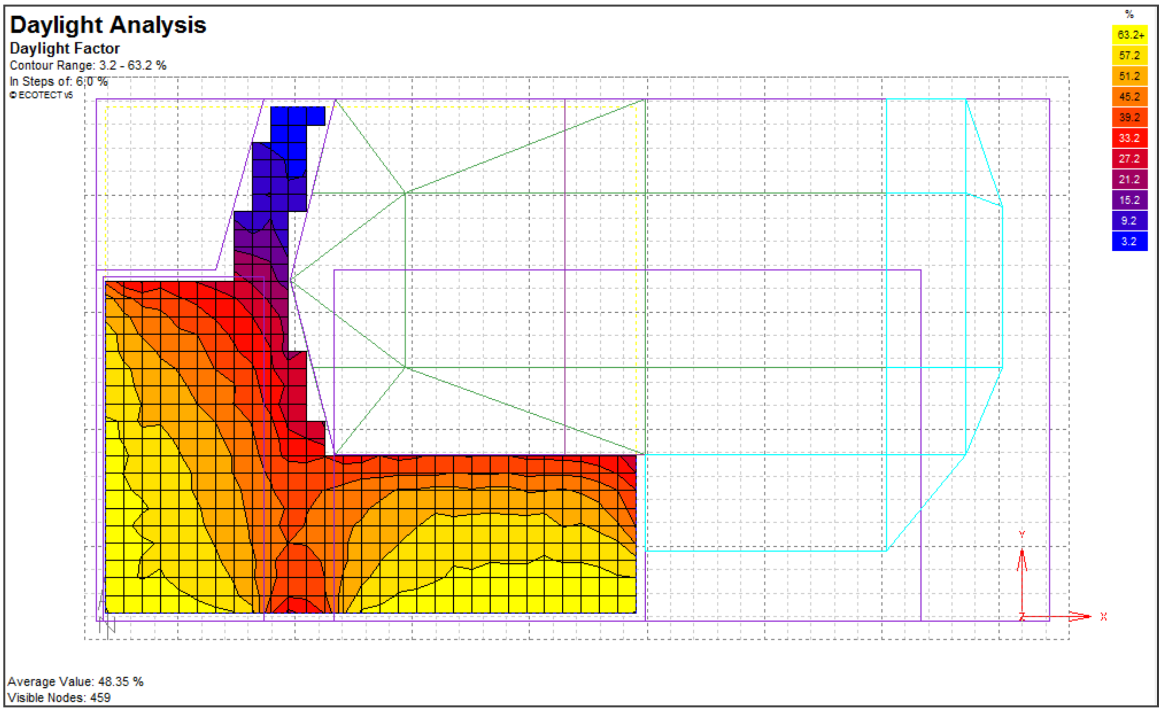


Illustration 185 Daylight Factor in Plan (T.Z.(A)) – With ETFE

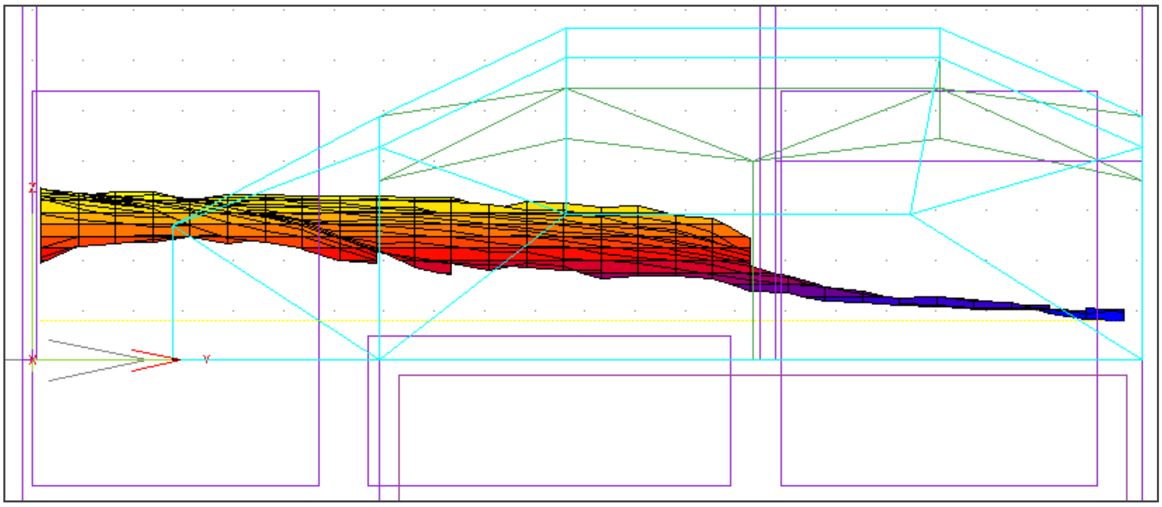


Illustration 186 Daylight Factor in Section (T.Z.(A)) – With ETFE

AVERAGE VALUE: 48.35%
VALUES RANGE: 6.9% (Top of Plan) **– 67%** (Attached to Windows)

5.3.4.2 Daylight Autonomy Case A

ANALYSIS CONDTION: With Skylights and Shading
Total Area: 3023.601 m2 **Floor Area:** 633.412 m2 **Volume:** 9110.485 m3
Sky Conditions: CIE Overcast Sky 8500 Lux
Calculation Value: 500Lux

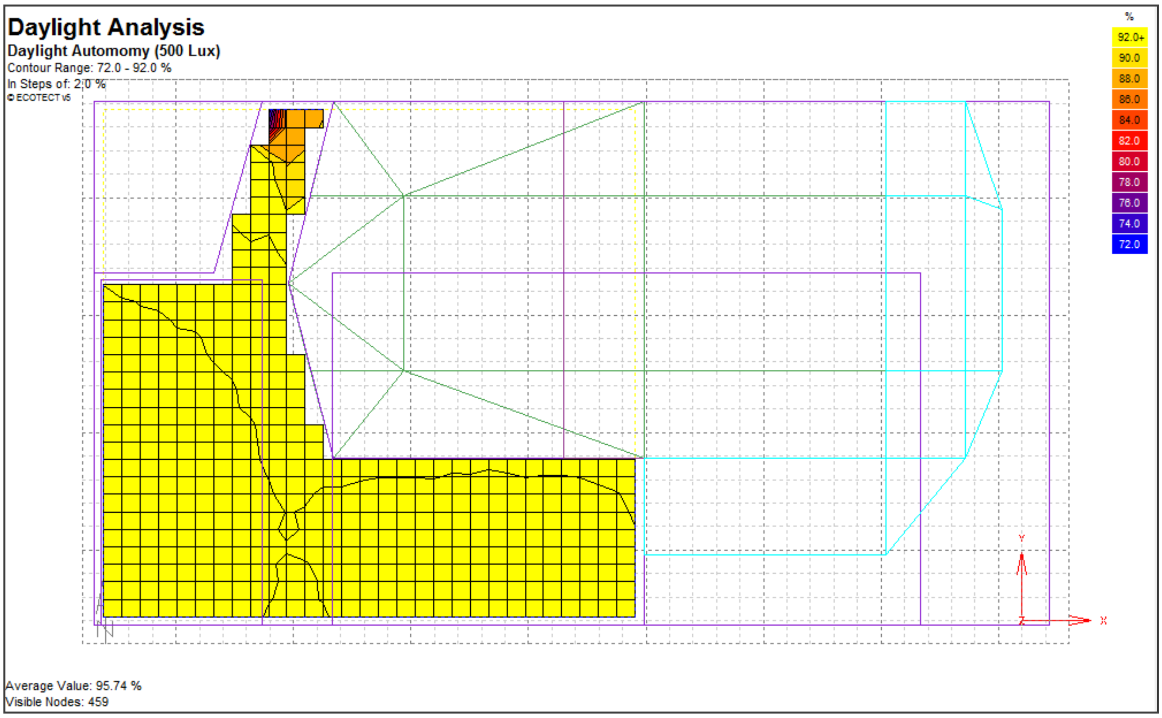


Illustration 187 Daylight Autonomy in Plan (T.Z.(A)) – With ETFE

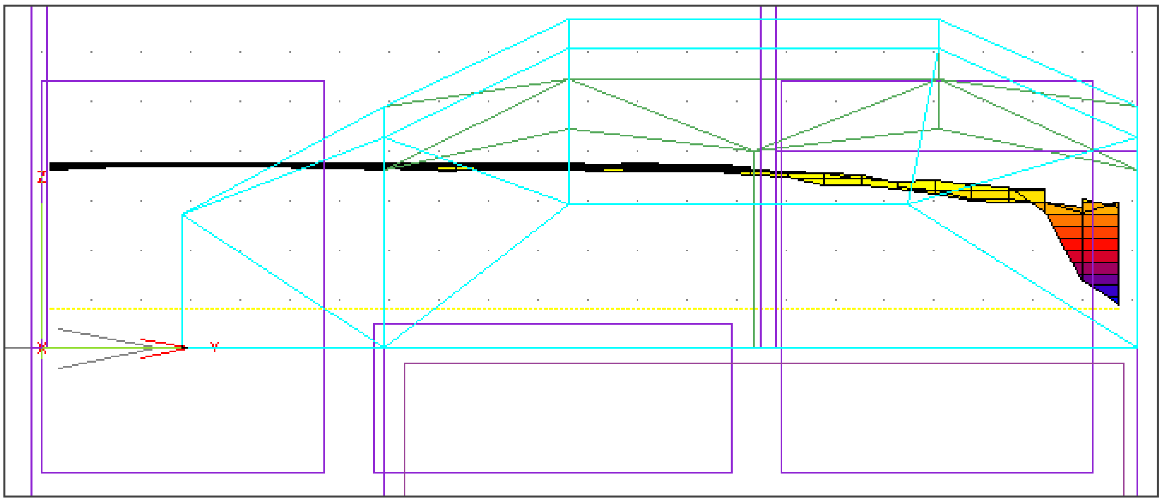


Illustration 188 Daylight Autonomy in Section (T.Z.(A)) – With ETFE

AVERAGE VALUE: 95.74%
VALUES RANGE: 72% (Top of Plan) **– 92%** (Attached to Windows)

Notices: In this space, on the zero level, with a clear height of 9m; daylight factor minimum value is 6.9% which is good. The average DF value is very good for such a space usage, on the bright days; the ETFE air pressure mechanism can change the shading value to reach better results.

5.3.4.3 Daylight Factor Case B

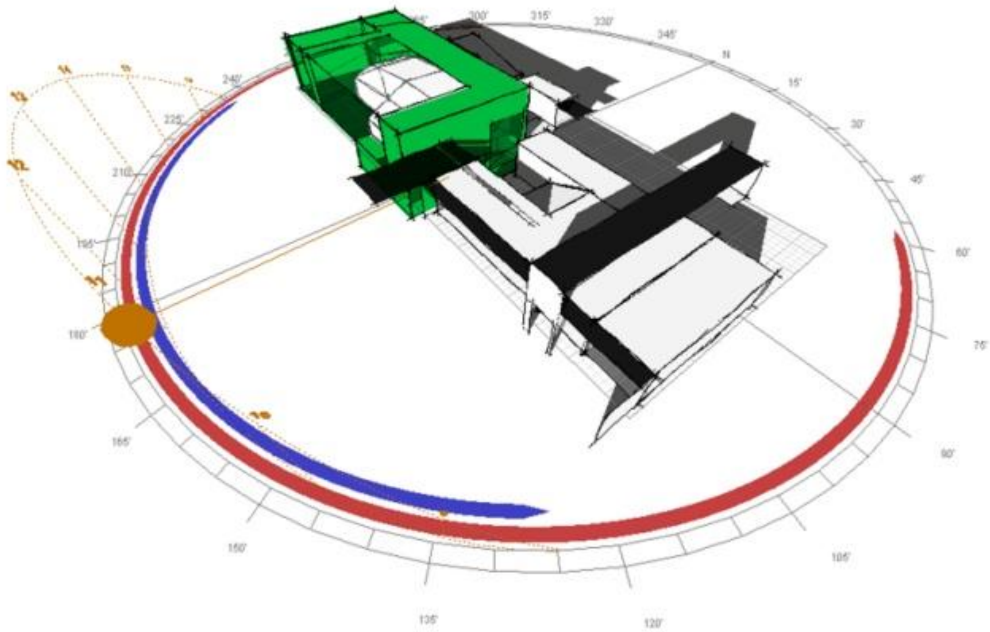


Illustration 189 Highlighted zone (Transitional zone) in Case B

ANALYSIS CONDTION: With Skylights and Shading
Total Area: 3023.601 m2 **Floor Area:** 633.412 m2 **Volume:** 9110.485 m3
Sky Conditions: CIE Overcast Sky 8500 Lux

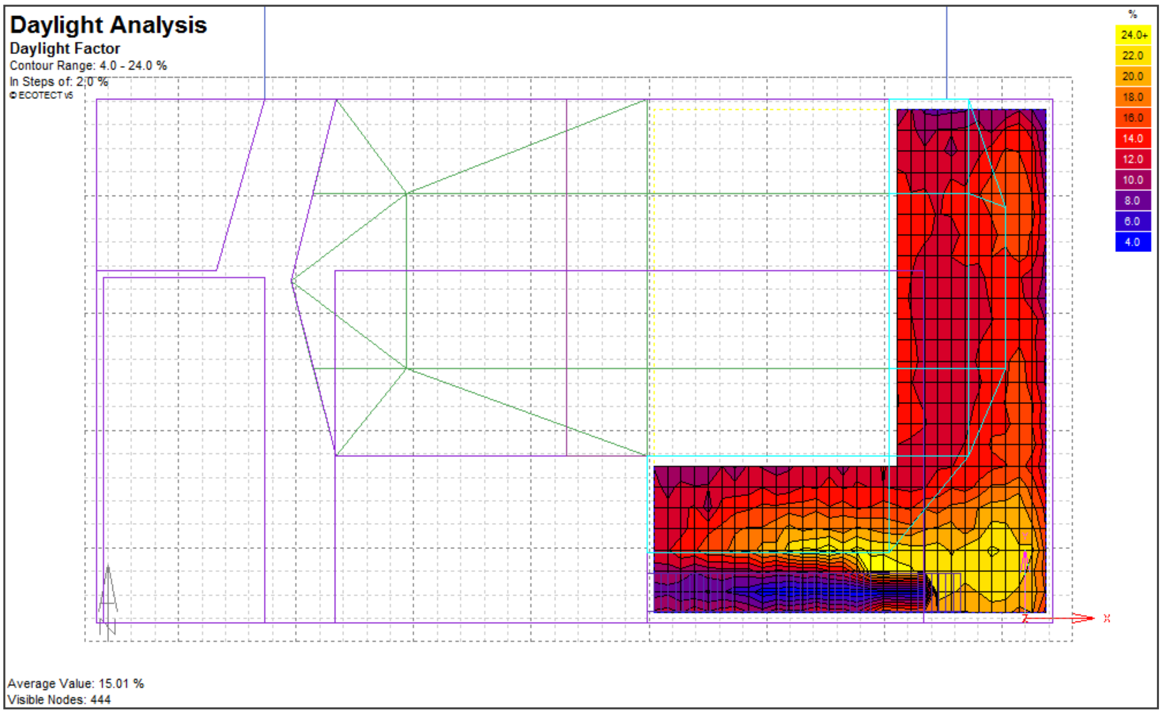


Illustration 190 Daylight Factor in Plan (T.Z.(B)) – With ETFE

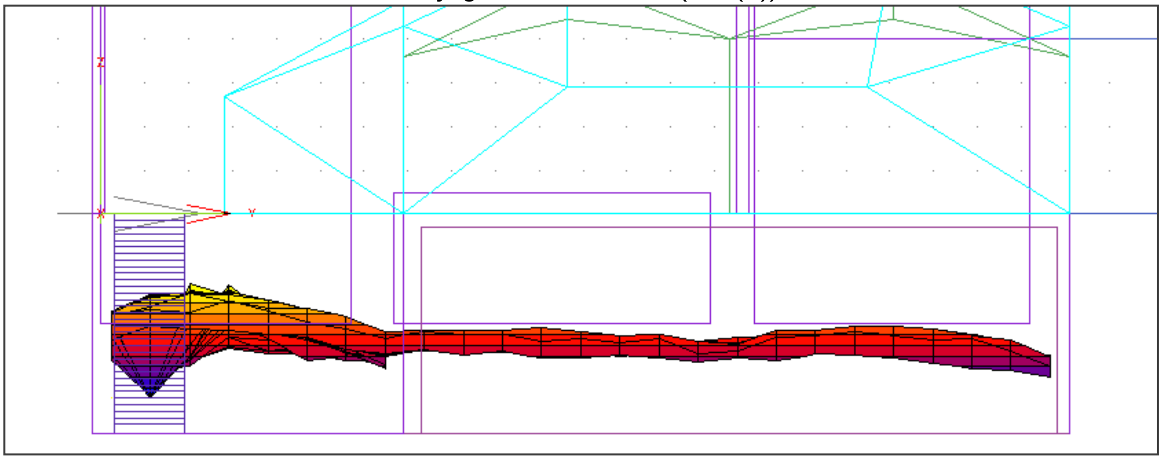


Illustration 191 Daylight Factor in Section (T.Z.(B)) – With ETFE

AVERAGE VALUE: **15.01%**
VALUES RANGE: **7%** (Under the stairs) **– 25%** (Close to Windows)

5.3.4.4 Daylight Autonomy Case B

ANALYSIS CONDTION: With Skylights and Shading
Total Area: 3023.601 m2 **Floor Area:** 633.412 m2 **Volume:** 9110.485 m3
Sky Conditions: CIE Overcast Sky 8500 Lux
Calculation Value: 500Lux

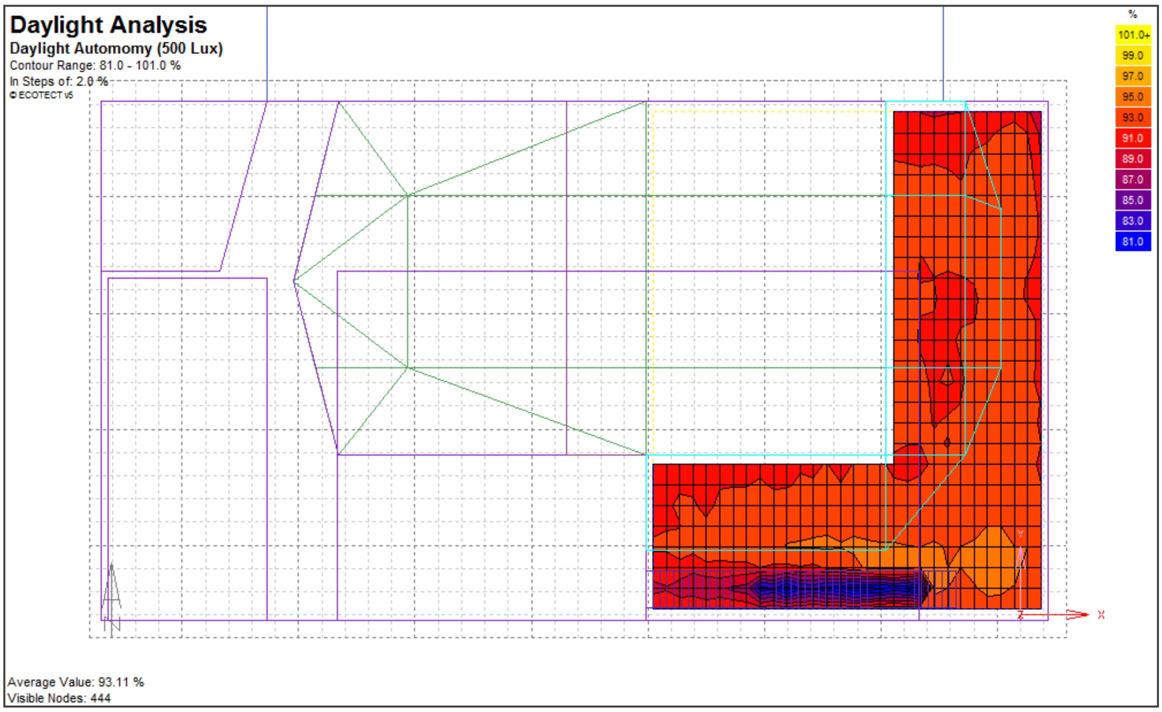


Illustration 192 Daylight Factor in Plan (T.Z.(B)) – With ETFE

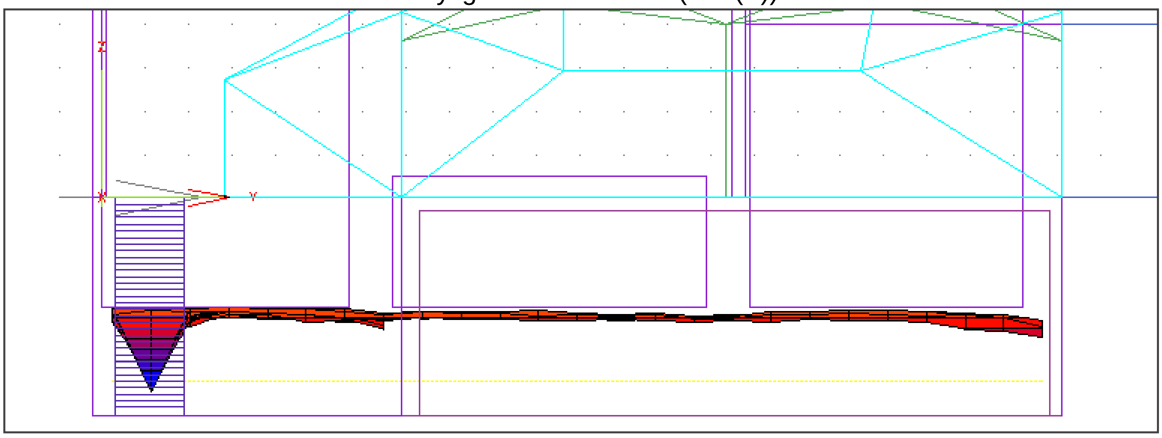


Illustration 193 Daylight Autonomy in Section (T.Z.(B)) – With ETFE

AVERAGE VALUE: **93.11%**
VALUES RANGE: 79% (Under the stairs) **– 95%** (Close to Windows)

Notices: In this space, on a level of 5m under zero level, with a clear height of 14m; daylight factor minimum value is 7% which is good. The average DF value is acceptable. The lighting levels distribution is coherent. Daylight Autonomy is 93%, which is a very good indicator.

5.3.5 ZONE: EXHIBITION HALL

5.3.5.1 Daylight Factor Case A

ANALYSIS CONDTION: With Skylights and Shading
Total Area: 692.220 m2 **Floor Area:** 207.810 m2 **Volume:** 1039.043 m3
Sky Conditions: CIE Overcast Sky 8500 Lux

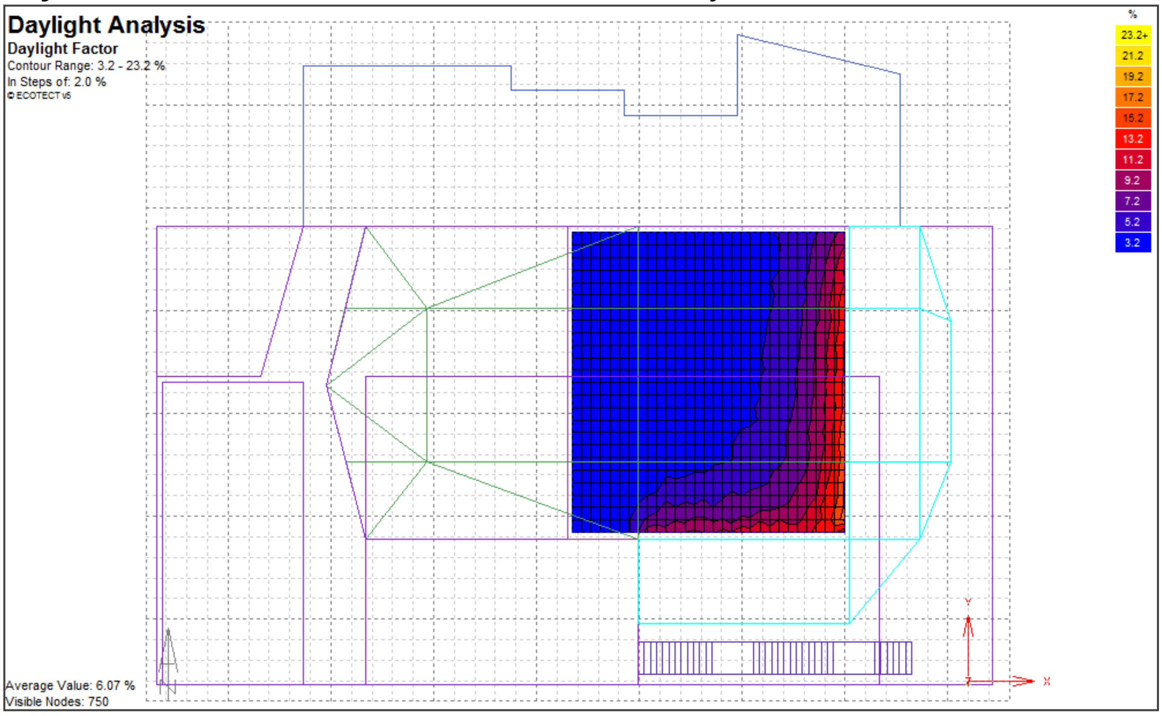


Illustration 194 Daylight Factor in Plan (Exhibition)

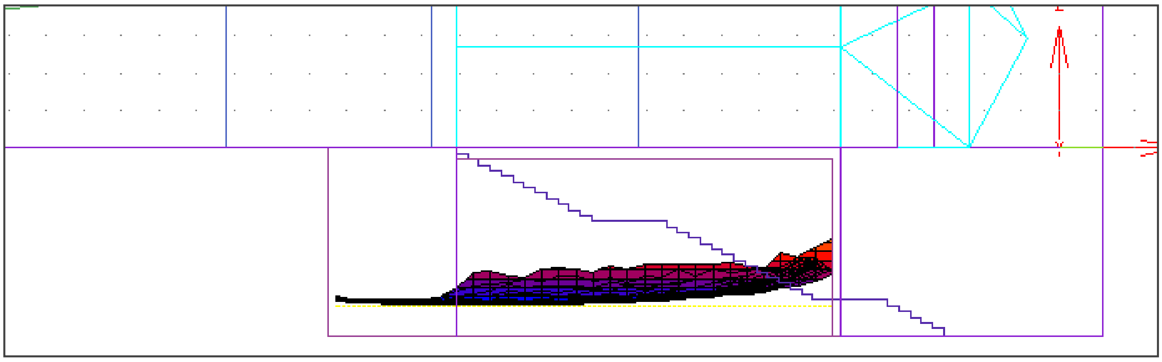


Illustration 195 Daylight Factor in Section (Exhibition)

AVERAGE VALUE: **6.07%**
VALUES RANGE: **3.8%** (Upper left part of Plan) **– 20.63%** (Close to Windows)

5.3.5.2 Daylight Autonomy Case A

ANALYSIS CONDTION: With Skylights and Shading
Total Area: 692.220 m2 **Floor Area:** 207.810 m2 **Volume:** 1039.043 m3
Sky Conditions: CIE Overcast Sky 8500 Lux
Calculation Value: 500Lux

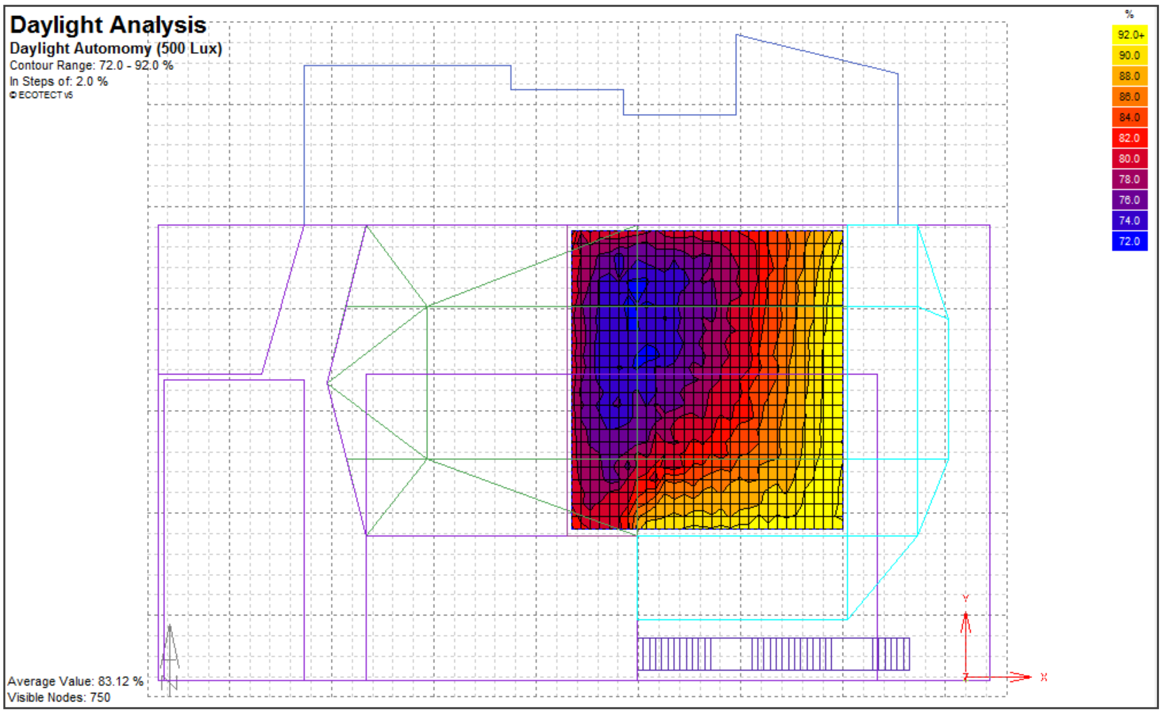


Illustration 196 Daylight Factor in Plan (Exhibition)

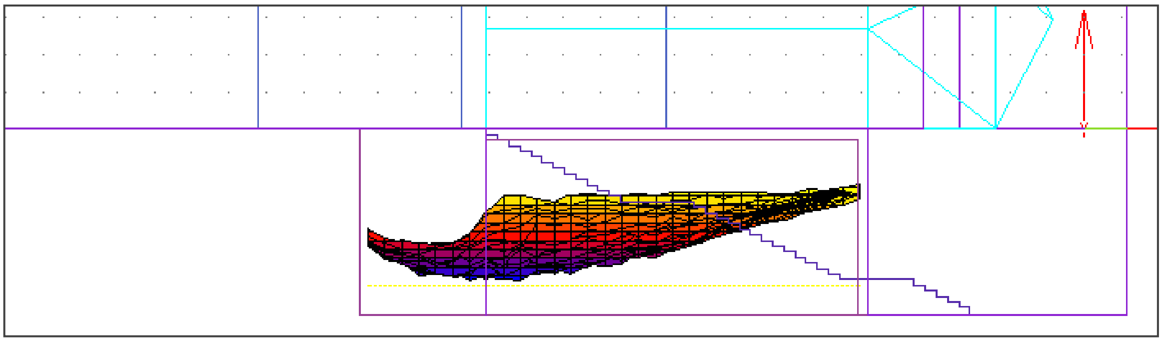


Illustration 197 Daylight Autonomy in Section (Exhibition)

AVERAGE VALUE: **83.12%**
VALUES RANGE: **72%** (Upper left part of Plan) **– 92%** (Close to Windows)

Notices:
In this space, on a level of 5m under zero level, with a clear height of 4m; it's clear that in order to have a clear vision, an adequate amount of artificial lighting needs to be installed, not only for the fact that the minimum daylight factor value

is 3.8% (which is lower than the minimum preferable value, but also due to the function. The average DF value is acceptable. The lighting levels distribution is coherent. Daylight Autonomy is 83%, which is a good indicator.

CONCLUSION

As we can see from these graphs, the interior of the inner parts of the bar and gallery is trend to present high opacity and although it has a minimum of 4% which is considered sufficient as a minimum value for such an use, outside of a one which requires lighting for activities that involve concentration, such as in a school.

The restaurant on the other hand presents fairly homogeneous lighting values, a factor which increases the sense of comfort within the space. The Theater use determines the fact that natural lighting will not be of importance.

The rectangular lines visible in the graphs represent the roof skylights above the bar, gallery and restaurent, which increase the lighting levels within the spaces, their contribution is specifically important in the deep parts of these spaces.
As for the layout of the furniture, obviously it will affect the distribution of light in different areas, important to avoid creating shade; it was decided to use the model Okalux RETRO which is an insulating glass which contains specially shaped reflective blades in the cavity perpendicular to the direction of the glazed surface; that allows sunlight to guarantee better illumination and penetration of the light to the interior of the building.

5.4 SOLAR EXPOSURE ANALYSIS (Incident Solar Radiation)

Incident solar radiation, also termed “insolation”, refers to the wide spectrum radiant energy from the Sun which strikes an object or surface within the building. This includes both a *direct* component from the Sun itself (sunshine) and a *diffuse* component from the visible sky (skylight).

The direct component (E_{direct}) is given as a value in W/m² and is measured on a surface directly facing the Sun. As the Sun moves through the sky, this measurement surface tracks it so that the direction of incident radiation is always normal (straight on) to it.

The diffuse component ($E_{diffuse}$) is also given in W/m² and is taken as the energy available from the entire sky dome, minus the direct radiation value, as measured on a flat horizontal surface. Once this value is known, it can be moderated by the tilt angle of each surface in the model. For example a vertical surface, no matter which way it faces, will only ever see at best one half of the sky dome - meaning that will only ever receive half of the available diffuse component. A horizontal surface that faces upwards, however, it will see it all.

It is important to note that “insolation” refers only to the amount of energy actually falling on a surface, which is not affected in any way by the surface properties of materials or by any internal refractive effects. Material properties only affect the amount of solar radiation absorbed and/or transmitted by a surface, which are idle in this case.

Insolation ($E_{incident}$) is therefore affected only by the angle of incidence of the radiation (A), the fraction of the surface currently in shadow from other surrounding geometry (F_{shad}), the fraction of the diffuse sky actually visible from the surface (F_{sky}) and, if a surface is partially adjacent to another zone, the area of surface actually exposed to solar radiation (*ExposedArea*). These factors affect the beam normal (E_{beam}) and diffuse sky ($E_{diffuse}$) radiation differently, such that:

$$E_{incident} = [(E_{beam} \text{ x } \cos(A) \text{ x Fshad}) + (E_{diffuse} \text{ x } F_{sky})] \text{ x ExposedArea}$$

5.4.1 South Elevation

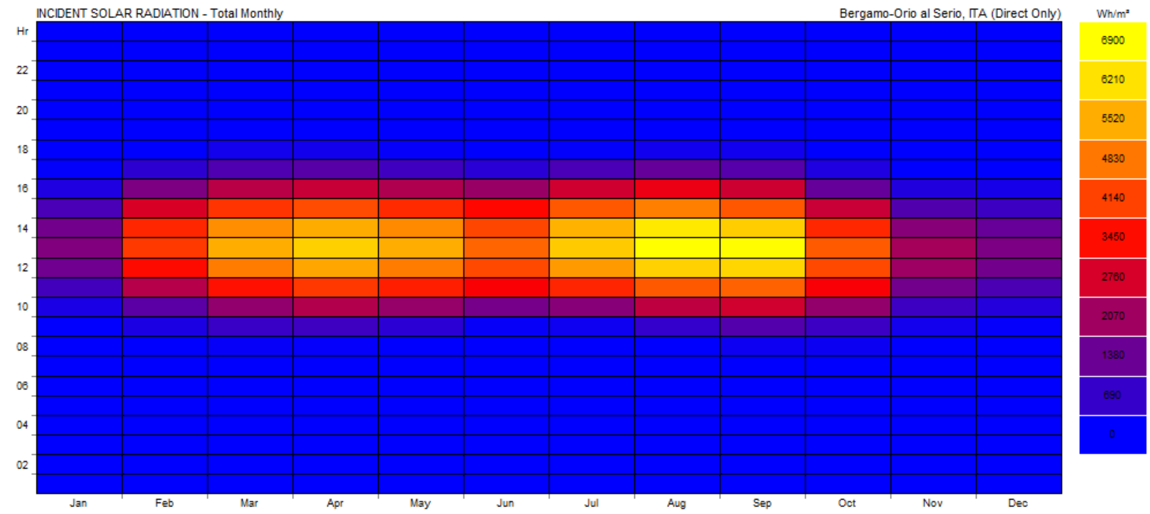


Illustration 198 Total Monthly Solar Exposure – SOUTH ELEV – Without Okalux or Shed

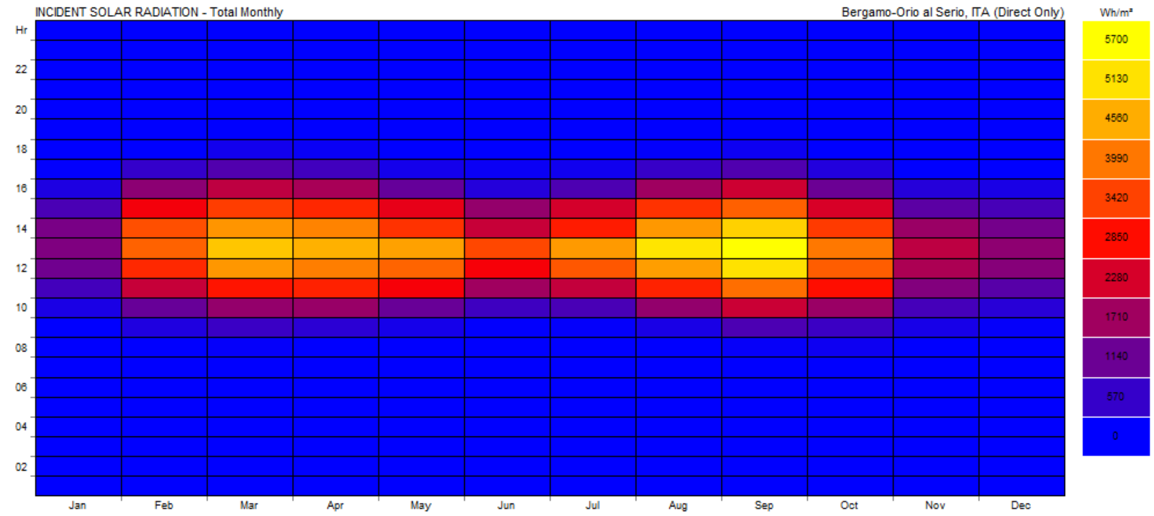


Illustration 199 Total Monthly Solar Exposure – SOUTH ELEV – With Okalux

TOTAL MONTHLY SOLAR EXPOSURE								
Location:	Site: Calco, Italy Time Zone: +1.0hrs							
Position:	Longitude: 9.7 ° Latitude: 45.7 ° Altitude: 238 m							
Surface area:	169.320 m2							
MONTH	AVAILABLE SOLAR RADIATION	WITHOUT OKALUX			WITH OKALUX			SHADING CONTRIBUTION DUE TO OKALUX GLAZING
		AVERAGE SHADE	INCIDENT SOLAR RADIATION		AVERAGE SHADE	INCIDENT SOLAR RADIATION		
	kWh/m2		kWh/m2	TOT. MWh		kWh/m2	TOT. MWh	
Jan	8,57	0%	7,21	1,22	7%	6,73	1,14	7%
Feb	26,50	0%	20,11	3,40	10%	18,25	3,09	9%
Mar	48,85	0%	29,44	4,98	17%	25,02	4,24	15%
Apr	76,63	13%	32,42	5,49	42%	24,66	4,18	24%
May	96,61	27%	28,80	4,88	63%	18,03	3,05	37%
Jun	108,78	40%	23,91	4,05	73%	12,90	2,18	46%
Jul	125,62	37%	30,79	5,21	71%	17,21	2,91	44%
Aug	103,68	20%	36,31	6,15	52%	25,22	4,27	31%
Sep	69,32	4%	35,45	6,00	27%	28,54	4,83	19%
Oct	33,52	0%	22,81	3,86	12%	20,20	3,42	11%
Nov	12,17	0%	9,94	1,68	8%	9,14	1,55	8%
Dec	8,13	0%	6,97	1,18	6%	6,61	1,12	5%
TOTAL	718,38	12%	284,14	48,11	32%	212,51	35,98	28%

Table 25 Shading Contribution Due to Okalux

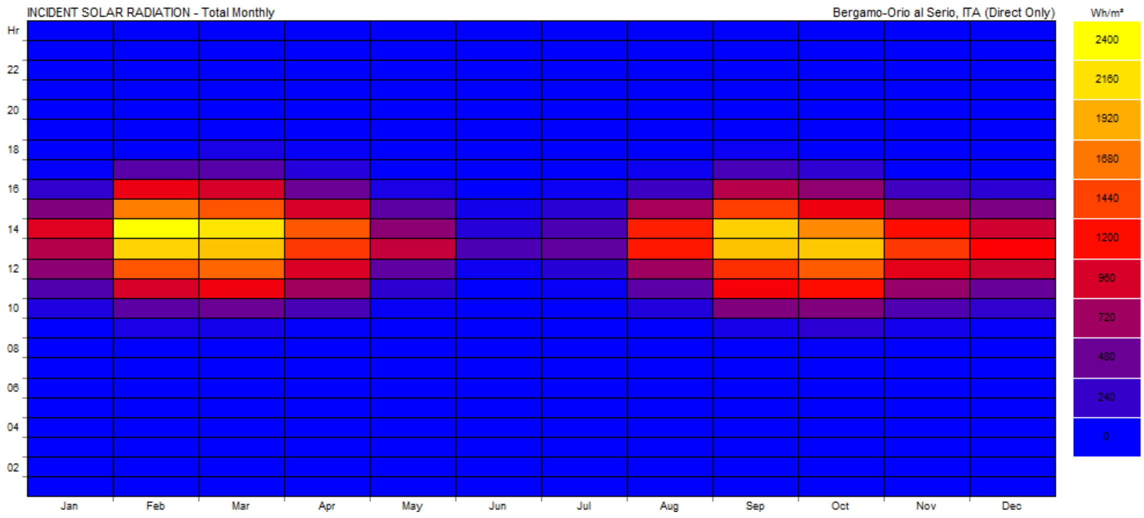


Illustration 200 Total Monthly Solar Exposure – SOUTH ELEV – With Okalux+Shed

TOTAL MONTHLY SOLAR EXPOSURE								
Location:	**Site:** Calco, Italy **Time Zone:** +1.0hrs							
Position:	**Longitude:** 9.7 ° **Latitude:** 45.7 ° **Altitude:** 238 m							
Surface area:	169.320 m2							
MONTH	**AVAILABLE SOLAR RADIATION**	**WITHOUT OKALUX OR SHED**			**WITH OKALUX+SHED**			**SHADING CONTRIBUTION DUE TO OKALUX + SHED**
		AVERAGE SHADE	INCIDENT SOLAR RADIATION		AVERAGE SHADE	INCIDENT SOLAR RADIATION		
	kWh/m2		kWh/m2	TOT. MWh		kWh/m2	TOT. MWh	
Jan	8,57	0%	7,21	1,22	42%	4,23	0,72	**41%**
Feb	26,50	0%	20,11	3,40	51%	10,37	1,76	**48%**
Mar	48,85	0%	29,44	4,98	68%	10,36	1,75	**65%**
Apr	76,63	13%	32,42	5,49	86%	6,81	1,15	**79%**
May	96,61	27%	28,80	4,88	96%	2,44	0,41	**92%**
Jun	108,78	40%	23,91	4,05	99%	0,66	0,11	**97%**
Jul	125,62	37%	30,79	5,21	98%	1,24	0,21	**96%**
Aug	103,68	20%	36,31	6,15	92%	5,16	0,87	**86%**
Sep	69,32	4%	35,45	6,00	77%	9,58	1,62	**73%**
Oct	33,52	0%	22,81	3,86	61%	9,33	1,58	**59%**
Nov	12,17	0%	9,94	1,68	45%	5,64	0,95	**43%**
Dec	8,13	0%	6,97	1,18	38%	4,44	0,75	**36%**
TOTAL	**718,38**	**12%**	**284,14**	**48,11**	**71%**	**70,25**	**11,90**	**81%**

Table 26 Shading Contribution Due to Okalux+SHED

5.4.2 West Elevation

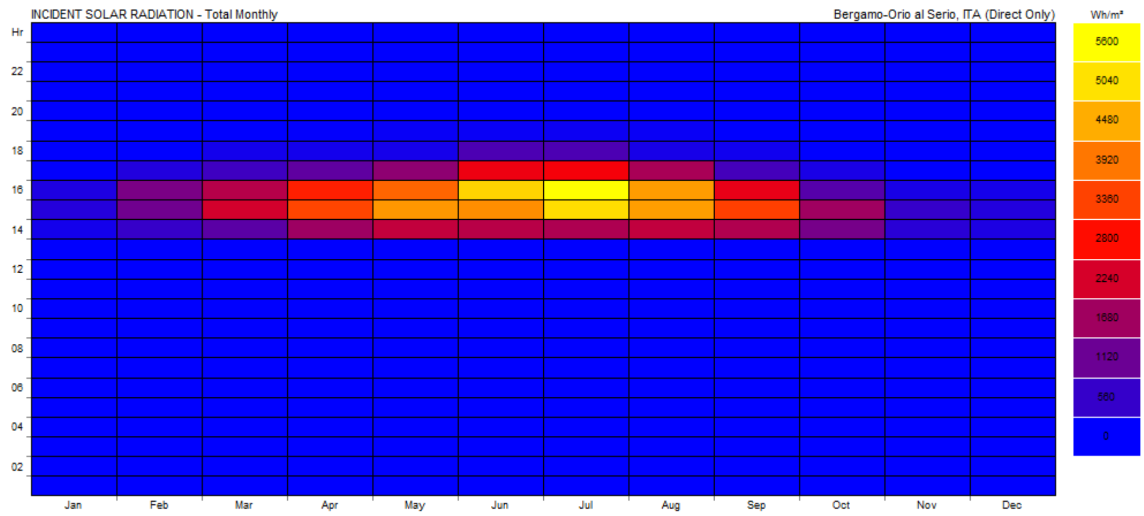


Illustration 201 Total Monthly Solar Exposure – WEST ELEV – Without Shed

Illustration 202 Total Monthly Solar Exposure – WEST ELEV – With Shed

TOTAL MONTHLY SOLAR EXPOSURE								
Location:	**Site:** Calco, Italy **Time Zone:** +1.0hrs							
Position:	**Longitude:** 9.7 ° **Latitude:** 45.7 ° **Altitude:** 238 m							
Surface area:	32.130 m2							
MONTH	**AVAILABLE SOLAR RADIATION**	**WITHOUT SHED**			**WITH SHED**			**SHADING CONTRIBUTION DUE TO SHED**
		AVERAGE SHADE	INCIDENT SOLAR RADIATION		AVERAGE SHADE	INCIDENT SOLAR RADIATION		
	kWh/m2		kWh/m2	TOT. MWh		kWh/m2	TOT. MWh	
Jan	9,86	59%	1,09	0,04	91%	0,29	0,01	**74%**
Feb	25,75	61%	3,27	0,11	94%	0,68	0,02	**79%**
Mar	50,75	67%	6,15	0,20	95%	0,96	0,03	**84%**
Apr	78,82	73%	9,53	0,31	95%	1,58	0,05	**83%**
May	99,01	75%	12,13	0,39	95%	2,28	0,07	**81%**
Jun	107,00	73%	14,22	0,46	96%	1,86	0,06	**87%**
Jul	124,88	74%	15,74	0,51	95%	2,56	0,08	**84%**
Aug	104,43	73%	12,88	0,41	95%	2,33	0,07	**82%**
Sep	67,38	72%	8,27	0,27	95%	1,29	0,04	**84%**
Oct	30,23	69%	3,67	0,12	96%	0,42	0,01	**89%**
Nov	12,26	68%	1,26	0,04	94%	0,28	0,01	**78%**
Dec	8,01	62%	0,87	0,03	91%	0,24	0,01	**72%**
TOTAL	**718,38**	**69%**	**89,09**	**2,86**	**94%**	**14,77**	**0,47**	**84%**

Table 27 Shading Contribution Due to SHED

5.4.3 East Elevation

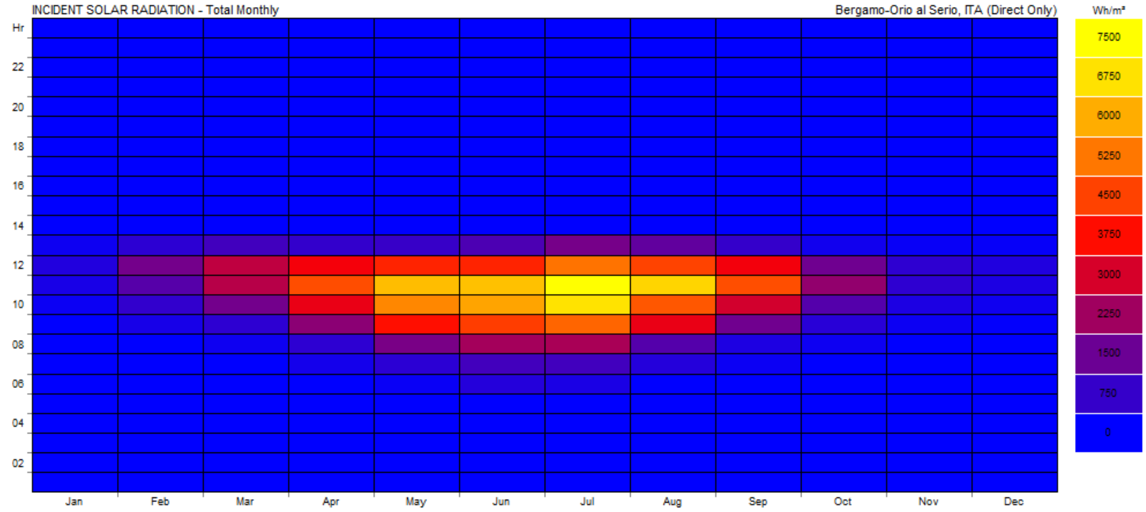


Illustration 203 Total Monthly Solar Exposure – EAST ELEV – Without Shed

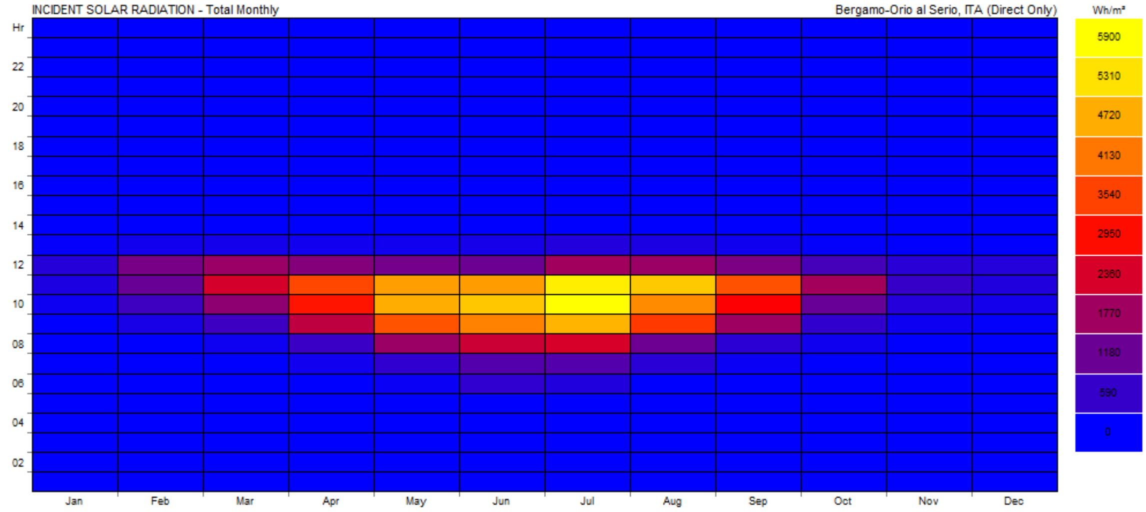


Illustration 204 Total Monthly Solar Exposure – EAST ELEV – With Okalux

TOTAL MONTHLY SOLAR EXPOSURE								
Location:	**Site:** Calco, Italy **Time Zone:** +1.0hrs							
Position:	**Longitude:** 9.7 ° **Latitude:** 45.7 ° **Altitude:** 238 m							
Surface area:	65.855 m2							
MONTH	AVAILABLE SOLAR RADIATION	WITHOUT OKALUX			WITH OKALUX			SHADING CONTRIBUTION DUE TO OKALUX
		AVERAGE SHADE	INCIDENT SOLAR RADIATION		AVERAGE SHADE	INCIDENT SOLAR RADIATION		
	kWh/m2		kWh/m2	TOT. MWh		kWh/m2	TOT. MWh	
Jan	8,57	54%	1,34	0,16	70%	1,09	0,13	19%
Feb	26,50	59%	4,44	0,52	72%	3,57	0,42	20%
Mar	48,85	62%	8,62	1,00	75%	6,69	0,78	22%
Apr	76,63	60%	15,87	1,85	75%	11,87	1,38	25%
May	96,61	58%	21,82	2,54	72%	16,14	1,88	26%
Jun	108,78	58%	25,85	3,01	71%	19,19	2,23	26%
Jul	125,62	59%	29,60	3,45	72%	21,79	2,54	26%
Aug	103,68	61%	22,63	2,63	75%	16,77	1,95	26%
Sep	69,32	61%	13,28	1,55	76%	9,90	1,15	25%
Oct	33,52	57%	5,82	0,68	73%	4,47	0,52	23%
Nov	12,17	48%	1,97	0,23	67%	1,63	0,19	17%
Dec	8,13	49%	1,22	0,14	67%	1,06	0,12	13%
TOTAL	**718,38**	**57%**	**152,44**	**17,75**	**72%**	**114,17**	**13,29**	**25%**

Table 28 Shading Contribution Due to OKALUX

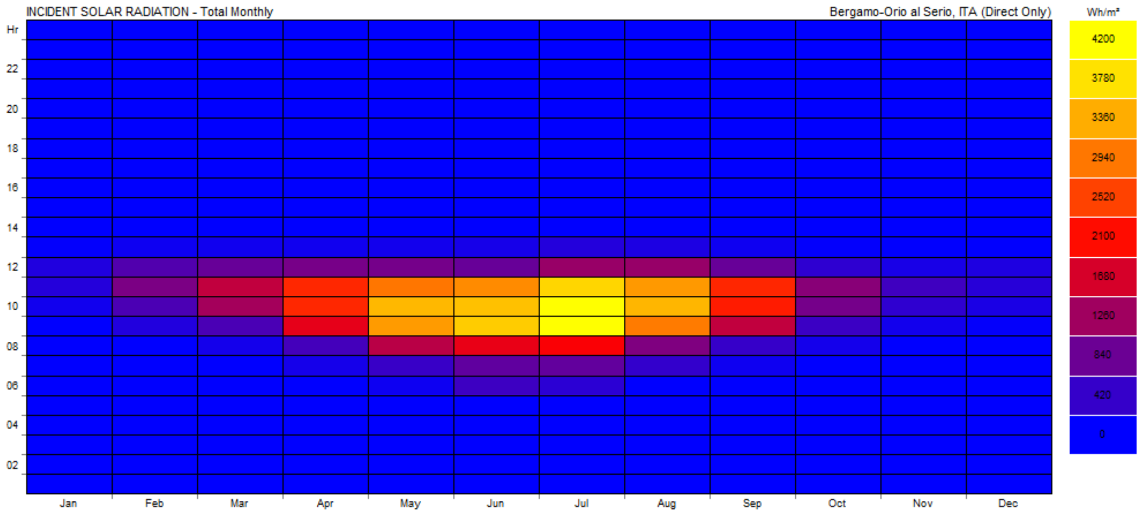


Illustration 205 Total Monthly Solar Exposure – EAST ELEV – With Okalux + Shed

TOTAL MONTHLY SOLAR EXPOSURE								
Location:	**Site:** Calco, Italy **Time Zone:** +1.0hrs							
Position:	**Longitude:** 9.7 ° **Latitude:** 45.7 ° **Altitude:** 238 m							
Surface area:	65.855 m2							
MONTH	AVAILABLE SOLAR RADIATION	WITHOUT OKALUX OR SHED			WITH OKALUX+SHED			SHADING CONTRIBUTION DUE TO OKALUX + SHED
		AVERAGE SHADE	INCIDENT SOLAR RADIATION		AVERAGE SHADE	INCIDENT SOLAR RADIATION		
	kWh/m2		kWh/m2	TOT. MWh		kWh/m2	TOT. MWh	
Jan	8,57	54%	1,34	0,16	78%	0,81	0,09	40%
Feb	26,50	59%	4,44	0,52	81%	2,52	0,29	43%
Mar	48,85	62%	8,62	1,00	84%	4,50	0,52	48%
Apr	76,63	60%	15,87	1,85	82%	8,68	1,01	45%
May	96,61	58%	21,82	2,54	79%	12,15	1,41	44%
Jun	108,78	58%	25,85	3,01	78%	14,47	1,69	44%
Jul	125,62	59%	29,60	3,45	78%	16,41	1,91	45%
Aug	103,68	61%	22,63	2,63	81%	12,62	1,47	44%
Sep	69,32	61%	13,28	1,55	83%	7,14	0,83	46%
Oct	33,52	57%	5,82	0,68	82%	3,02	0,35	48%
Nov	12,17	48%	1,97	0,23	77%	1,21	0,14	39%
Dec	8,13	49%	1,22	0,14	76%	0,81	0,09	34%
TOTAL	718,38	57%	152,44	17,75	80%	84,33	9,82	46%

Table 29 Shading Contribution Due to OKALUX+SHED

CONCLUSION

This section determines the period over which solar radiation values will be calculated monthly, and how the results will be displayed in each graph. All such calculations are based on the hourly *beam normal* and *diffuse horizontal* solar radiation values in the currently loaded climate data set.

6 THERMAL ANALYSIS

6.1 INTRODUCTION:

Buildings are usually designed to provide shelter as well as thermal comfort in the occupied space, backed up by mechanical heating and air-conditioning systems as necessary. The envelope of the building is a transition space through which interaction between indoor and outdoor environment takes place. The selection and arrangement of building envelope components can significantly impact its thermal performance which is a determining factor in its consumption of energy. In dealing with the building as a thermal system, the proper selection of its components and their relationships is of great importance in order to optimize its performance.

The aim of this chapter of the thesis is to describe the basic building thermal design optimization model of the proposed project by defining building design variables, a criterion of optimality, constraints, and a suitable thermal simulation model integrated into the optimization technique. This leads to the general aim of the thesis, which is to design a thermally optimum building with minimum reliance upon mechanical systems, in order not to sacrifice neither aesthetics nor function of the building.

Building design is a decision making process in which decisions are made on the shape, orientation and selection of the physical components of the building and their arrangements to achieve certain objectives. These decisions are usually limited by certain constraints some of which are outside the control of the designer. The framework of input, process and output approach is influenced by many factors in the building design process: [121]

Inputs:

Design know-how (professional and

Technical:

Climatic conditions
Energysources

Objectives:

Human needs
Social needs
Environmental objectives
Technical objectives

Constraints:

Cost
Technology
Human characteristics

[121] DEGELMAN, Legel et allTthe framework of an optimization model for the thermal design of building envelopes. Proceedings of the Ninth Symposium on Improving Building Systems in Hot and Humid Climate. Argton texas.1994 p 105

Physical environment
Aesthetics
Practicality

6.2 OBJECTIVE FUNCTION

The ultimate goal of building design is to provide occupants with a comfortable environment. In order to determine an optimum thermal design performance based on occupant comfort, it is necessary to establish a relationship between thermal comfort and the factors that have an impact on the thermal performance of buildings. The relationship can then be used to select an optimum combination of building design parameters that achieve the desired objectives. In order to control the design process in a systematic approach, it is necessary to formulate a criterion that can be used to compare the process outputs to objectives. Building thermal design can be optimized with the objective of minimizing building capital and operating cost, minimizing thermal load or minimizing thermal discomfort in the occupied space.

6.3 BUILDING THERMAL PERFORMANCE SIMULATION:

Ecotect was found to adequately represent the specified building thermal design parameters with accuracy while maintaining simplicity of simulation. The simulation program will be used to evaluate the annual heating/cooling loads depending on which type of system used to provide them, in this case, a Mixed Mode Ventilation system is used. This system has been chosen in the analysis, since it's similar to that of the one used in the research. It is a combination of air-conditioning and natural ventilation where the HVAC system shuts down whenever outside conditions are within the defined thermostat range. It should be noted that Ecotect assumes that either the system continues running on an supplying mechanical ventilation or the windows are opened. In either case, the air change rate increases as described above. Note also that Ecotect does not consider energy used in the ducting of air when it calculates heating and cooling loads - these are both given as space loads not plant loads.
The analysis will be made considering two cases:

- Case A: in which the wall layers and U-Values are the ones designed by the researchers in Chapter 5
- Case B: in which a standard walls, roofs and slabs systems have been assigned to the building. The chosen systems are described in details in table 30

This comparison will show the difference in performance tested results for air-conditioned buildings between the two cases, as will be shown later on. This difference will determine the enhancement or degradation in the building thermal performance.

6.3.1 Considerations for the demand of the various zones:

6.3.1.1 Skin layers and U-values

CASE A:

Details are explained in Chapter 5

CASE B:

SKIN TYPE	LAYERS	U-VALUE
Outer Walls (Brick Timber Frame)	110mm external brick plus, 75mm timber frame with 10mm plasterboard inside.	**1.77** $W/m^2.K$
Inner Partitions (Framed Plasterboard)	80mm framed wall as air gap, with 10mm plaster board either side.	**2.2** $W/m^2.K$
Roof Slab (Concrete Roof Asphalt)	6mm asphalt cover, with 150mm concrete lightweight, and 10mm Plaster Building (Molded Dry).	**0.896** $W/m^2.K$
Floor Slab (Concrete Slab On Ground)	100mm thick concrete slab on ground, with 1500mm Soil layer (Avg. Properties)	**0.88** $W/m^2.K$

Table 30 Input data for calculation case B

6.3.1.2 System occupancy (for both cases A and B)

BAR

The number of users of the bar expecting 1.5 rotations in average per day during the day = 1.5 * 40 = 60 people.

AUDITORIUM

The number of users for the Auditorium/Hall will be equal to its maximum capacity (300 people).

GALLERY (STORE)

Te number of sellers is considered to be 2 for the gallery/store.

RESTAURANT:

The number of users for the restaurant/bar is considered to take into account 1.5 average rotations in the capacity of the tables per day = 1.5 * 70 = 105 people

All the facilities (except the Auditorium/hall) will be considered to run for a total period of labor = 365 days - 12 celebrations days – 15 days Ferr-August – 5 days Eastern - 50 Sundays = 283 days.

The Auditorium/hall is considered to be used for an average of 3 times per week without taking into account holidays, in this way, the number of days of usage is = 156 – 6 days Ferr-August – 3 days Eastern = 147 days.

For the sake of simplificity it is considered a constant demand of users throughout the year represented as an average of the possible number of users per month.

6.3.2 Heating & Cooling Loads

6.3.2.1 Auditorium / Hall

CASE A

Analyzed Zone: All thermal Zones within the Auditorium / Hall
Active System: Mixed Mode Ventilation.
Comfort band/thermostat range: Varies depending on Zone
Operation: Varies depending on Zone
Occupancy: Varies depending on Zone

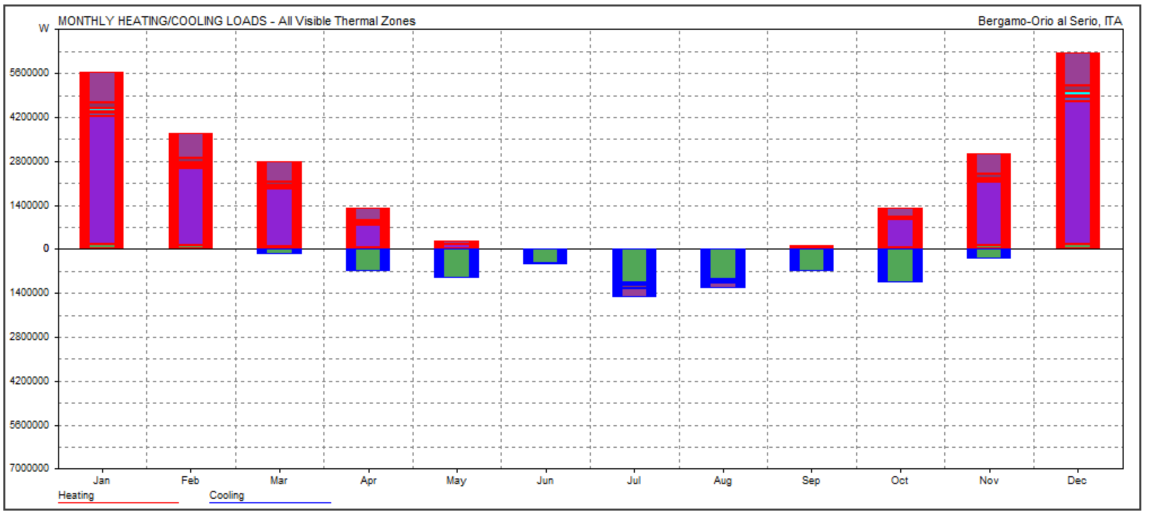


Illustration 206 Total monthly Heating/Cooling Loads Auditorium Hall building (CASE A)

MONTHLY HEATING & COOLING LOADS			
MONTH	**HEATING** (Wh)	**COOLING** (Wh)	**TOTAL** (Wh)
Jan	5,659,496	0	5,659,496
Feb	3,700,882	0	3,700,882
Mar	2,811,215	165,634	2,976,848
Apr	1,309,480	720,398	2,029,878
May	265,568	918,046	1,183,613
Jun	27,842	475,559	503,401

Jul	7,291	1,516,790	1,524,081
Aug	0	1,248,889	1,248,889
Sep	143,504	718,225	861,729
Oct	1,328,516	1,076,131	2,404,647
Nov	3,031,390	313,964	3,345,354
Dec	6,252,002	0	6,252,002
TOTAL	**24,537,186**	**7,153,635**	**31,690,820**
PER m^2	**14,397**	**4,197**	**18,595**
FLOOR AREA	**1730.855 m^2**		
MAX HEATING	**62,419 W** at 18:00 on 13th January		
MAX COOLING	**34917 W** at 16:00 on 15th July		

Table 31 Total Heating and Cooling Loads of the Auditorium/hall building

6.3.2.1.1 Theater & Projection room

Active system: mixed mode ventilation
Comfort band/thermostat range: 20 – 26 c
Operation: 15:00 – 19:00 for 147 days/year
Occupancy: 300 pers

MONTHLY HEATING & COOLING LOADS			
MONTH	**HEATING** (Wh)	**COOLING ONLY** (Wh)	**TOTAL** (Wh)
Jan	257,151	0	257,151
Feb	211,839	0	211,839
Mar	143,334	165,634	308,967
Apr	79,806	720,398	800,204
May	5,908	902,660	908,568
Jun	1,555	468,184	469,740
Jul	0	1,078,042	1,078,042
Aug	0	966,438	966,438
Sep	1,528	718,225	719,753
Oct	64,399	1,076,131	1,140,530
Nov	170,199	313,964	484,163
Dec	298,870	0	298,870
TOTAL	**1,234,587**	**6,409,676**	**7,644,264**
PER m^2	**6,592**	**17,479**	**24,071**
FLOOR AREA	**472.487 m^2**		
MAX HEATING	**8,993 W** at 18:00 on 13th January		
MAX COOLING	**25,717 W** at 16:00 on 15th July		

Table 32 Total Heating and Cooling Loads of the Theater + projection room space

6.3.2.1.2 Transition space

Active system: mixed mode ventilation

Comfort band/thermostat range: 16 – 31 c
Operation: 09:00 – 21:00 for 147 days/year
Occupancy: 30 pers

MONTHLY HEATING & COOLING LOADS			
MONTH	**HEATING** (Wh)	**COOLING** (Wh)	**TOTAL** (Wh)
Jan	4,079,970	0	4,079,970
Feb	2,454,666	0	2,454,666
Mar	1,819,071	0	1,819,071
Apr	734,683	0	734,683
May	145,224	0	145,224
Jun	8,720	0	8,720
Jul	7,291	0	7,291
Aug	0	0	0
Sep	89,948	0	89,948
Oct	916,089	0	916,089
Nov	2,032,064	0	2,032,064
Dec	4,537,832	0	4,537,832
TOTAL	**16,825,558**	**0**	**16,825,558**
PER m^2	**26,563**	**0**	**26,563**
FLOOR AREA	**633.412 m^2**		
MAX HEATING	**52,073 W** at 21:00 on 17th December		
MAX COOLING	**NO COOLING**		

Table 33 Total Heating and Cooling Loads of the Transition space

6.3.2.1.3 Gallery/exhibition hall

Active system: mixed mode ventilation
Comfort band/thermostat range: 20 – 26 c
Operation: 09:00 – 21:00 for 147 days/year
Occupancy: 20 pers

MONTHLY HEATING & COOLING LOADS			
MONTH	**HEATING** (Wh)	**COOLING** (Wh)	**TOTAL** (Wh)
Jan	978,193	0	978,193
Feb	780,504	0	780,504
Mar	662,147	0	662,147
Apr	403,620	0	403,620
May	105,065	12776	117,841
Jun	16,225	7374	23,599
Jul	0	285452	285,452
Aug	0	174520	174,520
Sep	48,095	0	48,095
Oct	284,592	0	284,592
Nov	646,863	0	646,863
Dec	1,034,996	0	1,034,996

TOTAL	4,960,300	480,122	5,440,422
PER m^2	23,869	2,310	26,180
FLOOR AREA	207.810 m^2		
MAX HEATING	6,737 W at 21:00 on 17th December		
MAX COOLING	3,664 W at 16:00 on 15th July		

Table 34 Total Heating and Cooling Loads of the Gallery/exhibition space

6.3.2.1.4 Services

Active system: mixed mode ventilation
Comfort band/thermostat range: 20 – 26 c
Operation: 15:00 – 19:00 for 147 days/year
Occupancy: 30 pers

MONTHLY HEATING & COOLING LOADS			
MONTH	HEATING (Wh)	COOLING (Wh)	TOTAL (Wh)
Jan	344,182	0	344,182
Feb	253,875	0	253,875
Mar	186,664	0	186,664
Apr	91,373	0	91,373
May	9,370	2,609	11,980
Jun	1,342	0	1,342
Jul	0	153,296	153,296
Aug	0	107,932	107,932
Sep	3,932	0	3,932
Oct	63,436	0	63,436
Nov	182,265	0	182,265
Dec	380,304	0	380,304
TOTAL	1,516,744	263,837	1,780,581
PER m^2	16,001	2,876	18,878
FLOOR AREA	417.147 m^2		
MAX HEATING	5,720 W at 17:00 on 13th January		
MAX COOLING	5,491 W at 17:00 on 3rd of August		

Table 35 Total Heating and Cooling Loads of the Services spaces

CASE B

Analyzed Zone: All thermal Zones within the Auditorium / Hall
Active System: Mixed Mode Ventilation.
Comfort band/thermostat range: Varies depending on Zone
Operation: Varies depending on Zone
Occupancy: Varies depending on Zone

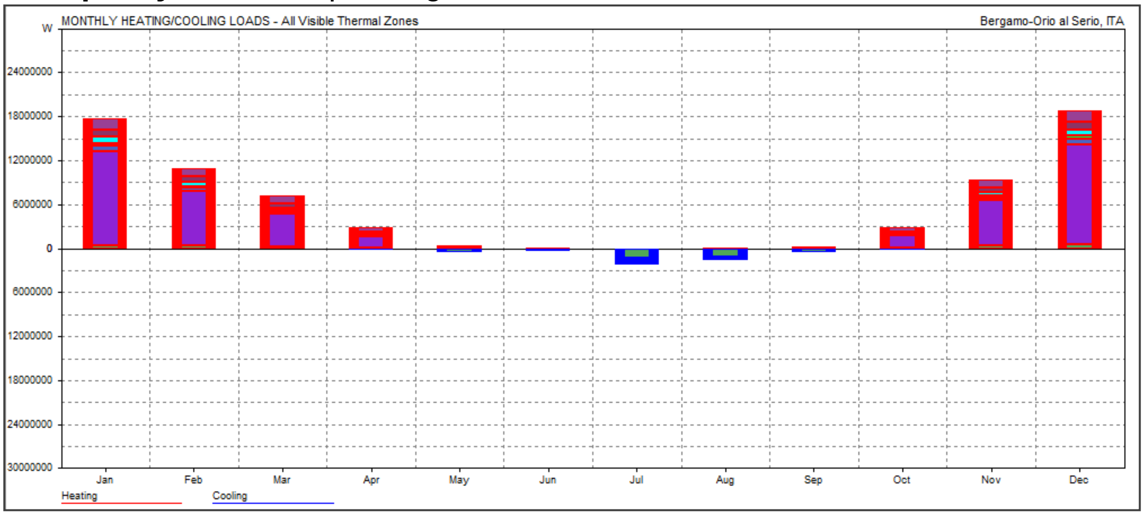


Illustration 207 Total monthly Heating/Cooling Loads Auditorium Hall building (CASE B)

MONTHLY HEATING & COOLING LOADS			
MONTH	**HEATING** (Wh)	**COOLING** (Wh)	**TOTAL** (Wh)
Jan	17,659,382	0	17,659,382
Feb	10,959,992	0	10,959,992
Mar	7,194,528	0	7,194,528
Apr	2,906,171	182,317	3,088,488
May	374,902	508,501	883,404
Jun	37,615	375,263	412,878
Jul	0	2,174,102	2,174,102
Aug	2,824	1,596,719	1,599,543
Sep	276,929	471,380	748,310
Oct	2,810,043	267,333	3,077,376
Nov	9,311,925	0	9,311,925
Dec	18,758,164	0	18,758,164
TOTAL	**70,292,480**	**5,575,616**	**75,868,096**
PER m^2	**35,619**	**2,825**	**38,445**
FLOOR AREA	**1730.855 m^2**		
MAX HEATING	**124,718 W** at 16:00 on 13th January		
MAX COOLING	**48,143 W** at 18:00 on 3rd August		

Table 36 Total Heating and Cooling Loads of the Auditorium/hall building (CASE B)

6.3.2.2 *Restaurant/ bars*

CASE A

Analyzed Zone: All thermal Zones within the Restaurant, Bar and Gallery Zone
Active System: Mixed Mode Ventilation.
Comfort band/thermostat range: 20 – 26 c
Operation: 09:00 – 21:00 for 283 days/year
Occupancy: Varies depending on Zone

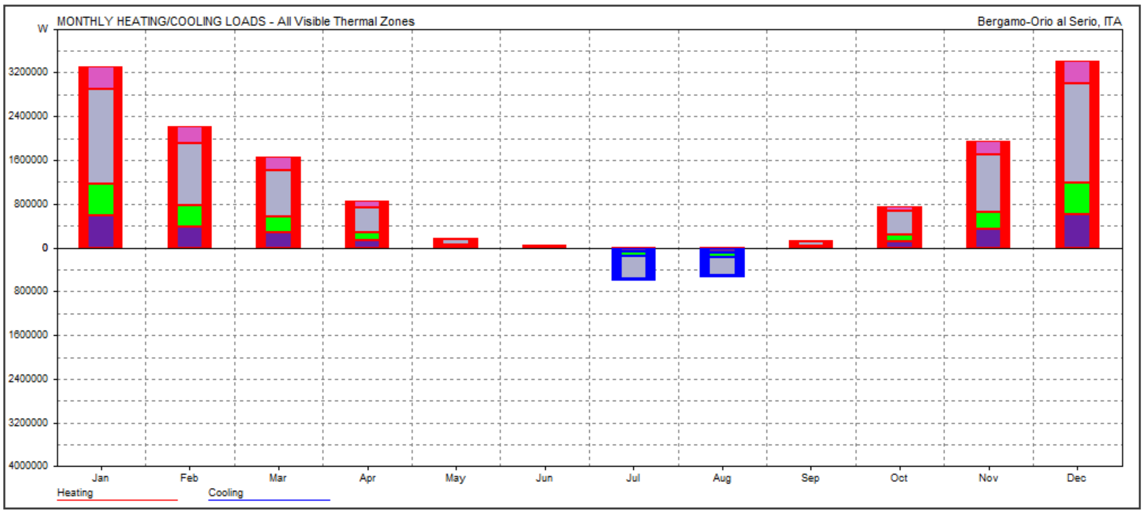


Illustration 208 Total monthly Heating/Cooling Loads Restaurant/bar building (CASE A)

MONTHLY HEATING & COOLING LOADS			
MONTH	**HEATING** (Wh)	**COOLING** (Wh)	**TOTAL** (Wh)
Jan	3,314,371	0	3,314,371
Feb	2,209,749	0	2,209,749
Mar	1,655,612	0	1,655,612
Apr	862,115	0	862,115
May	184,992	0	184,992
Jun	49,837	0	49,837
Jul	7,342	598,876	606,217
Aug	1,000	537,051	538,051
Sep	125,353	0	125,353
Oct	759,421	0	759,421
Nov	1,950,652	0	1,950,652
Dec	3,417,294	0	3,417,294
TOTAL	**14,537,738**	**1,135,926**	**15,673,664**
PER m^2	**22,872**	**1,787**	**24,660**
FLOOR AREA	**635,6 m^2**		
MAX HEATING	**19,827 W** at 21:00 on 17th of December		

MAX COOLING	**11,855 W** at 13:00 on 2ND of August

Table 37 Total Heating and Cooling Loads of the Restaurant/bar building

6.3.2.2.1 Bar

Active system: Natural Ventilation and radiant floor
Comfort band/thermostat range: 20– 26 c
Operation: 09:00 – 21:00 for 283 days/year
Occupancy: 60 pers

MONTHLY HEATING & COOLING LOADS			
MONTH	HEATING (Wh)	COOLING (Wh)	TOTAL (Wh)
Jan	593,867	0	593,867
Feb	391,676	0	391,676
Mar	285,002	0	285,002
Apr	141,673	0	141,673
May	24,268	0	24,268
Jun	6,122	0	6,122
Jul	776	73,416	74,192
Aug	0	82,509	82,509
Sep	15,691	0	15,691
Oct	122,948	0	122,948
Nov	336,766	0	336,766
Dec	610,110	0	610,110
TOTAL	2,528,898	155,925	2,684,823
PER m^2	18,432	1,136	19,569
FLOOR AREA	137.2 m^2		
MAX HEATING	**3,448 W** at 21:00 on 17th of December		
MAX COOLING	**1,893 W** at 13:00 on 2ND of August		

Table 38 Total Heating and Cooling Loads of the Bar space

6.3.2.2.2 Gallery/store

Active system: Natural ventilation and radiant floor
Comfort band/thermostat range: 20– 26 c
Operation: 09:00 – 21:00 for 283 days/year
Occupancy: 20 pers

MONTHLY HEATING & COOLING LOADS			
MONTH	HEATING (Wh)	COOLING (Wh)	TOTAL (Wh)
Jan	566,662	0	566,662
Feb	371,637	0	371,637
Mar	274,289	0	274,289

Apr	139,337	0	139,337
May	26,665	0	26,665
Jun	6,845	0	6,845
Jul	876	90,947	91,824
Aug	0	91,044	91,044
Sep	16,221	0	16,221
Oct	120,296	0	120,296
Nov	320,607	0	320,607
Dec	582,564	0	582,564
TOTAL	**2,426,000**	**181,991**	**2,607,992**
PER m²	**17,682**	**1,326**	**19,009**
FLOOR AREA	**137.2 m²**		
MAX HEATING	**3,369 W** at 21:00 on 17th of December		
MAX COOLING	**1,892 W** at 13:00 on 2ND of August		

Table 39 Total Heating and Cooling Loads of the Gallery/store space

6.3.2.2.3 Restaurant

Active system: natural ventilation and radiant floor
Comfort band/thermostat range: 20– 26 c
Operation: 09:00 – 21:00 for 283 days/year
Occupancy: 105pers

MONTHLY HEATING & COOLING LOADS			
MONTH	**HEATING** (Wh)	**COOLING** (Wh)	**TOTAL** (Wh)
Jan	1,736,677	0	1,736,677
Feb	1,138,797	0	1,138,797
Mar	856,002	0	856,002
Apr	446,015	0	446,015
May	109,712	0	109,712
Jun	31,118	0	31,118
Jul	5,472	403,268	408,740
Aug	1,000	328,631	329,631
Sep	83,014	0	83,014
Oct	425,626	0	425,626
Nov	1,051,534	0	1,051,534
Dec	1,798,819	0	1,798,819
TOTAL	**7,683,787**	**731,899**	**8,415,686**
PER m²	**31,273**	**2,979**	**34,252**
FLOOR AREA	**245.7 m²**		
MAX HEATING	**10,588 W** at 21:00 on 17th of December		
MAX COOLING	**7,335 W** at 13:00 on 2ND of August		

Table 40 Total Heating and Cooling Loads of the Restaurant space

6.3.2.2.4 Services

Active system: mixed mode ventilation
Comfort band/thermostat range: 20– 26 c
Operation: 09:00 – 21:00 for 283 days/year
Occupancy: 10 pers

MONTHLY HEATING & COOLING LOADS			
MONTH	**HEATING** (Wh)	**COOLING** (Wh)	**TOTAL** (Wh)
Jan	417,164	0	417,164
Feb	307,639	0	307,639
Mar	240,319	0	240,319
Apr	135,091	0	135,091
May	24,346	0	24,346
Jun	5,752	0	5,752
Jul	217	31,245	31,462
Aug	0	34,866	34,866
Sep	10,427	0	10,427
Oct	90,552	0	90,552
Nov	241,746	0	241,746
Dec	425,803	0	425,803
TOTAL	**1,899,055**	**66,111**	**1,965,166**
PER m^2	**16,442**	**572**	**17,014**
FLOOR AREA	**115.5 m^2**		
MAX HEATING	**2,421 W** at 21:00 on 17th of December		
MAX COOLING	**892 W** at 15:00 on 15th of July		

Table 41 Total Heating and Cooling Loads of the Services space

CASE B

Analyzed Zone: All thermal Zones within the Restaurant, Bar and Gallery Zone
Active System: Mixed Mode Ventilation.
Comfort band/thermostat range: 20 – 26 c
Operation: 09:00 – 21:00 for 283 days/year
Occupancy: Varies depending on Zone

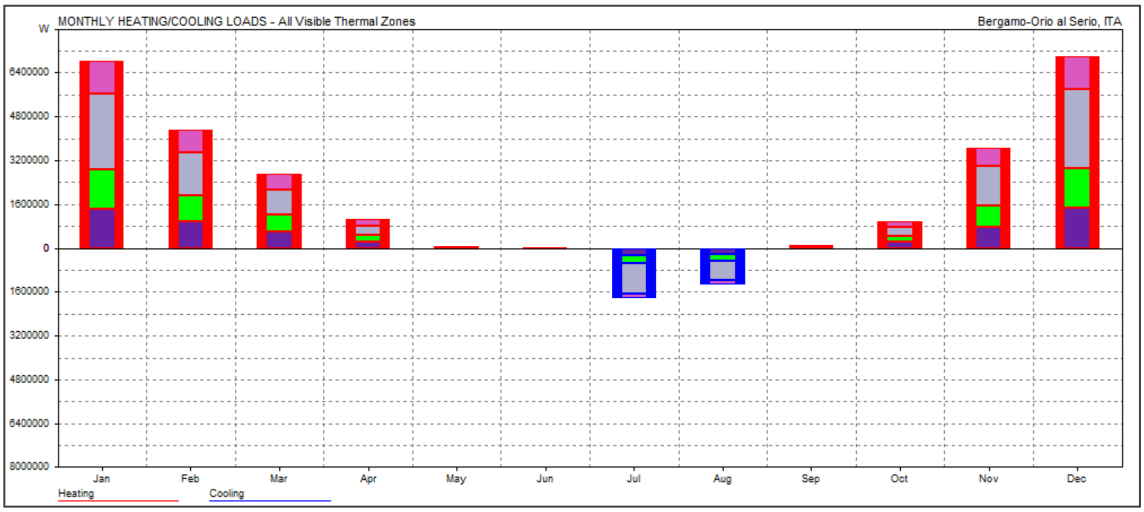


Illustration 209 Total monthly Heating/Cooling Loads Restaurant/bar building (CASE B)

MONTHLY HEATING & COOLING LOADS			
MONTH	**HEATING** (Wh)	**COOLING** (Wh)	**TOTAL** (Wh)
Jan	8,766,994	0	8,766,994
Feb	6,186,578	0	6,186,578
Mar	4,382,331	0	4,382,331
Apr	2,007,613	0	2,007,613
May	269,307	0	269,307
Jun	70,063	0	70,063
Jul	0	1,855,594	1,855,594
Aug	10,122	1,060,693	1,070,815
Sep	298,994	0	298,994
Oct	2,064,421	0	2,064,421
Nov	5,388,829	0	5,388,829
Dec	8,983,939	0	8,983,939
TOTAL	**38,429,192**	**2,916,287**	**41,345,480**
PER m^2	**60,461**	**4,588**	**65,050**
FLOOR AREA	**635,6 m^2**		
MAX HEATING	**39,495 W** at 21:00 on 17th of December		
MAX COOLING	**19,187 W** at 17:00 on 15th of July		

Table 42 Total Heating and Cooling Loads of the Restaurant/bar building (CASE B)

CONCLUSION:

In the following table, the difference between the wall systems and their thermal characteristics in both cases clearly shows a better performance of the building behavior in the proposed solution (Case A) than in the regular case (Case B). It should be noted that the analysis have been executed using a “Mixed Mode” HVAC system; and that the wall systems proposed are described into details in Chapter 5

ZONE	CALCULATION	CASE A	CASE B	REDUCTION %
AUDITORIUM / HALL	TOTAL HEATING AND COOLING LOADS (Wh)	31690820 Wh	75868096 Wh	**58.23%**
	TOTAL HEATING AND COOLING LOADS PER m^2 (Wh/m^2)	18595 Wh/m^2	38445 Wh/m^2	**51.63%**
RESTAURANT, BAR AND GALLERY	TOTAL HEATING AND COOLING LOADS (Wh)	15673664 Wh	41345480 Wh	**62.09%**
	TOTAL HEATING AND COOLING LOADS PER m^2 (Wh/m^2)	24660 Wh/m^2	65050 Wh/m^2	**62.09%**

Table 43 Comparison between the heating and cooling loads of the building for cases A and B

It is interesting to underline how the changes into the thermal transmittance of the physical boundaries of the building, can drive the thermal behavior of the facility in a proportion of 20% less for every 0.3 $W/m^2.K$ increase into the transmittance of the components.

7 HVAC SYSTEMS

7.1 METHODOLOGY

The methodology for the estimation of the Heating, cooling loads and the system power is the one described by the ASHRAE (American Society of Heating, Refrigerating and Air-Conditioning Engineers).

7.2 SYSTEM SELECTION

The wide amount of uses that the structures will be holding, as well as the different internal loads and building envelope provided, makes indispensable the division of the project into two or more zones, which will have probably different ventilation systems that can satisfy the best solution in terms of energy saving. As a result, there are considered 5 heating zones distributed in two main buildings as follows:

7.2.1 Zone 1: Auditorium/hall

The solution consists on an HYBRID SYSTEM that comprises an all-air conditioning system supplying both heating and cooling needs for the space and natural ventilation powered by the fans of the air handling units. The system consists on an AHU that supplies the air conditioned into a cavity below the floor of the theater, which will regulate the velocity of air supply to the zone by means of floor-diffusers located approximately below the audience. According to the season and heating or cooling demands, the system will run by natural ventilation or air conditioning conditions. The system will consist on the next stages.

1. Intake and Air conditioning: the air handling unit at first will condition the external air to indoor temperature and humidity as required.
2. Supply: the air is supplied to a transition chamber right underneath the theater, reducing the velocity of the main duct supply needed for the correct ventilation and to avoid draughts or high velocities inside the conditioned zone.
3. Displacement ventilation: the air supplied to the zone will be heated up by the internal loads, being its density lower than the original fresh air coming from the bottom of the theater; the air will circulate to the top of the room where it will be extracted.
4. Extraction & recycling: the already preheated air by action of the sunspace cavity, outside the auditorium, will be mixed with the exhausted air coming from the space; a fan will redirect the mixed-air to the system after passing it by a heat exchanger, which will provide a profitable heat “recycle” into the air conditioning system.

5. End of cycle: a fraction of mixture of recycled air will be conditioned + a fraction of outdoor air, in order to guarantee a sufficient air quality. The mixed of air will be supplied again to the zone.

When the heating or cooling needs are not high enough to be supplied by the all-air system, natural ventilation will provide the constant flow of fresh air into the zone, the fans will work according to the need of fresh air, and openings in the sun space will release the exhausted air to the atmosphere.

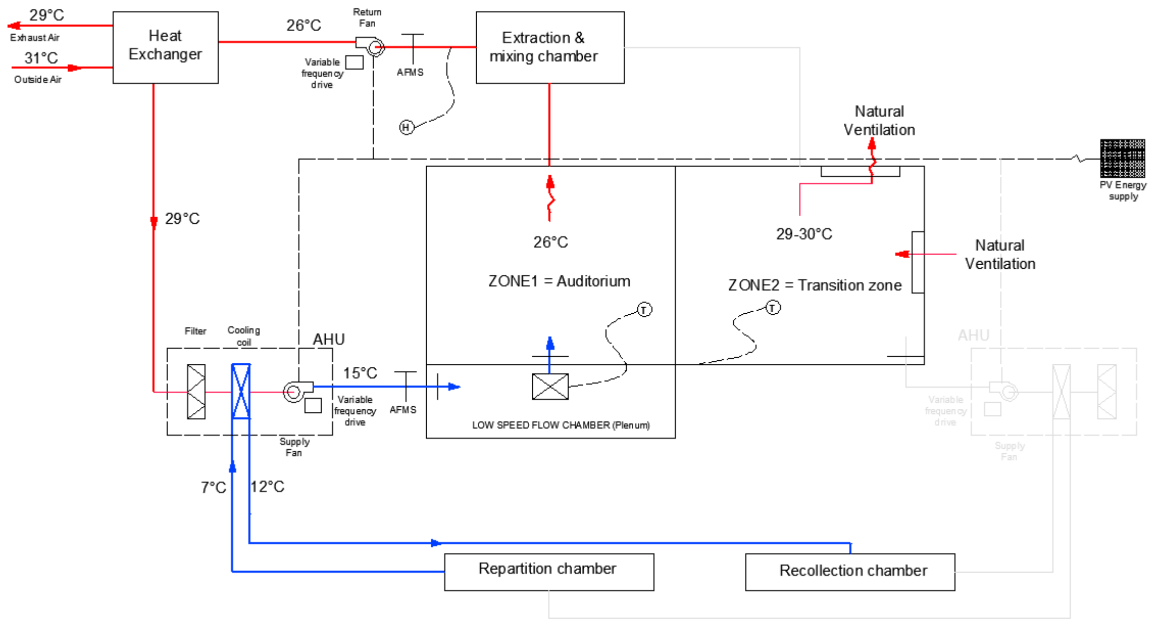


Illustration 210 Zone 1 and 2 summer air conditioning scheme

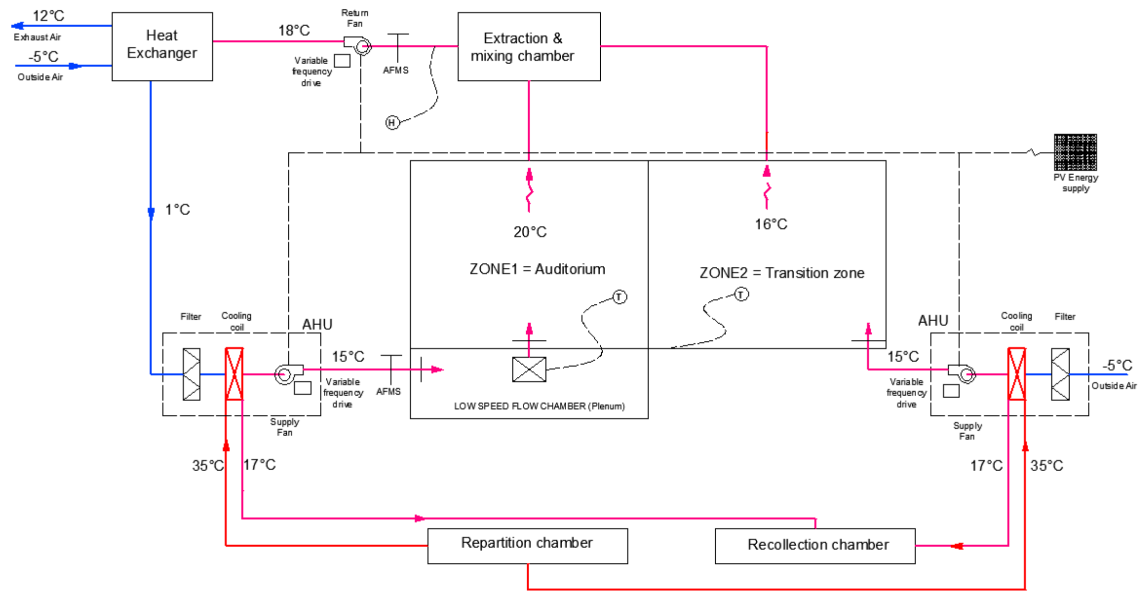


Illustration 211 Zone 1 and 2 winter air conditioning scheme

7.2.2 Zone 2: Lobby, Foye – glazed area.

This mainly considered “transition spaces”, where occupants will not hold the main activities of the building and rarely will be staying for long periods of time, are going to be provided with a system focused, nor in the satisfaction internal comfort, but in counterbalance the effect on the heating performance of the building, which can be compromised due to the extensive glazed area and the high difference of temperature between heated and not heated zones such as the theater and this space. As a result, a basic air handling unit supplying air close to the glazed wall is projected for this zone during winter condition. On the other hand, the walls of the foyer are expected to be wide open on summer time, becoming part of the solar protection skin of the building, as a result, the temperature of the space is supposed to be equal to the ambient temperature minus a small drop of temperature due to ventilation and slow wind draughts expected to supply certain comfort to the shaded zone.

7.2.3 Zone 3: Gallery/temporary exposition

This zone is characterized by medium internal loads, partial o temporary occupation and an partial opaque facade. A simple recovery air handling unit in economizer cycle can threat and reticulate the fresh air that enters into the zone. A scheme of the approach selected is described in the next scheme.

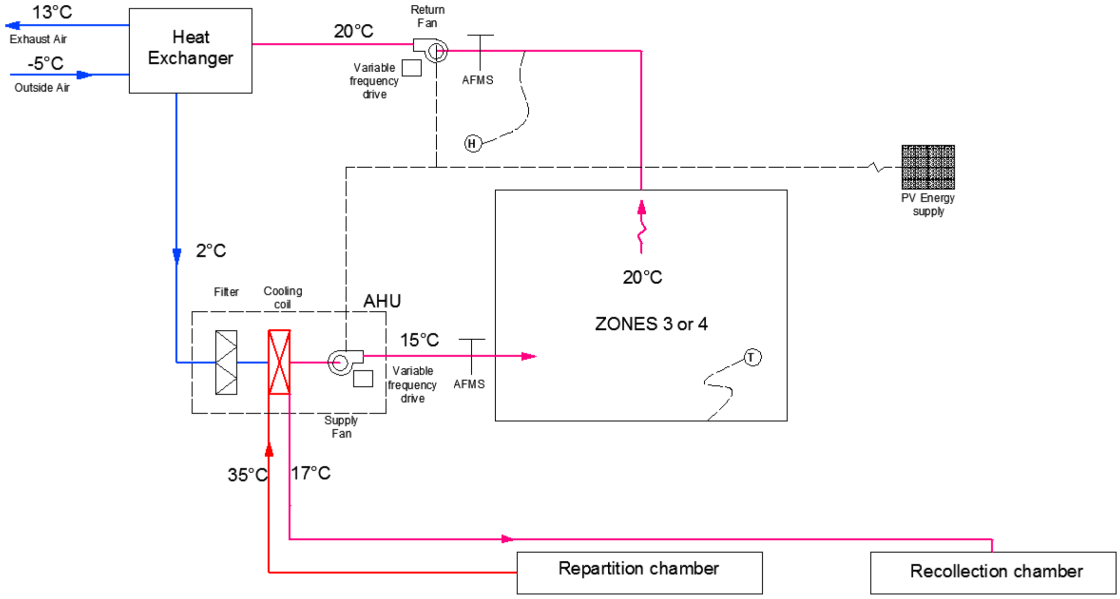


Illustration 212 Zone 3 and 4 winter air conditioning scheme

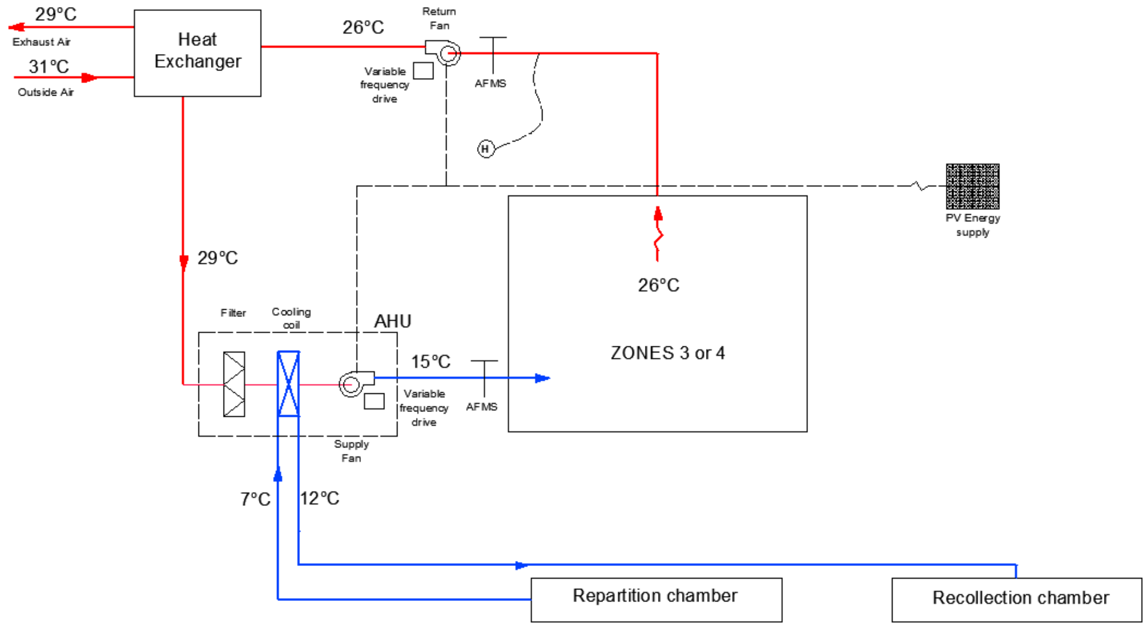


Illustration 213 Zone 3 and 4 summer air conditioning scheme

7.2.4 Zone 4: Auditorium services areas.

This zone is characterized by low internal loads, occupation and an entirely opaque façade. The same approach described above can be applied for this zone.

7.2.5 Zone 5: Restaurant/bars

This zone is characterized by medium to high constant occupancy in a partial-opaque façade. Different to the other zones, the restaurant and bars have a constant 8 hours per day running period, for which a system such as floor radiant panels can give the constant heating and cooling demand needed without long interrupting periods of operation. Natural ventilation will provide the air changes needed to maintain the air quality of the space

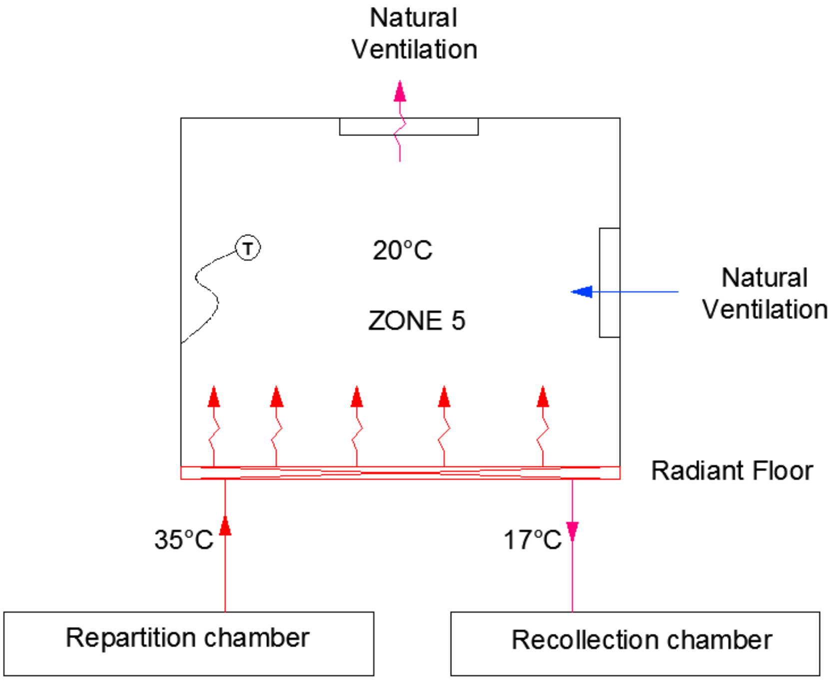


Illustration 214 Zone 5 winter air conditioning scheme

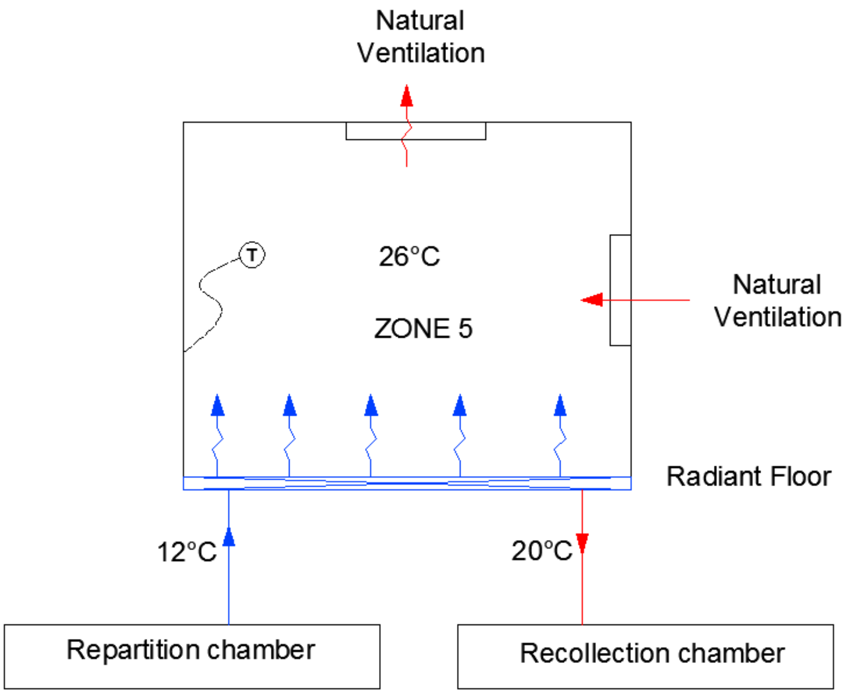


Illustration 215 Zone 5 summer air conditioning scheme

7.3 HVAC SYSTEM SIZING

7.3.1 Zone 1: Auditorium hall

People: 300
Approximated air volume: 2900 m3 considering an air tight building with minimum air infiltration rate

According to the scheme established above, the size of the system will consist on getting the air flow rate passing throughout all the ducts and chambers, and then computing the area needed for a maximum velocity of 5 m/s for main ducts, and 0.5 m/s for the flow coming out through floor diffuser located above the low speed flow chamber.

For air quality reasons it is considered a minimum air flow rate needed of Qmin =10 l/s per person and a Number of volume change rate between 6 and 10 ach. [122]

$$Qmin \left(\frac{l}{s}\right) = 10 * 300 = 3000\, l/s$$

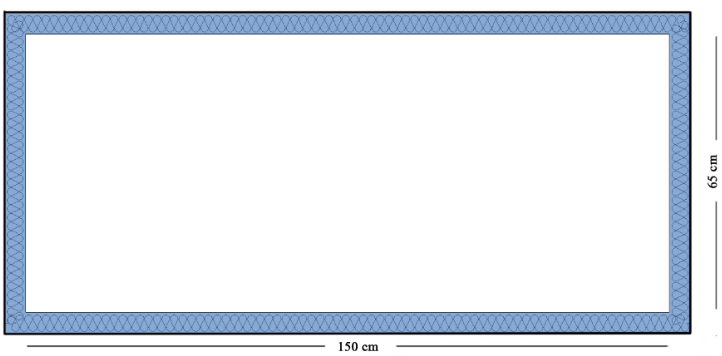
$$N\ (ach) = \frac{Q * Units\ factor}{V} = \frac{3000 * 3.6}{2900} = 0.26\, ach < 6$$

So the flow should be increased:

$$Q\left(\frac{l}{s}\right) = N * V = 6 * 2900 * Units\ factor = \ \ 4800 l/s$$

As a result the main duct going out from the AHU will have the next dimensions:

$$A(m2) = \frac{Q}{v} = \frac{4800 * units\ factor}{5} = 0.96\, m2$$



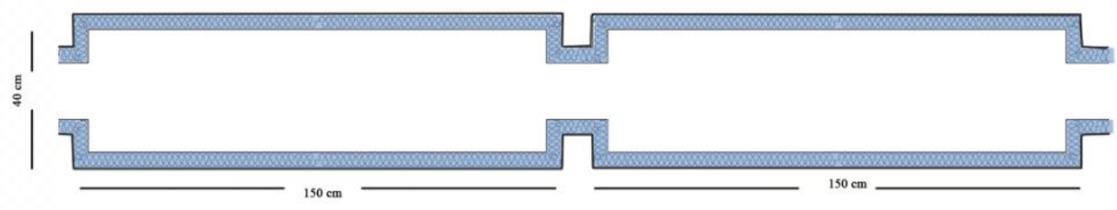
Graphic 74 Main duct sizing and dimensions zone 1

[122] GREENO, Roger; HALL, Fred. Building services handbook. 2007. P 159

On the other hand, the size of the plenum or low flow chamber can be obtained considering 0.4 m available of space under the floor of the theater (height) and the air flow intake to be equal to 0.5 m/s.

$$L = \frac{Q}{v * h} = \frac{4800 * units\, factor}{0.5 * 0.4} = 24\, m$$

As a result, it has been decided to select parallel hanging rectangular ducts, interconnected to each other in order to achieve all the area needed.



Graphic 75 Plenum ducts system zone 1

Once the flow and diameters are obtained it is calculated the heating and cooling demands of energy due to ventilation.

For Heating:

$$q\ (kW) = 1.23 * Q * \Delta T = 1.23 * 4800 * (20 - 15) = 29\ kW$$

Equation 12 Heating load due to ventilation zone 1

For Cooling:

$$q\ (kW) = 1.23 * Q * \Delta T = 1.23 * 4800 * (26 - 15) = 64\ kW$$

Equation 13 Cooling load due to ventilation zone 1

7.3.2 Zone 2: Lobby, Foye – glazed area.

People: 30
Approximated air volume: 4200 m3 considering an air tight building with minimum air infiltration rate

For air quality reasons it is considered a minimum air flow rate needed of Qmin =10 l/s per person and a Number of volume change rate between 2 and 4 ach.[123]

$$Qmin\ \left(\frac{l}{s}\right) = 10 * 30 = 300\ l/s$$

[123] GREENO, Roger; HALL, Fred. Building services handbook. 2007. P 159

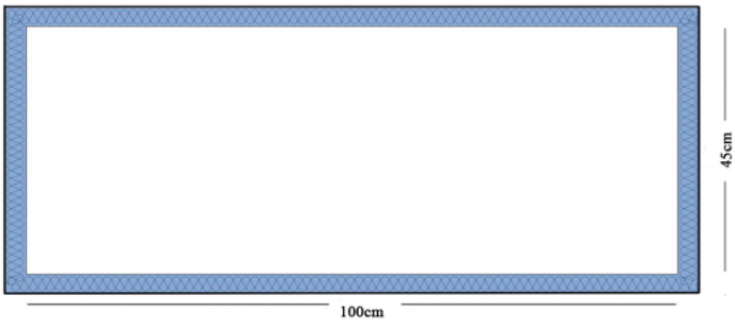
$$N\ (ach) = \frac{Q * Units\ factor}{V} = \frac{300 * 3.6}{4200} = 0.26\ ach < 2$$

So the air flow should be increased:

$$Q\left(\frac{l}{s}\right) = N * V = 2 * 4200 * Units\ factor = \ 2330\ l/s$$

As a result the main duct going out from the AHU will have the next dimensions:

$$A(m2) = \frac{Q * Units\ factor}{v} = \frac{2330 * 0.001}{5} = 0.45\ m2$$



Graphic 76 Main duct sizing and dimensions zone 2

Once the flow and section size are obtained it is calculated the heating and cooling demands of energy due to ventilation.

For Heating:

$$q\ (kW) = 1.23 * Q * \Delta T = 1.23 * 2330 * (16 - 15) = 3\ kW$$

Equation 14 Heating load due to ventilation zone 2

7.3.3 Zone 3: Gallery/temporary exposition

People: 20
Approximated air volume: 1000 m3 considering an air tight building with minimum air infiltration rate

For air quality reasons it is considered a minimum air flow rate needed of Qmin =10 l/s per person and a Number of volume change rate between 3 and 6 ach.[124]

[124] GREENO, Roger; HALL, Fred. Building services handbook. 2007. P 159

$$Qmin\left(\frac{l}{s}\right) = 10 * 20 = 200\, l/s$$

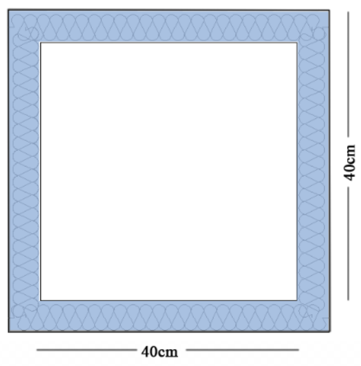
$$N\,(ach) = \frac{Q * Units\ factor}{V} = \frac{200 * 3.6}{1000} = 0.25\, ach < 3$$

So the air flow should be increased:

$$Q\left(\frac{l}{s}\right) = N * V = 3 * 1000 * Units\ factor = \ 830\, l/s$$

As a result the main duct going out from the AHU will have the next dimensions:

$$A(m2) = \frac{Q * Units\ factor}{v} = \frac{830 * 0.001}{5} = 0.16\, m2$$



Graphic 77 Main duct sizing and dimensions zone 3

Once the flow and section size are obtained it is calculated the heating and cooling demands of energy due to ventilation.

For Heating:

$$q\,(kW) = 1.23 * Q * \Delta T = 1.23 * 830 * (20 - 15) = 5.4\, kW$$

Equation 15 Heating load due to ventilation zone 3

For Cooling:

$$q\,(kW) = 1.23 * Q * \Delta T = 1.23 * 830 * (26 - 15) = 11.2\, kW$$

Equation 16 Cooling load due to ventilation zone 3

7.3.4 Zone 4: Auditorium Services areas

People: 30

Approximated air volume: 1100 m3 considering an air tight building with minimum air infiltration rate.

For air quality reasons it is considered a minimum air flow rate needed of Qmin =10 l/s per person and a Number of volume change rate between 3 and 6 ach.[125]

$$Qmin\left(\frac{l}{s}\right) = 10 * 30 = 300\, l/s$$

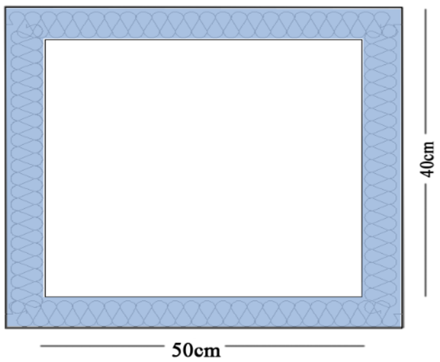
$$N\,(ach) = \frac{Q * Units\ factor}{V} = \frac{300 * 3.6}{1100} = 0.98\, ach < 3$$

So the air flow should be increased:

$$Q\left(\frac{l}{s}\right) = N * V = 3 * 1100 * Units\ factor = \ 916\, l/s$$

As a result the main duct going out from the AHU will have the next dimensions:

$$A(m2) = \frac{Q * Units\ factor}{v} = \frac{916 * 0.001}{5} = 0.19\, m2$$



Graphic 78 Main duct sizing and dimensions zone 4

Once the flow and section size are obtained it is calculated the heating and cooling demands of energy due to ventilation.

For Heating:

$$q\,(kW) = 1.23 * Q * \Delta T = 1.23 * 916 * (20 - 15) = 5.6\, kW$$

Equation 17 Heating load due to ventilation zone 4

For Cooling:

$$q\,(kW) = 1.23 * Q * \Delta T = 1.23 * 916 * (26 - 15) = 12\, kW$$

[125] GREENO, Roger; HALL, Fred. Building services handbook. 2007. P 159

Equation 18 Cooling load due to ventilation zone 4

7.4 WATER CHILLER/HEATER SIZING

7.4.1 Demand: thermal loads

Using the program ECOTEC, it has been realized the analysis for heating and cooling loads required to maintain the degree of comfort desired inside the building, taking into account the temperature distribution shown in the schemes presented above and the next sort of assumptions:

- The number of users for the Auditorium/Hall will be equal to its maximum capacity (300 people).
- The auditorium is considered to be used at full occupation for a period of 4 h/day 3 times per week.
- The number of users for the exposition gallery underneath the Auditorium is equal to 20 people.
- The exposition gallery is considered to be used at full occupation for a period of 12 h/day 3 times per week.
- The number of users for the restaurant/bar is considered to take into account 1.5 average rotations in the capacity of the tables per day = 1.5 * 70 = 105 people.
- The number of users of the bar expecting 1.5 rotations in average per day during the day = 1.5 * 40 = 60 people
- The number of sellers is considered to be 2 for the gallery/store.
- The operation hours of the restaurant/bar and gallery/store is considered to be equal to 12 h/day
- All the facilities (except the Auditorium/hall) will be considered to run for a total period of labor = 365 days - 12 celebrations days – 15 days Ferr-August – 5 days Eastern - 50 Sundays = 283 days.
- However the Auditorium/hall is considered to be used for an average of 3 times per week without taking into account holidays, in this way, the number of days of usage is = 156 – 6 days Ferr-August – 3 days Eastern = 147 days.
- For the sake of simplification it is considered a constant demand of users throughout the year represented as an average of the possible number of users per month.

Due to practical purposes the thermal loads needed for the sizing of the system correspond to the maximum heating and/or cooling loads needed in each zone. The next table represents a summary of these loads obtained from the software-output. However, in order to size the chilling water system, the heating loads mainly due to conduction, convection, radiation, sensible and latent which are calculated by the software have to be sum up to the load due to ventilation calculated in the last chapter.

It is supposed (as it was previously stated) that the system will chill and store the dairy cold water demand running at full capacity during night (when the electrical fees are lower) and during day.

Location	Max Heating load (kW)	Op. hours/day	Heating load (kWh/day)
Zone 1 Auditorium/hall	9	4	36
Zone 2 Transition space	52	12	624
Zone 3 Gallery/temporal exposition	6.7	12	80.4
Zone 4 Services Auditorium	5.7	4	22.8
Zone 4 Services restaurant	2.4	12	28.8
Zone 5 Restaurant/bars	17.4	12	208.8
Total			***1000.8***

Location	Max Cooling load (kW)	Op. hours/day	Cooling load (kWh/day)
Zone 1 Auditorium/hall	25.7	4	102.8
Zone 2 Transition space	0	12	0
Zone 3 Gallery/temporal exposition	3.6	12	43.2
Zone 4 Services Auditorium	5.5	4	22
Zone 4 Services restaurant	0.9	12	10.8
Zone 5 Restaurant/bars	10.9	12	130.8
Total			***309.6***

Table 44 Summary of diary peak thermal loads

7.4.2 Sizing

The sizing of the chilled water tank storage is done by calculating the chilling capacity needed in order to attend the cooling demand. The next equation is employed to attain this scope considering that the chiller will be running in off-peak periods at full capacity. (12h.day).

For cooling:

$$q\ (kW) = \frac{Cooling\ load}{Running\ period} = \frac{310\ kWh.day}{12h.day} = \mathbf{26\ kW}$$

For heating:

$$q\ (kW) = \frac{Heating\ load}{Running\ period} = \frac{1000\ kWh.day}{12h.day} = \mathbf{83\ kW}$$

In these order of ideas, the chilled water storage is sized according to the heat capacity of the water and the considered efficiency of the system (in this case, a simple insulated water tank storage), thus:

$$Ctank\ (m^3) = \frac{Cooling\ load}{Water\ heat\ capacity * efficency} = \frac{310\ kWh.day}{8\ kwh/m3.day} = \mathbf{40\ m3}$$

7.5 ELECTRIC CONSUMPTION

7.5.1 HVAC System

The electric consumption of the HVAC system can be calculated as result of the average power needs of the supply and return duct fans, which are considered to be operating at the same air flow rate for approximation purposes. The fans are supposed to be operating all the time that the building is used, supplying air even when it is not necessarily conditioned due to favorable external conditions.

The next table shows the total annual flow rate of air needed to be supplied into the entire compound of buildings.

Location	Air flow (m3/s)	Op. hours/day	Operation days	Total annual air flow (m3/s)
Zone 1 Auditorium/hall	4.8	4	143	2746
Zone 2 Transition space	2.33	12	143	3998
Zone 3 Gallery/temporal exposition	0.83	12	143	1424
Zone 4 Services Auditorium	0.916	4	143	524
Total				***8692***

Table 45 Summary of yearly air flow rate

In order to calculate the power needs, it is considered a total pressure drop in the fans, of 500 Pa for the supply duct, and 250 Pa for the extract duct[126]. As a result applying the formula:

$$P\frac{(MWh)}{year} = 1.5 * AP(MPa) * Q(\frac{m3}{s})$$

For Supply fans:

$$P\frac{(MWh)}{year} = 1.5 * 0.0005 * 8692 = \mathbf{6.5\ MWh}$$

For Extract duct:

$$P\frac{(MWh)}{year} = 1.5 * 0.00025 * 8692 = \mathbf{3.25\ MWh}$$

7.5.2 Water chiller/heater

The total consumption of energy per year is considered to be equal to the total refrigeration demand plus a percentage of energy applied to the system in the compression work (20%). It is considered a conversion factor from heating to

[126] RAPISARDA. Giuseppe. Schematic design of HVAC Systems. 2011. Pag 31.

electrical energy needs equal to 0.4. The next table shows the total refrigeration demand per year in the compound of buildings.

Location	Heating load (MWh)	Cooling load (MWh)
Zone 1 Auditorium/hall	1.2	6.4
Zone 2 Transition space	17	0
Zone 3 Gallery/temporal exposition	4.9	0.48
Zone 4 Services Auditorium	1.5	0.26
Zone 4 Services restaurant	1.8	0.06
Zone 5 Restaurant/bars	14	1.13
Subtotal	**40.4**	**8.33**
Total	***48.73***	

Table 46 Summary of annual thermal loads

As a result the electrical consumption of the water chiller/heater is equal to 49*1.2*0.4 = **24 MWh**/year

8 GEOTHERMAL HEAT PUMP ENERGY

8.1 METHODOLOGY

The selection and design of the system is oriented to obtain the flow rate of ground water needed in order to supply the heating and cooling demand of the building. Once the flow rate is obtained, it can be sized the number of wells, piping size and the electrical energy needed for pumping.

8.2 SYSTEM SELECTION

According to historical and geomorphologic data available for the area of San Vigilio, the project's zone is characterized by the presence of a constant running water body located at 2 m below ground level. The presence of a water body right in the boundaries of the project, constitute a high opportunity to apply an OPEN LOOP SYSTEM which requires basically an intake minimum of 10 m in order to avoid freezing or changes in the temperature of ground according to the season; other systems such as the closed loop systems will required more area (horizontal systems) or drilling depth (vertical systems) which would increase considerably the initial cost of installation and subsequent operation costs due to maintenance. Due to the size of the building and zones distribution, it has been decided to use (2) two independent open loop systems to supply ground heat to the project, 1 for the zones 1,2,3 and another one for the zones 3 and 4. On more important consideration is the inclusion of a chilled water storage system for the zones 3 and 4, knowing that a saving energy strategy in the case of high cooling loads can be achieved by cooling the on-day demand of chilled water in non-peak times (at night) running the system at full capacity, when the electrical fees are lower.

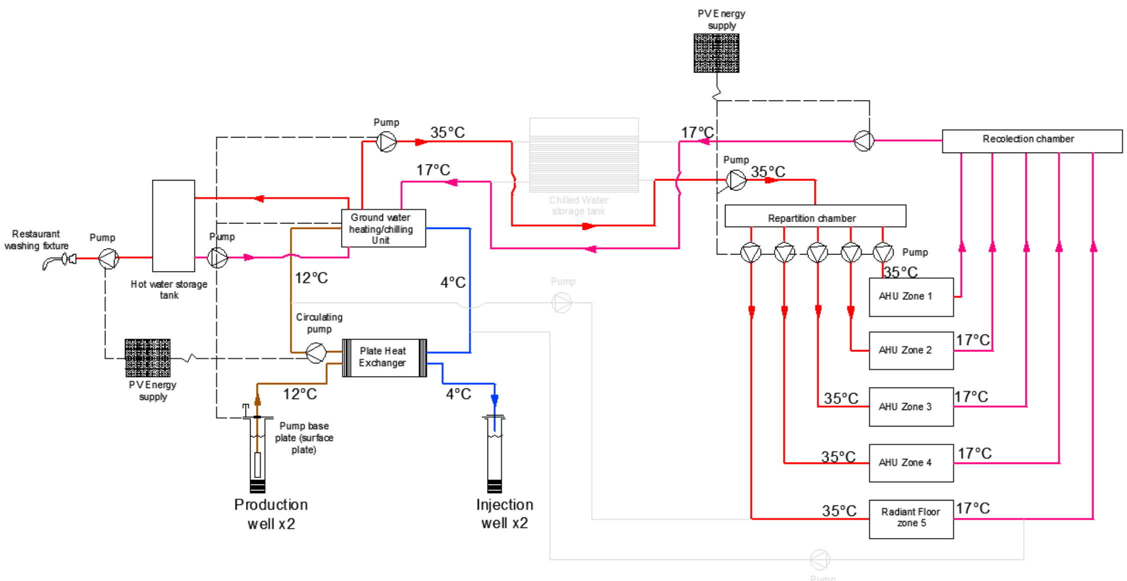


Illustration 216. Winter Heating energy system supply

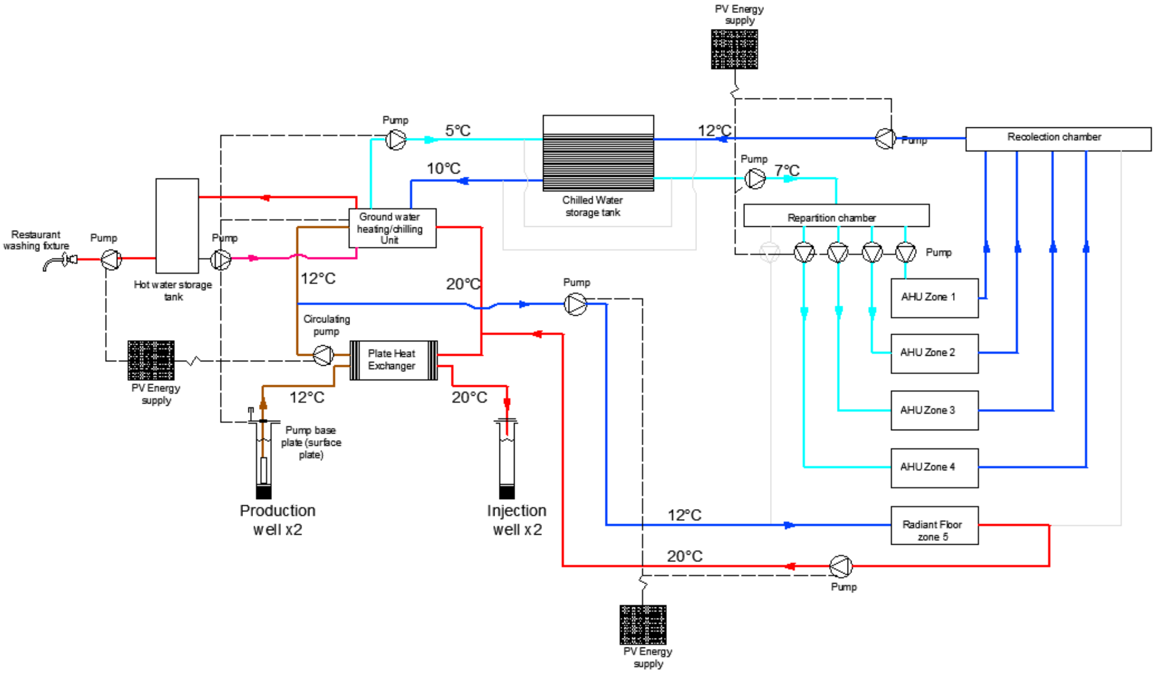


Illustration 217. Summer cooling energy system supply

On the other hand, the use of ground heating pumping for supplying the needs of hot water to the restaurant can be established as it is indicated in the next scheme:

8.2.1 Water heating pump wells

The system will be composed by a production well and injection well, in which running water at a constant temperature of 12°C[127] will be extracted from the water body and then released to it after a heat exchange process is run throughout the system. In order to avoid serious problems caused by circulating groundwater directly to the building, the energy provided by the well pumping is extracted by a heat exchanger where "Clean water" will absorb (Heating cycle) or release energy (Cooling cycle) towards and/or from the main system circuit.

In the next set of graphics it is shown a basic plan of the water heat pump wells connection to the main heating and cooling system of the building.

[127] MCQUAY International. Geothermal Heat pump design manual. Application guide. Appendix 1: Ground temperatures. Heating and cooling with a heat pump. 2011. p 38

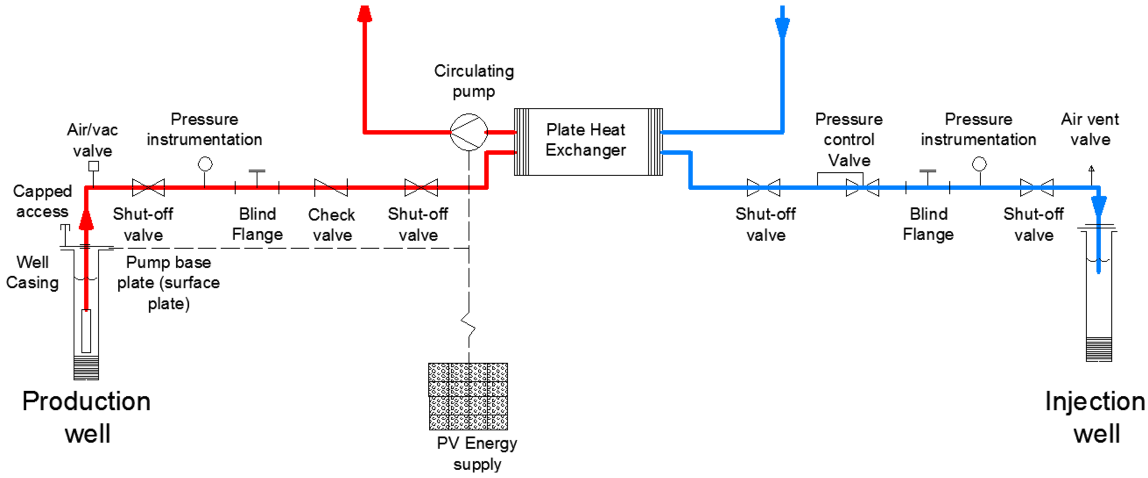


Illustration 218. Winter water heating source plan

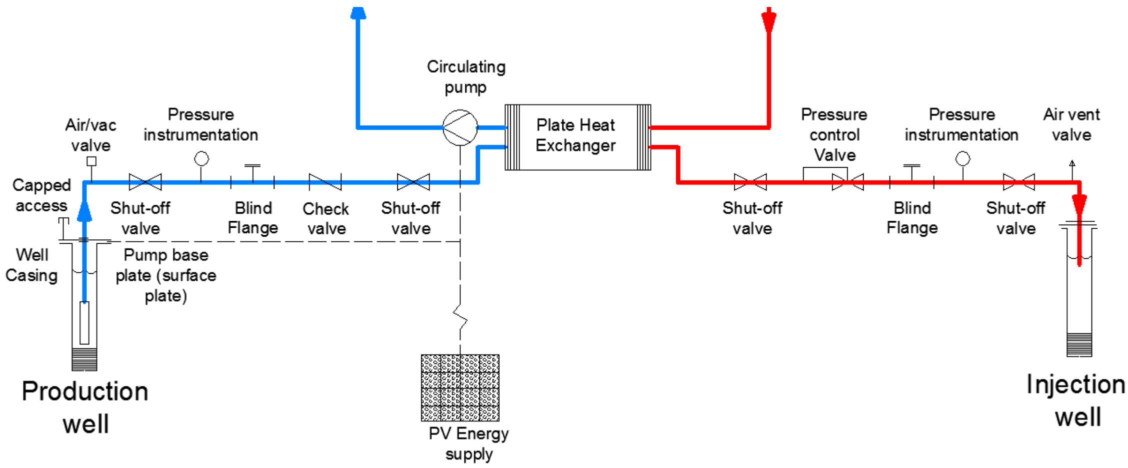


Illustration 219. Summer water heating source plan

8.2.2 Ground water heating/chilling units[128]

In the heating cycle, the water/refrigerant which has absorbed heat energy form the ground water is transported to the (GWHU) existing in each one of the zones of the building, the water boils to become a low-temperature vapor; a reversing valve then sends the refrigerant vapor to the compressor. The vapor is then compressed which reduces its volume, causing it to heat up, the excess of heat is taken by a desuperheater. A desuperheater is a small, auxiliary heat exchanger that uses superheated gases from the heat pump's compressor to heat water, this hot water then circulates through a pipe to the storage water heater tank. Finally, the reversing valve sends the now-hot gas to the condenser coil, where it gives up its heat. Water passes across the coil, heated, and supplied to the air handling units or under floor panels. Given up its heat, the refrigerant passes through the expansion valve, where its temperature and

[128] NATURAL RESOURCES OF CANADA. Heating and cooling with a heat pump. 2011 (Available on-line), ttp://oee.nrcan.gc.ca/publications/infosource/pub/home/ Heating_and_Cooling _with_a_Heat_Pump_Section4.cfm

pressure are dropped down further before it returns to the primary heat exchanger.

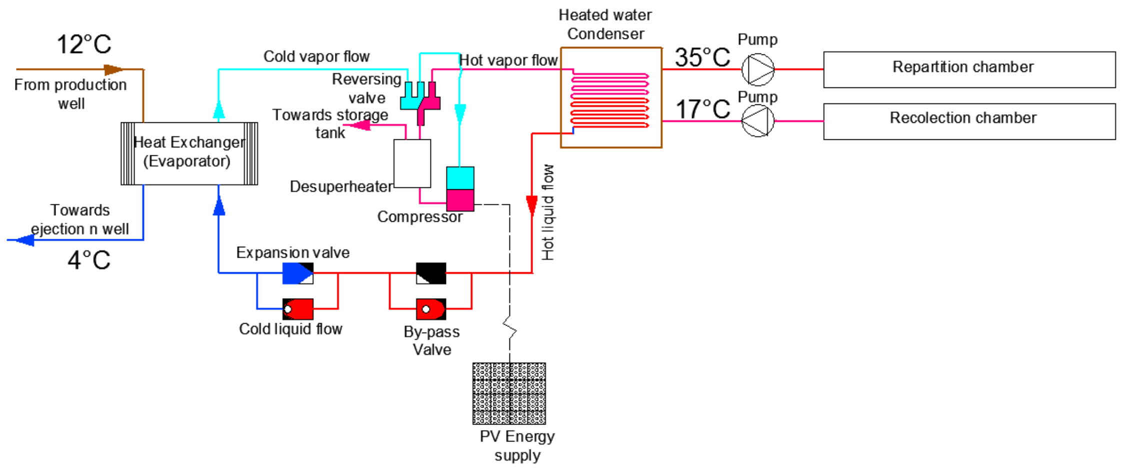


Illustration 220 Winter GHP internal Heating cycle.

On the other hand, the cooling cycle is basically the reverse of the heating cycle. The direction of the water is changed by the reversing valve. The water picks up heat from the air and transfers it directly to the ground water. The heat is then pumped outside, into the water body. However, excess of hot in the compressor cycle is pumped through the desuperheater to the hot water storage tank for its subsequent use.

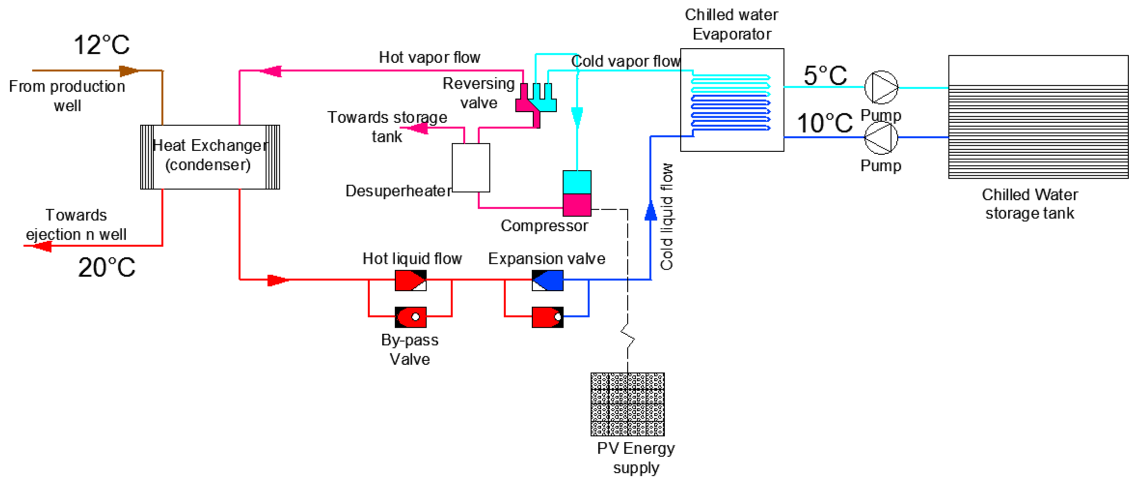


Illustration 221 Summer GHP internal Cooling cycle.

8.3 SIZING

The sizing of the systems consists basically on the capacity of the appliances to pump the required flow of energy of the chiller/heater. This value can be obtained by means of computation between the energy flow throughout the system, and the difference in temperatures of the process intake and outtake. For this application, the peak value of chilling/heating water capacity will drive the size of the geothermal pump.

Hence, taking into consideration the water heater/chilling unit maximum capacity = 40 kW. (as it was presented in the last chapter) , and a difference of temperature between the extraction and injection wells of 8°C, the total pumping flow required is equal to:

$$Q\ (l/s) = \frac{Cooling\ load}{\Delta T * 1.23 *} = \frac{83000\ Wh}{(12-4)\ ℃ * 1.23} = 8434\ l/h$$

Thus, a heating pump that can supply water to 8434 l/h is used for the described application.

8.4 ELECTRICAL CONSUMPTION

The electrical consumption of the open loop ground heating pump can be estimated by calculating the flow demand of the pump and its consequent electric consumption throughout the year.

As a result, taking into consideration an annual heating and cooling load requirement of 40.4 MWh and 8.33 MWh, (as it was presented in the last chapter) , and a difference of temperature between the extraction and injection wells of 8°C, the total pumping flow per year required is equal to:

During heating season:

$$Q\ (l/s) = \frac{Heating\ load}{\Delta T * 1.23 *} = \frac{40.1x10^{6}\ Wh}{(12-4)\ ℃K * 1.23} = \mathbf{4.07x10^{6}} l/s$$

During cooling season:

$$Q\ (l/s) = \frac{Cooling\ load}{\Delta T * 1.23 *} = \frac{0.8x10^{6} Wh}{(20-12)\ ℃K * 1.23} = \mathbf{0.8x10^{6}} l/s$$

With these results the electrical consumption of the pumping unit can be approximated considering an average 0.6 efficiency along the year, and a head of pressure equal to the height of the perforation well (10m) plus 20% for losses due to friction:

$$P\frac{(MWh/year)}{year}=\frac{Q*\gamma*h}{n}=\frac{6.1x10^{6}*10*1.2*1*(Units\ factor)}{0.6}$$
$$=\mathbf{1\ MWh/year}$$

9 DOMESTIC HOT WATER

9.1 METHODOLOGY

The methodology for the estimation of the domestic water heater/storage is done according to the guidelines established by the U.S.A Energy department. Basically, the size of the system is provided in terms of the water heater's first hour rating (FHR). *"The first hour rating is the amount of hot water in gallons the heater can supply per hour (starting with a tank full of hot water). It depends on the tank capacity, source of heat (burner or element), and the size of the burner or element."*[129] *And, on the other hand, the input water temperature (which is considered to be 20℃*

9.2 PEAK HOUR DEMAND

The main demand of hot water supply for the systems is considered to be required by the bars and restaurant zone, which will carry out activities such as hand dishwashing, automatic dishwasher and food preparation.

$$\mathrm{FHP(gal)} = \sum_{i=1}^{n} C * N$$

Where: FHP = First hour peak demand
C = Consumption appliance
N= number of times of use of the appliance in one hour
n= number of appliances.

Equation 19 First hour hot water peak demand calculation

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The peak hour demand is determined from the next table:

Use	Average water consumption per use (gal)	Times used in 1 hour	FHR (gal)
Hand dishwashing	4	10	40
Automatic dishwasher	14	3	42
Food preparation	5	10	50
Total peak hour consumption (gal.h)			**132**

Table 47 FHR calculation

[129] U.S Energy department. Sizing Storage and Heat Pump (with Tank) Water Heaters.(Available online) http://www.energysavers.gov/your_home/ water_heating/index.cfm/mytopic=12990

9.3 SIZING

The sizing of the storage tank/heater and its electrical consumption is calculated according to the parameters supplied by the manufacturer Bradford white in terms of maximum first hour peak demand delivery and the recommended size of tank according to the appliances located in the restaurant/bar zone. As a result, the next graphic shows the output of the analysis, selection and electrical consumption of the tank, taking into account that a input of preheated water of around 20 °C coming from the desuperheater is heated up to 60 °C for its final use

BRADFORD WHITE CORPORATION

RightSpec® Commercial Water Heater Sizing Recommendations

Resize Job | Main Menu

Job Specifications	
Date:	9/14/2011
Application:	Food Service/Restaurant
Installation Type:	Indoor
Fuel:	Electric (ASME)
VentType:	N/A
Immersion Thermostat Required?:	Yes
Inlet Temp:	70°F
Stored Temp:	140°F
General Requirements:	
	2 Double Pot Sinks
	2 Hand Sinks
	2 Bar Sinks
Laundry Requirements:	
	2 Washers (20 Pound Capacity)

	Energy Saver Recommendation # 1	Energy Saver Recommendation # 2	Energy Saver Recommendation # 3
Heaters Required:	1	1	1
Heater Model No.:	50A-45-3	50A-54-3	80A-45-3
Heater Capacity:	50 Gallons	50 Gallons	80 Gallons
Input per Hour:	45 kW	54 kW	45 kW
Storage Tanks Required:	None	None	None
Storage Tank Model No.:			
Storage Tank Capacity:			
Usable Storage:	35 Gallons	35 Gallons	56 Gallons
Recovery:	265 GPH @ 70°F Rise	318 GPH @ 70°F Rise	265 GPH @ 70°F Rise
1st Hour Delivery:	300 Gallons	353 Gallons	321 Gallons
3 Hour Average Delivery:	277 GPH	330 GPH	284 GPH
Approx. Storage Recovery:	11 Minutes	9 Minutes	18 Minutes
% of Demand Satisfied:	107%	128%	110%
Heater Top Vent Height:	47 3/4"	47 3/4"	60 1/4"
Heater Diameter:	24"	24"	26"

Illustration 222 Bradford white calculation form[130]

[130] BRADFORD WHITE. Sizing commercial /foodservices heat water tanks.(Available online) http://rightspec.bradfordwhite.com/ Sizing/FoodService.aspx

9.4 ELECTRICAL CONSUMPTION

Choosing a water storage/heater electric tank with an input power of 45 kWh used half an hour per day to produce the total heating need, during operation time of the bar/restaurant facilities (283 days) a total electrical consumption per year equal to 45*0.5*283 = **6.2 MWh/year.**

On the other hand, if we analyze the behavior of the system in terms of energy consumption by considering the no use of a desuperheater, and thus having a typical intake of water at 5°C. we would obtain a consumption equal to 57*0.5*283 = 8 MWh/year. Hence it can be inferred an electrical energy saving of 1.8 Mwh/year only using a desuperheater appliance.

BRADFORD WHITE CORPORATION

RightSpec® Commercial Water Heater Sizing Recommendations

Resize Job | Main Menu

Job Specifications	
Date:	9/16/2011
Application:	Food Service/Restaurant
Installation Type:	Indoor
Fuel:	Electric (ASME)
VentType:	N/A
Immersion Thermostat Required?:	Yes
Inlet Temp:	40°F
Stored Temp:	140°F
General Requirements:	
	2 Double Pot Sinks
	2 Hand Sinks
	2 Bar Sinks
Laundry Requirements:	
	2 Washers (15 Pound Capacity)

	Energy Saver Recommendation # 1	Energy Saver Recommendation # 2	Energy Saver Recommendation # 3
Heaters Required:	1	1	1
Heater Model No.:	50A-54-3	80A-54-3	120A-54-3
Heater Capacity:	50 Gallons	80 Gallons	119 Gallons
Input per Hour:	54 kW	54 kW	54 kW
Storage Tanks Required:	None	None	None
Storage Tank Model No.:			
Storage Tank Capacity:			
Usable Storage:	35 Gallons	56 Gallons	83 Gallons
Recovery:	223 GPH @ 100°F Rise	223 GPH @ 100°F Rise	223 GPH @ 100°F Rise
1st Hour Delivery:	258 Gallons	279 Gallons	306 Gallons
3 Hour Average Delivery:	234 GPH	241 GPH	250 GPH
Approx. Storage Recovery:	13 Minutes	22 Minutes	32 Minutes
% of Demand Satisfied:	100%	103%	107%
Heater Top Vent Height:	47 3/4"	60 1/4"	64 1/2"
Heater Diameter:	24"	26"	30 1/4"

Resize Job | Main Menu

725 Talamore Drive, Ambler, PA 19002-1815
Email: info@bradfordwhite.com or Phone: 800.523.2931

Illustration 223 Bradford white calculation form without desuperheater[131]

[131] BRADFORD WHITE. Sizing commercial /foodservices heat water tanks.(Available online) http://rightspec.bradfordwhite.com/ Sizing/FoodService.aspx

10 SOLAR PHOTOVOLTAIC SYSTEM

10.1 METHODOLOGY

The methodology for the estimation of the electrical energy production given by the system is the one indicated by the Joint Research center of the European commission. In general the system is planned to produce equal but not more than the energy required, in order to be able to consume all the energy needed, and sell the less possible to the electrical grid (which payback is less than the obtained by consuming energy).

10.2 SYSTEM SELECTION

According to facts analyzed in the chapter “strategies”, and the areas available for the positioning array of solar photovoltaic panels, it has be chosen a system of free-standing monocrystalline silicon PV panels that can be projected for the areas over the roof of the Auditorium/Hall and the parking spaces at an optimum inclination angle of 39° towards south. The photovoltaic arrange will provide the electric demand to the appliances throughout the all building. Taking into account the low reliability of the system to be able to accumulate and supply the whole energy to the building constantly, a grid-connected system is proposed in order to obtain the necessary energy from the grid in winter conditions (out of the one utilized from solar radiation), and export the overflow of energy in summer when solar radiation is higher and the battery storage is full.

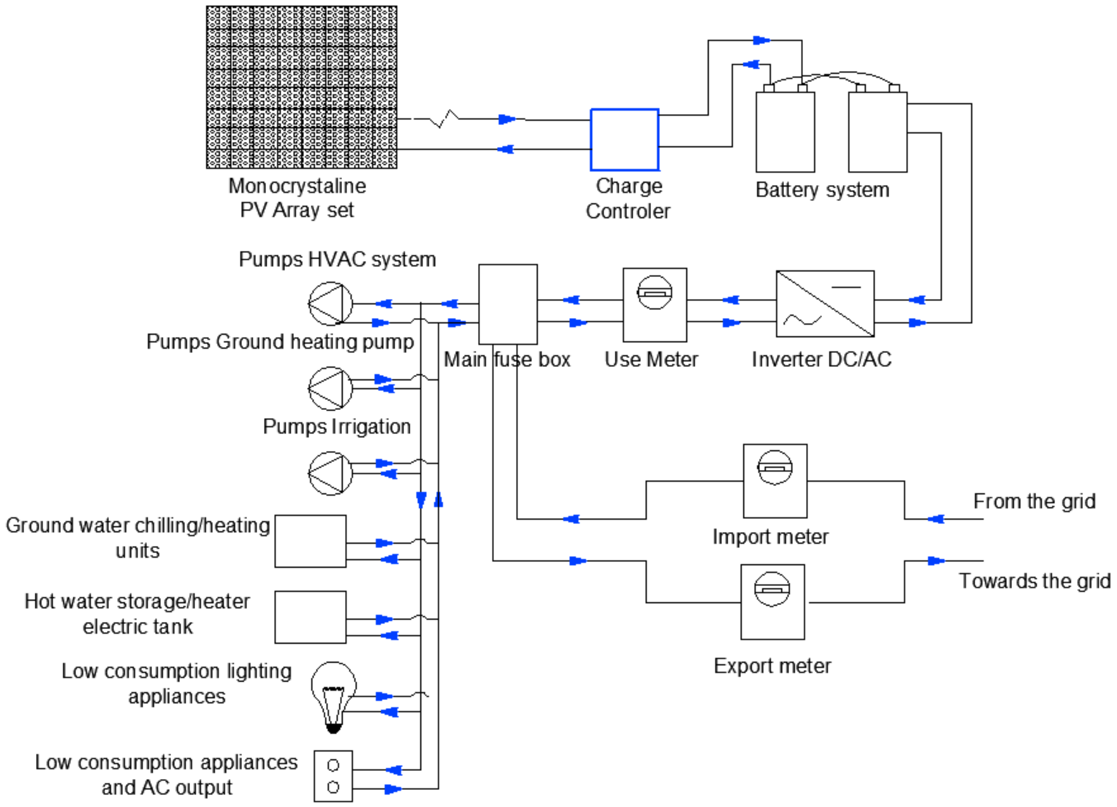


Illustration 224 Photovoltaic system scheme.

The maximum energy that can be produced by this kind of panels is considered to be 1kWp per every 8 m2.

10.3 ENERGY DEMANDS

The electrical energy demands considered are obtained from the results presented in the last chapters. However, electrical consumptions that are not measured and are outside of the scope of the present analysis (I.e lighting, electrical appliances) are hence estimated:

Location	Miscellaneous electrical (Wh/m2) year	Area (m2)	Op. hours/day	Operation days	Total annual energy (MWh)
Zone 1 Auditorium/hall	15	480	4	143	4.118
Zone 2 Transition space	15	350	12	143	9.009
Zone 3 Gallery/temporal exposition	15	200	12	143	5.148
Zone 4 Services Auditorium	15	270	4	143	2.317
Zone 5 Restaurant/bars	15	800	12	283	40.752
Total					***61.34***

Location	Light (Wh/m2) year	Area (m2)	Op. hours/day	Operation days	Total annual energy (MWh)
Zone 1 Auditorium/hall	12.5	480	4	143	3.432
Zone 2 Transition space	12.5	350	12	143	7.508
Zone 3 Gallery/temporal exposition	12.5	200	12	143	4.290
Zone 4 Services Auditorium	12.5	270	4	143	1.931
Zone 5 Restaurant/bars	12.5	800	12	283	33.960
Total					***51.12***

Table 48 Miscellaneous and lighting electrical energy estimated consumption

- Lighting. 51 MWh/year.
- Miscellaneous energy consumption. 61 MWh/year.
- AHU supply and return fans. 9.7 MWh/year.
- Ground heating pumping. 1 MWh/year.
- Refrigeration cycle heating/cooling. 24 MWh/ year.
- Hot water storage/heating. 6.2 MWh/year.

TOTAL ANNUAL ELECTRIC DEMAND: 152 MW

If we compare this value with the average consumption of an low energy office building operating at the same hours and time than the spaces located in the building (50w/m2):

Location	Low energy Office (Wh/m2) year	Area (m2)	Op. hours/day	Operation days	Total annual energy (MWh)
Zone 1 Auditorium/hall	50	480	4	143	13.728
Zone 2 Transition space	50	350	12	143	30.030
Zone 3 Gallery/temporal exposition	50	200	12	143	17.160
Zone 4 Services Auditorium	50	270	4	143	7.722
Zone 5 Restaurant/bars	50	800	12	283	135.840
Total					***204.48***

Table 49 Comparison consumption of an office building.

It can be seen that the sized system consumes 25% less energy per year than a low energy consumption office building.

10.4 SIZING

The sizing of the electrical system is realized taking into account the electric demand of the building and the maximum yearly production of the power PV system.

10.4.1 Energy production capacity

The energy production capacity is calculated for nominal peak energy of 1kWp, and the next sort of assumptions and verifications obtained by the software of the Joint research center. [132]

- Nominal power of the PV system: 1.0 kW.
- Optimal inclination angel and azimuth: 39° , 0°.
- Efficiency of the modules: 12%
- Estimated losses due to temperature: 8.6%.
- Estimated loss due to angular reflectance effects: 2.7%
- Other losses (cables, inverter etc.): 14.0%
- Combined PV system losses: 23.5%

[132] JOINT RESEARCH CENTRE. Photovoltaic geographical information system, interactive maps. (Online web content). http://re.jrc.ec. europa.eu/pvgis/ apps4/ pvest.php

The result of the analysis using the web-based tool of the Joint Research center is represented in the next table, where it can be seen that the maximum yearly energy production of electrical energy for each kWp installed is equal to 1.2 MWh/year.

Performance of Grid-connected PV

NOTE: before using these calculations for anything serious, you should read [this]

PVGIS estimates of solar electricity generation

Location: 45°43'33" North, 9°24'41" East, Elevation: 285 m a.s.l.,

Solar radiation database used: PVGIS-CMSAF

Nominal power of the PV system: 1.0 kW (crystalline silicon)
Estimated losses due to temperature: 8.5% (using local ambient temperature)
Estimated loss due to angular reflectance effects: 2.5%
Other losses (cables, inverter etc.): 14.0%
Combined PV system losses: 23.3%

,

Fixed system: inclination=39°, orientation=0°				
Month	E_d	E_m	H_d	H_m
Jan	2.33	72.3	2.78	86.3
Feb	3.25	91.0	3.96	111
Mar	3.91	121	4.98	154
Apr	3.90	117	5.09	153
May	4.24	132	5.68	176
Jun	4.70	141	6.40	192
Jul	4.83	150	6.63	206
Aug	4.42	137	6.07	188
Sep	3.92	118	5.24	157
Oct	2.81	87.3	3.62	112
Nov	2.46	73.8	3.03	90.8
Dec	1.92	59.7	2.31	71.6
Yearly average	**3.56**	**108**	**4.65**	**142**
Total for year		**1300**		**1700**

E_d: Average daily electricity production from the given system (kWh)
E_m: Average monthly electricity production from the given system (kWh)
H_d: Average daily sum of global irradiation per square meter received by the modules of the given system (kWh/m^2)
H_m: Average sum of global irradiation per square meter received by the modules of the given system (kWh/m^2)

window.focus();

Table 50 Photovoltaic yearly energy generated by the system

According to the data acquired it has been decided to realize the analysis of the demand vs offer in terms of electrical loads to be supplied by the PV panels. This initiative is done taking into consideration the amount of electrical loads needed in the building and the possible economical feseability of the system. As a result, it is analysed the possibility to supply the electrical energy demand due to the heating/cooling systems of the building which are considered a priority over the lighting and miscellaneous energy demands.

As a result, in the next table are shown the size requirements of the photovoltaic system according to the electric demand needed for heating and cooling mainly:

Heating/cooling	Electrical load (MWh/year)	Capacity Pv array 8m2 (MWh/year)	Peak production needed (kWp)	Area needed (m2)
AHU supply and return fans.	9.7	1.3	7	60
Ground heating pumping.	1	1.3	1	6
Refrigeration cycle heating/cooling.	24	1.3	18	148
Hot water storage/heating.	6.2	1.3	5	38
Total			***31***	***252***

Table 51 PV array sizing for electrical energy due to cooling/heating

Taking into account the space available in the boundaries of the set of buildings, and the minimum capacity required for the Italian government incentive policies, according to the PEP[133]. it has been decided to locate the area required for a minimum peak production of 31 kWh (252m2) on the roof of the Auditorium/hall building.

In a long term it can be presented the addition of a higher photovoltaic system that can supply the loads required for lighting or others. This analysis is presented in the next table.

Heating/cooling	Electrical load (MWh/year)	Capacity Pv array 8m2 (MWh/year)	Peak production needed (kWp)	Area needed (m2)
Miscellaneous loads	61	1.3	47	375
Lighting	51	1.3	39	314
Total			***86***	***689***

Table 52 PV array sizing for electrical energy due to lighting and others

[133] PIANO ENERGETICO PROVINCIALE DI LECCO. Scheda di Intervento. 2009. Pg 4:44.

11 ACOUSTICAL SYSTEM

11.1 METHODOLOGY

The calculation process has been done taking into account the instances and material properties obtained from different manufacturers of panels and the standard UNI 12354. For the sake of simplicity, and taking into account the expected use and size of the theater/ auditorium, it has been considered to evaluate the reverberation time of the space as a measurement of the quality of sound that the space will present in a concert, speech-theater or any other multipurpose activity at small scale.

11.2 SYSTEM SELECTION

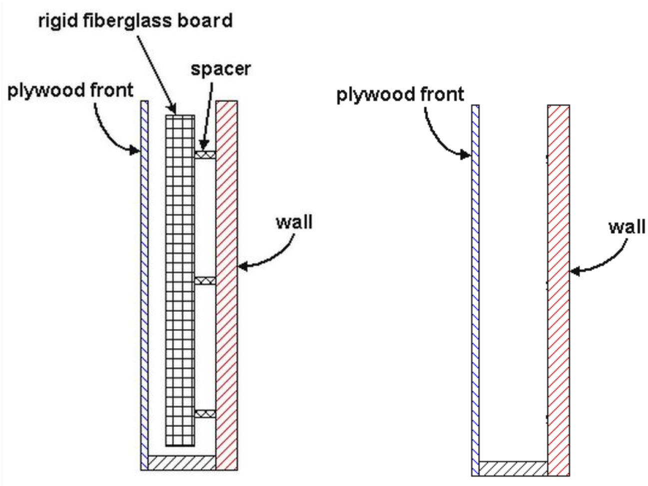
Multi-purpose uses, demands that auditorium acoustics satisfy acoustical needs for theatrical performances, concerts, speeches, assemblies, and public gatherings equally well. The auditorium context designed for a capacity of 300 seats can be seen as a minimum area to realize high efficient acoustical performance, however, some considerations about internal acoustic insulation and straight perforated panels on roof and walls can enhance the brightness and warmth of the sound around the hall.

It has to be considered that in most of the cases conflicting requirements can occur between the different activities for which the room is conditioned, due to the main objectives that a concert or on the other hand a speech are trying to attain in the room. In particular terms, the acoustics of a space designed for mainly speech activities must ensure basically the intelligibility, definition and understanding in the gestural and vocal communication process carried out in the room, as a result, it can be considered that the quality of the speech signal is not too critical, as long as the speaker's voice and accent are recognizable. On the other hand, music audiences are expecting for good qualities of sound for various styles of music, while the clarity and recognition is not influent considered influent in the performance and it is considered to give the impression of brittleness or dryness in the act, by also giving low levels of brightness, which is required in a concert. Another crucial difference between this two activities is that music can consist of a great range of frequencies (20 Hz – 20 kHz) while speech mainly occurs at a narrow band signal (500 Hz – 4kHz).

Taking into account the conditions stated above, it has been considered to use the next compound of systems to produce the dynamic behavior of the multipurpose auditorium/hall.

11.2.1 Absorbers

In order to provide the necessary sound absorption for the multipurpose auditorium/hall, it has been proposed a layered scheme of the main absorbing walls, giving the flexibility to the inclusion or exclusion of absorptive material (fiberglass) depending on the need of the design, while keeping the architectural finishing of the room. The location of the absorbers in the room will be around all the perimeter of the vertical walls of the room.



Graphic 79 Absorber-wall scheme- with and without fiberglass layer. (Extracted from Wiener) [134]

11.2.2 Reflectors

The hanging reflectors to be located into the auditorium are meant to produce the maximum reflection of the first waves produced to the audience form and to all the parts of the room.

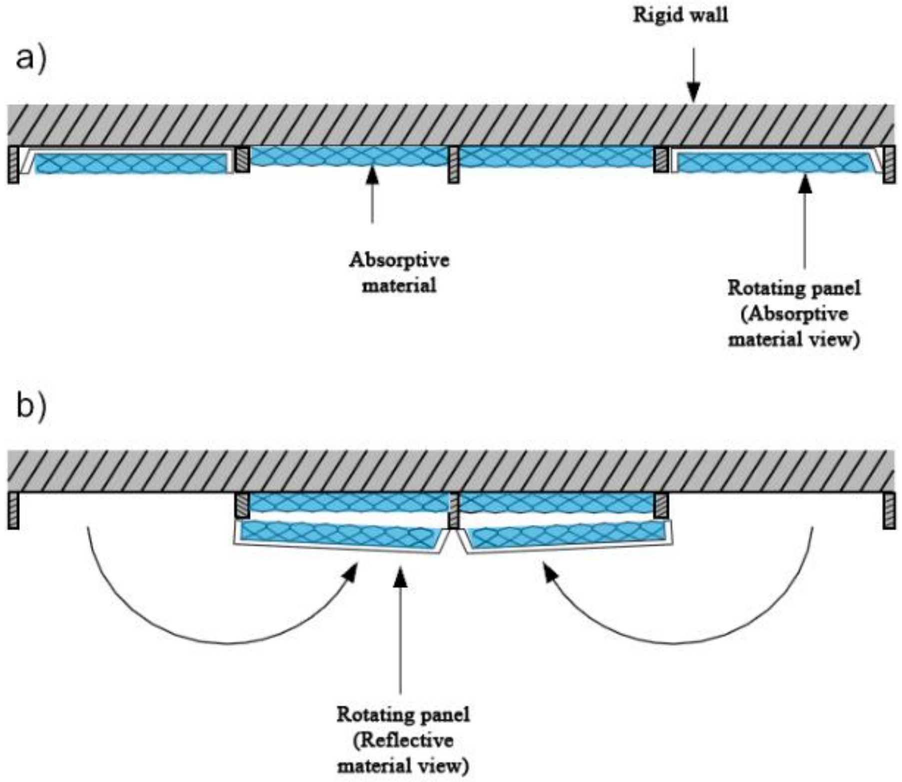
The reflectors will be mainly located in the ceiling of the auditorium starting from the end line of the stage towards the end line of the backseats.

11.2.3 Rotating panels

Being one of the simplest types of appliances that can be used and fit into the design of the building, it has been chosen a dynamic system that can reproduce the levels of reflection and absorption desired during each activity to be performed. As a result, the operation of the panels will generate the required reverberation times for a theatrical/recital/musical activity when the absorber face is close, letting a maximum reflection that can enhance the sound quality of these activities. On the other hand, when the rotating panels are wide open, (absorber face open) the level of absorption will rise, lowering the reverberation time of the room, which is a need in order to obtain the balance sound in the narrow band signal of a speech activity. The location of these panels will be on

[134] Wiener, Ethan. Acoustic treatment and design for listening rooms and recording studios. A [Available online]. http://www.ethanwiner.com/acoustics.html

the long walls of the theater, parallel to the seating in order to provide the reflection needed directly to the audience.



Graphic 80 Rotating panels' scheme. a.) Open position. b.) Closed position.

11.3 REVERBERATION TIME CHECKING

The reverberation time is given taking into account the effect of air in the absorption of the sound overall high at frequencies (2 kHz – 4 kHz).

$$T_{60} = \frac{0.163 * V}{A} \quad ; \quad A = \sum_{i=1}^{n} S_i * \alpha_i$$

Where: t60 = Reverberation time (s)
A = Total absorption (m2.sabine)
V = volume of the space.
S = Area of the surface (m2)
α = Absorptive of the surface

Equation 20 Reverberation time equation

In order to provide a satisfactory design to a multipurpose hall, the acoustic requirements must fulfill suitable conditions when the room is hosting mainly “speech” activities (theatrical performances and speech), and when it is hosting a concert or a recital.

11.3.1 Speech performance

According to the requirements stated above, and taking into account the size of the space in which the activity is performed, the ability of the design to ensure a production of recognizable and intelligible speech in the room relies on the idea of maintaining a short reverberation time according to BARRON (refers to Cremer and Müller (1982) [135] explains how by experimental results in general conditions a reverberation time below 1 second does not create distinctness in the room and reduces the rising of bass’ sounds in theatrical performances, however a too short reverberation time such as those bellow 0.5 s the acoustics would sound too dry for comfort, even though intelligibility is likely to be good. As a result, it can be inferred that a time of reverberation between 0.7 and 0.8 seconds is a suitable solution for this kind of activity. Hence it is performed an iterative analysis of the acoustical performance of the building obtaining a final reverberation time (as it is shown in the next table) that would satisfy the requirements stated above taking into account the next considerations:

- Rotating panels should be wide open in order to produce the maximum absorption of the acoustical system, and thus to be able to facilitate the expected reverberation time for either full occupation or empty room.
- Ovation reflection panels cover 70% of the area of the roof while 30% is absorption material.

				Absorption				Sabine			
Location	Material	Area	%	500 Hz	1 kHz	2 kHz	4 kHz	500 Hz	1 kHz	2 kHz	4 kHz
South wall	Perforated panel Decortech HR 513	50.8	100%	1.05	0.81	0.37	0.19	53.4	41.2	18.8	9.7
South wall +2m	Fiberglass board (25mm(1") thick)	103.0	100%	0.65	0.9	0.95	0.98	67.0	92.7	97.9	100.9
South wall +2m	Perforated panel Decortech HR 513	103.0	100%	1.05	0.81	0.37	0.19	108.2	83.4	38.1	19.6
South wall +2m	Ovation reflector panel	103.0	0%	0.03	0.04	0.05	0.14	0.0	0.0	0.0	0.0
North wall	Perforated panel Decortech HR 513	50.8	100%	1.05	0.81	0.37	0.19	53.4	41.2	18.8	9.7
North wall +2m	Fiberglass board (25mm(1") thick)	103.0	100%	0.65	0.9	0.95	0.98	67.0	92.7	97.9	100.9
North wall +2m	Perforated panel Decortech HR 513	103.0	100%	1.05	0.81	0.37	0.19	108.2	83.4	38.1	19.6
North Wall +2 m	Ovation reflector panel	103.0	0%	0.03	0.04	0.05	0.14	0.0	0.0	0.0	0.0
Back Wall	Fiberglass board (25mm(1") thick)	29.0	100%	0.65	0.9	0.95	0.98	18.8	26.1	27.5	28.4
Back Wall	Perforated panel Decortech HR 513	29.0	100%	1.05	0.81	0.37	0.19	30.4	23.5	10.7	5.5
Back Wall- Window	Glass (small pane)	7.7	100%	0.03	0.03	0.02	0.02	0.2	0.2	0.2	0.2
Back Wall	Perforated panel Decortech HR 513	44.8	100%	1.05	0.81	0.37	0.19	47.0	36.2	16.6	8.5
Front wall	Plaster (gypsum or lime, on masonry)	69.3	100%	0.02	0.03	0.04	0.05	1.4	2.1	2.8	3.5
Spectators	Seats (fabric-upholsterd, fully occupied)	80.0	100%	0.88	0.96	0.93	0.85	70.4	76.8	74.4	68.0
Floor	Wood parquet on concrete	293.0	100%	0.07	0.06	0.06	0.07	20.5	17.6	17.6	20.5
Roof	Perforated panel Decortech HR 513	310.0	30%	1.05	0.81	0.37	0.19	97.7	75.3	34.4	17.7
Roof	Ovation reflector panel	310.0	70%	0.03	0.04	0.05	0.14	6.5	8.7	10.9	30.4
				T60				**0.64**	**0.68**	**0.92**	**0.93**

T60	0.79

Table 53 Calculation reverberation time for speech performance

[135] BARRON, Michael. Auditorium acoustics and Architectural design. 2009. P. 249

11.3.2 Musical performance

The reverberation time of spaces such as the one considered in the present project can be considered to be similar to the one required for a small recital hall which can differ from the one needed for a big opera house/theater or concert halls basically on its capacity. As an example, the reverberation time for symphony concert halls is a function of the “programme” only, while smaller halls depend directly, or are more sensitive to the volume of the space as a result of an empirical application. Recommendations in the design of small halls find suitable the use of a reverberation time between 1.4 – 1.7 for a volume of up to 3000 m3. Hence it is performed an iterative analysis of the acoustical performance of the building obtaining a final reverberation time (as it is shown in the next table) that would satisfy the requirements stated above taking into account the next considerations:

- Rotating panels should be closed in order to produce the minimum absorption of the acoustical system, and thus to be able to facilitate the expected reverberation time for either full occupation or empty room.
- Ovation reflection panels cover 70% of the area of the roof while 30% is absorption material.

Total volume (m3)	Material			m					4mV				
2986.086	Air			0	0.00025	0.00075	0.001	0.00225	0	3	9	12	27
				Absorption					4mV				
Location	**Material**	**Area**	**%**	**125 Hz**	**250 Hz**	**500 Hz**	**1 kHz**	**2 kHz**	**125 Hz**	**250 Hz**	**500 Hz**	**1 kHz**	**2 kHz**
South wall	Perforated panel Decortech HR 513	50.8	100%	0.31	0.81	1.05	0.81	0.37	15.8	41.2	53.4	41.2	18.8
South wall +2m	Perforated panel Decortech HR 513	103.0	50%	0.31	0.81	1.05	0.81	0.37	16.0	41.7	54.1	41.7	19.1
South wall +2m	Ovation reflector panel	103.0	50%	0.15	0	0.03	0.04	0.05	7.7	0.0	1.5	2.1	2.6
North wall	Perforated panel Decortech HR 513	50.8	100%	0.31	0.81	1.05	0.81	0.37	15.8	41.2	53.4	41.2	18.8
North wall +2m	Perforated panel Decortech HR 513	103.0	50%	0.31	0.81	1.05	0.81	0.37	16.0	41.7	54.1	41.7	19.1
North Wall +2 m	Ovation reflector panel	103.0	50%	0.15	0	0.03	0.04	0.05	7.7	0.0	1.5	2.1	2.6
Back Wall	Fiberglass board (25mm(1") thick)	29.0	100%	0.06	0.2	0.65	0.9	0.95	1.7	5.8	18.8	26.1	27.5
Back Wall	Perforated panel Decortech HR 513	29.0	100%	0.31	0.81	1.05	0.81	0.37	9.0	23.5	30.4	23.5	10.7
Back Wall- Window	Glass (small pane)	7.7	100%	0.04	0.04	0.03	0.03	0.02	0.3	0.3	0.2	0.2	0.2
Back Wall	Perforated panel Decortech HR 513	44.8	100%	0.31	0.81	1.05	0.81	0.37	13.9	36.2	47.0	36.2	16.6
Front wall	erboard (12mm(1/2") in suspended ceiling	69.3	100%	0.15	0.11	0.04	0.04	0.07	10.4	7.6	2.8	2.8	4.9
Spectators	Seats (fabric-upholsterd, fully occupied)	80.0	100%	0.6	0.74	0.88	0.96	0.93	48.0	59.2	70.4	76.8	74.4
Floor	Wood parquet on concrete	293.0	100%	0.04	0.04	0.07	0.06	0.06	11.7	11.7	20.5	17.6	17.6
Roof	Perforated panel Decortech HR 513	310.0	20%	0.31	0.81	1.05	0.81	0.37	19.2	50.2	65.1	50.2	22.9
Roof	Ovation reflector panel	310.0	80%	0.15	0	0.03	0.04	0.05	37.2	0.0	7.4	9.9	12.4
				T60					**2.11**	**1.34**	**0.99**	**1.14**	**1.65**

T60	1.45

Table 54 Calculation reverberation time for speech performance

12 RAIN WATER RECOLLECTION SYSTEM

12.1 METHODOLOGY

The following calculation is made according to the data presented in the last chapter regarding characteristic monthly average precipitation rates for the zone of the project, and following the methodology described in the Rainwater tank harvesting anual[136] and the Texas[137] rain water harvesting manuals. For simplification purposes, and given the level of detail to be produced at the end of this work, the theory is assumed to be concise for feasibility purposes, although factors such as evaporation rates, wind velocity and other parameters are not estimated as an influence in the design, but however it has been demonstrated that can influence real efficiency of a system. For estimating demands it has been decided to use the instances purposed by the Water System design Manual.[138] On the other hand, the design of gutters has been done following the instances given by the standard UNI EN 12056 – 3 – Sistemi per l'evacuazione delle acque meteoriche, progettazione e calcolo.

12.2 SCHEMATIC DESIGN

The design of the rain water recollection systems consists of 2 parts: a catching system composed by a series of gutters that recollect the rain water coming from the available roof area, a second part consist on an storage system that will supply the water by means of gravity to each one of the toilet rooms existing in the compound of buildings. In the next series of graphic it is shown the system complexity.

[136] THE CABELL BRAN CENTER Virginia Rainwater tank harvesting manual. 2007. P33.
[137] TEXAS WATER DEVELOPMENT BOARD. The texas Manual on rainwater harvesting. 2005. P32.
[138] WASHINGTON STATE DEPARTMENT OF HEALTH. Water System design Manual. 2009. P37-38

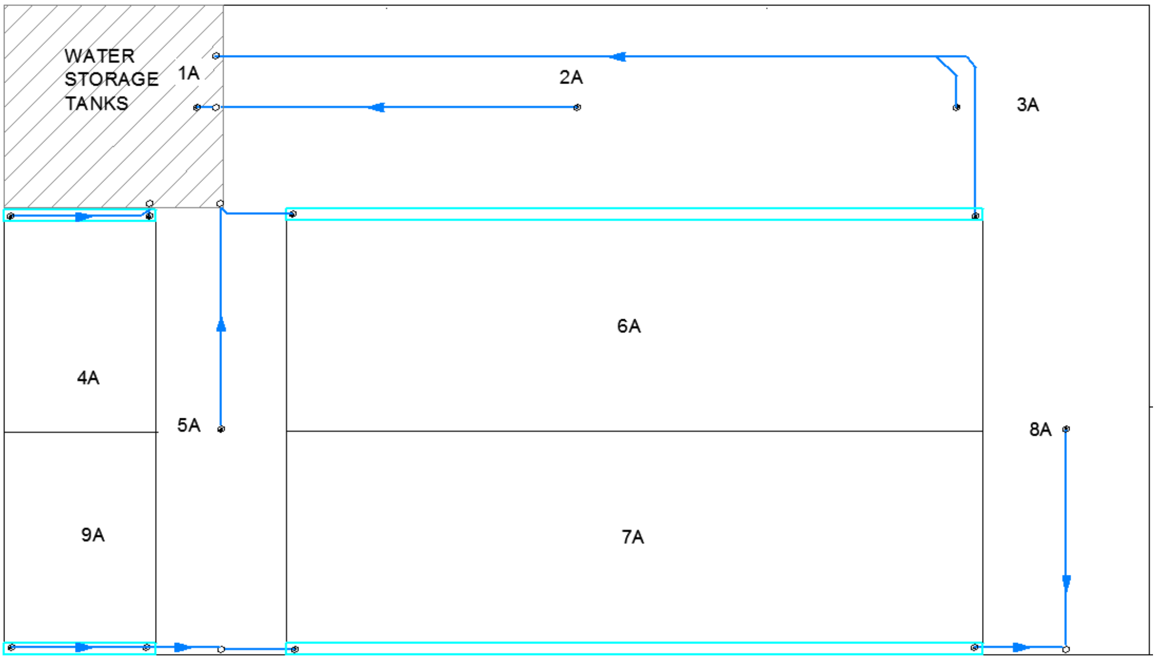


Illustration 225 Auditorium/hall water catching system - gutters and channels scheme

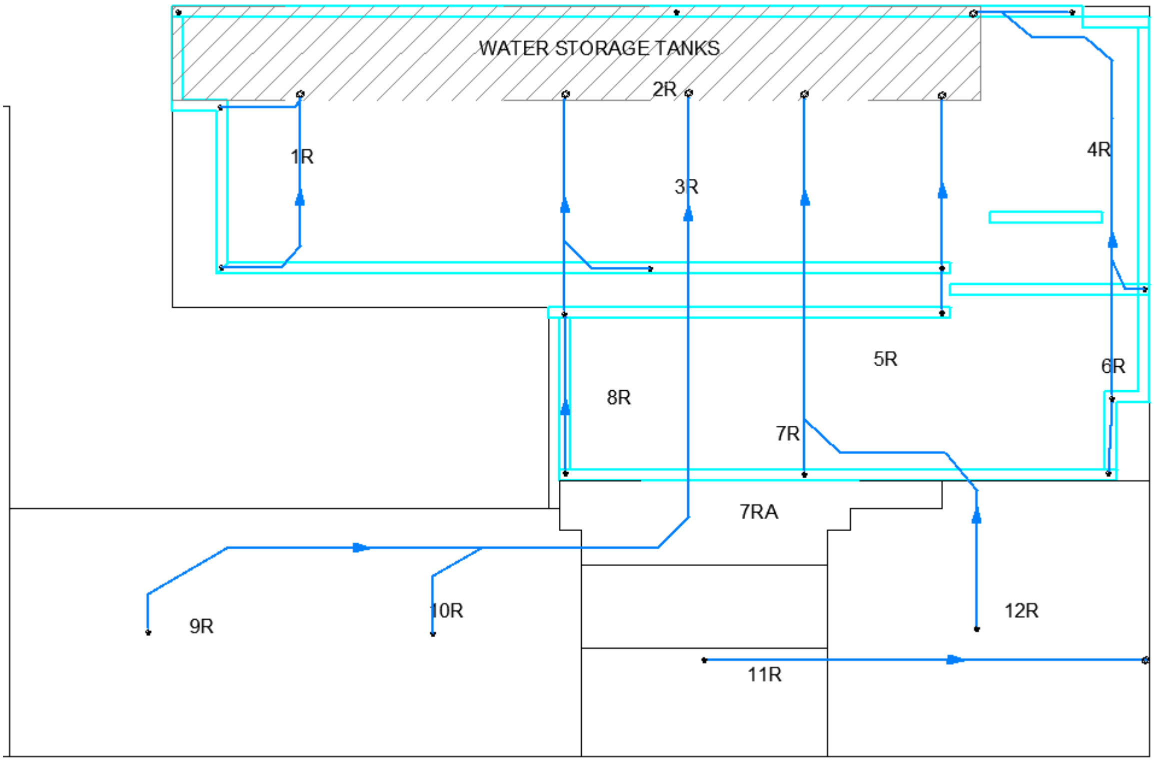


Illustration 226 Restaurant/bar water catching system - gutters and channels scheme

According to the area of the building, it has been estimated that the water catching area available be reduced up to the point in which it can be satisfied the whole demand for water consumption of toilets and irrigation. This consideration is done taking into account that a bigger area is proportional to the number of gutters and network lines needed in order to move all the recollected water to its storage. According to this, some areas of the auditorium roof (areas 7A, 9A and 8A) and of the restaurant/bar (area 11 R) area neglected inside the calculation of water storage, but its gutter and channel design is done normaly.

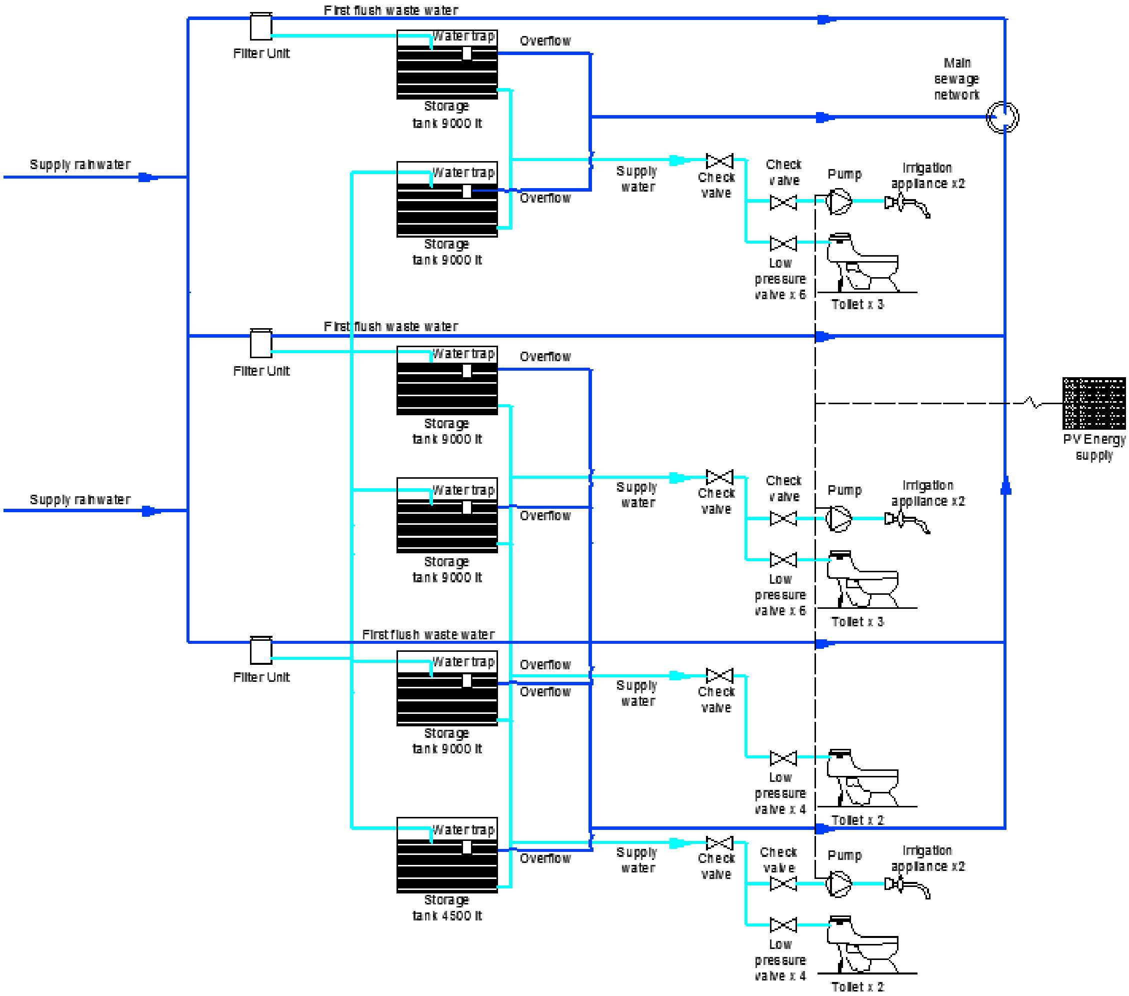


Illustration 227 Restaurant/bar storage and supply scheme

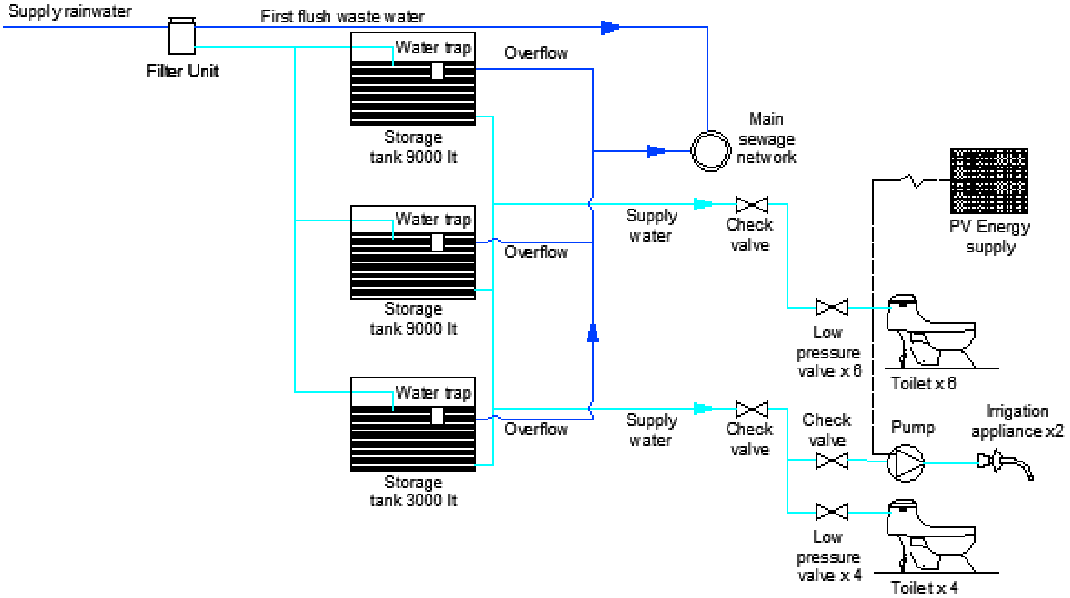


Illustration 228 Auditorium/hall storage and supply scheme

12.3 CHANNELS DESIGN

12.3.1 Sizing:

The sizing of channels is given according to the different geometry and distribution water catching areas throughout the roof of the compound of buildings. In the next graphic it is shown the catchment areas which are adjacent to the channels for its sizing.

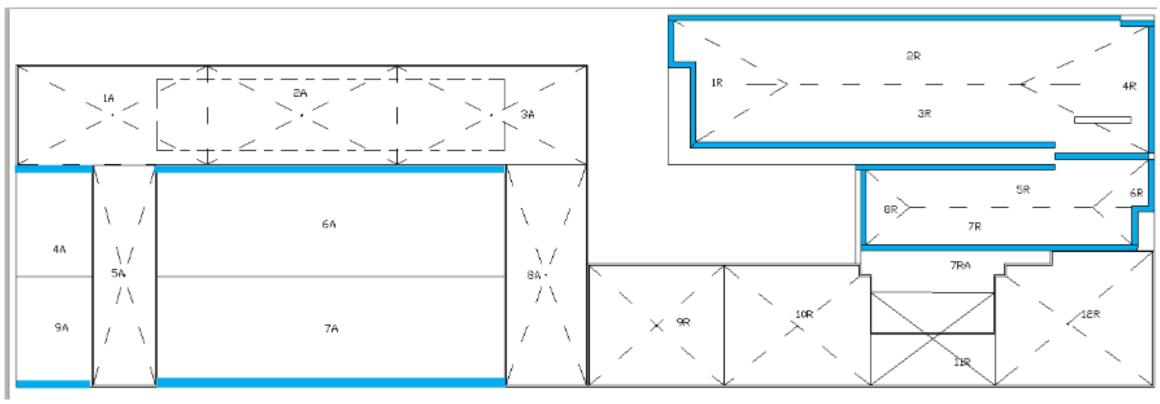
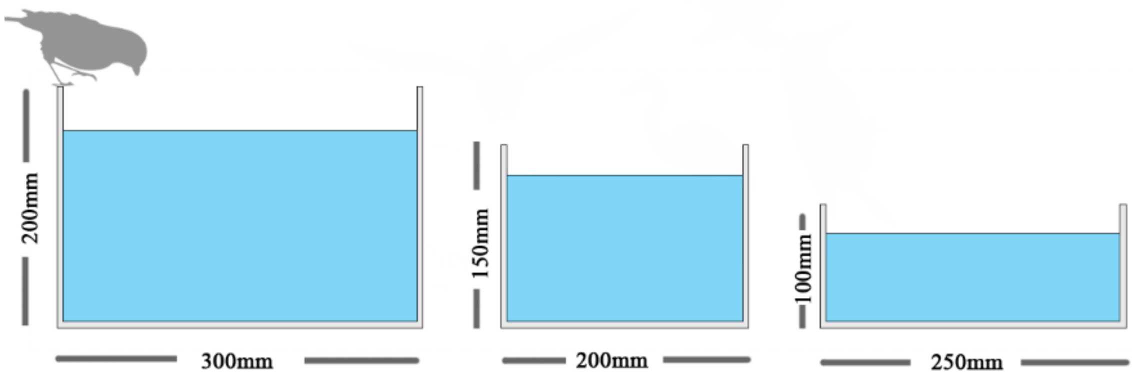


Illustration 229 channels distribution in the building (roof - plan view)



Graphic 81. Sizing of rainfall catching channels.

12.3.2 Rainwater demand

The demand of rainfall water for the gutters and channels is calculated independently for each one of the buildings that compose the project (Auditorium/hall, Restaurant/bar) as well as it has been done for the storage capacity calculation. The value obtained of the demand should be assessed against the capacity of the channels in order to obtain its size and specific dimensions:

$$Q\ (l/s) = r' * k * A * C \leq\ Q_l\ (l/s)$$

Where: Q = demand of the system to transport
r = Raining intensity. (l/s*m2), k = risk coefficient (when r' cannot be calculated by statistical methods.
A= Effective roof area (m2)
C= runoff coefficient = 1

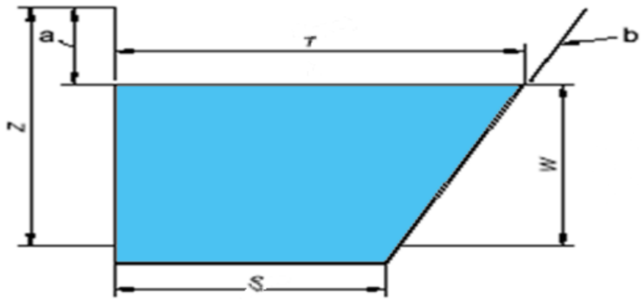
Equation 21 Expected demand of the system.

Taking into account the impossibility to calculate for statistical methods the rainfall intensity, it has been chosen a conservative value of rainfall intensity r = 0.05 l/m2.s times a k coefficient = 2, due to the high amount of channels inside the boundaries of the building. However, for the channels of the roof in ETFE which are considered to be outside of the structure, k = 1.

Situazione	Coefficiente di rischio
Cornicioni di gronda	1,0
Cornicioni di gronda situati in punti in cui la tracimazione dell'acqua causerebbe disagi particolari, per esempio sopra l'ingresso di un edificio pubblico	1,5
Canali di gronda interni e nel caso in cui piogge straordinariamente abbondanti o ostruzioni del pluviale potrebbero provocare un'infiltrazione di acqua all'interno dell'edificio	2,0
Canali di gronda interni di edifici per i quali si richiede un grado di protezione eccezionale, per esempio: - ospedali/teatri - impianti di telecomunicazione - depositi di sostanze che danno origine a emissioni tossiche o infiammabili se bagnate con acqua - edifici nei quali sono conservate opere d'arte di valore eccezionale	3,0

Illustration 230 Risk coefficients k. (Extracted from UNI-12056)

12.3.3 Capacity



Graphic 82. Design scheme for capacity.

In the design it must be satisfied:

- For Channels Z< 80 mm, amin = 25mm
- For channels with Z up to 250 mm, amin = 0.3*Z.
- For channels with Z more than 250 mm, amin = 75mm.

The capacity of the channels should be more or at least equal to the demand established with the equation stated before. The calculation is given for long and short channels. When the length of a gutter is considered to be < 50*height, the gutter can be considered as a short channel, otherwise, it will be considered a long channel. Hence:

$$Q_{l}(l/s) = 0.9 * 3.48 * 10^{-5} * A_{channel}^{1.25} * F_{d} * F_{s}$$

Where: Q = Capacity of the system
Fs = Shape relation coefficient
A= Area chanel (mm2)
Fd= Deep relation coefficient

Equation 22 Expected capacity of the system for short channels

$$Q_{l}(l/s) = 0.9 * 3.48 * 10^{-5} * A_{channel}^{1.25} * F_{d} * F_{s} * F_{l}$$

Where: Q = Capacity of the system
Fs = Height relation coefficient
A= Area channel (mm2)
Fd= Deep relation coefficient
Fl= discharge coefficient

Equation 23 Expected capacity of the system for long channels

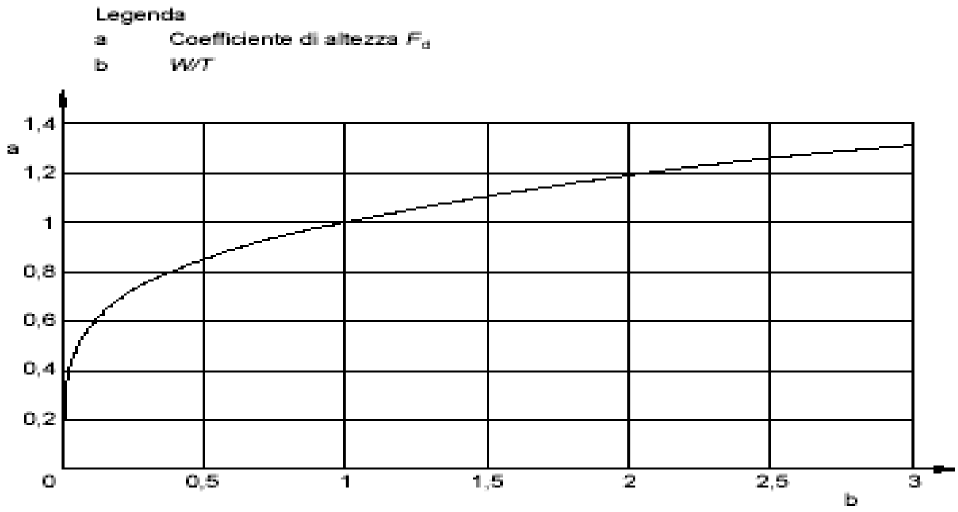


Illustration 231 Height relation coefficient Fd. (Extracted from UNI-12056)

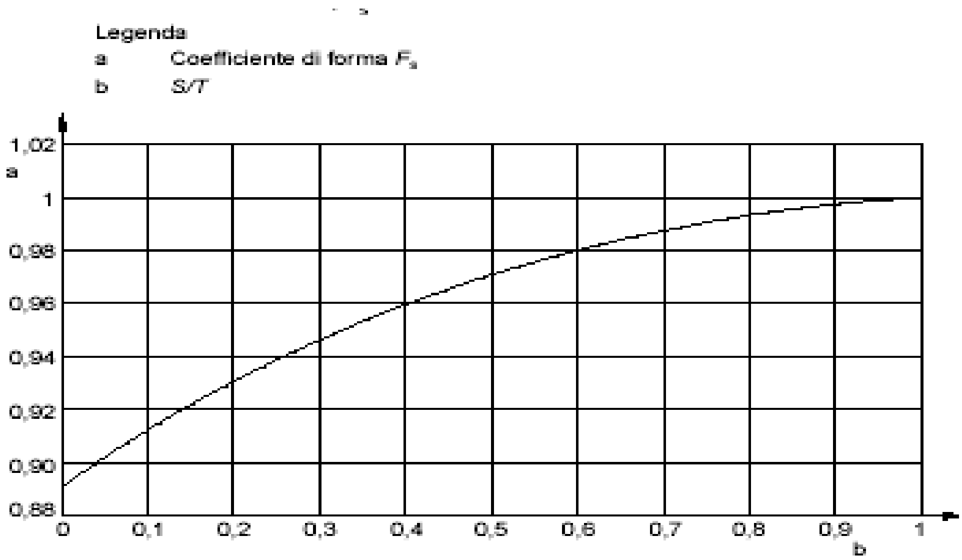


Illustration 232 Shape relation coefficient Fd.. (Extracted from UNI-12056)

$\frac{L}{W}$	Coefficiente di scarico, F_L				
	Nominalmente orizzontale da 0 mm a 3 mm/m	Pendenza 4 mm/m	Pendenza 6 mm/m	Pendenza 8 mm/m	Pendenza 10 mm/m
50	1,00	1,00	1,00	1,00	1,00
75	0,97	1,02	1,04	1,07	1,09
100	0,93	1,03	1,08	1,13	1,18
125	0,90	1,05	1,12	1,20	1,27
150	0,86	1,07	1,17	1,27	1,37
175	0,83	1,08	1,21	1,33	1,46
200	0,80	1,10	1,25	1,40	1,55
225	0,78	1,10	1,25	1,40	1,55
250	0,77	1,10	1,25	1,40	1,55
275	0,75	1,10	1,25	1,40	1,55
300	0,73	1,10	1,25	1,40	1,55
325	0,72	1,10	1,25	1,40	1,55
350	0,70	1,10	1,25	1,40	1,55
375	0,68	1,10	1,25	1,40	1,55
400	0,67	1,10	1,25	1,40	1,55
425	0,65	1,10	1,25	1,40	1,55
450	0,63	1,10	1,25	1,40	1,55
475	0,62	1,10	1,25	1,40	1,55
500	0,60	1,10	1,25	1,40	1,55

Note:

L Lunghezza di scarico della grondaia, in millimetri (mm);

W Altezza teorica dell'acqua, che per le grondaie esterne corrisponde alla profondità totale della grondaia fino al livello di tracimazione e per le grondaie di compluvi o parapetti corrisponde alla profondità fino al livello di tracimazione meno la tolleranza del bordo libero, in millimetri (mm).

Illustration 233 Discharge coefficient for long channels (Extracted from UNI-12056)

12.3.4 Results

Here after there are presented the calculation data and results for the channels sizing. The code given, is aimed to identify the channel which catches the water from the adjacent area named as it was shown above.

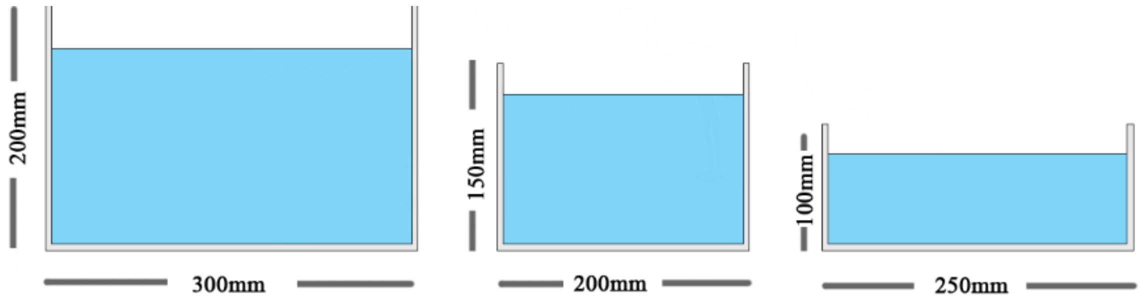
Channels design Sheet

Demand Calculation

Location	CODE	Area (m2)	r '(l/m2.s)	k	C	Q (l/s)
Auditorium/hall	4AC	43.4	0.05	2	1	4.34
	6AC	199.8	0.05	2	1	19.98
	7AC	199.8	0.05	1	1	9.99
	9AC	43.4	0.05	1	1	2.17
Bar/restaurant	1RC	35	0.05	2	1	3.5
	2RC	117.4	0.05	1	1	5.87
	3RC	121.2	0.05	1	1	6.06
	4RC	42	0.05	2	1	4.2
	5RC	54.8	0.05	2	1	5.48
	6RC	13.7	0.05	2	1	1.37
	7RC+7RAC	70.1	0.05	2	1	7.01
	8RC	10.7	0.05	2	1	1.07

Capacity Calculation

	Channel dimensions													
Channel	L (m)	Z (m)	b (m)	W (m)	S (m)	T (m)	Type	Pend. (%)	Area (mm2)	fd	fs	fL	Ql (l/s)	Q<Ql
4AC	5.5	0.120	0.03	0.095	0.25	0.25	Long	0.8	23750	0.812	1.000	0.99	7.36	OK!!
6AC	25	0.250	0.075	0.175	0.30	0.30	Long	0.8	52500	0.889	1.000	1.15	25.24	OK!!
7AC	25	0.200	0.060	0.14	0.20	0.20	Long	0.8	28000	0.913	1.000	1.15	11.80	OK!!
9AC	5.5	0.120	0.03	0.095	0.25	0.25	Long	0.8	23750	0.812	1.000	0.99	7.36	OK!!
1RC	10.3	0.120	0.03	0.095	0.20	0.20	Long	0.8	19000	0.857	1.000	1.12	6.62	OK!!
2RC	32.6	0.120	0.03	0.095	0.25	0.25	Long	0.8	23750	0.812	1.000	1.40	10.41	OK!!
3RC	32.6	0.120	0.03	0.095	0.25	0.25	Long	0.8	23750	0.812	1.000	1.40	10.41	OK!!
4RC	9.1	0.120	0.03	0.095	0.20	0.20	Long	0.8	19000	0.857	1.000	1.09	6.48	OK!!
5RC	21	0.120	0.03	0.095	0.20	0.20	Long	0.8	19000	0.857	1.000	1.40	8.31	OK!!
6RC	7.3	0.120	0.03	0.095	0.20	0.20	Long	0.8	19000	0.857	1.000	1.05	6.21	OK!!
7RC+7RAC	19.6	0.120	0.03	0.095	0.25	0.25	Long	0.8	23750	0.812	1.000	1.40	10.41	OK!!
8RC	5.4	0.120	0.03	0.095	0.20	0.20	Long	0.8	19000	0.857	1.000	0.99	5.85	OK!!



12.4 GUTTERS DESIGN

12.4.1 Sizing:

The sizing of vertical gutters is given according to the different geometry and distribution of the water catching areas throughout the roof. In the next graphic it is shown the catchment areas which supply the water demand to the gutter. For simplification purposes the gutters nomenclature will be given according to its adjacent area.

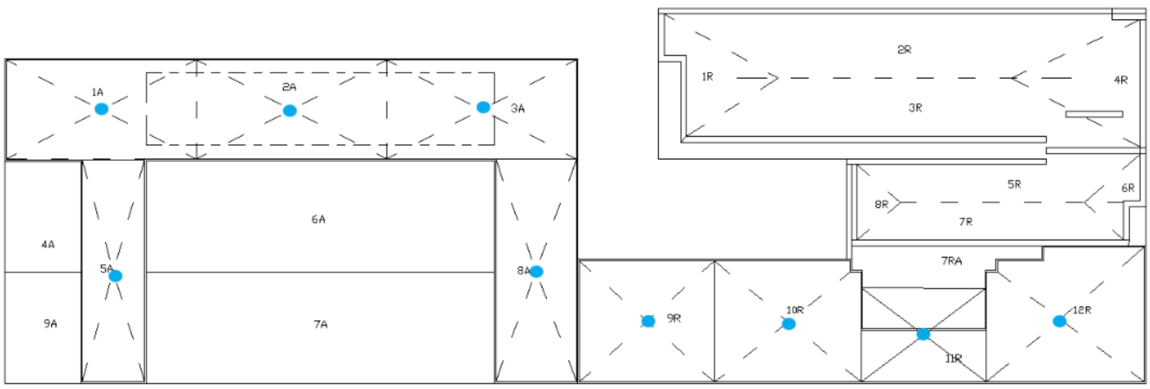


Illustration 234 Main Gutters distribution in the building (roof - plan view)

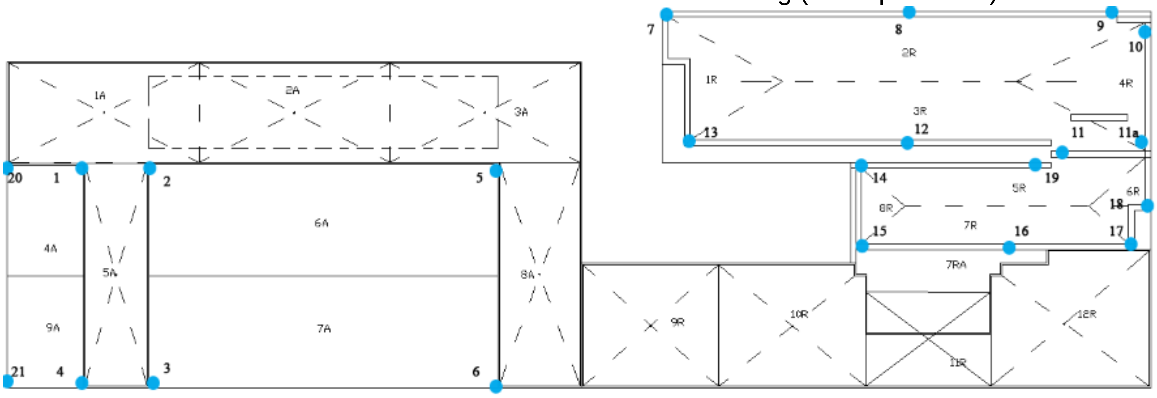
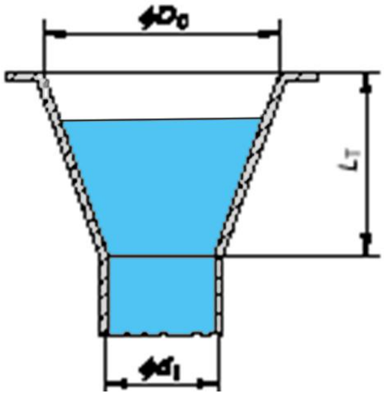


Illustration 235 Gutters of main channel distribution in the building (roof - plan view)



Graphic 83 sizing of rainfall catching gutters

12.4.2 Rainwater demand

The rainwater demand can be calculated in the same way than the method explained above for channels sizing.

12.4.3 Capacity for gutters of Main channels

The capacity of the gutters that receive the water from the main channels is given by:

$$Q_D\ (l/s) = \frac{k_0 * D * h^{1.5}}{7500};\ \ h \leq D/2$$

Or,

$$Q_D\ (l/s) = \frac{k_0 * D^2 * h^{0.5}}{15000};\quad h > D/2$$

Where:

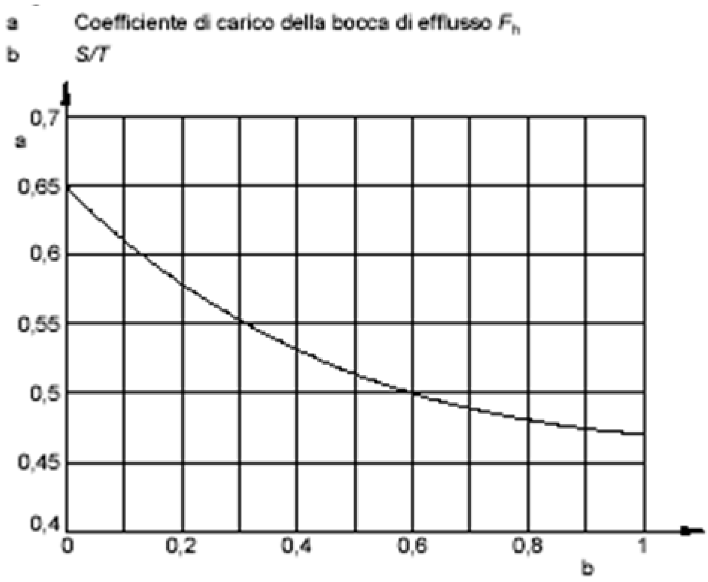
QD = Capacity of the Intake.
. Lt = vertical length of the drainage intake (cone) (mm)
D = effective diameter D= D0 for D0 > 1.5* d1, Lt >D0 (mm)
h = Water head (mm),
K = Drainage coefficient

$$h = W * F_h;$$

Where:

W = Internal Height of main channel
. Fh = Intake Coefficient

it has to be taken into account that the intake will have probably a filter in order to clean the first intake of water for its storage; in this way, a coefficient of drainage k = 0.5 is used.



12.4.4 Capacity for Main gutters

The capacity of a circular pipe with a conic intake can be simplified by just applying the values described in the next graphic for a full-filling ratio of the transversal section equal to 0.33.

Diametro interno del pluviale d_i (mm)	Capacità idraulica Q_{RWP} (l/s)		Diametro interno del pluviale d_i (mm)	Capacità idraulica Q_{RWP} (l/s)	
	Grado di riempimento f = 0,20	Grado di riempimento f = 0,33		Grado di riempimento f = 0,20	Grado di riempimento f = 0,33
50	0,7	1,7	140	11,4	26,3
55	0,9	2,2	150	13,7	31,6
60	1,2	2,7	160	16,3	37,5
65	1,5	3,4	170	19,1	44,1
70	1,8	4,1	180	22,3	51,4
75	2,2	5,0	190	25,7	59,3
80	2,6	5,9	200	29.5	68.0
85	3,0	6,9	220	38.1	87.7
90	3,5	8,1	240	48,0	110,6
95	4,0	9,3	260	59,4	137,0
100	4,6	10,7	280	72,4	166,9
110	6,0	13,8	300	87,1	200,6
120	7,6	17,4	>300	Utilizzare l'equazione di Wyly-Eaton	Utilizzare l'equazione di Wyly-Eaton
130	9,4	21,6			

Nota
Sulla base dell'equazione di Wyly-Eaton:

$$Q_{RWP} = 2,5 \cdot 10^{-4} \cdot k_b^{-0,167} \cdot d_i^{2,667} \cdot f^{1,667}$$

dove:
Q_{RWP} è la capacità del pluviale, in litri al secondo (l/s);
k_b è la scabrezza del pluviale, in millimetri (considerata 0,25 mm);
d_i è il diametro interno del pluviale, in millimetri (mm);
f è il grado di riempimento, definito come proporzione della sezione trasversale riempita d'acqua, adimensionale.

Illustration 236 Wyly-Eaton hydraulic capacity calculation (Extracted from UNI-12056)

12.4.5 Results

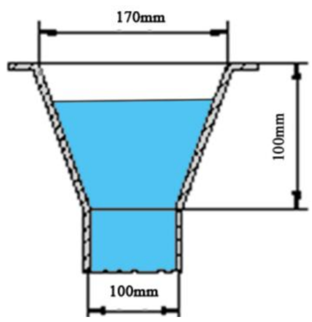
Main gutters design Sheet

Demand Calculation

Location	CODE	Area (m2)	r '(l/m2.s)	k	C	Q (l/s)
Auditorium/hall	1AG	97.1	0.05	2	1	9.71
	2AG	97.1	0.05	2	1	9.71
	3AG	97.1	0.05	2	1	9.71
	5AG	71.8	0.05	2	1	7.18
	8AG	92.8	0.05	2	1	9.28
Bar/restaurant	9 RG	84.6	0.05	2	1	8.46
	10RG	91.6	0.05	2	1	9.16
	11RG	60.3	0.05	2	1	6.03
	12RG	105.3	0.05	2	1	10.53

Capacity Calculation Gutter dimensions

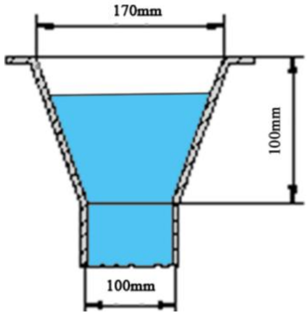
Location	CODE	lt (mm)	d0 (mm)	D (mm)	QRWP (l/s)	Q<Ql
Auditorium/hall	1AG	120	100	170	10.7	OK!!
	2AG	120	100	170	10.7	OK!!
	3AG	120	100	170	10.7	OK!!
	5AG	120	100	170	10.7	OK!!
	8AG	120	100	170	10.7	OK!!
Bar/restaurant	9 RG	120	100	170	10.7	OK!!
	10RG	120	100	170	10.7	OK!!
	11RG	120	100	170	10.7	OK!!
	12RG	120	100	170	10.7	OK!!



Gutters of the main Channels design Sheet

Demand Calculation

Channel (s) of supply	# Gutter	Q (l/s)
4AC/2	1	2.17
6AC/2	2	9.99
7AC/2	3	5.00
9AC/2	4	1.09
6AC/2	5	9.99
7AC/2	6	5.00
1RC/2+3RC/4	7	4.78
2RC/3	8	1.96
2RC/3	9	1.96
4RC/2	10	2.10
3RC/4+5RC/4	11	4.40
4RC/2+5RC/4	11a	2.10
3RC/3	12	4.40
1RC/2+3RC/4	13	4.78
8RC/2+5R/4	14	1.91
8RC/2+7RC/3	15	2.87
7RC/3	16	2.34
6RC/3+7RC/3	17	2.87
6RC/3	18	0.46
5RC/4	19	1.37
4AC/2	20	2.17
9AC/2	21	1.09



Capacity Calculation

		Gutter dimensions									
Location	CODE	lt (mm)	d0 (mm)	D (mm)	k0	(s/t)	W (mm)	fh	h (mm)	Q (l/s)	Q<Ql
Auditorium/hall	1	120	100	170	0.5	1.0	140.00	0.47	66	6.05	OK!!
	2	120	100	200	0.5	1.0	180.00	0.47	85	10.38	OK!!
	3	120	100	170	0.5	1.0	140.00	0.47	66	6.05	OK!!
	4	120	50	70	0.5	1.0	140.00	0.47	66	1.33	OK!!
	5	120	100	200	0.5	1.0	180.00	0.47	85	10.38	OK!!
	6	120	100	170	0.5	1.0	140.00	0.47	66	6.05	OK!!
Bar/restaurant	7	120	100	200	0.5	1.0	110.00	0.47	52	4.96	OK!!
	8	120	100	170	0.5	1.0	100.00	0.47	47	3.65	OK!!
	9	120	100	170	0.5	1.0	100.00	0.47	47	3.65	OK!!
	10	120	100	170	0.5	1.0	100.00	0.47	47	3.65	OK!!
	11	120	100	200	0.5	1.0	110.00	0.47	52	4.96	OK!!
	11A	120	100	170	0.5	1.0	100.00	0.47	47	3.65	OK!!
	12	120	100	200	0.5	1.0	110.00	0.47	52	4.96	OK!!
	13	120	100	200	0.5	1.0	110.00	0.47	52	4.96	OK!!
	14	120	100	170	0.5	1.0	100.00	0.47	47	3.65	OK!!
	15	120	100	170	0.5	1.0	100.00	0.47	47	3.65	OK!!
	16	120	100	170	0.5	1.0	100.00	0.47	47	3.65	OK!!
	17	120	100	170	0.5	1.0	100.00	0.47	47	3.65	OK!!
	18	120	50	70	0.5	1.0	100.00	0.47	47	1.12	OK!!
	19	120	100	170	0.5	1.0	100.00	0.47	47	3.65	OK!!
	20	120	100	170	0.5	1.0	140.00	0.47	66	6.05	OK!!
	21	120	50	70	0.5	1.0	100.00	0.47	47	1.12	OK!!

12.5 STORAGE TANK DESIGN

12.5.1 Monthly water catching

The expected monthly water catching rate is calculated according to the next equation:

$$C\ (m3/month) = 0.001 * (P *\ A * r * n)$$

Where: P = Average monthly rainfall (mm/month)
A = Catchment area (m2)
r = Rainoff coefficient
n = system efficiency

Equation 24 Expected monthly water catching rate equation

For calculation purposes, it is considered an 85% of efficiency of the system, where 5 % of the water recollected is lost in the first flush and 15% for assumed evaporation rate. The runoff coefficient depends on the capacity of a surface to recollect water, taking into account the possible absorption and roughness properties that affect the final catchment of water.

SURFACE TYPE	HIGH	LOW
Roof		
Metal, glavel, asphalt, shingle, fiber glass, mineral paper.	0.95	0.90
Paving		
Concrete, Asphalt	1.0	0.90
Glavel	0.70	0.25
Soil		
Flat, bare	0.75	0.20
Flat, with vegetation	0.60	0.10
Lawns		
Flat, bare	0.1	0.05
Flat, with vegetation	0.17	0.13

Table 55 Rainoff coefficients (Extracted from H. Waterfall) [139]

[139] WATERFALL PATRICIA harvesting rainwater for landscape use. 2006. P 20

Efficiency (%)		85		
Rainoff coefficient (-)		0.95		
Catchment area (m2)		625.6		
Month	Rain fall (mm)	Supply (m3)	Seasonal (m3)	
March	59	30	142	S
April	90	46		
May	131	66		
June	136	68	198	S
July	96	48		
August	159	81		
September	134	68	185	A
October	77	39		
November	155	78		
December	98	50	131	W
January	89	45		
February	74	37		
TOTAL (m3/year)			**656**	

Table 56 Expected monthly and annual water catching form the Auditorium/Hall roof surface.

Efficiency (%)		85		
Rainoff coefficient (-)		1		
Catchment area (m2)		834.7		
Month	Rain fall (mm)	Supply (m3)	Seasonal (m3)	
March	59	42	199	S
April	90	64		
May	131	93		
June	136	96	277	S
July	96	68		
August	159	113		
September	134	95	260	A
October	77	55		
November	155	110		
December	98	70	185	W
January	89	63		
February	74	52		
TOTAL (m3/year)			**921**	

Table 57 Expected monthly and annual water catching form the Restaurant & bars zone roof surface.

12.5.2 Monthly water demand

In order to estimate the water demand to supply the fixtures projected for this chapter. It can be taken into account similarly sized facilities and historical consumption of water systems in a location similar to the new one where the project is going to be constructed; however in the next table it is shown approximated estimates of average water demands for the uses foreseen of the structure (WSDH)[140]; however, taking into account that the values given by this entity are based in a median value of 3.5 gpf (average standard toilet efficiency since 1980's in the united states until today), considering the use of efficient ULFT (Ultra low flush toilets, as the one shown in the picture) with an average consumption of 1.6 gpf. Values for store and gallery have been estimated according to the rules described in the table. The calculation formula for the average demand will be:

$$D\ (m3/month) = 0.0038 * (U * \ C * ND)$$

Where: U = Users per day
ND = Number of days of use of the space in the month
C= Consumption per user per day in Gal.

Equation 25 Expected monthly water demand rate equation

Establishment	Consumption Gal/day.	
	3.5 gpf	1.6gpf
Restaurant		
Toilets (per patron)	4 - 7	2 - 4
No toilet facilities (per patron)	2½ - 3	2½ - 3
Bar and cocktail lounge (+ per patron)	2	1
Theater		
Toilet facilities (auditorium seat)	3	1.6
No toilet facilities (auditorium seat)	2½ - 3	2½ - 3
Cleaning		
1 m2 - diary.	0.05	0.05
Store		
Per salesman, 2 flush/day	7	3.5
Gallery		
Per patron 50% of probability	1.5	0.5

Table 58 Approximated water demand per fixture type [141]

- The number of users for the Auditorium/Hall will be equal to its maximum capacity (300 people).
- The number of users for the restaurant/bar is considered to take into account 1.5 average rotations in the capacity of the tables per day = 1.5 * 70 = 105 people.

[140] WASHINGTON STATE DEPARTMENT OF HEALTH. Water System design Manual. 2009. P38
[141] Ibid.. Water System design Manual. 2009. P39

- The number of users of the bar expecting 1.5 rotations in average per day during the day = 1.5 * 40 = 60 people
- The number of sellers is considered to be 2 for the gallery/store.
- All the facilities (except the Auditorium/hall) will be considered to run for a total period of labor = 365 days - 12 celebrations days – 15 days Ferr-August – 5 days Eastern - 50 Sundays = 283 days.
- However the Auditorium/hall is considered to be used for an average of 3 times per week without taking into account holidays, in this way, the number of days of usage is = 156 – 6 days Ferr-August – 3 days Eastern = 147 days.
- For the sake of simplification it is considered a constant demand of users throughout the year represented as an average of the possible number of users per month.

Month	# User.day	Consumption gal/day -user	# days of Use	Water demand (m3)	Seasonal (m3)	
March	300	1.6	13	23.6	65	S
April	300	1.6	14	25.4		
May	300	1.6	9	16.4		
June	300	1.6	13	23.6	60	S
July	300	1.6	14	25.4		
August	300	1.6	6	10.9		
September	300	1.6	13	23.6	71	A
October	300	1.6	13	23.6		
November	300	1.6	13	23.6		
December	300	1.6	13	23.6	71	W
January	300	1.6	13	23.6		
February	300	1.6	13	23.6		
TOTAL (m3/year)					267	

Table 59. Expected annual water demand toilets for the Auditorium/hall

Month	# User.day	Consumption gal/day -user	# days of Use	Water demand (m3)	Seasonal (m3)	
March	105	3	25	29.8	85	S
April	105	3	21	25.0		
May	105	3	25	29.8		
June	105	3	25	29.8	75	S
July	105	3	25	29.8		
August	105	3	13	15.5		
September	105	3	25	29.8	89	A
October	105	3	25	29.8		
November	105	3	25	29.8		
December	105	3	24	28.6	88	W
January	105	3	25	29.8		
February	105	3	25	29.8		
TOTAL (m3/year)					337	

Table 60 Expected annual water demand toilets for the restaurant/bar

Month	# User.day	Consumption gal/day -user	# days of Use	Water demand (m3)	Seasonal (m3)	
March	60	3	25	**17.0**	**48**	S
April	60	3	21	**14.3**		
May	60	3	25	**17.0**		
June	60	3	25	**17.0**	**43**	S
July	60	3	25	**17.0**		
August	60	3	13	**8.9**		
September	60	3	25	**17.0**	**51**	A
October	60	3	25	**17.0**		
November	60	3	25	**17.0**		
December	60	3	24	**16.4**	**50**	W
January	60	3	25	**17.0**		
February	60	3	25	**17.0**		
TOTAL (m3/year)					**193**	

Table 61 Expected annual water demand toilets for the bar

Month	# User.day	Consumption gal/day -user	# days of Use	Water demand (m3)	Seasonal (m3)	
March	2	3.5	25	**0.7**	**2**	S
April	2	3.5	21	**0.6**		
May	2	3.5	25	**0.7**		
June	2	3.5	25	**0.7**	**2**	S
July	2	3.5	25	**0.7**		
August	2	3.5	13	**0.3**		
September	2	3.5	25	**0.7**	**2**	A
October	2	3.5	25	**0.7**		
November	2	3.5	25	**0.7**		
December	2	3.5	24	**0.6**	**2**	W
January	2	3.5	25	**0.7**		
February	2	3.5	25	**0.7**		
TOTAL (m3/year)					**7**	

Table 62 Expected annual water demand toilets for the Store/gallery

The demand for irrigation and/or cleaning of outdoor areas for this type of use is estimated to be used mainly for the diary cleaning of bathrooms and floors.

$$I\ (m3/month) = 0.0038 * (U * \ C * ND)$$

Where: m = Area floors to be cleaned (m2)
ND = Number of days of use of the space in the month
C= Consumption of water for /m2

Equation 26 Expected monthly water demand for Cleaning

Month	Area (m2)	Consumption gal/day -m2	# days of Use	Water demand (m3)	Seasonal (m3)	
March	1000	0.05	13	**2.5**	**7**	S
April	1000	0.05	14	**2.6**		
May	1000	0.05	9	**1.7**		
June	1000	0.05	13	**2.5**	**6**	S
July	1000	0.05	14	**2.6**		
August	1000	0.05	6	**1.1**		
September	1000	0.05	13	**2.5**	**7**	A
October	1000	0.05	13	**2.5**		
November	1000	0.05	13	**2.5**		
December	1000	0.05	13	**2.5**	**7**	W
January	1000	0.05	13	**2.5**		
February	1000	0.05	13	**2.5**		
TOTAL (m3/year)					**28**	

Table 63 Expected annual water demand for cleaning for the Auditorium/hall

Month	Area (m2)	Consumption gal/day -m2	# days of Use	Water demand (m3)	Seasonal (m3)	
March	270	0.05	25	**1.3**	**4**	S
April	270	0.05	21	**1.1**		
May	270	0.05	25	**1.3**		
June	270	0.05	25	**1.3**	**3**	S
July	270	0.05	25	**1.3**		
August	270	0.05	13	**0.7**		
September	270	0.05	25	**1.3**	**4**	A
October	270	0.05	25	**1.3**		
November	270	0.05	25	**1.3**		
December	270	0.05	24	**1.2**	**4**	W
January	270	0.05	25	**1.3**		
February	270	0.05	25	**1.3**		
TOTAL (m3/year)					**14**	

Table 64 Expected annual water demand for cleaning for the restaurant/bar

Month	Area (m2)	Consumption gal/day -m2	# days of Use	Water demand (m3)	Seasonal (m3)	
March	130	0.05	25	**0.6**	2	S
April	130	0.05	21	**0.5**		
May	130	0.05	25	**0.6**		
June	130	0.05	25	**0.6**	2	S
July	130	0.05	25	**0.6**		
August	130	0.05	13	**0.3**		
September	130	0.05	25	**0.6**	2	A
October	130	0.05	25	**0.6**		
November	130	0.05	25	**0.6**		
December	130	0.05	24	**0.6**	2	W
January	130	0.05	25	**0.6**		
February	130	0.05	25	**0.6**		
TOTAL (m3/year)					**7**	

Table 65 Expected annual water demand for cleaning for the bar and store/gallery (same area)

According to the expected supply of water from the recollection system, and the expected demand, it has been decided to satisfy 100% of the total demand due to the low needs of irrigation and toilets fixtures water demands

12.5.3 Storage capacity

For this purpose, the methodology suggested by the Texas water development board called the "*water balance method"* consists on starting the calculation with an assumed volume of water already in the tanks, the volume captured each month is added to the previous balance and the demand is subtracted. The initial volume of water in the tanks would be provided by hauling or capturing water prior to withdrawing water from the system. The efficiency of the storage system will be assessed according to the final capacity given by the tank according to the total potential capacity given by a full storage system. Due to the values and demands obtained from the studies done before, it is decided to dimension a tank working at full storage capacity all the time.

Estimated tank capacity (m3)	21
Starting storage size February (m3)	21.0

Month	D (m3)	I (m3)	C (m3)	Potential End month storage (m3)	End month real storage (m3)	Quantity End month exhausted(m3)
March	23.6	**2.5**	30.0	24.9	21.0	3.9
April	25.4	**2.6**	45.7	38.6	21.0	17.6
May	16.4	**1.7**	66.2	69.1	21.0	48.1
June	23.6	**2.5**	68.5	63.4	21.0	42.4
July	25.4	**2.6**	48.5	41.4	21.0	20.4
August	10.9	**1.1**	80.5	89.5	21.0	68.5
September	23.6	**2.5**	67.7	62.6	21.0	41.6
October	23.6	**2.5**	39.1	34.1	21.0	13.1
November	23.6	**2.5**	78.4	73.4	21.0	52.4
December	23.6	**2.5**	49.5	44.5	21.0	23.5
January	23.6	**2.5**	44.8	39.7	21.0	18.7
February	23.6	**2.5**	37.2	32.1	21.0	11.1

STORAGE EFICENCY	41%

Table 66 Calculation of storage needed for Auditorium/hall

The storage capacity is finally given in order to satisfy the total demand per month without incurring in high costs (due to storage capacity) or too low, but a high quantity of water wasted. For this aim, it has been decided to work with a efficiency of the water storage system close to the 40%, respect to the availability of water and the real storage.

Estimated tank capacity (m3)		49.5				
Starting storage size February (m3)		52				
Month	D (m3)	I (m3)	C (m3)	Potential End month storage (m3)	End month real Storage (m3)	Quantity end month exhausted(m3)
March	47.51	**2.6**	42	44.2	44.2	0.0
April	39.91	**2.1**	64	66	49.5	16.8
May	47.51	**2.6**	93	92	49.5	42.8
June	47.51	**2.6**	96	96	49.5	46.1
July	47.51	**2.6**	68	68	49.5	18.0
August	24.70	**1.3**	113	137	49.5	87.1
September	47.51	**2.6**	95	94	49.5	45.0
October	47.51	**2.6**	55	54	49.5	4.9
November	47.51	**2.6**	110	110	49.5	60.1
December	45.61	**2.5**	70	71	49.5	21.5
January	47.51	**2.6**	63	62	49.5	12.8
February	47.51	**2.6**	52	52	49.5	2.1

STORAGE EFICENCY	62%

Table 67. Calculation of storage needed for the restaurant/bars zone

In order to check the feasibility of the systems under dry conditions, it is assessed the capability of the storage tanks to not run out of water after a 21-days (3 weeks) dry period, which can occur usually in the month with less precipitation rate (March).

	Estimated tank needed (m3)		21			
	D (m3)	I (m3)	C (m3)	Potential End week storage (m3)	End week real storage (m3)	
February	5.91	0.62	9.29	14.5	14.5	
	5.91	0.62	9.29	17.2	17.2	
	5.91	0.62	9.29	20.0	20.0	
	5.91	0.62	9.29	22.8	21.0	
MARCH	5.91	0.62		14.5	14.5	
	5.91	0.62	DRY PERIOD	8.0	8.0	
	5.91	0.62		1.4	1.4	ok
	5.91	0.62	29.99	24.9	21.0	
April	6.36	0.66	11.41	25.4	21.0	
	6.36	0.66	11.41	25.4	21.0	
	6.36	0.66	11.41	25.4	21.0	
	6.36	0.66	11.41	25.4	21.0	

Table 68 Verification dry period capacity for Auditorium/Hall storage tank

	Estimated tank needed (m3)		49.5			
	D (m3)	I (m3)	C (m3)	Potential End week storage (m3)	End week real storage (m3)	
February	11.88	0.64	13.05	37.0	37.0	
	11.88	0.64	13.05	37.5	37.5	
	11.88	0.64	13.05	38.0	38.0	
	11.88	0.64	13.05	38.6	38.6	
MARCH	11.88	0.64		26.1	26.1	
	11.88	0.64	DRY PERIOD	13.5	13.5	
	11.88	0.64		1.0	1.0	ok
	11.88	0.64	42.13	30.6	30.6	
April	9.98	0.54	16.03	36.2	36.2	
	9.98	0.54	16.03	41.7	41.7	
	9.98	0.54	16.03	47.2	47.2	
	9.98	0.54	16.03	52.7	49.5	

Table 69 Verification dry period capacity for Restaurant/bar zone storage tank

12.5.4 Results:

As a result of the analysis, there are considered:

- 2 storage tanks of a capacity equal to 9000 l/each and one of a capacity equal to 3000 lt to supply the Auditorium/hall system.
- On the other hand, for the Restaurant/bar zone, there are considered 5 storage tanks with a capacity of 9000 l/each + one with a capacity of 4500 l.
- The tanks must be located at a height (Base level) at least equal to + 2 m, in order to satisfy a minimum pressure in the appliances of around 20 kPa, when a low pressure valve is applied, or 50 kPa for other type and in order to satisfy better functioning of the fixture.

13 NET ZERO FOOT PRINT STANDARD

In order to achieve a Net zero foot print standard it is hereafter assessed the capacity of the system to produce or purchase renewable energy.

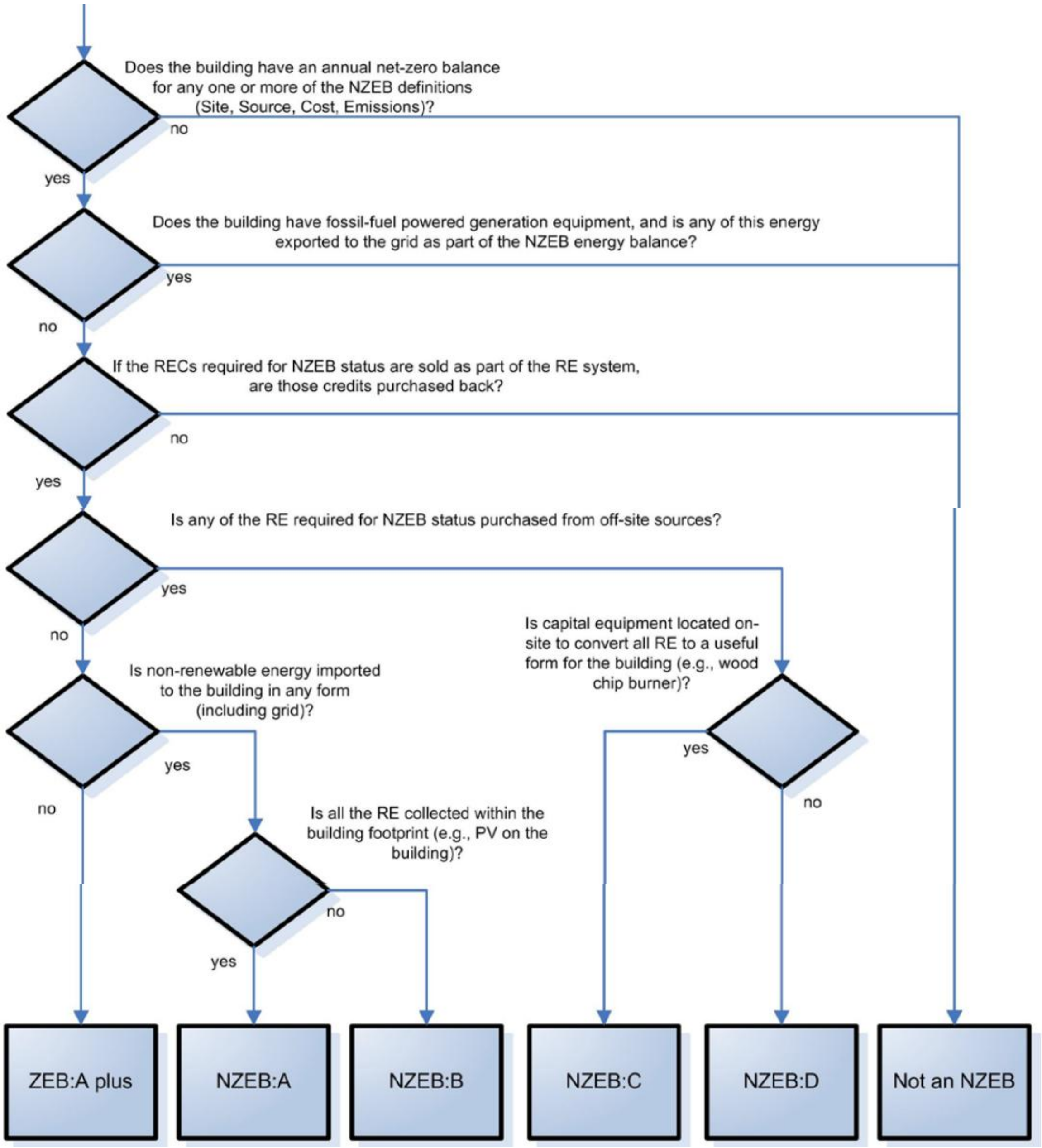


Illustration 237 NZEB Classification guide (Extracted from U.S Energy department) 142

142 Torcellini, Paul. Pless, Shanti. – U.S Department of Energy. Net Zero Energy Buildings: A Classification System Based on Renewable Energy Supply Option. Pag 13. 2010.

1. Does the building have an annual Net zero balance for any of the NSEB definitions. (Site, Source, Cost).

R: Yes!!, by sizing the photovoltaic system to supply the electric demand needed to run completely the building, the system would be able to generate and export to the grid as much energy as it is generated, even if the electrical energy storage is not enough on the site. A Net SITE zero balance can be achieved.

2. Does the building have Fossil-fuel powered generation equipment, and is any of this energy exported to the grid part of the NZEB energy balance.

R: No!!, al the systems that generate energy in the building does not operate with fossil fuels or another non-renewable type of combustible.

3. If the renewable sources required for NZEB status are sold as part of the renewable energy system, are those credits purchased back?

R: Yes! As a matter of fact, in case that the the electrical power would not be able to supply all the demand due to constant changing environmental conditions or unexpected energy consumptions, the system backup will rely on the idea of importing off-site electrical energy, which can be produced from hydroelectric available in the zone of the project.

4. Is any of the Renewable energy required for NSEB status purchased from off-site sources?

R: Yes, as it was explained above.

5. Is capital equipment located on-site to convert all Renewable energy to a useful form for the building?

R: Yes, it can be seen that all the systems designed into the building are powered by electric energy which are able to generate heat and cooling energy, operate ventilation systems, generate light, and other more uses.

As a result the building can be categorized as:

NZEB: C

CONCLUSIONS

By leaving behind the almost unified typological and historical references to Calco's past, the project is seeking a contemporary authentic expression of Calco's current and future ambitions, adding a new layer to Calco's future. By the same token, leveled open spaces and green areas explore a new balance between urbanism and landscape. The subordination of ground and landscape by buildings has been reversed to offer a unique symbiotic experience.

The building relates to the surroundings in scale, proportion and in the way it adds to the established rhythm of leveling masses along the back path. Yet, our aim is to create some kind of contrast, to express characteristic clarity, but most importantly to highlight the beauty of the surroundings.

On aim achieved is also the use small means to create an array of different spatial experiences in this small project.

TECHNOLOGICAL DESIGN

The inclusion of renewable energy strategies such as small hydropower plants constitutes from the projection point of view, a profitable opportunity for the city of Calco which according to the data obtained, it could generate up to 8% of the total electrical consumption of the population with a payback time of 7 to 10 years of the infrastructure investment.

On the other hand, it has to be underlined that the system configuration presented in the present project has attained the requirements of a net zero foot print building, acquiring a classification C.

Achievement of 0.00 CO2 emissions for both heating and cooling systems by using renewable energy supply (PV panels and ground heat pumping), and a combination of energy saving strategies in matter of thermal behavior of the building and ventilation.

The use of ETFE foils with integrated shading system connected to the building heating-cooling system constitutes a technical approach that can control the amount of radiation entering into the building, and, thus, reduce the cooling and heating demands throughout the whole year of operation.

Characteristics considered in the building envelope components such as low thermal coefficients, but also the strategies considered in terms of solar orientation, operable glazed transition spaces and hybrid ventilation, have resulted into the reduction of the expected heating and cooling consumption of the building, (compared to traditional materials and heating/cooling systems) in a percentage of 60%

If we compare the energy consumption value with the average consumption of an low energy office building operating at the same hours and time than the spaces located in the building (50w/m2) It can be seen that the sized system consumes 25% less energy per year than a low energy consumption office building.

SERVICES

By using an integrated heat recovery system (desuperheater) in the water chiller/heater appliance, it can be achieved the total heating needs for domestic hot water consumption. Having an intake of water of around 20°C coming from the compressor work, instead of 5°C coming from regular water sources, the system can save around 2 Mwh year in energy consumption.

The use of Chilled water storage system constitutes a feasible strategy that can generate in off-peak periods the diary refrigeration load required for the compound of buildings, saving energy in terms of efficiency of the system working at full capacity and, on the other hand saving money by using the system on off-peak periods when the electrical fees are lower than In on-peak periods (day).

Open loop- ground heating pump systems used in the project have constituted one of the highest energy saving options included into the thermal energy supply strategies; according to the results obtained from the suitable conditions of the area (water body underneath the project, constant temperature at -10 m.b.t.l), the ground heating pump can generate around 50 MW/year of heating and cooling energy by using a low electric energy consumption of 1 MWh/year.

The harvesting of rainwater system is able to generate the WC -water flow demands of the entire complex of buildings by making use of 80% of the total roof area available. The simple but effective proposed system takes advantage of the vertical dimension of the set of buildings to generate a water flow without the need of electricity or mechanical energy. This approach constitutes an entire sustainable idea from the point of view of renewable sources consumption.

STRUCTURAL

The use of ETFE foils from the structural point of view can be considered an alternative that is able to reduce up to 96.5% of the structural load due to glazing[143]. Considering an approximated total glazed area of the Auditorium/hall equal to 480 m2, the weight of the structure has been reduced in considerable 14 tons = 14 median cars.

[143] Weight 3 foils = 1.05 kg/m2, Weight double glazed window = 30 kg/m2. MAKMAX. ETFE panels properties. Available online. http://www.makmax.com/business/etfe_brochure.pdf

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