CONCERTO COMMUNITIES IN EU DEALING WITH OPTIMAL THERMAL AND ELECTRICAL EFFICIENCY OF BUILDINGS AND DISTRICTS, BASED ON MICROGRIDS

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Guide for bioclimatic design

Revised Version

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Bioclimatic design offers energy efficient, healthy, environmental friendly and architecturally valuable solutions. A pilot design for a kindergarten and for a new office building will be established in the Szentendre demonstration project and also in the new buildings in Vitoria and Dale. Research will follow and support the process from the design of airtight and thermal bridge free installation until the realisation. The sunspaces will be analysed in the design phase with simulation models and monitored after construction. The outcome of the research would be a guide for bioclimatic design in new and retrofitted buildings.

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LIST OF ABBREVIATIONS

AHU	Air Handling Unit
CTB	Concealed Toughened Blind
CTE	Código Técnico de la Edificación – Spanish Building Regulations
EPS	Expanded Polystyrene
ET	Equation of Time
FRP	Fibre Reinforced Polyester
HVAC	Heating Ventilation and Air-Conditioning
IGU	Insulated Glass Unit
INM	Instituto Nacional de Meteorología – National Meteorological Institute of Spain
LCA	Life Cycle Assessment
LL	Local Longitude
LSoT	Local Solar Time
LST	Local Standard Time
LSTM	Local Standard Time Meridian
MVHR	Mechanical Ventilation with Heat Recovery
NE	North East
NW	North West
OMSZ	Országos Meteorológiai Szolgálat – National Meteorological Service of Hungary
PC	Poly-Carbonates
PCM	Phase Change Material
PHPP	Passivhaus Projektirungs Paket – Passive House Planning Package
PMMA	Polymethyl-Methacrylate
PTFE	Polytetrafluoroethylene
PV	Photo Voltaic
RES	Renewable Energy Sources
RH	Relative Humidity
SE	South East
SHGC	Solar Heat Gain Coefficient
SW	South West
VIP	Vacuum Insulation Panel
XPS	Extruded Polystyrene

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1 Introduction

Nowadays energy consumption far exceeds what the planet is able to produce. We are using the energy savings that the Earth has stored for millions of years throughout its history. Until the time of the industrial revolution, cities had a more limited control over their resources, materials and energy, among other things, due to the technological restrains to obtain them in large quantities or from faraway places.

Industrialization carried out more efficient technologies to obtain and transport energy and materials. Nowadays these abilities have turned out into over exploitation of resources and the new challenge of sustainability. Thus, a more efficient use of materials and energy is required by laws and regulations to achieve these sustainability objectives. Another important aspect to take into account is the consumption of fuels in our cities that produce not only the depletion of resources but significant air pollution too.

It is an accepted fact today that human activity is responsible for the Earth overwarming and that about 50% of the emissions that cause this effect are due to our buildings. CO_2 emissions have been rising from the beginning of the industrial revolution to our days in despair of international agreements and regulations, or the improvements applied on buildings.

This may be explained for three reasons:
- the population growth,
- the average age and energy consumption of the existing buildings,
- the increasing consumption of equipments and cooling loads.

On the other hand approximately 35% of the energy consumption and emissions is generated by transportation. Cities are responsible of a 75% to 80% of global emissions summing the transportation and building consumptions.

For this reasons, over the last years, there have been many agreements, directives and laws being drafted to achieve a more sustainable development in cities. However, practice is necessary to prove their application and improvements, since in many cases decisions far to achieve their objectives.

Bioclimatic design offers energy efficient, healthy, environmentally friendly and architecturally valuable solutions. Bioclimatic criteria are commonly useful on general planning, analysing life cycle and reducing negative impacts on the air, water and soil, and using energy on the most efficient way.

This document approaches bioclimatic design from general to particular cases, in order to establish a sustainable interaction among building and nature. The principles of bioclimatic architecture are illustrated through several demonstration projects: the refurbishment of a kindergarten and a new office building in the Szentendre (Hungary) and also new buildings in Vitoria (Spain) and Dale (Norway). Research will follow and support the process from the design of airtight and thermal bridge free installation until the realisation. The sunspaces will be analysed in the design phase with simulation models and monitored after construction. The outcome of the research would be a guide for bioclimatic design in new and retrofitted buildings.

2 Definition of bioclimatic design

Bioclimatic design means that a building is designed in such a way that, based on local climate data, environmental sources such as sun, wind, air, vegetation, soil and sky are taken into consideration as much as possible for heating, cooling and lighting to reduce the overall energy consumption of the building and to provide comfortable and pleasant living spaces for the inhabitants.

Before carrying out the design, local climate data needs to be collected. Guidance on climate analysis is given in section 3.

The main features of bioclimatic design are:
- Proper thermal insulation of the external envelope of the building and air-tight structures (see section 5.2.1).
- The use of solar energy for heating in winter time. This can be achieved by a proper passive solar heating system (see section 5.2.2).
- Removal of the heat from the building by passive cooling systems and natural ventilation (see sections 5.3.1 and 5.3.2).
- Protection of the building from overheating by proper shading solutions and vegetation in summer time (see sections 5.3.3 and 5.3.4).
- The use of solar energy for day-lighting all year round (see section 5.4).
- Providing a pleasant and comfortable indoor and outdoor environment for the inhabitants (see section 4).

3 Climate analysis

There are several climatic factors to be always taken into account on bioclimatic architecture to approach any analysis. These factors may be characteristically defined for a certain location and environment. All different data should be collected to provide an effective analysis before the design.

Parameters determining climate conditions:
- Spatial variability: the influence of astronomical, geographical factors and latitude, which define different climatic zones of diverse extension regional, local or microclimates.
- Variability along time for different periods as annually or longer.

According to extension climates may be classified as:

- macroclimates: constant climatic zone on extensions smaller than 2000 km,
- regional climates or mesoclimates: extensions between 200 km and 2000 km,
- local climate: on small extensions but with significant differences, this may be due to latitude, altitude, vegetation or the presence of water masses,
- microclimate of an even more reduced extension due to a type of soil, vegetation or humidity.

The main characteristics of the climate are the temperature, the sunshine, the wind, relative humidity (see 3.1, 3.2, 3.3 and 3.4 chapters). Precise knowledge of the path of the sun is essential to accurately model and mathematically predict, annualized solar performance. A wind rose must also be consulted to predict wind driven ventilation. The climate information on temperatures, precipitation and humidity must be collected, and the soil temperatures as well. Other environmental information such as air quality, green or water areas of the building site may also be needed. These climate data should be collected during a considerable period of time, and even though we may consider that climate is on constant evolution and may not adjust to statistical values.

3.1 Sun and solar radiation

The Sun and its incidence over the Earth is the main factor determining the temperature on the surface of the Earth and by extend the heat gains of our buildings too. Both radiation and air movement are also determined as it is humidity, by the incidence of the Sun.

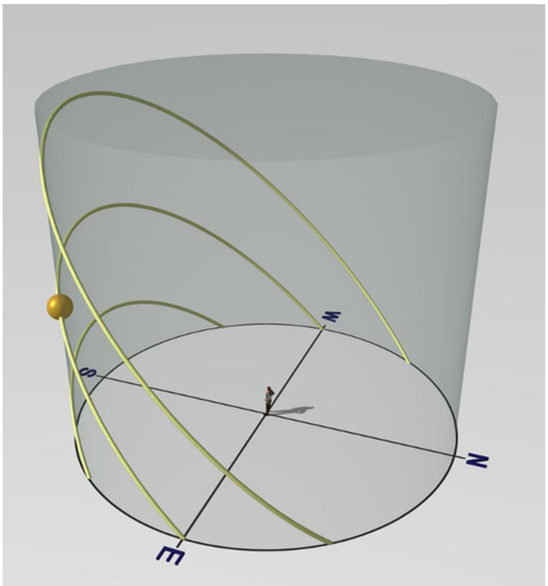
Since the Sun is the main energetic source for bioclimatic design, it is important to study the sun path all around the year. Summer and winter differences are due to the tilted axis of the Earth rotation related to its orbit around the Sun. It is for this reason that not all parts of the Earth receive the same radiation from the Sun, existing significant differences from the poles to the equator. All dates used ahead are those for to the North Hemisphere.

By the knowledge of solar geometry we can determine the influence of the sun on our buildings, as well as the best orientations and other designing parameters. From the solar geometry we can obtain the shadows that the building will receive and the shades that would be necessary to prevent from undesirable solar gain.
In order to find out the altitude and latitude of the solar incidence we may need:

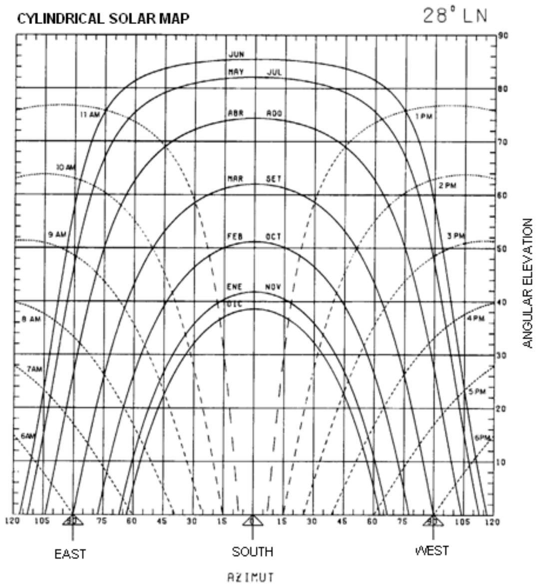
- Solar elevation: angle formed on the vertical plane over the horizon
- Azimuth: the angle between the projected vector of the position of the sun and the North on the reference plane of the horizon.

On the study of sun incidence over architecture and urbanism it is somehow necessary to retake an anthropocentric concept of the universe, supposing the sun follows its path over the sky with our position as its centre.

The singular points on the sky are the highest elevation reached and the lowest over the horizon among with the main orientation (N, S, E and W).
It is important to use local solar time specific to the location when the sun azimuth and elevation is determined. Using solar time, the sun is always due south at exactly noon.
When calculating local solar time, the clock time must be modified to compensate the relationship between the local time zone and the local longitude, the daylight saving time and the Earth's slightly irregular motion around the Sun.
There are several graphics available representing solar path (elevation and azimuth) which are useful to find out the incidence of the sun, it can be shown either on a cylindrical or stereographic diagram. These diagrams are shown below.

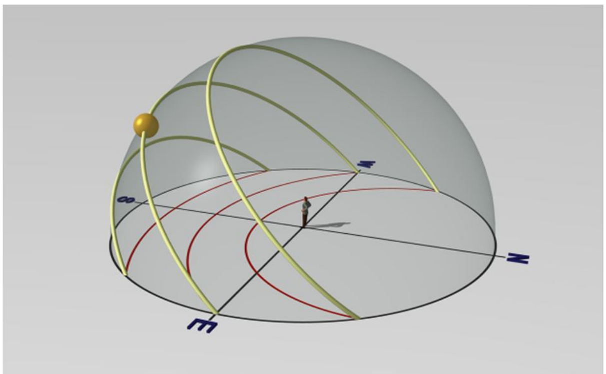


Source: EMI



Source:www.editorial.cda.ulpgc.es/ambiente/2_clima/2_soleamiento/9_anexo/index.htm

Cylindrical diagram



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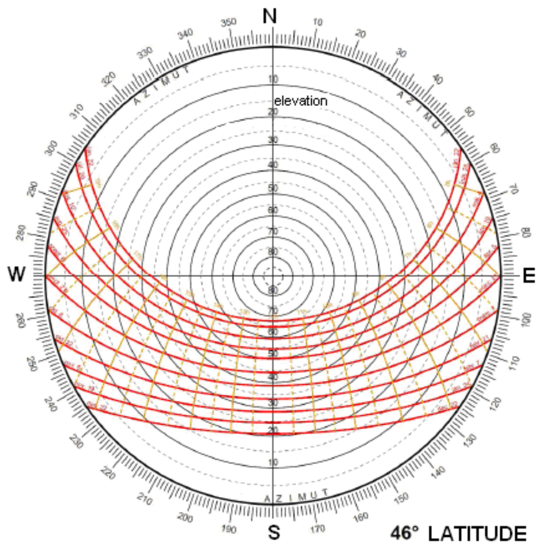
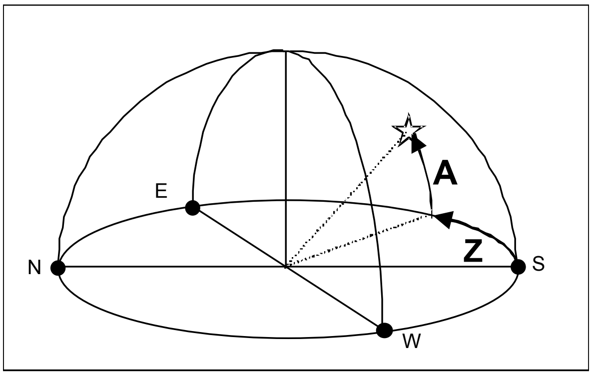


Source: EMI

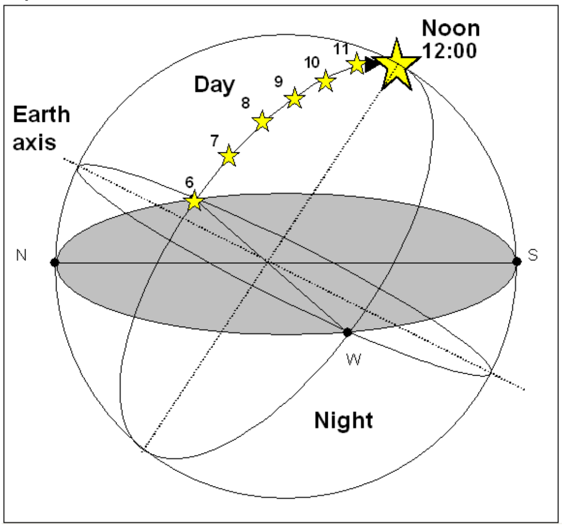
Stereographic diagram

The celestial coordinate systems are able to locate any point by its elevation and azimuth.



Source: www.editorial.cda.ulpgc.es/ambiente/2_clima/2_soleamiento/9_anexo/index.htm

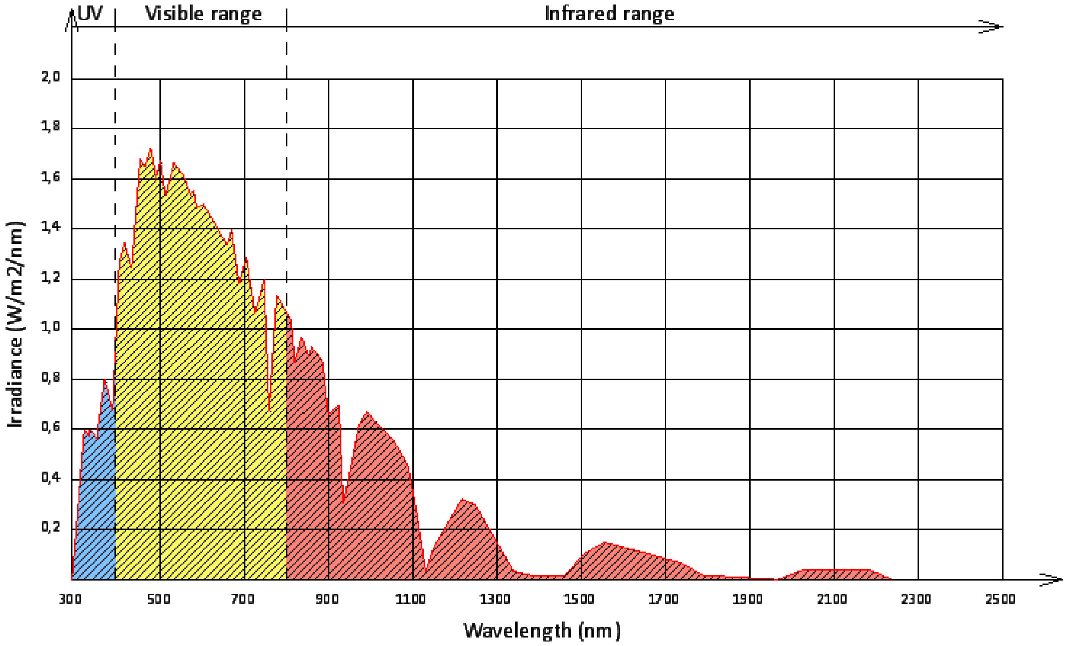
Equinox: The sun path on september 21st and March 22nd are caracteristic because the sunrise is exactly on East at 6:00am and the sunset coincides with West at 18:00, both days last 12 hours. The word equinox comes from latin equi-noccio which means equal to night.
We can see on the sun chart that noon (tour 12:00) is all year long over the South, with an azimuth of z=0, and its zenith (orthogonal angle to the horizon) is the location latitude φ. Sun elevation may be defined as $A = 90 - \varphi$.
The sun path during daytime are semicircular, its axis is the same as for the Earth. The sun path cover 360° over 24 hours, each hour angle is ω=15°. Equinox are the only days on which the sun path during the day lasts 12 hours.



Source: www.editorial.cda.ulpgc.es/ambiente/2_clima/2_soleamiento/9_anexo/index.htm

It is not only the exact solar path in the sky and shading objects which determine the solar gain but the continuously changing athmosperic conditions due to clouds and the expected sunny hours also have an effect on the real solar radiation.

The solar radiation is generated by its incandescent surface (5700°K), a "dwarf" with a 1,4 km diameter. Its radiation travels over 150 km to reach the exterior layers of the Earth's atmosphere, with a constant incidence of I_o = 1353 W/m², which is called solar constant. The radiation that reaches the Earth's surface is less than 1000 W/m², due to the absorption and reflection on the atmosphere, and to the inclination of the solar beams.



Typical solar spectrum on Earth's surface – Source: EMI

Part of this radiation comes through the atmosphere and reaches the Earth surface with the same direction, this we call direct radiation. The rest may be absorbed or reflected by particles and gasses, or by steam on clouds. The reflected energy changes its direction and is partly returned to the outside, and partly spread over the sky on what is called diffuse radiation.

The total or global radiation is the addition of both direct and diffuse radiation. The total radiation is around the 45% of the solar constant, but it varies during daytime reaching a highest rate during central hours of the day and decreasing on the first hours of the day.

3.2 Wind

Wind is the flow of air and is caused by differences in pressure. Wind is blowing from higher to lower pressure places and on a global scale the driving factors of winds are the differential heating between equator and the poles and the rotation of Earth. Due to friction, the speed of the wind is lower close to the Earth's surface than it would be otherwise.

Natural ventilation design takes advantage of the movement of the air caused by wind. For a proper design, the dominant direction, speed and frequency of the wind must be known for the whole year. Modern instruments used to measure wind speed and direction are called anemometers and wind vanes respectively.

This data can be collected from weather stations, however local conditions near the building, such as landscape, vegetation and other large objects can affect the air flow, which should also be considered in the design.

3.3 Temperatures

Temperature of the air

Since solar radiation reaching the Earth varies from day to day, from season to season, and from latitude to latitude, temperature of the external air near the ground is also various. When the sun shines, the Earth receives a constant flow or radiant short-wave energy from the sun and the Earth also radiates long-wave energy to space. During the day, the short-wave radiation of the sun absorbed by the Earth exceeds the long-wave energy emitted, and the surface temperature increases heating the air near the ground by convection.

During the night no short-wave radiation strikes the Earth, however long-wave radiation is still emitted from the surface. Therefore, surface temperature along with the air temperature decreases.
The temperature of the air is measured by thermometers placed 1,5-2,0 m above ground and exposed to the air but sheltered from direct solar radiation.
Daily and monthly mean air temperature data is easily available from weather stations. The temperature of the external air is an important input data when the heating and cooling system of a building is designed.

Temperature of the sky

The atmosphere, the sun and its radiation are responsible for the existence of life over the Earth. The atmosphere is a compound of different gases that acts as a filter for the sun radiation and as the same time avoids the radiation of the heat absorbed by the ground from being lost to the exterior. This helps keeping the temperature on the Earth. The layer of the atmosphere in contact with the ground is the troposphere, and its thickness varies from 10-12 km, has a constant composition of gases and its temperatures decreases 0,6°C every 100 meters. Temperature becomes constant on the stratosphere.

The temperature of the sky is lower all year long; we may use this to reduce the overheating by several bioclimatic strategies which gain thermal exchanges.

Temperature of the ground

The ground stores heat energy, which may be both solar gained or geothermal. The temperature of the ground is almost constant. The first layer of 0,20 to 0,30 m deep suffers from day-night temperature fluctuation, from 0,80 to 2,00m deep the variation occurs only on longer periods. 12,00 m and deeper is not affected by seasonal differences. The energy may be exchanged by convection.

3.4 Precipitation and relative humidity

Precipitation is the condensation of atmospheric water vapour that falls under gravity. The main forms of precipitation include drizzle, rain, sleet, snow and hail. It occurs when a local portion of the atmosphere becomes saturated with water vapour and the water condenses. There are two possible ways which can result in saturated air: the air cools down or the water vapour content increases. Saturated air has a relative humidity of 100%.
Average annual precipitation is a vital piece of climatic data. Precipitation is measured in units over a given time period.

Wind, buildings, trees, topography, and other factors can modify the amount of precipitation that falls so rainfall and snowfall tend to be measured away from obstructions. A thirty-year average of annual precipitation is used to determine the average annual precipitation for a specific place.
The amount of precipitation and the number of annual rainy days influence the external air temperature, the relative humidity and the amount of sunny hours. When a rainwater harvesting system is designed, the average annual precipitation is also an important input data.

4 Comfort

Air quality

For an interior space occupied by living creatures, the oxygen consumption and its substitution by carbon dioxide may cause organic disorders that may lead lethal consequences. Breathing and transpiration may cause undesirable odours on interior areas too.

Ventilation is a simple way to mend these problems, by the substitution of interior air by fresh air from the exterior. From both hygienic and condensation risk point of view proper ventilation, corresponding with the function of the building, is a very important issue. Besides comfort problems, excessive ventilation leads to an over consumptions on the terms of HVAC and the insufficient ventilation is one of the main causes of the so called sick building syndrome.

By renovating air we gain several results:

- Oxygen is provided for breathing;
- Combustion smoke is removed;
- Odours are avoided;
- Gasses escapes are removed;
- Overheated air is removed;
- Condensations are avoided.

The minimum ventilation rate to keep oxygen provided is 6 l/s, this rate has been increased for both higher quality requirements and higher carbon dioxide levels from the outside. Actually the rate used is 6,4 l/s·met, considering the activities to be Developer on an office or a home as 1,25 met, we obtain a 8 l/s rate.

Microclimate

Climate has been related till the moment as it influences the buildings energy behaviour. Now we will approach the interior microclimate conditions to ensure hydrothermal comfort. Human being is a warm-blooded animal whose interior temperatures about 37°C, at general climatic conditions the human body is constantly giving heat out.

Hydrothermal design

To keep human thermal comfort the body must keep a constant interior temperature. Exterior climatic conditions should be studied to design the correct protections. Bioclimatic diagrams will provide useful information for the hydrothermal design.

Thermal comfort

Thermal comfort is reached when the heat generated by human metabolism can be dissipated; maintaining a thermal equilibrium with the surroundings and the internal temperature is constant. The dissipation of heat must keep the same rate as its production by the human metabolism. Any heat loss beyond produces cold sensation, as any heat gain beyond produces heat sensation. Thermal comfort is affected by heat conduction, convection, radiation, and evaporative heat loss. Dissipation of heat may be produced by convection (C), due to the air temperature and flow, by conduction (K) with other solid bodies in direct contact, by radiation (R), depending to the temperatures and properties of the near surfaces; or by evaporative heat loss depending on the temperature of the air and the relative humidity. All kinds of dissipation of heat are affected by the clothing that is worn. Heat produced by human metabolism for a period of time (M) will depend on the activities performed.

Thermal comfort is reached when:

$$M = \pm C \pm K \pm R \pm E$$

There are several factors determining thermal comfort, some influence the metabolic rhythm and others the dissemination of heat in any of their kinds:

a) Activity performed (M)
b) Clothing (C, K, R, E)
c) Air temperature (C, E)
d) Air flow rate (C, E)
e) Humidity (E)
f) Surface temperatures in the environment (R) or in contact with the human body (K).

Comfort zone is defined by the mentioned factors that keep heat exchange equilibrium. Nowadays it is described for light clothing, low air flow rates and low humidity. These conditions are ensured by the use of both passive strategies and HVAC technical equipments.

Bioclimatic comfort chart

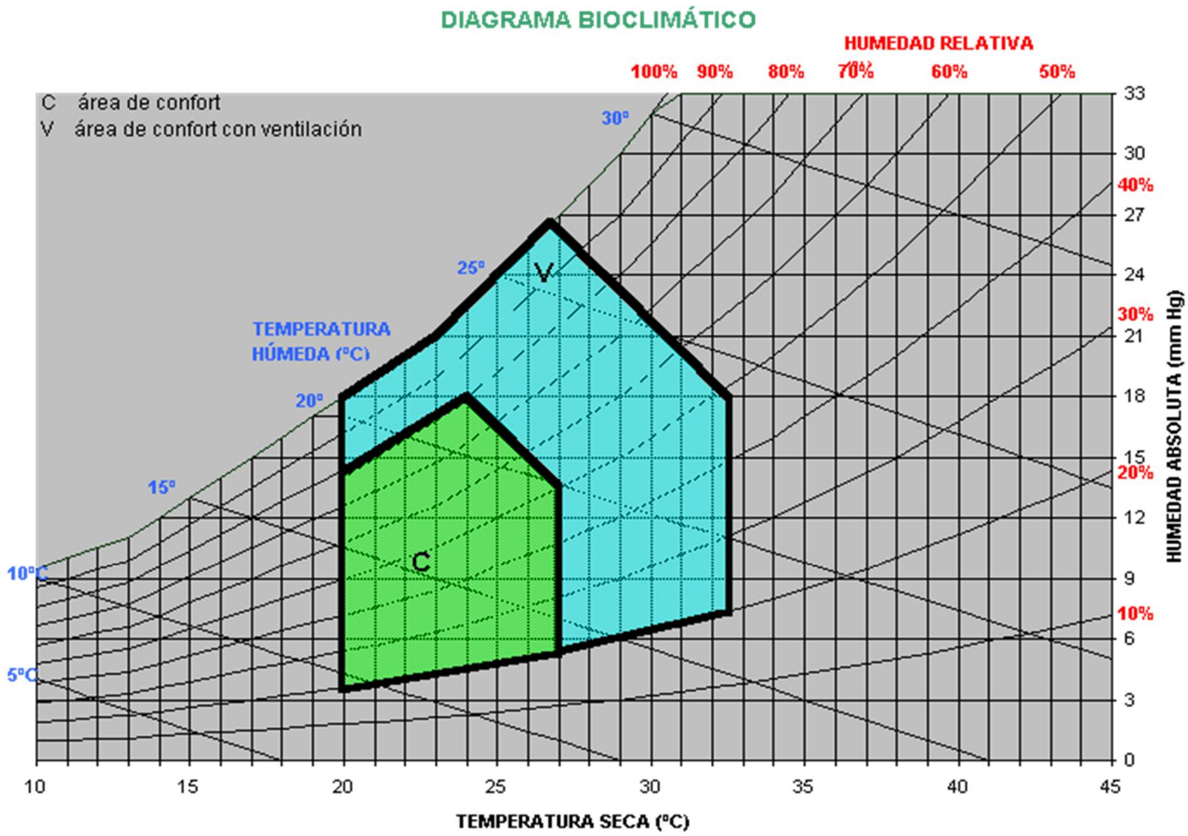
The bioclimatic comfort chart is the representation of a comfort zone for different temperature and humidity conditions. Each point represents a certain environment condition defined by temperature (T) and humidity (H).

There are two possible measures for humidity:

- Absolute humidity, as the partial pressure of water vapour [Hg mm] represented on the diagrams y-axis.
- Relative humidity, as the percentage of humidity for the total amount of water vapour for saturation at that temperature. Represented by several curves on the diagram.

There are also two ways to observe the temperature:

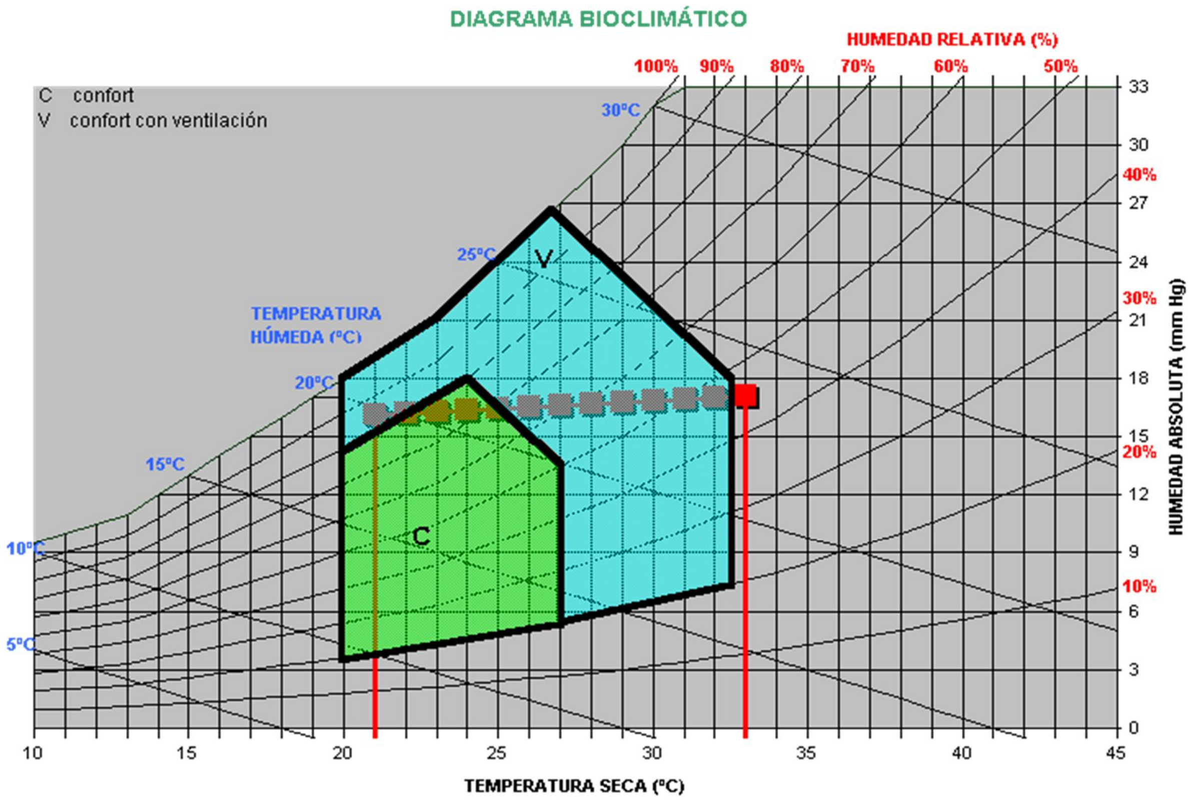
- Dry bulb temperature, is represented on the x-axis the thermometer is freely exposed to air.
- Wet bulb temperature, the thermometer bulb is constantly wet reflecting the physical properties of a system with a mixture of a gas and water vapour. Its value is always lower than the dry bulb temperature. For dry air conditions wet bulb temperature decreases since evaporation is faster. For almost saturated air conditions the wet bulb temperature rises and reaches the dry bulb temperature. It is represented on the diagram by curves.



Explanation: Axis X: Dry bulb temperature, Axis Y: Absolute humidity, RED: Relative humidity, BLUE: Wet temperature, C: Comfort area without ventilation, V: Comfort area with ventilation
Source: www.arquitecturasostenible.com

Comfort area without ventilation represented as ‘C’, is described for a light clothed, resting or seated that is not receiving solar radiation. Dry bulb temperatures for comfort area between 20-27°C and relative humidity goes from 20 to 80%.
Comfort area with ventilation (V) is defined as the previous one but can admit higher temperature and relative humidity. Temperature can reach 32,5°C for 50% humidity and even 27°C for 100% humidity.
Comfort areas may extend to 11-13°C for cold climates if defined for heavier clothing.

Climatic line can be used over the same diagram representing particular conditions for a certain month on a specific location. This line represents 4 parameters, minimum daily temperature (T_{min}), average daily maximum temperature (T_{max}), average minimum daily relative humidity (H_{min}), and average maximum daily relative humidity (H_{max}). When represented over the diagram (T_{min}, H_{max}) and (T_{max}, H_{min}), drawing the line we will obtain three important points: minimum (MIN) on the (T_{min}, H_{max}), and maximum (MAX) defined by (T_{max}, H_{min}), and the average (MED).

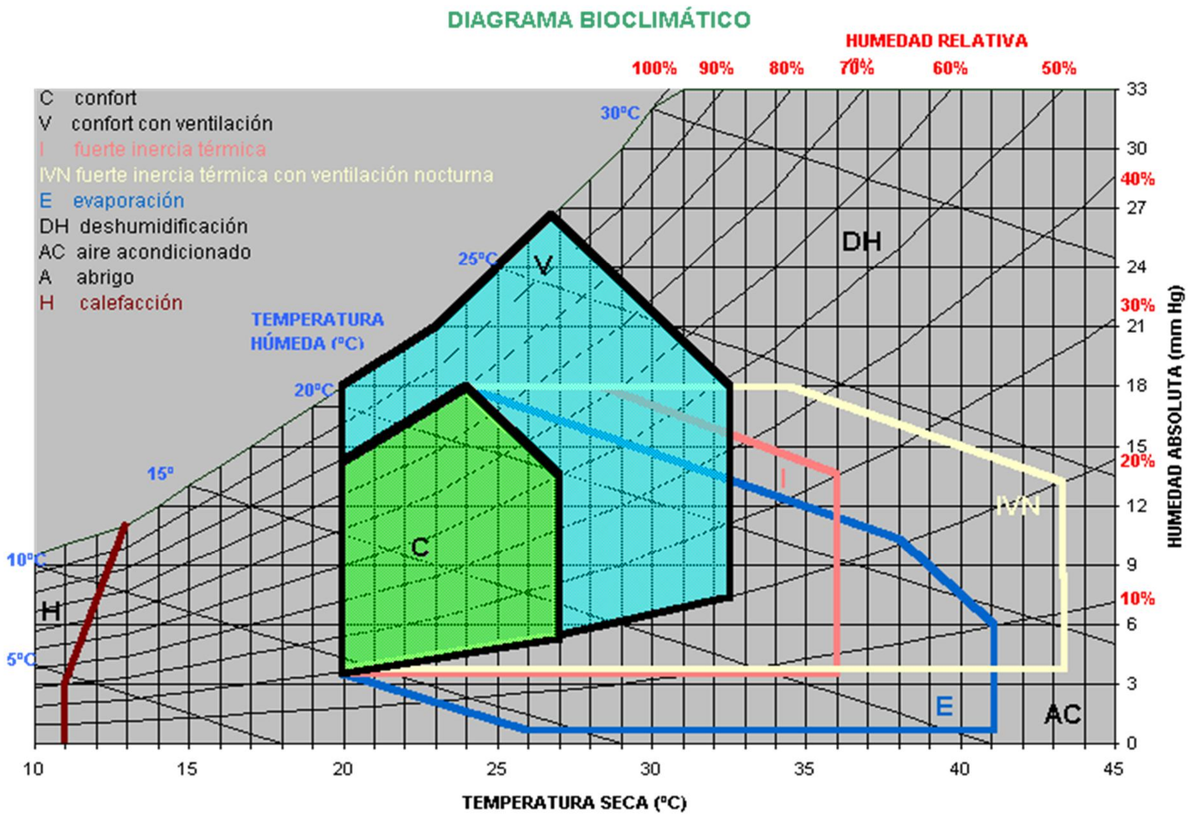


Explanation: Axis X: Dry bulb temperature, Axis Y: Absolute humidity, RED: Relative humidity, BLUE: Wet temperature, C: Comfort area without ventilation, V: Comfort area with ventilation
Source: www.arquitecturasostenible.com
Comfort conditions in Sidi Bou Said (Tunisia)

The diagram above represents the climatic line in red described for the conditions in Sidi Bou Said (Tunisia) during August: (T, H) are (21,0°C, 85%) and (33,0°C, 45%). Absolute humidity on this particular case is almost constant around 16-17mm Hg, but relative humidity changes among with temperatures from 20 to 24°C. Using ventilation comfort area is possible for these conditions most of the time, only some maximum temperatures escape zone 'V'.

According to the same general method, several conditions may be also represented on the bioclimatic chart.

- High thermal inertia zone (I). If a building has a high thermal inertia interior temperature will vary much less than the exterior temperatures. If the average temperature from the climatic line (MED) is inside the comfort zone, and the MAX is among 'I' zone, it will be possible to keep a permanent comfort inside the building. Solar gains must be avoided on the roof and glazing.
- High thermal inertia ventilated zone (IVN). If MED point is not among the comfort zone, but both MIN and MAX points are among IVN, it would be possible to keep comfort temperatures inside a high thermal insulated building if it is protected from solar gains and make good use of nocturne ventilation.



Explanation: Axis X: Dry bulb temperature, Axis Y: Absolute humidity, RED: Relative humidity, BLUE: Wet temperature, C: Comfort area without ventilation, V: Comfort area with ventilation, I: Thermal inertia, IVN: Thermal inertia without nocturnal ventilation, E: Evaporation, DH: Dehumidification, AC: Air conditioning, A: shelter, H: heating
Source: www.arquitecturasostenible.com

- Evaporative cooling zone (E). If climatic line points are among this zone, comfort may be obtained by the use of evaporative cooling. Exterior air used for ventilation is previously humidified. This technique may be used on hot dry climates, and precise no mechanical needs.
- Dehumidifier zone (DH). Comfort may be obtained by dehumidifiers for the points among this zone.
- Air conditioning zone (AC). The use of air conditioning devices is needed to gain comfort. Zone outside the previous on the right side of the diagram.
- Heating zone (H). Heating or solar gains will be needed to gain comfort. For a high thermal insulated building if MED is among the H zone heating will be necessary.

5 Conventional and innovative bioclimatic solutions for refurbishments and new buildings with adaptation to different climates

5.1 General design considerations

Placement, orientation

When a building or a building complex is planned, it is important to take into consideration all micro-climate effects. The landscape and climate are more important features that define the most proper placement, orientation, shaping, materials and open appearance. The planning success depends on the decisions of the designer / owner / architect / engineer / contractor and how they incorporate the natural elements and create harmonious architecture with the environment.

Orientation strongly relates a building to the natural environment - the sun, wind, weather patterns, topography, landscape, and views. Decisions made in site planning and building orientation will have impacts on the energy performance of the building over its entire life cycle.

The designer must consider and prioritize all factors and site conditions affecting building orientation. For example, a building might have to take heed of multiple orientation factors depending on functional requirements: designing for cooling load or heating load. To take advantage of north–south day-lighting, the building may be oriented along an east–west axis. But this may be counter to street lines and other site considerations. Orientation of the building entrance may have to respect street access, activity zones, and local urban design guidelines.

For most regions, optimum façade orientation is typically south. South-facing glass is relatively easy to shade with an overhang during the summer to minimize solar heat gain. Light shelves also can work well with the higher sun in the southern exposure. North-facing glass receives good daylight but relatively little direct radiation, so heat gain is less of a concern.

East and west window orientations and horizontal orientation (skylights) all result in more undesired heat gain in the summer than winter. East and west sun glare is also more difficult to control for occupant comfort because of low sun angles in early morning and late afternoon.

Wind in general affects tall buildings more than low structures. Design for wind direction - admitting favourable breezes and shielding from storms and cold weather winds. Wind information is often available from airports, libraries and/or county agricultural extension offices.

In temperate and northern climates, locate deciduous trees for south-side shading in the cooling season; in the heating season, the dropped leaves will permit desired solar gain.

In urban settings, orientation may be strongly determined by local regulation, view easements, and urban design regulations. Be aware of unique local and site-specific conditions, such as lake or coastal exposures, effect of mountainous conditions, and special scenic easements.

Energy conservation strategies relating to building orientation are:

- Maximizing north and south façade exposure for daylight harvesting to reduce lighting electrical loads.
- Using southern exposure for solar heat gain to reduce heating loads in the heating season.
- Using shading strategies to reduce the overheating in summer caused by solar gain on south façades.
- Turning long façades toward the direction of prevailing breezes to enhance the cooling effect of natural ventilation.
- Turning long façades in the direction parallel to slopes to take advantage of cool updrafts to enhance natural ventilation.
- Shielding windows and openings from the direction of harsh winter winds and storms to reduce heating loads.
- Orienting the most populated building spaces toward north and south exposures to maximize day-lighting and natural ventilation benefit.
- Determining building occupant usage patterns for public, commercial, institutional, or residential buildings, and how occupants will be affected by the building orientation, by time of day, on different exposures.

Main environmental factors at planning

Geographical areas

All kind of soil has a special structure. The corresponding building and structures in special circumstances may not be used without changes in other situations. Different areas have totally different solutions.

Vegetation

The diversity of plant life provides many opportunities for the architect or the designer. Different types of vegetation can be used to modify the microclimate of the area as well.
The presence of trees may affect both wind flow and shadowing. The surfaces that the wind covers before ventilating a building may affect the temperature of the air. The air may have been cooled by flowing over a water or green surface, or it may have been heated after cover a parking extension. Location of buildings and the distances and angles they form among each other, has an important influence on the wind flow and shadows on each other.

The origin terrain

The planning and the surrounding area can affect a variety of buildings. The drainage, sunshine, wind-, storm- and snow protection, the lowering of the ground structure, fit into the environment and many other characteristics depend on the terrain. All geographic type suggests a certain kind of solution that is most suitable to take full advantage of potential opportunities of the area while minimizing potential disadvantages.

Water

The water supplies may very vary depends on the climate. The area may be completely wet or it would be without any water. The quantity, the quality and the local occurrence controls the suitability of the area for life. The location of the water compared to the earth surface is crucial in relation to water supply, construction sites, surface drainage, vegetation and many other things in terms of selection.

Local building materials

Each area has its own "natural" material set. These materials are typical of the specific part of the landscape and their shapes and structures can be very instructive at designing. The use of local materials is very beneficial and we may minimize the energy content of imported materials.

In terms of sustainability materials should accomplish several requirements, such as:

– Plentiful and natural;
– Not pollutant and low volatile compounds containing;
– High energy performance for the particular purpose used during the whole life cycle;
– Renewable, recycled or recyclable;

They should be extracted, obtained or manufactured in a near location to the construction site to avoid energy consumption due to their transportation. During the processes of extraction, and manufacturing no pollution should be produced non aerial or water pollution.
The energy consumption during the extracting and manufacturing processes during the whole life cycle should be also considered. The use of recycled or recyclable materials should be prioritized in order to extend their life cycle and to minimize the waste.

High volatile organic compounds materials should be avoided, as well as toxic substances or hard combustion materials and also those emitting electromagnetic radiation.

The election of the materials must obtain the best energy performance for the building designed. Several characteristics should be also considered depending on the particular use of each material such as density, conductivity and heat capacity.

Pollution

It is known that pollution destroys our health and it also affects our decisions. Strangely, the nature also contaminants himself, the air will be polluted by forest fires or the rivers will be muddy time to time. This is natural process. But the men pollute and poison the nature by establishments of waste disposals, smog emissions, radioactive clouds, and unfortunately there are many other activities. It seems that the extent of contamination is directly related to the human population. Our living environment's major source of pollutants is caused by traffic pollution. The other main problem is the spread of the increased traffic noise.

Colour

Colour is an important factor on the thermal performance of buildings. Colour election according to climatic requirements is important to reduce solar gains during the summer or to improve solar gains during winter. It is important to consider that certain colours may cause glare in the exterior and interior areas of the buildings. Colour is also important to reflect light as have already explained. Reflection for different colours is shown in the next table.

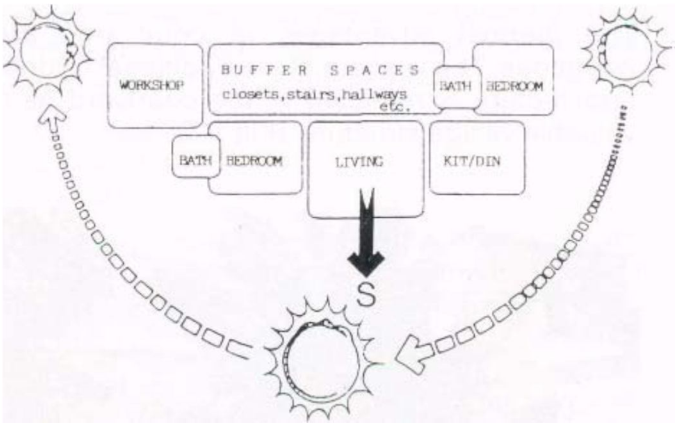
Colour	**Reflection**
White	0,80 - 0,70
Light colours	0,70 - 0,50
Pastel	0,50 - 0,30
Light bright colour	0,30 - 0,10
Dark bright colour	0,1
Dark colour	<,010

Colours may also be classified by the field of colour psychology that identifies the associations and effects on human emotions. One common classification is warm colours (yellow, orange, red) and cold colours (green, blue).

Layout

Layouts of buildings have a big effect on internal comfort and energy consumption during use. Therefore, it is very important to consider the sun path when orientation of rooms is determined during design. This method is called zone planning.

Generally the rooms according to their sunlight requirement, and the sequence of the activities housed in them, should follow the sun-path from South-East to South and South-West. Spaces with minimal heating and lighting requirements should be placed along the North face as a buffer area.



Building layout to follow the sun path (zone planning)

Internal heat gains generated in certain spaces (by people and equipment) should be either utilized to supply heat, or isolated according to the demands of the spaces.

There are many different types of spaces in a building, each with its own spatial characteristics and functional requirements, which require that systems serving them be differentiated accordingly. All design objectives - accessibility, aesthetics, cost-effectiveness, functionality, historic, productive, security/safety, and sustainability - and their interrelationships must be understood, evaluated, and appropriately applied within the spaces.

Building spaces may be grouped or zoned by several categories or combinations of categories:

- Site relationship: orientation, solar exposure, daylighting orientation, wind orientation, view, natural features;
- Program: functional activity, space population, time of day/night use, interior/exterior relationships;
- Location within the building: interior or exterior zone, a high-rise core or perimeter, or a low-, mid-, or high-level floor;
- Building codes: by fire hazard and building type groups.

Building spaces can maximize energy savings if their zoning and configuration are integrated with other sustainable design strategies for daylighting, cooling, and heating. Space zoning opportunities should be used for energy savings and reduction of carbon emissions considering the following:

- Maximize daylighting to reduce use of electric lighting.
- Orient the long axis of the building on an east–west axis so the long façades face north–south.

- Establish daylighting space zones: perimeter for maximum use of daylighting, transitional where both daylighting and electric lighting are used, and interior zones where only electric lighting is used. Depth of daylighting space zones will vary with true building orientation, time of day, time of year, latitude of the building location, ceiling height, and openness of interior space layout.
- Integrate HVAC systems with space zoning and provide adjustable individual controls.
- Group people-intensive spaces (eg. living room, bedrooms etc.) along the north and south perimeter zones for maximum daylighting benefit to occupants.
- Group spaces that require security, privacy, and service spaces in interior zones.
- Provide open space layouts to maximize daylight penetration to the interior.
- Reduce depth of spandrel beams and mechanical systems at the perimeter of the building to permit maximum penetration of high daylight.
- Provide flexible and adjustable electric lighting controls in perimeter and transitional zones to adjust to changing daylighting conditions.
- Provide interior windows and borrowed lights and use skylights and clerestories to provide daylighting to enable daylight exposure for spaces in the transitional and interior zones.

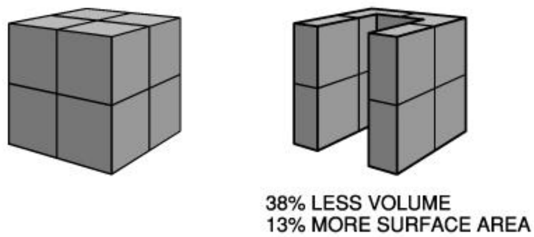
5.1.3 Compactness (surface – volume ratio)

Building form and its opposite, space, constitute the primary elements of architecture. Form can be thought as the external three-dimensional outline, appearance or configuration of something. Building form defines the space that shelters our interior human activity and the negative space, the void between building forms, shapes our exterior human activities in the built environment.

In designing a building form the architect must simultaneously consider site, aesthetic, programmatic, contextual, and functional issues, and then enclose the building in the most satisfactory way possible. In the world of planning regulations and commercial building, maximizing yield from the zoning envelope too often drives the design of the building form. The architect designs the resultant building form by manipulating standard aesthetic design devices such as shape, massing, scale, proportion, materials, rhythm, surface articulation, texture and colour, and light. Variables, such as building orientation to solar access, wind exposure, amount of surface area, and complexity of building form can profoundly influence the energy consumption characteristics of a building throughout its life time, thereby impacting carbon reduction.

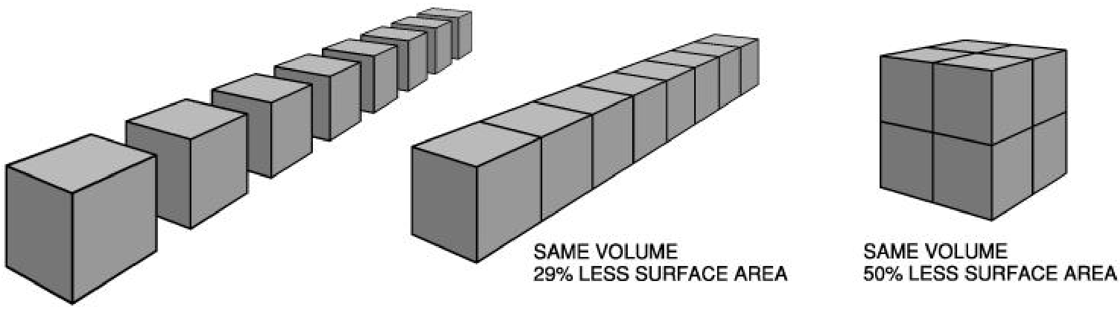
From an integrated building perspective the architect must balance and reconcile the functional, contextual, and economic drivers of the building form; and at the same time investigate passive solar, day-lighting, sun shading, landscaping, and natural ventilation strategies to optimize use of the natural features of the site to maximize energy efficiency of the building form.

By trimming the surface area of the building's thermal envelope, you can dramatically reduce heat transfer. Surface area is closely related to the geometry or form of the building. The shape and complexity of a house design affects the surface area and the overall energy used for heating and cooling. Compact form is the most basic strategy for conserving heat. This is because heat loss increases with surface area. This shows up in the Q = U*A*dT equation, but we all know it instinctively – it is why mittens are warmer that gloves; why cold fingers close into fists; and why dogs and cats curl up on cold nights, or sprawl loosely on hot afternoons.



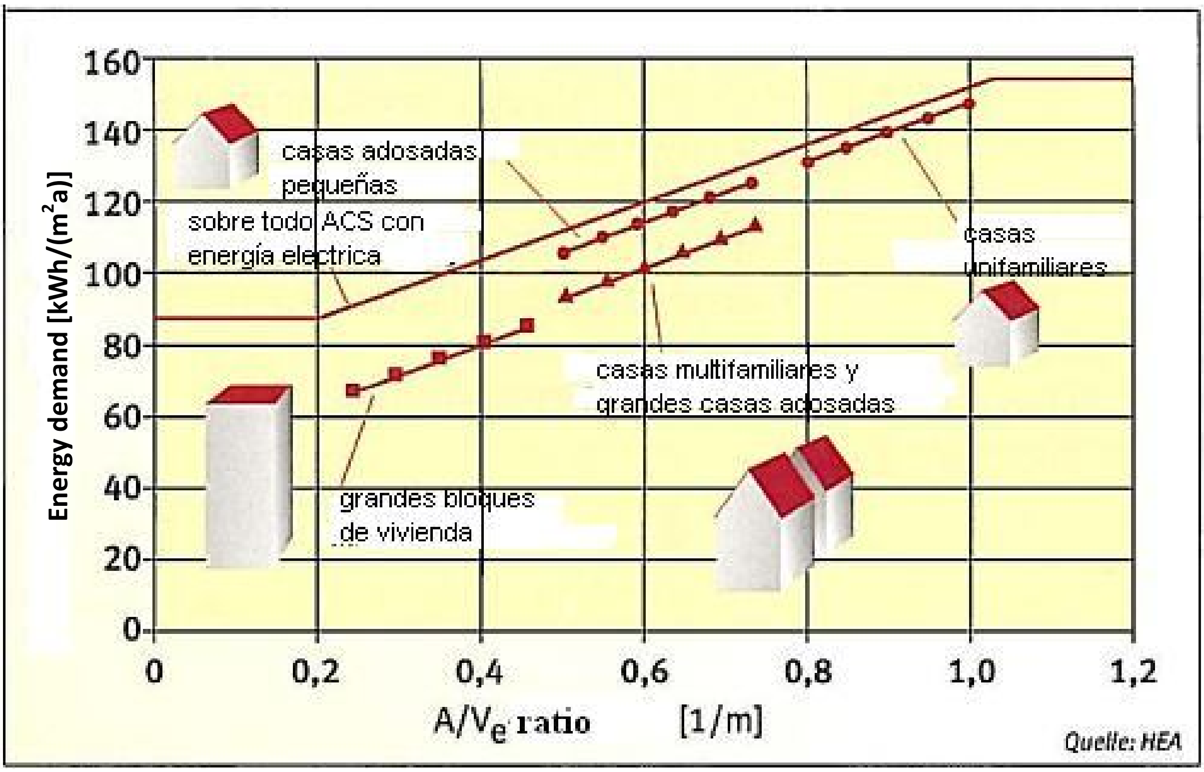
A cube is a compact form – if a slice is removed, its volume goes down, but it surface area increase (see the figure above). This is not to suggest that buildings need to be blocky – there are good reasons for them not to be – but it does emphasize that form effects energy use, and choices about form should be made with this in mind.

It is also true that larger forms enclose space more efficiently than smaller ones. In the example below, the eight cubes represent standalone houses. If eight row houses were built instead, the same amount of space could be enclosed with 29% less surface area; and, if apartments were built, the same space might require 50% less surface area. This means that the apartment would have 50% less heat loss while using the same wall, roof, and floor assemblies. This also means that, if saving energy is a priority, attached housing should be considered. We may minimize exterior surface complexity to reduce chance of leaks and energy loss.



A single family house could never gain the maximum reduction of heating demands when compared to that of a multi-family housing. Volume/external surface ratio for single family houses are around 2:3 (0,71), for a multi-family house semidetached ratio may be around 1:2 (0,45). The lower the ratio, the better energy efficiency is gained.

On cold or mild temperatures climates, compact buildings perform much better on heat demands during winter and overheating in the summer period. An 0,65 ratio is recommended, of course it depends on the building type and its use. The next graphic shows the recommended ratio A/V for different housing building types and an estimated energy demand on a mild temperature climate.



Explanation:
Casas adosadas pequeñas: small terraced houses, sobretodo ACS con energía eléctrica: mostly with electric HDW, grandes bloques de viviendas: big collective blocks, casas multifamiliares grandes y grandes casas adosadas: big plurifamiliar houses and big terraced houses, casa unifamiliares: single-family house

Source: www.nea-architects.com

Glazing, fenetration

Glazing ratio of rooms has a big effect on energetic behaviour of buildings and comfort conditions in the interior. Although small openings allow less solar radiation into the interior in summer, this way solar gain is also reduced significantly in winter. During design the ratio of opaque and transparent surfaces needs to be established properly in accordance with local climate conditions. It is recommended using smaller openings in the Southern areas at warmer climate, while larger transparent surfaces are recommended in case of Northern climate conditions. However, in many cases a glass surface with a good thermal performance can be worse than an average insulated opaque structure.

Thermal mass

Adequate thermal mass, which is one of the most important pillars of bioclimatic design, has two main advantages: in winter it stores the solar heat gain collected during the day and radiates it to the rooms at night, while in summer it warms up slower than a light-weight structure provided proper ventilation during the night exists.
Section 5.2.2 gives further information on passive solar systems using thermal mass.

Possibility to use and recommendations

In case of new buildings architects have big freedom in using the tools mentioned above. However, a significant percentage of our buildings are existing houses and their basic architectural concept cannot be changed afterwards.

POSSIBILITY TO USE	new	existing
orientation	**	-
layout, zone planning	**	-
compactness	**	-
glazing, fenetration	**	*
thermal mass	**	*

** high possibility to use
* possibility to use
- not real possibility to use

The table below gives guidance, depending on the function of the building and the climatic conditions, where the basic architectural tools mentioned above are recommended. The building function has been split into residential and office function, where people stay permanently. The European climate has also been split into two parts; northern areas where summer is cool and winter is cold and southern (Mediterranean) areas where summer is dry and hot and winter is mild.

RECOMMENDATIONS	South		North	
	residential	office	residential	office
orientation	**	**	**	**
layout, zone planning	**	**	**	**
compactness	*	*	**	**
glazing, fenetration	**	**	**	**
thermal mass	**	**	**	**

** highly recommended
* recommended
- not recommended

As it can be seen from the table above, these basic tools are recommended for all climates with different content of course, e.g. see glazing ratio. On cold or mild temperatures climates, compact buildings perform much better on heat demands during winter and overheating in the summer period.

5.2 Principles again heat loss in winter

During bioclimatic design high attention should be paid to decrease the winter heat loss so that buildings can be made more convenient and their energy consumption lower. There are two pillars of the protection against winter heat loss: to decrease the heat loss through the fabric and increase the solar heat gain.

5.2.1 Heat protection of the building envelope

Heat transfer is classified into various mechanisms, such as heat conduction, convection, thermal radiation, mass transfer and phase-change transfer. Heat-transfer principles may be used to preserve, increase, or decrease temperature in a wide variety of circumstances.

Heat conduction (or diffusion) is the direct microscopic exchange of kinetic energy of particles through the stationary boundary between two systems or between objects that are in physical contact. This occurs between stationary masses where there is no movement to carry heat away, e.g. heat transfer through the stationary air layer immediately adjacent to an interior wall.
Heat convection is the transfer of energy between an object and its environment, due to fluid motion, and it occurs when bulk flow of a fluid (gas or liquid) carries heat along with the flow of matter in the fluid.

Radiation is the transfer of energy to or from a body by means of the emission or absorption of electromagnetic radiation. This occurs across vacuum and any transparent medium (solid or fluid) by means of electromagnetic waves. Solar radiation occurs predominantly through the roof and windows (but also through walls). Thermal radiation moves from a warmer surface to a cooler one. Roofs receive the majority of the solar radiation delivered to a house.
Mass transfer is the transfer of energy from one location to another as a side effect of physically moving an object containing that energy.
Transfer of heat through a phase transition in the medium - such as water-to-ice, water-to-steam, steam-to-water, or ice-to-water - involves significant energy.

Thermal insulations and radiant barriers

Thermal insulations are materials specifically designed to reduce the flow of heat by limiting conduction, convection, or both. Radiant barriers are materials that reflect radiation, and therefore reduce the flow of heat from radiation sources. Good insulations are not necessarily good radiant barriers, and vice versa. Metal, for instance, is an excellent reflector and a poor insulation.

The effectiveness of insulations is indicated by their 'R' value, or thermal resistance value. The R-value of a material equals the thickness (d) of the insulation divided by the thermal conductivity (λ). In most of the world, R-values are measured in SI units: [m^2K/W]. As the thickness of insulating material increases, the thermal resistance also increases. However, adding layers of insulation has the potential of increasing the surface area, and hence the thermal convection area.

The effectiveness of a radiant barrier is indicated by its reflectivity, which is the fraction of radiation reflected. A material with a high reflectivity (at a given wavelength) has a low emissivity (at that same wavelength), and vice versa. An ideal radiant barrier would have a reflectivity of 1, and would therefore reflect 100% of incoming radiation.

Houses with their heating systems form dissipative systems. In spite of efforts to insulate houses to reduce heat losses via their exteriors, considerable heat is lost, which can make their interiors uncomfortably cool or cold. For the comfort of the inhabitants, the interiors must be maintained out of thermal equilibrium with the external surroundings. In effect the thermal gradient between the inside and outside is often quite steep. This can lead to problems such as condensation and uncomfortable air currents, which can cause cosmetic or structural damage to the property. Such issues can be prevented by using of insulation techniques for reducing heat loss.

Thermal transmittance or ‘U’-value is the rate of transfer of heat through a structure divided by the difference in temperature across the structure. It is a measure of how well the building element is insulated and it is expressed in [W/m²K]. The lower the U-value is, the better the thermal performance of the structure will be.

There are essentially two types of building insulation: bulk insulation and reflective insulation. Most buildings use a combination of both types to make up a total building insulation system. The type of insulation used is matched to create maximum resistance to each of the three main forms of building heat transfer - conduction, convection, and radiation.

Bulk insulators block conductive heat transfer and convective flow either into or out of a building. The denser a material is, the better it will conduct heat. Because air has such low density, it makes a good insulator. Insulation to resist conductive heat transfer uses air spaces between fibres, inside foam or plastic bubbles and in building cavities like the attic. This is beneficial in an actively cooled or heated building, but can be a liability in a passively cooled building; adequate provisions for cooling by ventilation or radiation are needed.

Radiant barriers work in conjunction with an air space to reduce radiant heat transfer across the air space. Radiant barriers are often seen used in reducing downward heat flow, because upward heat flow tends to be dominated by convection. This means that for attics, ceilings, and roofs, they are most effective in hot climates. They also have a role in reducing heat losses in cool climates, although much greater insulation can be achieved through the addition of bulk insulators. Some radiant barriers are spectrally selective and will preferentially reduce the flow of infra-red radiation in comparison to other wavelengths. For instance low-emissivity (low-e) windows will transmit light and short-wave infra-red energy into a building but reflect back the long-wave infra-red radiation generated by interior furnishings. Similarly, special heat-reflective paints are able to reflect more heat than visible light, or vice-versa. Thermal emissivity values probably best reflect the effectiveness of radiant barriers, since ‘R’-value testing measures total heat loss in a laboratory setting and does not control the type of heat loss responsible for the net result. A film of dirt or moisture can alter the emissivity and hence the performance of radiant barriers.

Heat protection in different climates

In cold conditions, the main aim is to reduce heat flow out of the building. The components of the building envelope - windows, doors, roofs, walls, and air infiltration barriers are all important sources of heat loss. In an otherwise well insulated home, windows will then become an important source of heat transfer. The resistance to conducted heat loss for standard single glazing corresponds to an ‘R’-value of about 0,17 m^2K/W (compared to 2-4 m^2K/W for insulated structures). Losses can be reduced by good weatherisation, bulk insulation, and minimising the amount of non-insulating (particularly non-solar facing) glazing. Indoor thermal radiation can also be a disadvantage with spectrally selective (low-emissivity) glazing. Some insulated glazing systems can double or triple R values.


Cross-section of cellulose insulation

In hot conditions, the greatest source of heat energy is solar radiation. This can enter buildings directly through windows or it can heat the building shell to a higher temperature than the ambient, increasing the heat transfer through the building envelope. The Solar Heat Gain Co-efficient (SHGC) or 'G'-value (a measure of solar heat transmittance) of standard single glazing can be around 78-85%. Solar gain can be reduced by adequate shading from the sun, light coloured roofing, spectrally selective (heat-reflective) paints and coatings and various types of insulation for the rest of the envelope. Specially coated glazing can reduce 'G'-value to around 10%. Radiant barriers are highly effective for attic spaces in hot climates, and they are much more effective in hot climates than cold climates. For downward heat flow, convection is weak and radiation dominates heat transfer across an air space. Radiant barriers must face an adequate air-gap to be effective.

Opaque structures

In case of a building the opaque structures are the walls, the roof or the loft and the slab-on-ground or the slab of the basement.

Solid walls

Both internal and external solid wall insulation substantially reduce a home's heating costs and CO_2 emissions. However, they are quite different in terms of the effect they have on the building.

Internal wall insulation between a heated and a non-heated area in a building is generally non as complicated and expensive to install as the external wall insulation. It does not alter the appearance of outside walls but it will slightly reduce the floor area of any rooms where it is applied and during both the design and execution phase high attention should be paid and it requires adequate professional skills. If there are unresolved problems with penetrating or rising damp, these should be resolved before installation. Condensation occurs when warm air from inside the building meets a cold surface and when you fit internal wall insulation it stops the heat from the building reaching the wall so it will be a lot cooler. When insulation is applied on the inside of the external wall, a vapour barrier is applied to prevent moisture from the air in the building forming on the cold exterior wall.

Insulation should not in any circumstances be used to cover, hide or isolate damp. This could lead to more serious problems in the future. Before applying internal thermal insulation a full condensation calculation and assessment need to be carried out and the sensitivity of the external wall for colder conditions caused by the internal insulation (e.g. frost resistance) has to be taken into consideration as well.

There are three main alternatives to insulate a solid wall internally: rigid insulation boards, insulation boards with a stud wall or special insulation materials. If the insulated walls will support heavy fixtures like kitchen units, radiators or wash basins it may be the best to install a stud wall, otherwise rigid insulation boards can be fit.
Insulation boards technique involves fitting plasterboard backed with rigid insulation onto the inside of walls. Typically the insulation will be made of either expanded or extruded polystyrene (EPS or XPS), polyurethane or phenolic foam. The insulation is typically at least 60mm deep to meet recommended standards, and can be anything up to 100mm deep.
With stud wall technique, a metal or wooden studwork frame is attached to the wall and filled in with mineral wool fibre. It can then be plastered over, ready for redecoration.
Rather than finishing off a stud wall with plasterwork, rigid insulation boards can be added at the final stage instead. This combination of techniques will boost the performance of the insulation and reduce the running costs and risk of condensation even further.
There are special thermal insulation materials which can take the humidity of the room insulated and give it down into the interior when it is dryer.

External wall insulation can be applied without disruption to the household and does not reduce the floor area of the building, moreover it renews the appearance of ageing outer walls. Planning permission may be required. This method fills cracks and gaps in the brickwork reducing draughts and also increases the lifetime of a home’s wall by protecting the brickwork. External wall insulation reduces condensation on internal walls and can help prevent damp, although it will not solve rising or penetration damp which must be resolved prior to insulating the walls. However, interstitial condensation can occur in the structure if the external render or cladding has a high vapour resistance. Condensation risk has to be checked in such cases. It is not recommended for homes with structurally unsound outer walls that cannot be repaired. A layer of insulation material is fixed to the walls with mechanical fixings and/or adhesive then covered with a special type of render (plasterwork) or cladding. The finished look can be smooth or textured and painted, tiled, panelled, pebble-dashed (for easy maintenance) or finished with brick slips to provide a real masonry brick finish. As they will cover the whole of the outside of the property, any of these finishes are likely to change its appearance – and will cover existing brickwork.

Cavity walls

To insulate cavity walls, the installer drills small holes around 22mm in size at intervals of around 1m – 1,5m from the outside of the building. With specially designed equipment, they then blow insulation into the cavity. Typically, cavity wall insulation can be made out of mineral wool, beads or granules, cellulose or foamed insulations.

Roofs and lofts

There are three main types of loft insulation: quilts - mineral wool and natural wool; blown insulation - mineral wool and cellulose; boards - expanded/extruded polystyrene.
Loft insulation blankets, often referred to as quilts are made from glass or rock fibre, some of which will have been recycled**.** Mineral wool is the most common form, and natural wool is another, which is very environmentally friendly. Installing 270 mm of insulation in a loft compared with no insulation will save around a tonne of CO_2 per year. Typically, quilts are laid down between the joists and reach the top of the joist. Typically, this will make the insulation around 100mm to 150mm deep. More layers should then be added at right angles, to close up any gaps between the joist and the quilt, and to bring the depth to the required value.

Another type of loft insulation is blown insulation using special equipment which blows loose, fire-retardant insulation material into the specific, sectioned-off area of the loft to the required depth. It is blown mineral wool or cellulose fibre, which is made from newspapers.

If the plan is to convert the loft space into a living area, then instead of laying insulation between the joists, it is possible to fit rigid insulation boards made of expanded polystyrene between the rafters. If deeper insulation is needed, insulated plasterboards can also be fitted onto the rafters - although this will make the loft space a little smaller.

Timber floors can be insulated by lifting the floorboards and laying mineral wool insulation supported by netting between the joists. It is advised not to block under-floor airbricks in the outside walls, since floorboards will rot without adequate ventilation.

Ground floors and basements

Heat loss from an uninsulated, conditioned basement may represent up to 50% of a home's total heat loss in a tightly sealed, well-insulated home. Ground floor insulation is used primarily to reduce heating costs and has little or no benefit in lowering cooling costs. It also reduces the potential for condensation and corresponding growth of mould.
Ground floor types are either: full basement, slab-on-ground, or crawlspace. Deep frost lines and low water tables often make a full basement the primary foundation of choice. However, slab-on-ground construction is also common, and home additions often have crawlspace foundations.

For full basements the basement wall can be insulated either on the internal or external side. Interior insulation can use conventional framing with batt or wet-spray insulation. Rigid foam is also used on basement interiors. Extruded or expanded polystyrene or polyisocyanurate insulation boards can also be used. Fire codes usually require most of these interior insulations to be covered with drywall.

Exterior insulation typically uses extruded or expanded polystyrene directly on the exterior of basement walls. Insulation exposed above-grade must be covered to protect it from physical abuse and the damaging effects of the sun.

In crawlspaces the walls are just short basement walls. Exterior foam and foam-form insulation systems can be used. However, interior crawlspace wall insulation is usually either foam board or draped insulation. If crawlspaces are insulated with fibreglass or mineral wool batts, the batts are usually tacked to the sill plate and draped down and onto the floor. Somewhere a ventilated crawlspace is required to help control moisture, however it is significantly reduced if the floor of the crawlspace is covered with plastic sheeting. The floor over the crawlspace can also be insulated. This raises the thermal envelope from the crawlspace walls to the floor. While this technique offers many advantages, piping must be freeze-proofed, and heating and cooling ducts must also be insulated.

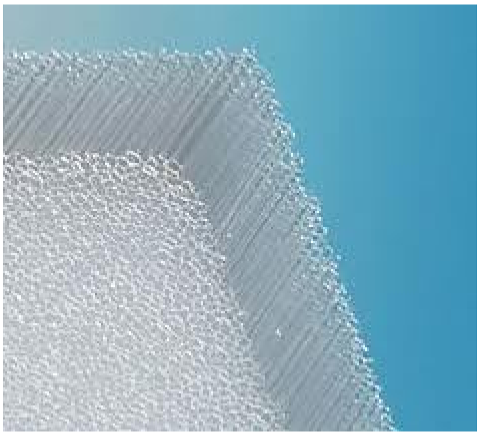
In case of slab-on-ground heat loss is greatest at or near the exterior grade. To reduce heating costs and reduce the cold-floor syndrome common to slab-on-ground construction, insulation is critical. Exterior foam insulation works well. Insulation should extend from the top of the slab to the top of the footing. Foam insulation inside the footing is also common.

Innovative thermal insulations

Transparent thermal insulation

Transparent thermal insulation relies on compensating heat loss with solar gains and, in addition, to use these gains for space heating. Transparent thermal insulation materials – as opposed to opaque thermal insulation materials, feature two properties that are highly important with a view to the energy balance of a building:

- highly efficient thermal insulation (i.e. low values for the thermal conductivity - λ)
- high transmittance for solar radiation (i.e. high values for the total energy transmission coefficient g).



Transparent thermal insulation
Source: www.archiexpo.com/prod/okalux/thermal-insulation-glass-3737-106184.html

Transparent thermal insulation materials usually consist of translucent plastics, such as polycarbonates (PC) or polymethyl-methacrylate (PMMA), with either tubular or honeycomb structure perpendicular to the wall surface. See more details in section 5.2.2.

Vacuum Insulated Panel

A vacuum insulated panel is a form of thermal insulation consisting of a nearly gas-tight enclosure surrounding a rigid core, from which the air has been evacuated. A vacuum insulated panel uses the insulating effects of a vacuum to produce much higher thermal resistance than conventional insulation since there is no heat convection in vacuum.

The thickness of vacuum insulated panels ranges from 1 to 5 cm and the panels have a size of maximum 60 x 100 cm. The most efficient core material is a compressed board made from pyrogenic silica powder. The fill material is surrounded by a gas-tight enclosure. The role of this enclosure is not only to hold the vacuum but it also helps to integrate the panel into the building structure. The enclosures are multi-foil systems from which the aluminium-foil systems are the most suitable for the construction industry.

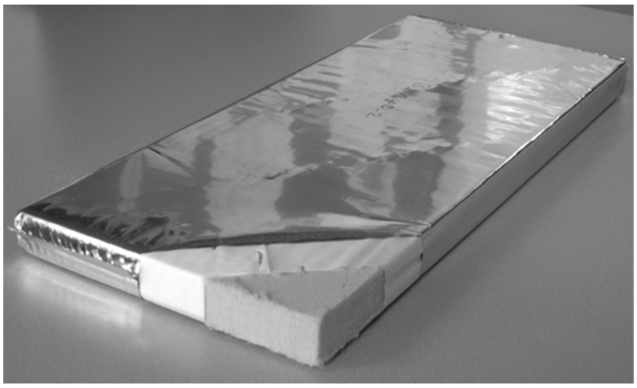


Figure: Vacuum insulated panel
Source: ZAE Bayern

The manufactured panels with an average internal pressure of 5 mbar have a thermal conductivity of between λ = 0,008 to 0,005 W/mK depending on the materials used. This value is 5 - 8 times better than the thermal conductivity of conventional thermal insulations.

Thickness	mm	10	15	20	30	40	60
U-value	W/m^2K	0,46	0,32	0,24	0,16	0,12	0,08
Mass	kg/m^2	1,6	2,4	3,2	4,8	6,4	9,6

Thermal insulation properties of vacuum insulated panels
(λ = 0,005 W/mK, density 160 kg/m^3)

The most typical fields of application of vacuum panels are building retrofitting and parapet glazing of curtain walls where only small place is available for the thermal insulation. It is also used where extremely good thermal insulation is required, for example for passive houses.

In addition to the low thermal conductivity, this innovative structure has some other features as well which make them different from other conventional structures, such as: high sensitivity against mechanical damage, strict prefabrication and dimension-coordination rules, more important role and effect of thermal bridges regarding the thermal insulation of the complete structure. These features require different thinking from the designer, from the constructor and even from the user.

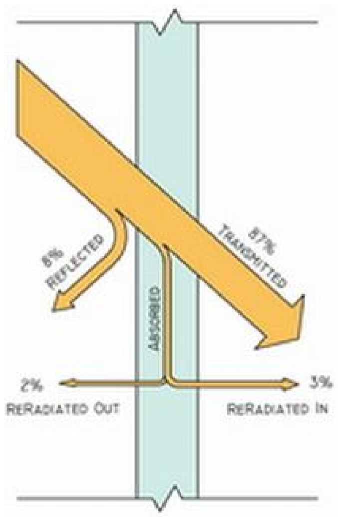
Transparent structures

Windows and other glazed external surfaces have a major impact on the energy efficiency of the building envelope. Windows also provide natural daylight, ventilation, noise control, security and allow views connecting interior and outdoor spaces. Glass is a good conductor of heat and also allows radiant heat to pass through freely. Energy from radiation can move into a window in the day time and out of the same window at night.

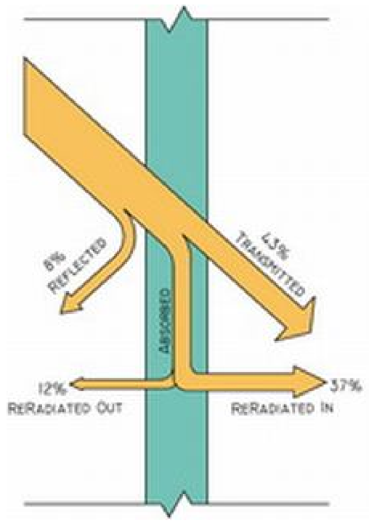
Heat loss and gain in a well-insulated home occurs mostly through the windows. In summer, the glass in direct sun can allow significant thermal energy in. Solar heat gain through windows can be reduced by insulated glazing, shading, and orientation. Solar heat gain can be significant even on cold clear days, however in winter, losses from a window can be ten or more times the losses through the same area of insulated wall. With good passive design windows can trap warmth in winter and repel summer heat. They admit cooling breezes and exclude cold winter winds.
Convective heat transfer through and around window coverings also degrade its insulation properties.

Tinted or "toned" glass is the most common type of absorbent glass. Toned glass acts like sunglasses to reduce the solar radiation entering into the building home, which helps to keep it cool in summer. "Supertoned" glass reduces the transmission of ultraviolet rays which, when combined with heat, are a major cause of fading of furnishings. As a special case, the transparent solar glass modules consist of transparent crystalline photovoltaic cells, or thin film transparent amorphous Si PV. In this case the absorbed light generates electricity.
Spectrally selective glazing is commonly used for cooling climates or for westerly elevations where solar control and natural lighting are a priority. Spectrally selective glazing maximises light transmission while simultaneously reflecting unwanted solar radiation (UV and near infrared). Spectrally selective coatings can also have low emissivity.

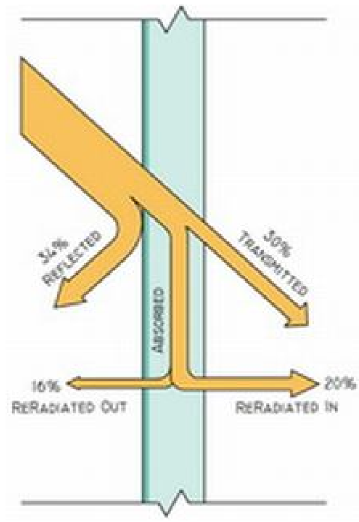
Reflective glass has either a vacuum-deposited metal coating or a pyrolytic coating. Vacuum-deposited coatings are soft and must be glazed facing indoors. Pyrolytic coatings are hard and durable and can be glazed facing outdoors.



Clear glass – most of the solar radiation is transmitted



Absorbing glass – most of the solar radiation is transmitted and re-radiated in



Reflective glass – most of the solar radiation is reflected

All properties lose heat through their windows. Installing energy efficient glazing is an effective way of reducing energy consumption and keeping the building warmer and quieter, and it reduces condensation build-up on the inside of windows. Double glazed windows use two sheets of glass with a gap between them which creates an insulating barrier, whilst triple glazed windows have three sheets of glass. Energy efficient windows are available in a variety of frame materials and styles, and they also vary in their energy efficiency, depending on how well they stop heat from passing through the window, how much sunlight travels through the glass and how little air can leak in or out around the window.

Insulated Glass Units (IGUs) are manufactured with glass in range of thickness from 3 mm to 10 mm or more in special applications. The most energy efficient glass for double glazing is low emissivity (Low-E) glass. This often has an unnoticeable coating of metal oxide, normally on one of the internal panes - next to the gap. It allows short wavelength energy (daylight) from the sun to pass into the house but reduces the amount of the long wavelength energy (infrared heat) that can escape through the window so it lets sunlight and heat in but cuts the amount of heat that can get out again.

All double glazed windows have pane spacers set around the inside edges to keep the two panes of glass apart. In a more efficient window, the pane spacers contain little or no metal. The maximum insulating efficiency of a standard IGU is determined by the thickness of the space containing the gas or vacuum. Too little space between the panes of glass results in conductive heat loss between the panes (the inside surface of one pane cools the surface of the other pane) while a too wide gap results in convection current losses (gas begins to circulate because of temperature differences and transfers heat between the panes). Double glazing has a gap of around 12 - 19 mm.

A practical alternative is to replace air in the space with a heavy gas that is more viscous than oxygen and nitrogen. Higher viscosity reduces convective heat transfer, as well as reducing the heat capacity portion coming from rotational degrees of freedom. Argon (argon has a thermal conductivity 67% that of air), krypton (krypton has about half the conductivity of argon) or xenon is used to increase the insulating performance. In general, the more effective a fill gas is at its optimum thickness, the thinner the optimum thickness is.

Regarding window frames the PVC frames are the most common type. They last a long time and can be recycled. Wooden frames can have a lower environmental impact therefore it's suggested but require maintenance. Aluminium or steel frames are slim and long-lasting, and they can be recycled, but aluminium is a good conductor of heat and can decrease the insulating value of a window by 20-30%. Fibre-reinforced polyester (FRP) frames are the most thermally efficient framing materials available. Composite frames have an inner timber frame covered with aluminium or plastic. This reduces the need for maintenance and keeps the frame weatherproof. They insulate about twice as well as standard aluminium frames but they are more expensive. IGU thickness is a compromise between maximizing insulating value and the ability of the framing system used to carry the unit. Issues arise with the use of triple glazing. The combination of thickness and weight results in units that is too unwieldy for most residential or commercial glazing systems, particularly if these panes are contained in moving frames or sashes.

Because replacement windows are usually more airtight than the original single glazed frames, condensation can build up in the building due to the reduced ventilation. If there is not a sufficient level of background ventilation in the room some replacement windows will have trickle vents incorporated into the frame that let in a small amount of controlled ventilation. Condensation can sometimes occur on the outside of new low-e glazing. This is because low-e glass reflects heat back into the building and as a result the outside pane remains cool and condensation can build up in cold weather.

A standard IGU consisting of clear uncoated panes of glass with air in the cavity has a typical U-value of 2,9 W/m^{2}K. Adding Argon gas decreases the value to about 1,9. Using low emissivity coating on surface #2 will provide a typical 'U'-value of 1,4. Properly designed triple glazed IGUs with low emissivity coatings on surfaces #2 and #4 and filled with argon or krypton gas in the cavities result in IG units with U-values as low as 0,8-1,1.

Large air space improves also the noise insulation quality or sound transmission class. Asymmetric double glazing, using different thicknesses of glass rather than the conventional symmetrical systems will improve the acoustic attenuation properties of the IGU at the cost of longevity if the unit is used to separate exterior and interior environments. If standard air spaces are used, sulfur hexafluoride is used to replace or augment an inert gas and improve acoustical attenuation performance. The most widely used glazing configurations for sound dampening include laminated glass with varied thickness of the interlayer and thickness of the glass. Including a structural, thermally improved aluminum thermal barrier air spacer in the insulating glass can improve acoustical performance by reducing the transmission of exterior noise sources in the fenestration system.

Secondary glazing works by fitting a secondary pane of glass and frame, inside the existing window reveal. This is likely to be less effective than replacement windows. The units tend to be not as well sealed, however it is considerably cheaper than double glazing.
Curtains lined with a layer of heavy material can further reduce heat loss from a room through the window at night and cut draughts.

Glazing in different climates

Heating (or alpine and cool temperate) climates are colder climates where most energy is used to heat the home. South facing glazing is ideal for these climates. It is desirable to maximise south facing glazing with solar exposure with high ‘g’-value glazing to increase solar gains in winter. Summer heat gain can then be controlled with adjustable external shading. Winter heat loss can be reduced using insulating glass and frames, and also with internal insulating treatments such as snug fitting insulating drapes with sealed pelmets or insulating blinds. East and west-facing windows will contribute to overheating in summer if not well shaded. An ideal solution is to use smaller insulating glass units on east and west facades to reduce heat loss in winter. Large areas of north facing glass will allow heat loss but do not allow compensating solar heat gain and should be avoided. Moderate north facing glass areas are required for cross ventilation and daylighting.

Cooling (or tropical, subtropical and hot arid) climates are warmer climates where most energy is used to cool the home. The window's role in a cooling climate is to reduce the amount of heat entering the building without reducing natural light to the extent that artificial lighting is required inside. Low g-value windows are designed to block the sun's heat and are appropriate in cooling climates. Low U-value windows keep hot outside air from entering the house, and are particularly important if the house is air-conditioned. It is advised to use solar control (tinted) glazing to reduce solar heat gain. Tinted windows reflect some heat and absorb some heat, which is then radiated both inwards and outwards, convects most of the heat away outside and transmits the rest. In cooling climates, heat radiated inwards can reduce thermal comfort near the window. A double glazed unit provides better performance in a cooling climate because the inner pane blocks some of the heat radiated inward by the outer pane. The best performance is obtained by using a low-emissivity (low-e) glass for the inner pane. Double-glazing also gives a low U-value, reducing infiltration of warm air from outside. However external shading should always be the first solution considered. Advanced glazing options can provide effective solutions on difficult sites where other shading options are not possible.

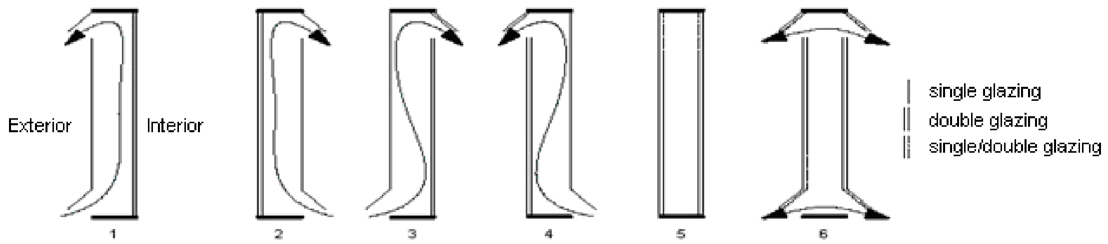
Mixed (or temperate) climates use energy for heating in winter and cooling in summer. The goal in these climates is to keep heat in during winter and out during summer. During winter, a low U-value and a high g-value are ideal to capture useful solar energy and reduce heat loss. During summer, good solar control and/or shading are required. Good design dictates that windows with good heating performance should be used on the south and north elevations and good cooling performance on the east and west elevations.
For heating energy reduction performance in temperate climates the windows are double glazed insulating units, with either clear glass or low-e glass. With a large number of windows and wide sliding doors, natural light floods the interior of the building. The use of double-glazing provides a benefit in summer by reducing the flow of warm air towards the cooler interior. Correctly sized eaves or other shading should be used to protect south-facing windows. This provides protection from summer heat and glare while still allowing sun penetration in winter.
For cooling energy reduction performance in temperate climates the windows are double glazed for insulation purposes but use adjustably shaded solar control glass to reduce the solar heat gain in summer. The double-glazing reduces conducted heat from high external temperatures entering the cooler interior. The solar control properties of the outer pane of glass reduce some of the unwanted radiated heat gain, especially for westerly orientations. If the toned glass windows have a light transmission of about 60%, it does not lead to an increased need for artificial lighting. The uPVC window frames do not condense on the inside even in the coldest weather, making them ideal for bathrooms. uPVC frames with double-glazing insulate the unit from the elements and the surrounding wall ensuring that minimal heat, cold, vibration and noise is transferred.

Double skin glazed facades

Double skin façade systems consist of two glass skins (single or double) placed in such a way that air can flow in the intermediate cavity. The distance between the skins usually varies from 0.2m up to 2m. For protection and heat extraction reasons solar shading devices are placed inside the cavity. The ventilation of the cavity can be natural, fan supported or mechanical; the origin and destination of the air can also vary depending on the location, the use and HVAC strategy of the building.

The main advantages of double skin façades compared with single skin facades are improved acoustic insulation, protection of shading devices and provision of natural ventilation in the internal spaces. However, energy reduction and provision of an improved indoor thermal environment can also be achieved, when these are designed and integrated properly. Due to the additional skin, a thermal buffer zone is formed which reduces the heat losses and enables passive solar gains. During the heating period, the solar preheated air can be introduced inside the building providing natural ventilation with a good indoor climate retained. Different configurations can result in different ways of using the façade, proving the flexibility of the system and its adaptability to different climates and locations.

There are six basic alternatives in relation to moving the air in the cavity between the two glass skins (see the figure below); external air curtain (1), internal air curtain (2), supply air (3), exhaust air (4), static air buffer (5), through ventilated (6). It is usually possible to change one of the alternatives to another on one façade during the use depending on the external weather conditions.



Six basic alternatives in relation to moving the air in the cavity between the two glass skins
Source: Ref. [13]

One of the glass skins is usually double glazed with noble gas filling and low-emission coating and the other skin is usually single glazing. The position of the glazing is determined by the air flow. If external air flows in the cavity, the internal skin will be double glazed. On the other hand, if internal air flows in the cavity, the external skin will be double glazed. In some cases both skins are double glazed, mainly where high acoustic requirements have to be met.

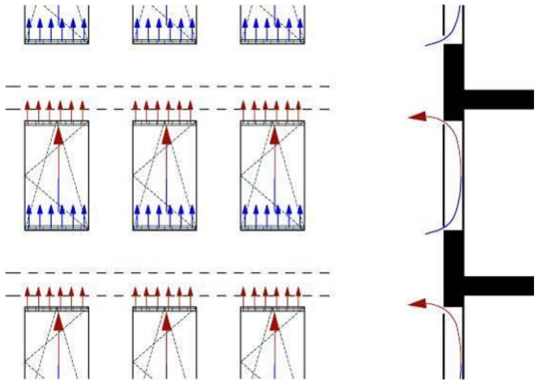
The ventilation of the cavity can be natural (passive) or mechanical (active). In most cases hybrid systems are used where mechanical ventilation helps the air-flow during those periods when passive ventilation is not possible.

In winter the façade should be operated as a closed cavity or an internal air-curtain to increase the solar gain and reduce the heat loss due to transmission. To provide the air-change needed, using the pre-heated air from the cavity can significantly reduce the ventilation heat loss. In addition, the thermal comfort level in the interior next to the glazing will be improved due to the higher internal surface temperature.

In addition to the air movement in the cavity, construction details also determine the operation of the façade. Basically there are two main alternatives: window-type and curtain wall-type installations. The ratio of the openings needed varies in different climates.

Box window façade

The box-window is the oldest form of double façade. It uses isolated cavity volume and outer skin for individual window units. It is mainly used for its higher acoustic performance. It also has some thermal advantages in the winter. Since the cavity height is limited, the risk of summer overheating is high so the ratio of the openings on the external skin should be as large as possible or mechanical ventilation is recommended.



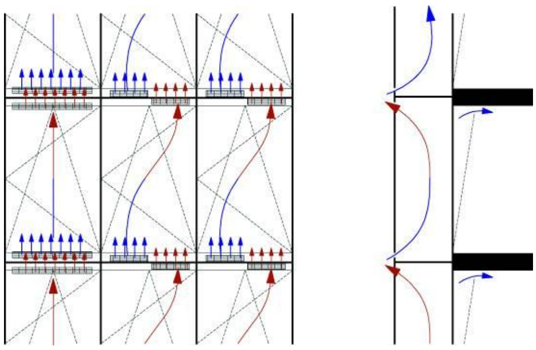
Box window façade

Berlin

Source: Ref. [13]

Connected windows

The cavity behind the external glass sheet is divided horizontally and vertically (at each level and each room). Natural ventilation in the cavity can occur in summer as well. It is a very good solution from acoustic point of view, sound transmittance between rooms is limited. When the ventilation inlet and outlet holes are made, it should be prevented that the fresh and used air are mixed.



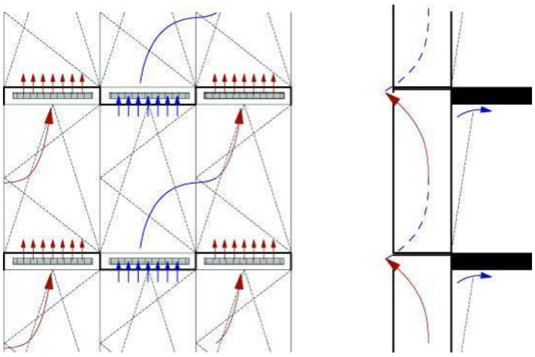
Connected window with straight and diagonal air-flow

Park Kollonaden, Berlin

Source: Ref. [13]

Corridor facade

The air cavity is divided horizontally at each floor level. There is no vertical separation in the cavity, so more intensive natural ventilation can occur using the advantage of the horizontally continuous cavity and wind conditions around the building. However, it is a weaker solution from acoustic point of view.

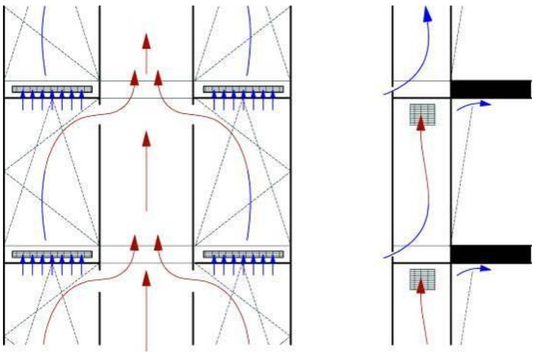


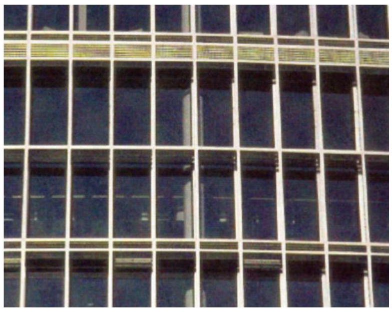
Corridor facade with diagonal air-flow ING headquarter, Amsterdam

Source: Ref. [13]

Connected windows with multi-storey shafts

There are multi-storey vertical shafts between the connected window units in which more intensive natural ventilation can occur even when the whole building is not too high and has not too many floor levels. For higher buildings, the height of the vertically ventilated shaft must be limited due to overheating at the higher floor levels.





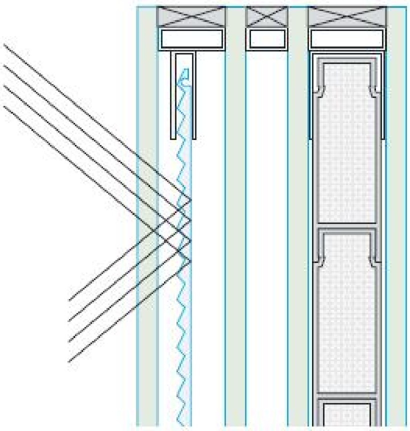
Multi-storey vertical shafts ARAG tower, Düsseldorf

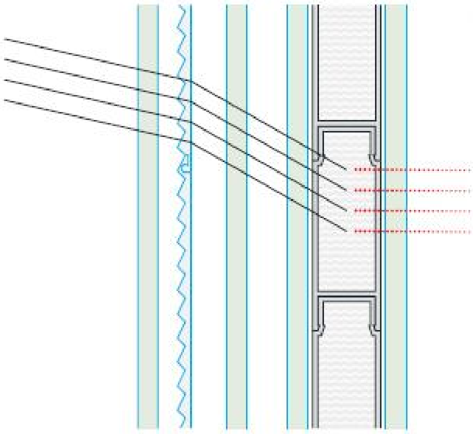
Source: Ref. [13]

Innovative glazing systems

GlassXCrystal glazing (Source: www.glassx.ch)

A recently developed translucent glazing system is capable of storing the solar energy and radiates this energy to the interior when it is necessary. The special advantage of the glazing that it is a combination of transparent insulation, energy conversion, thermal storage and it can also be used as a protection against overheating. Summer solar radiation is reflected by the air prism at the outer layer of the multi-layer insulated glass but the sun can pass through in winter time (see the figure below).





Summer (α > 40°) Winter (α < 35°)

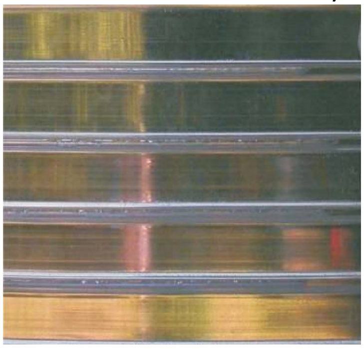
Source: www.glassx.ch

A triple glazing construction can provide excellent thermal insulation with a U-value of less than 0,5 W/m2K.

A prismatic glass implemented in the space between the panes reflects sun rays with an angle of incidence of more than 40° (in summer, when the sun is high in the sky). On the other hand, the winter sun with an angle of incidence of less than 35° passes through the prism so that the solar energy can be utilized.

The other key element of GlassXCrystal glazing is a heat storage module that absorbs and stores the solar energy and, after a while, releases it again as pleasant radiant heat. PCM (Phase Change Material) in the form of a salt hydrate is used as the thermal storage medium. The heat is stored by melting the PCM, and the heat stored is released again when the PCM cools down. The salt hydrate is hermetically sealed in polycarbonate containers that are painted grey to improve the absorption efficiency. On the interior side, the element is sealed by 6 mm safety glass that can be printed with any ceramic silk-screen print.

Transformation of GlassXCrystal glazing:



salt hydrate in liquid state

transformation

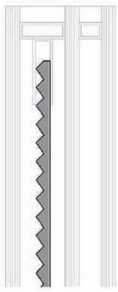
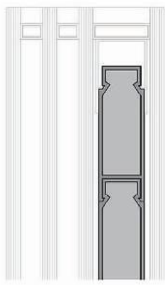
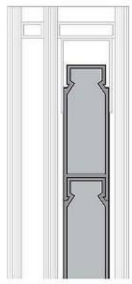
crystal state

Source: www.glassx.ch

The recommended glazing layers (from outside to inside):

- safety glass;
- cavity, noble gas filling, prism;
- safety glass, low-e coating;
- cavity, noble gas filling;
- safety glass, low-e coating;
- phase change material panels between the glass panes;
- safety glass.

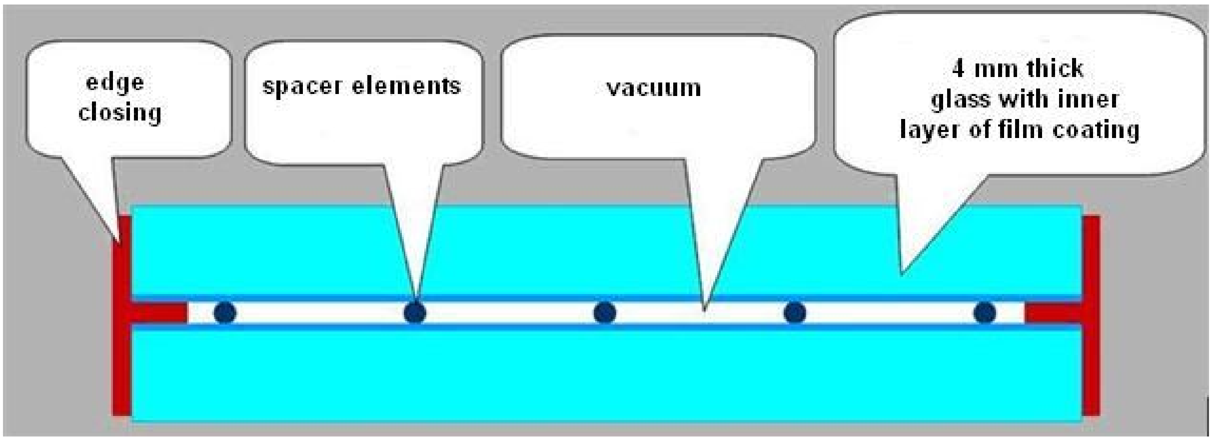
Different variations of the layers results in various thicknesses and U values.

			
GlassX Prism	GlassX Comfort	GlassX Comfort slim	GlassX Comfort „store”
48 mm	70 mm	53,5 mm	38 mm
U = 0,49 W/m^{2}K	U = 0,49 W/m^{2}K	U= 0,91 W/m^{2}K	No data available

Vacuum Insulated Glass

Vacuum glazing, similarly to vacuum insulated panels, is based on the theory that no convective heat transfer occurs in vacuum.
The substance of this method is that the gas filling between the glazing is replaced by vacuum. The production of vacuum glass is quite difficult because a very low (0.001 to 0.0001 mbar) pressure should be achieved to reach the proper insulation ability. Spacer elements are placed to balance the enormous atmospheric pressure without inhibiting the opacity. Vacuum glasses can be recognized by these special items of spacers (1000 pieces/m^2) and they have a very thin structure (only 7-9 mm) and low weight compared to traditional glasses.

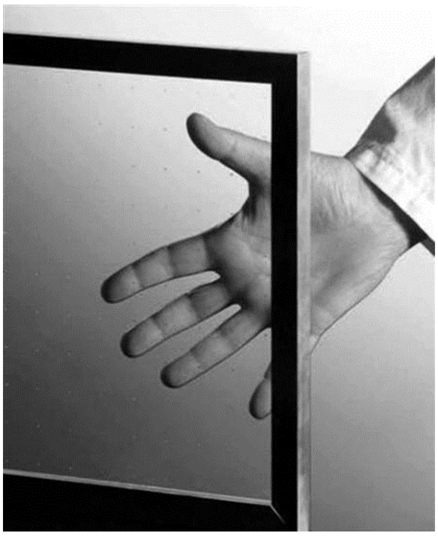
The basic technology is that the air is sucked out from the two 4-6 mm thick glasses. The internal side of both glass sheets are covered by low-e coating and the distance between them is 0,2 – 1,0 mm only.



The scheme of vacuum glazing
Source: Ref. [3]

The weak point of this structure is the glass sheet edge because proper air-tightness must be ensured on long therm. Metal sheets are used to close the edges but this solution creates significant thermal bridges. Promising experiments are currently conducted with plastic form to replace the metal parts.

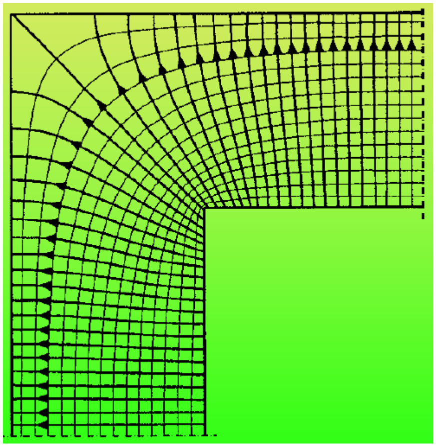
Using this technology a U_g value of 0,2 W/m^2K can be achieved in theory. However, due to manufacturing limits, a U_g value of 0,5 W/m^2K can be achieved in practice for the time being, which is still a very good result.


Vacuum glazing – Source: ZAE Bayern

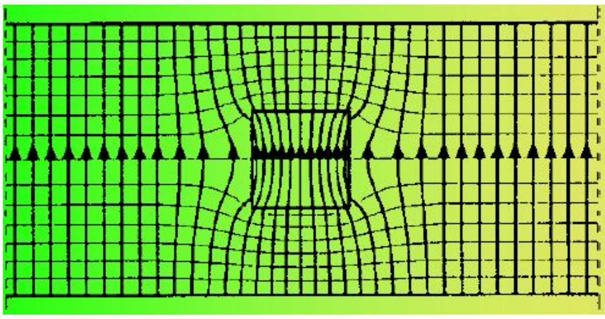
There are several existing variations of vacuum glass panes or under development by market leader glass manufacturers. They will probably be widely available on the market in 1-2 years. However, a new task must also be resolved: new window frames with similarly good performance need to be developed as well.

Thermal bridges

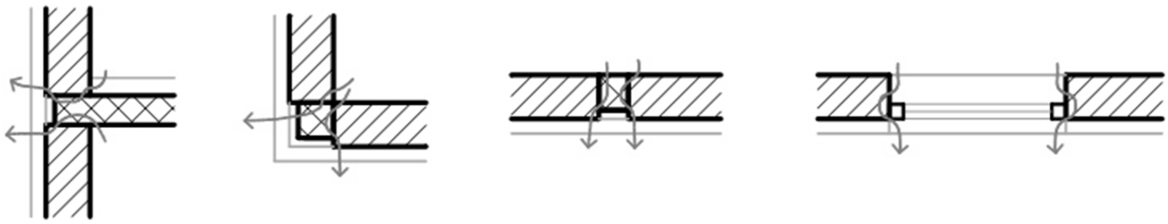
A thermal bridge or cold bridge is a fundamental of heat transfer where a penetration of the insulation layer by a highly conductive or non-insulating material takes place in the separation between the interior (or conditioned space) and exterior environments of a building envelope. The thermal bridge is a multi-dimensional heat flow which is formed at the joint of different materials (e.g. a reinforced concrete column in a clay masonry wall) with different thermal conductivity or caused by the geometry of the building (e.g. wall corners, T-joints, etc.). In many cases these effects are cumulated increasing the negative effect of the thermal bridge (e.g. reinforced concrete balcony cantilever) Moreover some forms of insulation transfer heat more readily when wet, and can therefore also form a thermal bridge in this state. The larger the difference between the temperature inside and outside the building is, the faster the building gains or losses heat.



Thermal bridge due to building geometry



Thermal bridge due to non-insulating material

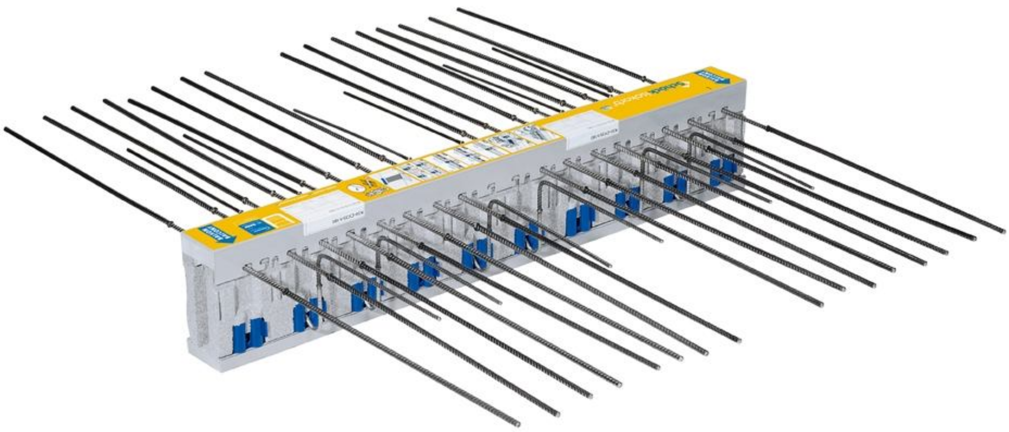


Typical thermal bridges of a column and beam construction

Due to thermal bridges, on the internal side of the external building elements surface condensation can occur, which can cause mould growth. The existence of mould can cause serious health problems for the occupants.

Insulating thermal bridges

For buildings with a lot of thermal insulation reducing the thermal bridges is very important since the heat loss through them can be quite significant.
Insulation around a bridge is of little help in preventing heat loss or gain due to thermal bridging; the bridging has to be eliminated, rebuilt with a reduced cross-section or with materials that have better insulating properties, or with a section of material with low thermal conductivity installed between metal components to retard the passage of heat through a wall or window assembly, called a thermal break. Another solution is to increase the bridge length, or decrease the number of thermal bridges. The heat conduction can be minimized further by the installation of an insulation board over the exterior outside wall, because they cover the most surface area of any building. Currently, the types of insulation that are being used are fibreglass or rock wool insulation, wood fibre board, foam board EPS XPS, insulating glass or polystyrene rigid board insulation, formed in place polyurethane insulation, cellulose/perlite/vermiculite loose fill, and insulated pre-cast concrete insulation.
Each type of insulating material is used most effectively in various parts of buildings including interior walls, exterior envelopes, flooring, roofing, and basements.



Structural element to connect balconies to floor slabs without thermal bridge
Source: www.buildinggreen.com/live/index.cfm/2010/7/15/Schck-Isokorb-for-Controlling-Thermal-Bridging and www.schoek.de

Air-tightness

For the proper use of buildings, depending on their function, the amount of air-change is specified, in order to keep the air in the building fresh, dry and healthy. Air should move around the rooms, and should be slowly exchanged with fresh air from outside. This stops the build up of damp and stale air. There are several different types of controlled ventilation:

- extractor fans – these extract damp air quickly in rooms where lots of moisture is produced (kitchens, bathrooms and utility rooms);
- under-floor grills – these help keep wooden beams dry;
- wall vents – these let small amounts of fresh air into rooms;
- trickle vents – modern windows often have small vents above them to let fresh air trickle in.

Contrarily, draught or air leakage is the uncontrolled movement of air in to and out of a building which is not for the specific and planned purpose of exhausting stale air or bringing in fresh air. Air leakage is measured as the rate of leakage per m^2 of external envelope per hour at an artificial pressure differential through the envelope of 50 Pa, i.e. x $m^3/hr/m^2$ at 50 Pa. In practice 10 $m^3/hr/m^2$ is an acceptable value, however a good performance reaches 5-7 $m^3/h/m^2$ and with best considerations 0,75-3 $m^3/h/m^2$ at 50 Pa could be achieved.

Air leakage is a major cause of energy loss, typically around 20% in older houses, from space heating. In modern houses, where heat loss is less through other means, ventilation counts for a higher proportion - estimated at between 35 - 40%. Older houses tend to be more air-tight than more modern houses - this might be because of the less precise nature of modern workmanship and materials assembly. Draughts occur where there are accidental gaps in the construction of the building, or if doors, windows, keyholes or letterboxes are left open or uncovered.

Draught proofing is one of the cheapest and most efficient ways to save energy in any type of building. Ensuring air-tightness is achieved through careful implementation of strategy throughout the design and construction, an achievable air-tightness performance target have to be defined at the beginning of the design work. The line of the air-tightness barrier has to be designed, which should be simple and buildable. Air testing is carried out when the envelope is complete. If possible, it is wise to test twice - once before the covering-up of the membrane when remedial work can easily be carried out, and again at completion. Testing will identify the overall 'leakage' of the building. Smoke generating sticks can be used to find air leakage points or lines and help in understanding air leakage paths.

Draughts can be found at any accidental gap in the building that leads outside. These are the most common places:

- Around the ends of floor joists or joist hangers, around internal timber joists that penetrate plaster walls;
- Windows, doors: beneath inner window sills and around window frames, through windows and/or hollow window frames, through and around doors – particularly double doors, beneath doors and doorframes;
- Along the top and bottom edges of skirting boards, through gaps behind plasterboard on dabs or hollow studwork walls;
- Between and around sections of suspended floors, usually timber floorboards;
- Around loft hatches, around roof-lights, through the eaves, around and through ceiling roses, behind polystyrene coving along wall to roof joints;
- Cracks or holes through a masonry inner leaf;
- Around and through electrical fittings and equipments on walls and ceilings, around pipework leading outside;

- Through MVHR or warm air heating systems, around and through wall-mounted extract fans and vents, through window spinner vents, around and through closed trickle vents;
- Through key holes and where locks and bolts prevent effective draught proofing, up chimneys, particularly where flue dampers are not fitted, through air bricks and partially closable hit-and-miss vents.

Attention should be paid about draught proofing rooms that need good ventilation, including:

- Areas where there are open fires or open flues – it is essential that areas like this have adequate ventilation.
- Rooms where a lot of moisture is produced, such as the kitchen, bathroom or utility room. Good ventilation helps reduce condensation and damp.

Air barriers must be impermeable to air, continuous, durable and accessible. Internal air barriers need to be airtight, external air barriers need to be wind-tight. Air barriers can be vapour open but require careful specification of adjoining construction and insulation materials. Having made the building airtight, mechanical ventilation is essential.

For windows that open, draught-proofing strips are needed to stick around the window frame. There are 2 main types: self-adhesive foam strips and metal or plastic strips with brushes or wipers attached. Gunned in compatible sealant is suitable for small joints, but where the openings are larger, a pre-compressed flexible expanding foam strip is necessary. Compatible gunned in sealant should be used to seal joints between door / window frames and the surrounding wall externally. Internally, apply sealant to gaps between the wall reveals / window boards and the window / door units. For sash windows brush seals are needed. For windows that do not open silicon sealant can be used.

Basically outside doors are needed to draught proof, however inside doors also need draught proofing if they lead to a room that is not heated normally, like spare room or kitchen. All the gaps should be filled in: the gap at the bottom, around the edges, the keyhole and the letterbox.

If the fireplace is not used, the chimney is probably a big source of unnecessary draughts. Redundant fireplaces should be blocked up. There are two main ways to draught proof a chimney: to fit a cap over the chimney pot or installing a chimney balloon – an inflatable cushion which blocks up the chimney.

Cracks in floorboards and skirting boards can be blocked using filler which is squirted into the gap. These are usually silicon-based fillers: flexible fillers, decorator’s caulk and mastic-type products. Room-conditioned hardboard can be laid over existing square-edged floor boards and the perimeter can be sealed.

Cracks in walls can be filled using cements or hard setting fillers. Loft hatches can be draught proofed by using strip insulation. Small gaps around pipework can be filled with silicon fillers. Larger gaps should be filled with expanding polyurethane foam. Holes around light fittings should also be sealed.

Possibility to use and recommendations

In case of existing buildings putting additional thermal insulation to the external envelope (except slab-on-ground floor) or replacement or retrofitting of existing windows can be executed easily for both single and multi-storey buildings. On the other hand, improving the air-tightness or eliminating thermal bridges could be a problem and in many cases cannot be done entirely.

POSSIBILITY TO USE		new	existing
thermal insulation of the building envelope	external wall	**	**
	roof, flat	**	**
	roof, pitched	**	*
	roof, loft	**	**
	ground floor	**	-
window, glazing		**	**
double skin facade		**	*
air-tightness		**	*
avoid / insulate the thermal bridges		**	*

** high possibility to use
* possibility to use
- not real possibility to use

Increased thermal insulation and air-tightness of opaque and transparent structures are recommended mainly for the northern cold climate to reduce the winter heat loss. Double skin facades are also recommended increasing winter solar heat gain, it is difficult to prevent overheating on hot summer days.

RECOMMENDATIONS		South		North	
		residential	office	residential	office
thermal insulation of the building envelope	external wall	*	*	**	**
	roof, flat	*	*	**	**
	roof, pitched	*	*	**	**
	roof, loft	*	*	**	**
	ground floor	*	*	**	**
window, glazing		**	**	**	**
double skin facade		-	-	*	**
air-tightness		*	*	**	**
avoid / insulate the thermal bridges		*	*	**	**

** highly recommended
* recommended
- not recommended

5.2.2 Passive solar heating systems

Passive solar heating systems utilize the energy of solar radiation without involving any mechanical or electrical devices. However, there are so called hybrid systems as well, where an active device is also used, mainly small ventilators, which help to transfer the heated air. This research study is dealing with completely passive systems only.

The main aim of passive solar heating systems is to reduce the overall energy consumption of buildings by converting as much as possible solar energy into usable heat.

During the design of a passive solar heating system local climate data in relation to the sun path over the whole year needs to be considered. More information on climate data is given in section 3. of this deliverable. Depending on the local climate data, the orientation, the layout, the compactness and the glazed areas of the building should be chosen in such a way that the solar gain is maximised. It is not only the orientation of the glazed surface but its inclination from the horizontal plane has to be taken into consideration as well.

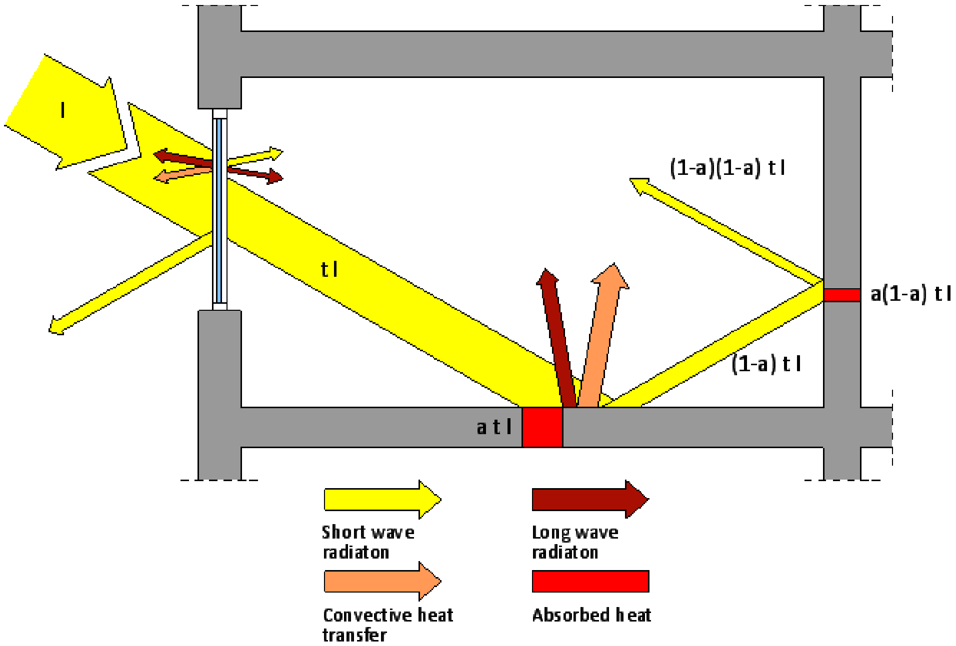
In addition, shading objects around the building, e.g. other buildings, trees, etc., affecting the amount of solar energy have to be taken into consideration as well. On the other hand, it should not be forgotten during the design, that large glazed areas can cause problems in summertime due to overheating. Therefore, proper shading solutions need to be applied and the right balance between solar gain and shading should be found. More information on different shadings is given in section 5.3.3 of this deliverable.

The main features of passive solar systems are:

- transparent glazed areas in the external walls and roofs, preferably on the southern sides, which collect and let the solar energy into the building;
- internal absorbing surfaces, preferably in dark colour to-absorb the solar radiation;
- internal, preferably heavy weight walls and floors with high thermal capacity to store as much as possible heat;
- the distribution of stored heat by natural ventilation and radiation;
- properly insulated and air-tight external envelope including opaque and transparent structures to minimise heat loss through the building fabric (see section 5.2.1 of this deliverable).

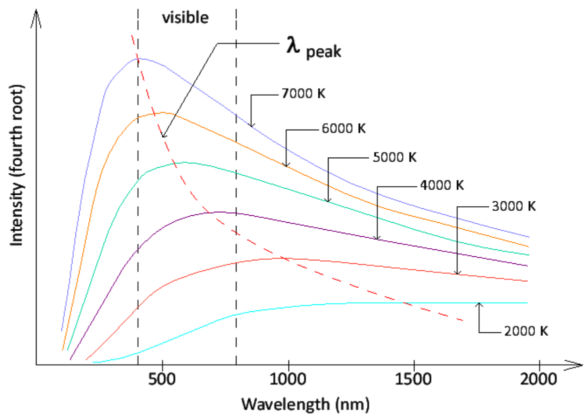
The operation of passive solar heating systems is based on the green-house effect. A transparent structure, such as glazing, lets the solar radiation into the room behind it. Some amount of the radiation entered into the room is absorbed by the floors and walls and some amount is reflected. The reflected part is absorbed again by the internal structures, and after two or three reflections the whole amount of solar radiation is absorbed. Due to the absorbed solar energy, the surface of the floor or wall gets warmer and it induces

- thermal conduction into the structure,
- convection between the surface and the internal air, and
- radiation emitted by the warmer surface depending on its own surface temperature.

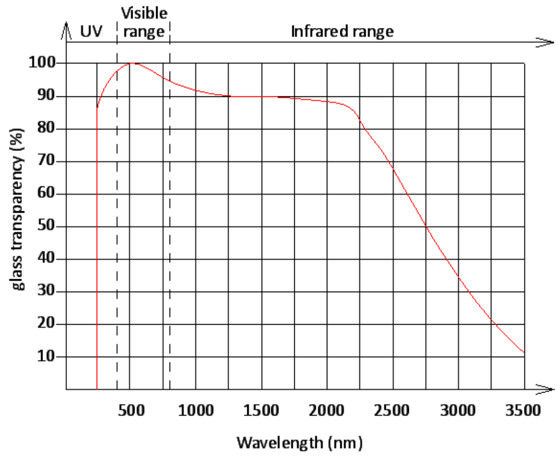


Green house effect – Source: EMI

As far as the thermal conduction is concerned, the larger the heat storage capacity of the internal floor and roof, the more amount of energy can be taken up by them and it takes more time to heat them up. In the same way, it takes more time while they cool down, so they can give off the stored heat during night time.
Due to convection, the temperature of the internal air is increasing until it reaches the temperature of the internal surface. It is a quick procedure and follows the changes of the radiation in a couple of minutes delay, as the mass of the air is negligible compared to the mass of heavy walls and floors.
As far as the radiation emitted by the internal surfaces is concerned, in accordance with Wien's displacement law, it is a long wavelength infrared radiation. The transparency of glazing depends on the wavelength of the radiation and glazing is not transparent to long wavelength radiation. It means that the solar energy entered through the glazing in the form of radiation in the range of visible light and short wavelength infrared cannot leave the room in the form of radiation. This phenomenon is called green-house effect which plays a big a role in passive solar heating systems.

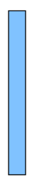
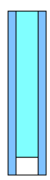
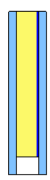
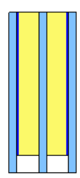


Wien's displacement law



Transparency of glass vs wavelength

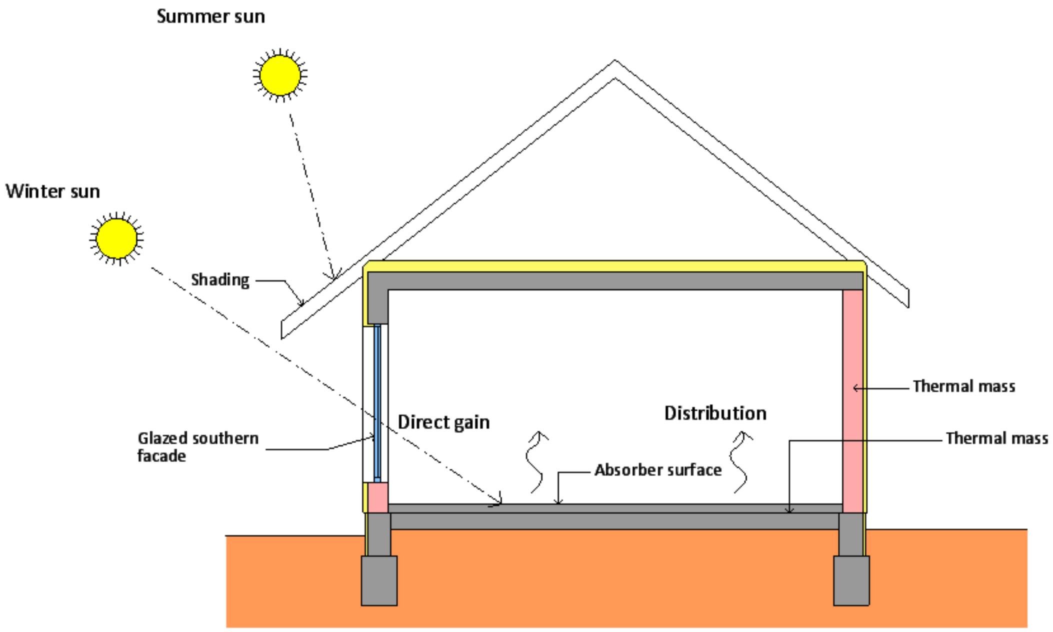
The amount of solar gain also depends on the glazing type. The glazing has a solar transmittance factor (g-value) which indicates the amount of heat gain from sunlight. This factor is expressed as number between 0 and 1. The lower the solar factor is, the less the heat gains. The following table shows some typical g-values for different glazing types. It can be seen that single glazing is the best from the point of view of solar gain but its U_g value is 8-9 times worse than a triple-glazed construction. In the other way round, although a triple glazing has a less 'g' value, it's very low U_g value can compensate this. An adequate balance should be found between the g-value and U_g value of the glazing.

Glazing type	Single	Double (conventional) with air filling	Double with low-e coating and Argon filling	Tripe with low-e coating and Argon filling
				
Typical g-value	0,92	0,80	0,62	0,50
Typical U_g value (W/m^2K)	5,60	2,80	1,20	0,65

Depending on the mechanism, a passive solar heating system can be direct, indirect or isolated. These different types are detailed in the following sections.

Direct systems

The most basic passive solar heating system is a direct system, where the solar energy enters into the rooms of the building through glazed windows and absorbed by the internal structures, which are capable to store the heat and release it during night time.



Scheme of a direct gain system – Source: EMI

There is no special structures applied, it can almost be said that a smartly designed building is equivalent to a good direct system.

Glazed areas should be focused on the southern sunny sides and their surface area should be in line with the heat storage capacity of the internal wall and floor structures behind the glazing. The most important structures are those which are directly hit by the sunlight, which are typically the floors. Walls usually get direct sunlight if skylight windows are used. Undersized thermal mass can cause overheating, however, excessive mass do not cause any problems. The ideal ratio between the glazed surface and thermal mass depends on the local climate.

Heat storage capacity of structures mainly depends on their mass [kg] and their specific heat capacity [J/(kgK)]. The greater the mass or the specific heat capacity of a structure, the more heat they are able to store. The internal structures intended to use for heat storage should not be covered by insulation materials or wall to wall carpets and it is recommended that they have a dark or medium dark colour.

Indirect systems
In an indirect system the structure storing the heat is located between the south-facing glazing and the living space.
The main features of an indirect system are:

- the solar radiation gets through a transparent structure which collects the solar energy,
- the solar energy is absorbed by an opaque structure located behind the glazing,
- the energy stored gets through the opaque structure by thermal conduction and/or,
- the energy is transported to the living space to be heated by free air flow convection.

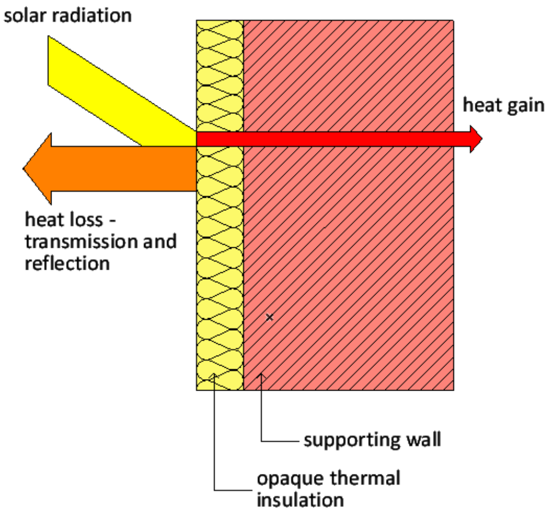
Typical indirect systems are:

- transparent thermal insulation;
- thermal storage walls such as mass wall, water wall and Trombe-wall;
- roof pond systems.

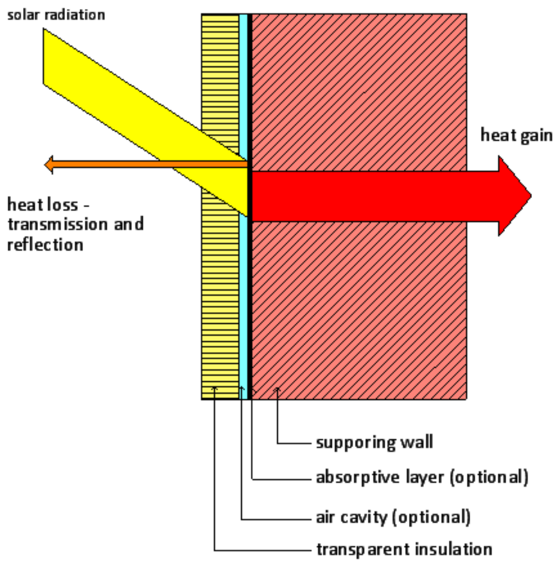
Transparent thermal insulation

Transparent thermal insulation installed on the external side of walls allows the solar radiation to get through the insulation layer so that the solar energy can mostly be absorbed on the external surface of the background wall. This surface is insulated from the external air, therefore the energy absorbed enters into the wall, which has a high heat storage capacity, since the wall has a lower thermal resistance. In summertime this surface can be really hot, so proper shading needs to be provided to avoid any deterioration in the material. The difference between conventional opaque and transparent thermal insulation is that conventional insulation simply reduces the heat loss of the external envelope while transparent insulation also utilises solar gain and uses this solar gain for heating.

Optionally, a thin unventilated air cavity and an absorbing layer can be placed between the transparent insulation and background wall to increase the efficiency.



Conventional (opaque) thermal insulation



Transparent thermal insulation

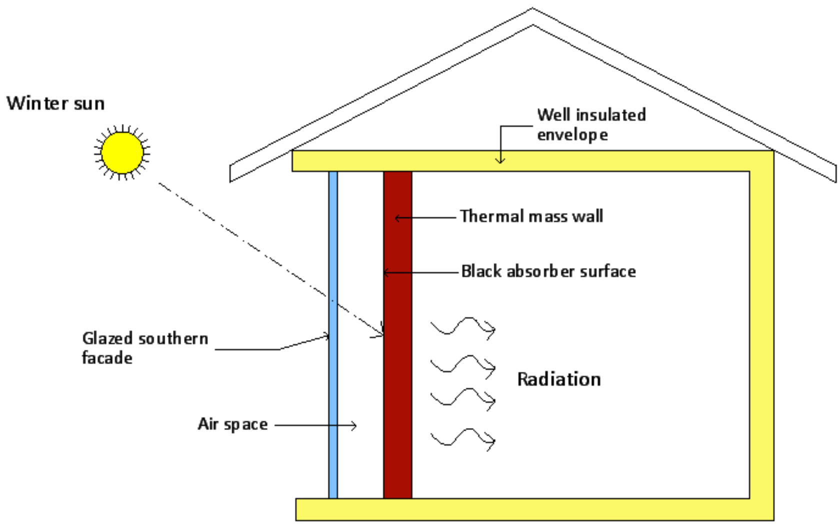
Source: EMI

Transparent insulation
Source: http://umwelt-wand.de

Thermal storage walls

Mass wall

A mass wall consists of a heavy weight wall with a high thermal capacity and a glazing in front of it. The typical distance between the glass and the wall is 3 to 12 cm. A mass wall is based on a "sun to mass to space" concept. Collection and storage are separated from the space, but linked thermally. Energy is transmitted by conduction through the wall, then by radiation to the space. In the mass wall system, storage is usually is in masonry or concrete with a dark external surface to increase the heat absorption and maximise the solar gain. Mass walls should be shaded during summer months.



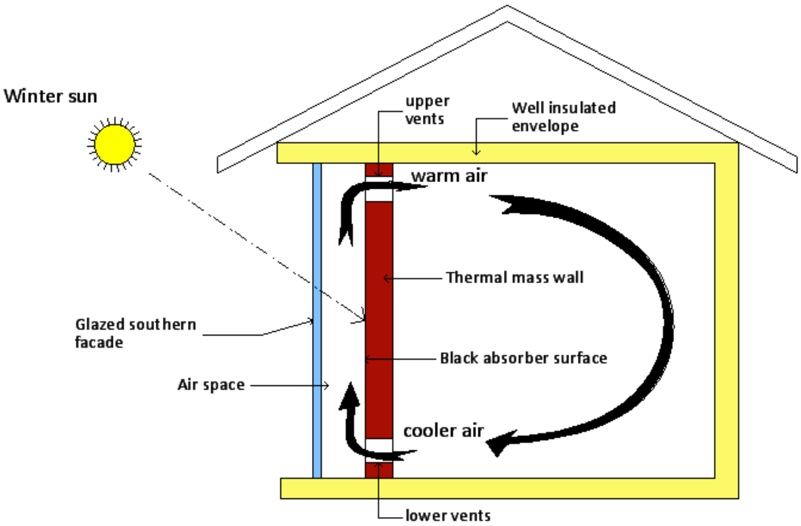
Operation of a mass wall – Source: EMI

In winter, 65% of the total heat loss occurs at night and 35% during the day. This means that 65% of the energy absorbed during the day has to be stored for the night. Heat storage has a great importance, so the energy of the sunlight entering through the large surface of windows is stored by the wall that transmits the heat to the room behind during the night. The delaying effect of the mass wall is a relevant element of the calculations.

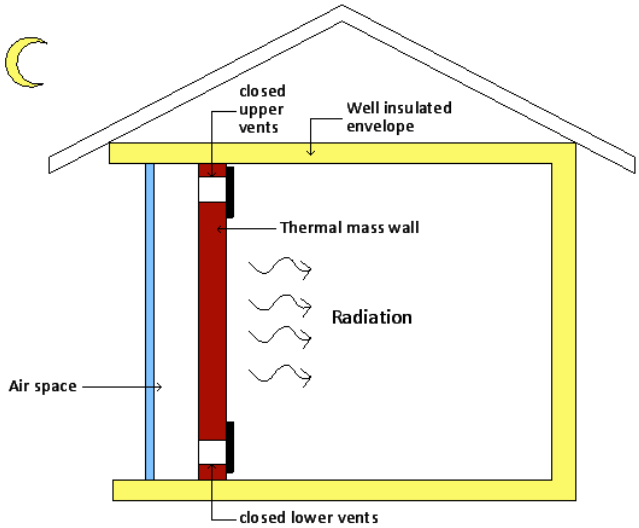
A water wall operates similarly to the mass wall. The difference is that it uses liquid, often held in barrels or tubes directly behind the glazing, as the thermal storage medium. The solar radiation is absorbed by the contained water. This energy is released gradually, as needed, to the interior. Freeze protection should be provided, where required.

Trombe wall
The innovation of the Trombe wall is that it has vents in the upper and the lower part of the wall to allow the air to circulate. It was named after professor Felix Trombe, who with architect J. Michel, studied a thermal storage wall system with holes in 1956 in the first, experimental solar houses in France. The circulation of the air is based on the warm air movement that escapes from the upper vent to the space behind the wall. Simultaneously, cooler air from the lower vents tends to fill the created air gap.
This arrangement assures that a natural air circulation is taking place, when the wall starts to warm up from the sun and continues for a few hours after the sun is set. The time that the air will continue to circulate, after the sun is set, is related to the amount of solar radiation that the wall would receive during the day, the climatic conditions, and the thermal storage capacity of the wall.
The other part of the heat is transferred to the inside by convection and radiation to the cooler surfaces of the other walls, floors and ceiling, for a certain period of time which depends on the material and the thickness of the wall. Typically, the thermal mass of the wall is designed to radiate heat through the inside surface of the wall for 10 to 12 hours after the sun has set.

During the night, a reverse circulation of air occurs, which means that the vents have to be shut to prevent the reverse circulation of air and therefore heat losses.



Operation of a Trombe wall in winter (daytime) – Source: EMI



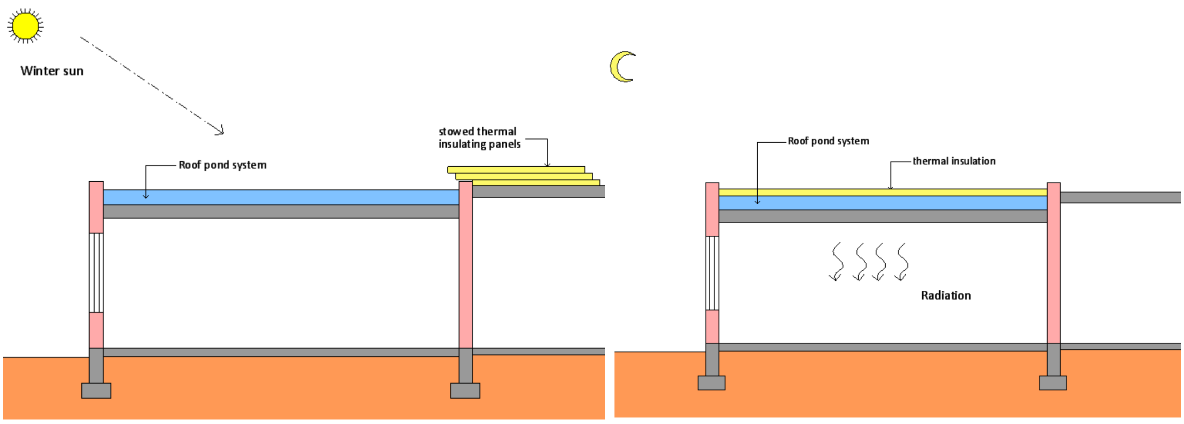
Operation of a Trombe wall in winter (night-time) – Source: EMI

In order to reduce the unnecessary solar gain flow in summer during daytime, the shading device behind the glazing has to be kept in shut position and the windows on top and down have to be kept open also. The heat protection of the trombe wall is more efficient in summer if the surface of the shading looking outside was treated with a reflective finish.
In summer during the night the mass wall performs a cooling potential if it was able to reflect heat from the surface to the environment in the infrared scope. The efficiency can be improved by the windows kept in open position. Usually, the vents towards the room behind are closed. This is detailed in section 5.3.1.

Mass wall
source: www.educate-sustainability.eu

Trombe wall
source: http://www.netspeed.com.au

Roof pond systems
In a roof pond system water is stored above the roof to absorb solar radiation during the day. Typical roof pond systems use a water mass from 100 mm to 250 mm in depth. At night, insulating panels are placed over the storage allowing stored heat to radiate into the interior of the building. The water in a roof pond is typically surrounded by or contained within black surfaces to maximise solar collection. Since the thermal storage is the ceiling of the building, it will radiate uniform low-temperature heat to the entire layout in both sunny and cloudy conditions.
A roof pond system can also be used for radiant cooling with no alteration of its components, simply by changing the operating cycle. This is detailed in section 5.3.1.



Operation of a roof pond system in the winter – Source: EMI

Isolated systems
In isolated systems heat gain occurs away from the building enclosure. Heat moves to or from the living space using a fluid, such as water, or air by natural or forced convection.

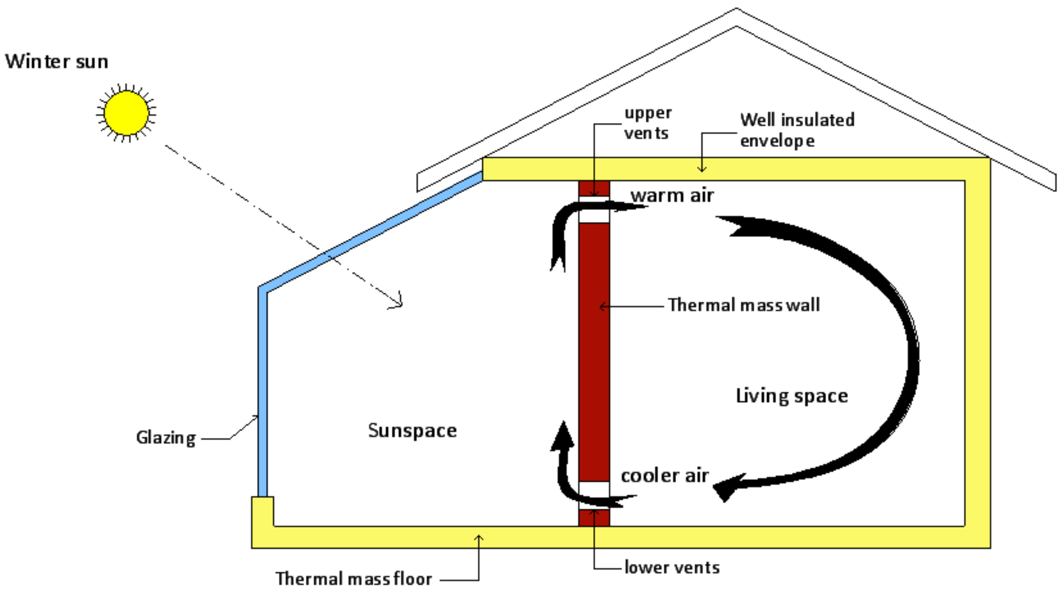
The isolated systems:

- Sunspaces (wintergarden)
- Thermosyphon

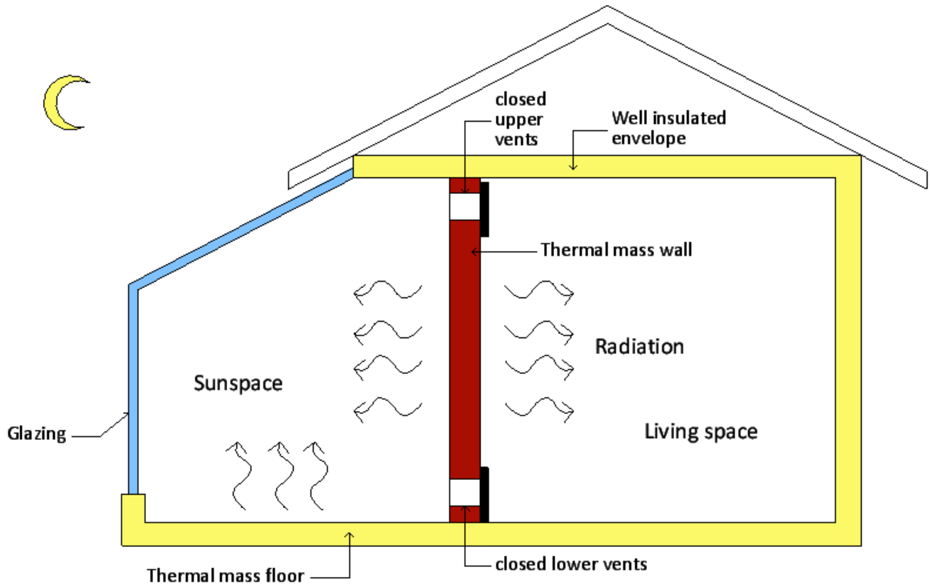
Sunspace

The most common isolated system is a sunspace or conservatory which can be built as part of a new house or as an extension to an existing building and employs a combination of direct gain and indirect gain system features. The simplest sunspace has vertical windows without overhead glazing which can be shaded by a properly sized overhang. The heat is collected by the sunspace area orientated on the southern side of the building and can be moderated by thermal mass structures and low-emissivity windows. The distribution of the heat to the living space is usually accomplished through upper and lower vents, windows, doors by natural convection where the warm air rises in the sunspace and passes into the adjoining space through an opening and cool air from the adjoining space is drawn into the sunspace to be heated. Uninsulated thermal mass walls between the house and the sunspace also transfer some heat into the living space by conduction.

Overhead or sloped glazing can cause more problems as a well-designed shading system needs to be applied to control the solar heat gain during the summer or even during the middle of a mild and sunny winter day. Sloped or overhead glazing is also a maintenance concern; they are exposed to the weather and structural design might also be necessary for larger spans. Overheating can be controlled by operable vents at the top of the sunspace where temperatures are the highest and at the bottom where temperatures are the lowest.



Operation of an indirect sunspace in winter (daytime) – Source: EMI

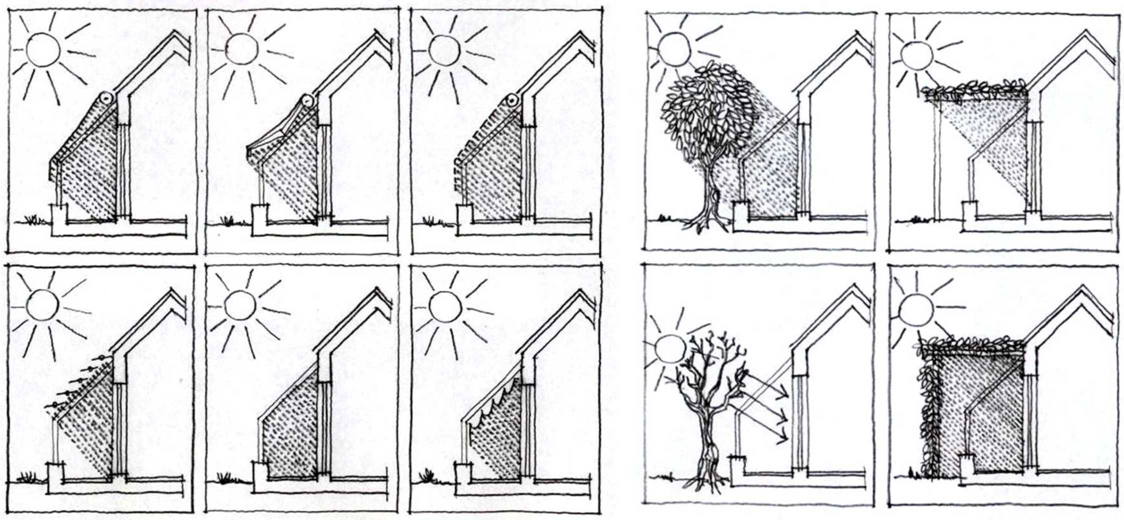


Operation of an indirect sunspace in winter (night-time) – Source: EMI

The significant heat gain becomes a disadvantage if it is very hot outside: the energy of solar radiation entering through the glass surfaces leads to overheating in summer. It has to be prevented by effective shading and ventilation.
The most efficient version is external shading, since it prevents solar radiation from getting to the glass surface. Internal shading is much less efficient but not as expensive as the external is.

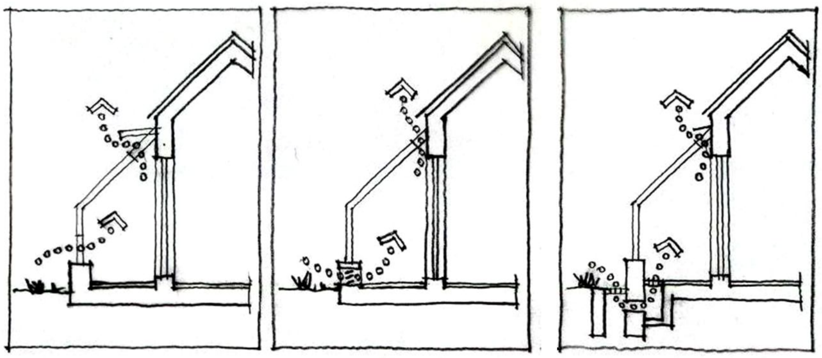
Major types of shading devices for sunspaces:

- External awnings;
- Canopies;
- Lamella shades;
- Adjustable big-lamella shades;
- Sun-protection glass;
- Internal textile shades
- shading by deciduous greenery and trees.



The possible solutions to shade the sunspaces
source: Gábor Becker Dr

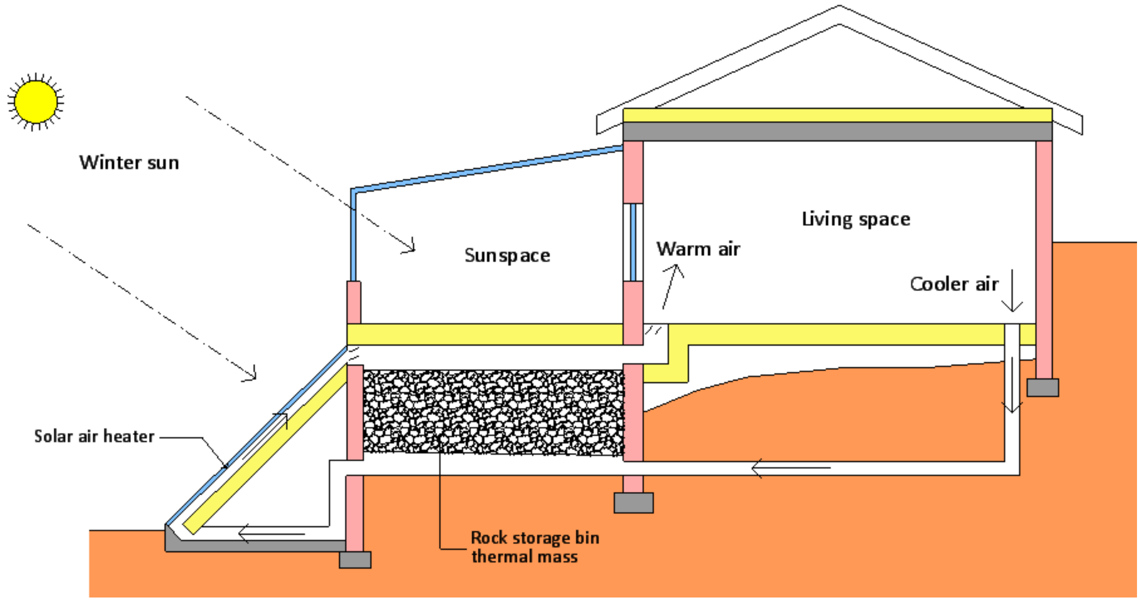
Ventilation will be efficient if air inlet and air outlet is at the lowermost and at the uppermost location, respectively, see figure below.



The ventilation possibilities of sunspaces
source: Gábor Becker Dr

Thermosyphon

Another example of isolated gain systems is a separated thermosyphon air heater and rock bed with the princeiple of this even the lower situated masses of the building can be used for heat storage without the use of an artificial energy source. The scheme of such a system combined with a sunspace is shown in the figure below.



Combination of a thermosyphon system and a sunspace
Source: EMI

The thermosyphon system has a cooling potential in summer as well.

Possibility to use and recommendations

The table below summarises the possibilities of passive solar tools for existing buildings. There are some slight possibilities to increase the solar radiation through the transparent structures by making the openings larger.

POSSIBILITY TO USE		new	existing
direct system (sunshine through the window)		**	*
indirect systems	transparent thermal insulation	**	**
	thermal storage walls (mass wall, trombe wall)	**	*
	roof pond	**	-
isolated systems	sunspace	**	*
	thermosyphon	**	-

** high possibility to use
* possibility to use
\- not real possibility to use

Transferring external walls into mass wall or trombe wall or creating sunspaces is possible only for single-storey buildings. Roof ponds and the thermosyphon system cannot be used for existing buildings.

RECOMMENDATIONS		South		North	
		residential	office	residential	office
direct system (sunshine through the window)		*	*	**	**
indirect systems	transparent thermal insulation	*	*	**	**
	thermal storage wall	*	*	**	**
	roof pond	**	**	*	*
isolated systems	sunspace	-	-	**	**
	thermosyphon air heater	**	**	**	**

** highly recommended
* recommended
- not recommended

This section deals with passive solar heating systems which are recommended mainly for the northern climate since in cold winter more attention should be paid to maximising the solar heat gain. On the other hand, on a hot southern climate it is quite difficult to avoid the overheating of these building structures. Roof ponds and thermosyphon systems are recommended for the southern climate because these tools can also be used for passive cooling of buildings.

5.3 Principles to avoid the summer overheating

Besides maximising the winter heat gain, high attention should be paid to avoid summer heat overload mainly in countries in South and Middle Europe. The basic bioclimatic tools to achieve this are: natural ventilation, shading, passive cooling systems and green surfaces on or adjacent to buildings.

5.3.1 Passive cooling systems

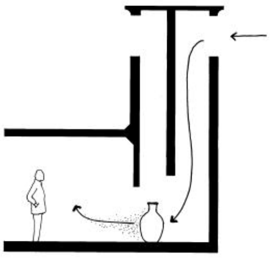
Passive cooling means that the temperature of a room is kept at an acceptable level without using any external energy source [15]. There are also hybrid systems which use external energy source as well for circulation but they are not subject of this guide.

The following below details the different solutions of evaporative, radiant and earth cooling.

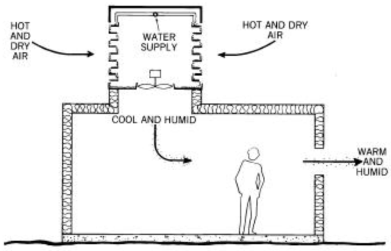
Evaporative cooling
Evaporative cooling is based on the heat drain of evaporating water. When water evaporates, it draws a large amount of heat from its surroundings and converts into latent heat in the form of water vapor. The intensity of evaporation (and the cooling effect) depends on the humidity and the speed of the surrounding air. Thus, evaporative cooling performs best on hot and dry climates with a lot of wind. However, in most cases evaporative cooling itself is not enough, it should be combined with other cooling methods.

Direct evaporative cooling: cooling tower

If the water evaporates in the building or in the fresh air supply, the method is called direct evaporative cooling. In this case the warm air warms up the water, thus a part of the water evaporates in the air, and the heat of evaporation goes (directly) into the air. Therefore the heat content of the air doesn't change but its temperature drops while its moisture increases. Increased humidity often causes a lot of problems, so at this method it is especially true, that it should be only used on hot and dry climates.



scheme of historical use



scheme of modern use

example of modern use

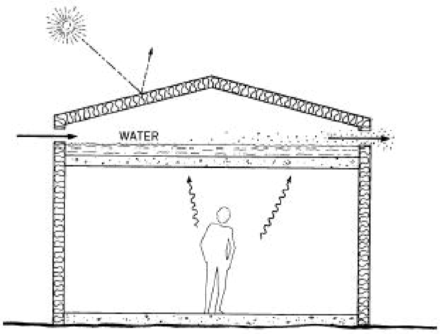
Source: Ref. [16]

The most popular and modern form of direct evaporative cooling is the evaporative cooling towers. Classic examples of it (mostly located in the Arab countries) used wetted clothes, while the modern ones uses wetted evaporative pads.

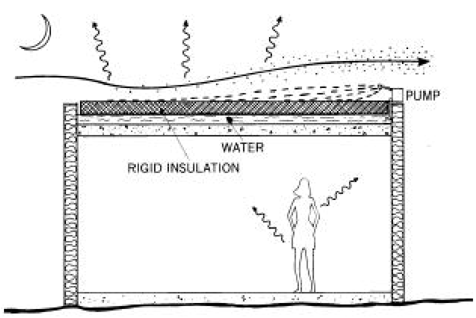
Indirect evaporative cooling: covered roof pond

If the building or indoor air are cooled by evaporation indirectly, without humidifying the indoor air, the method is called indirect evaporative cooling. This could be managed mostly by cooling the roof with the help of a green or water surface. In this case the evaporation draws heat from the roof of the building, which then becomes a heat sink to cool the interior (without increasing its humidity).

A critical aspect of evaporative cooling is that the heat of vaporization must come from what is to be cooled. Therefore, spraying a sunlit roof is not really effective because most of the water will be evaporated by the heat of the sun. Thus using a roof pond for evaporative cooling the water must be protected from the sun so the heat of vaporization comes from the building itself.



roof pond with a second roof



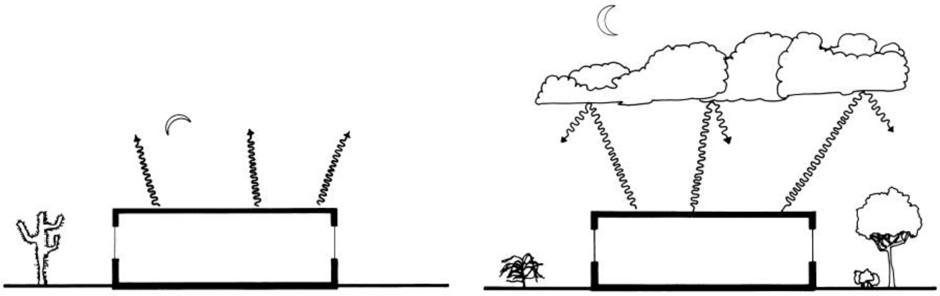
"roof pond with floating insulation"

Source: Ref. [16]

This could be achieved by shading the roof pond with either another (insulated) roof (see the figure on the left) or a "floating insulation" (see the figure on the right). The former solution is simpler but costs more. The latter is a clever alternative, because at night a pump sprays water on the top of the insulation, and it cools by both evaporation and radiation. In the morning the pump stops and the water remains under the insulation, where it is protected from the heat of the day, and can act (together with the roof structure) as a heat sink for the interior. The main disadvantage of both systems is the cost of waterproofing.

Radiant cooling

Radiant cooling is based on the heat emission of the building structures to the night sky. Since the roof has the greatest exposure to the sky, it is the best location for the (generally painted metal) radiator. Since it works during the night, thermal storage mass (e.g. a heavy roof) is required and because of the low cooling effect the whole roof area should be used. In its original way of use it cools only the top story of the building.



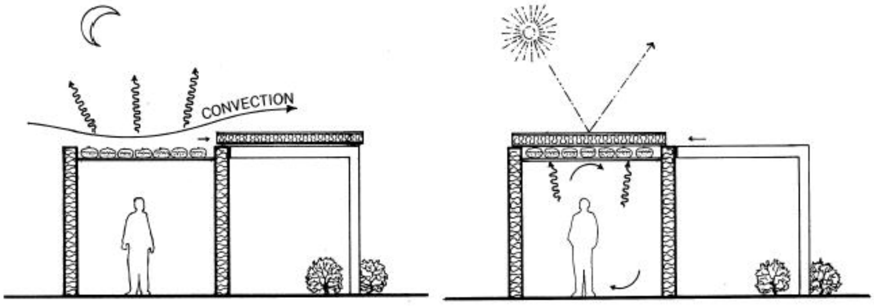
clear sky – strong radiation cloudy sky – weak radiation

Source: Ref. [16]

The intensity of radiation (and the cooling effect) depends on the humidity of the air and the presence of clouds. On humid nights the radiant cooling is less efficient, while clouds almost completely block the radiant cooling effect. Thus, radiant cooling performs best on regions where the summer has great daily temperature changes and the nights are dry and clear skied.

Direct radiant cooling: mechanically closable roof pond

The most efficient approach to radiant cooling is to make the roof itself the radiator. During night the roof (with a huge thermal storage mass) will rapidly lose heat by radiating it to the night sky. The next day the cool mass can effectively cool a building by acting as a heat sink. The roof, however, must then be protected from the heat of the sun and hot air by covering it with insulation in the daytime.



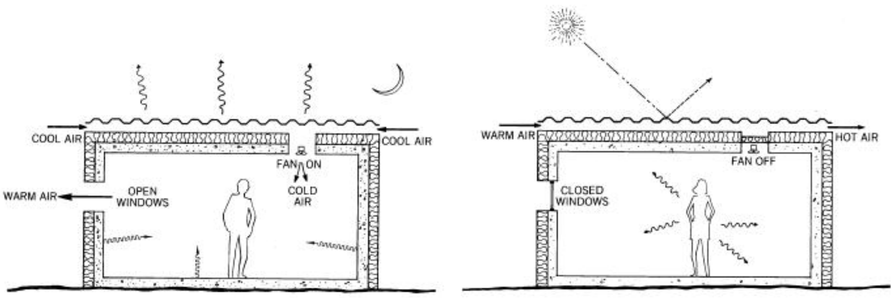
radiating (at night) acting as a heat sink (day)

Source: Ref. [16]

Because of its greater heat-holding capacity, water (as roof pond or filled in plastic bags) is often used for the thermal storage mass, rather than concrete. Great advance of the system is that it can also be used for passive heating during the winter with no alteration of its components, simply by changing the operating cycle.

Indirect radiant cooling: ventilated radiant roof panel

The problematic usage of movable insulation suggests the use of special, static radiators with heat-transfer fluid. This approach is much like active solar heating in reverse.



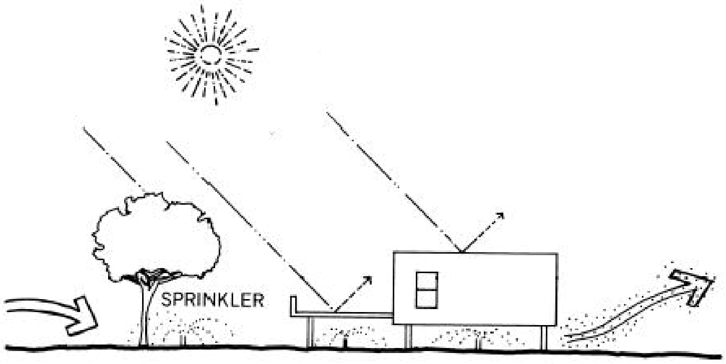
cooling the mass (at night) acting as a heat sink (day)

Source: Ref. [16]

The heat-transfer fluid is mostly air, which is cooled by leading it through the painted metal radiator and then blown into the building to cool the thermal mass inside. During the day the fan is turned off, and the cooled indoor mass acts as a heat sink. Unless the radiator is also used for passive heating (as an air collector), it should be painted white.

Earth cooling

Earth cooling is based on the steady state temperature of the deep soil layers. The temperature of the soil near the surface fluctuates widely according to the season. However, the soil temperature fluctuates less and less as the soil depth increases. Under the frost line the summer/winter fluctuations have almost disappeared and the temperature of the soil can be considered steady all year, which is equal to the average annual air temperature.

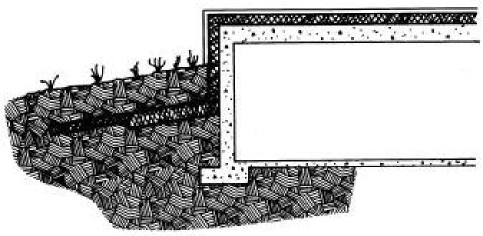


Source: Ref. [16]

The earth can always be used as a heat sink in the summer, but if the temperature difference is not great enough, earth cooling might not be practical. A lot of circumstances can affect the soil temperature, thus, it should always be examined before. The maximum earth temperature can also be reduced on purpose. Significantly reduces it, if the surface is shaded by vegetation, and also helps in addition if it is sprinkled with water (evaporative cooling). Ground water (despite the construction difficulties) can also reduce the earth temperature.

Direct earth cooling: built directly into the ground

The most efficient approach to earth cooling is to plant the building – partially or completely – directly on the ground. This could be managed most easily – particularly in case of one-story buildings – by planting the floor on the ground without insulating it. To avoid the heat loss in the winter, the earth around the building should be insulated from the cold winter air (but not from the building).

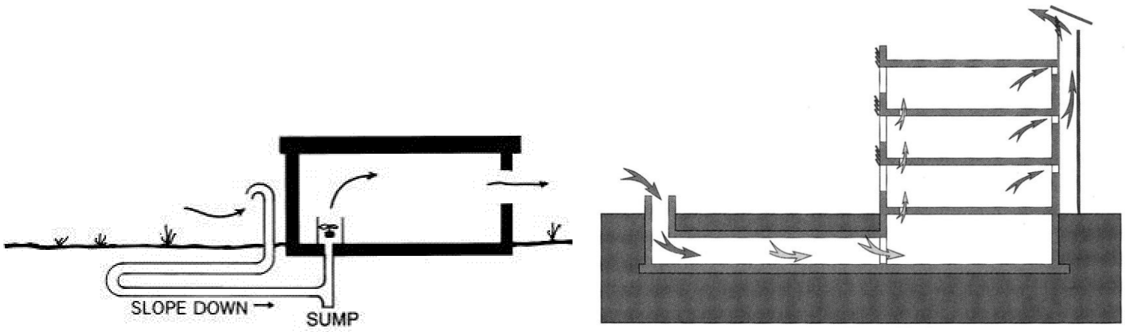


Insulating the earth from the cold winter air
Source: Ref. [16]

Earth-sheltered building can also have their walls in direct contact with the ground. Also in this case the earth around the building should be insulated under the frost line. However, this method can reduce the possibility of natural ventilation, which can be essential in hot and humid climates.

Indirect earth cooling

The cooling effect of the ground can be used indirectly by leading the ventilation air through it.



Indirect earth cooling with earth tubes and ventilation through the cellar
Source: Ref. [16 and 15]

Ventilation duct laid in the ground
This could be done mostly by the means of earth tubes. The tubes should be buried as deeply as possible to take advantage of that constant, deep earth temperature, and must be sloped to collect the water condensed from the air into a sump. In case of long tubes with a small cross-section, a fan should be used to decrease the huge convection resistance of the tube.

The system can be used directly for comfort ventilation or at night to cool the thermal mass of the building. It can also be combined with heat recovery ventilation. It can also be used in winter (with a lower efficiency) to preheat the fresh air supply, lowering thus the heating demand.

Ventilation through the cellar
Besides the soil, a cellar not separated from the ground and built from heavy structures can help in pre-cooling the air provided there is nothing in the cellar which could affect the quality of the air.

Possibility to use and recommendations

For existing single-storey buildings the evaporative cooling tower might be used from the passive cooling tools. It is usually not possible to use tools that change the existing roof structure. The ventilation system can be expanded by an existing cellar cooling down the rooms with cool air coming from the cellar. It is also possible that additional tubes laid into ground help the cooling system of the building.

POSSIBILITY TO USE		new	existing
evaporative cooling	direct (evaporative cooling tower)	**	*
	indirect (covered roof pond)	**	-
radiant cooling	direct (mechanically covered roof pond)	**	-
	indirect (ventilated radiant roof panel)	**	-
earth cooling	direct (direct building into the ground)	**	-
	indirect (ventilaton duct or cooling through a cellar)	**	*

** high possibility to use
* possibility to use
- not real possibility to use

These cooling systems are recommended mainly for buildings in hot climate with both residential and office functions. However, these tools are most efficient for single-storey buildings. Building into the ground in cold northern climate has positive effects in both summer and winter due to the high thermal mass and its heat attenuation effect of the adjacent ground, the air sucked into the ducts is preheated reducing the heat demand. On the other hand, building into the ground can limit the possibility of natural ventilation, which is very important for hot and wet climates.

RECOMMENDATIONS		South		North	
		residential	office	residential	office
evaporative cooling	direct (evaporative cooling tower)	**	**	-	-
	indirect (covered roof pond)	**	**	-	-
radiant cooling	direct (mechanically covered roof pond)	**	**	-	-
	indirect (ventilated radiant roof panel)	**	**	-	-
earth cooling	direct (direct building into the ground)	**	**	*	-
	indirect (ventilaton duct or cooling through a cellar)	**	**	*	-

** highly recommended
* recommended
- not recommended

5.3.2 Natural ventilation

Natural ventilation is the process that exchanges air from the interior of a building to the outside without any mechanical equipment. The air movement is caused by the different pressures due to the temperature differences or to the incidence of wind. The last type is known as wind driven ventilation.

Natural ventilation among with insulation, thermal mass and solar protections, may reduce drastically the necessity of HVAC on buildings. To obtain the benefits from wind driven ventilation the building should be exposed to the predominant winds, its façades should became permeable and the interior distribution of pressures should be studied.

The principles of air movement

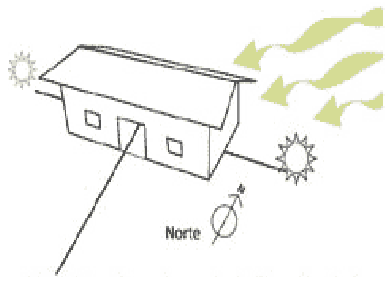
The air movement inside and around the building is determined by several parameters:

- Air movement inside the building is based on the different pressures within the interior areas.
- As the wind impacts the exterior surfaces of the building, both suctions and overpressure effects appear, this causes new air flows from the underpressured to the overpressured areas.
- Whenever the shape of the building may cause deeper disturbance on the wind flow, the greater pressure differences will be.
- Air tends to get into the building from the side where the wind is striking, depending on the characteristics and dimensions of the openings.
- If an area of the building has a single opening to the outside, a neutral zone may be created (coming inside on the upper part and getting out from the lower), this will lead to a scarce air renovation.

To gain the most benefits possible from wind driven ventilation the building and its construction elements must be correctly designed. Openings must face the dominant wind, interior openings between different areas should be planned to allow the air movement inside the building. The disturbance caused by any element in the surrounding should be taken into account. A proper design should take into account:

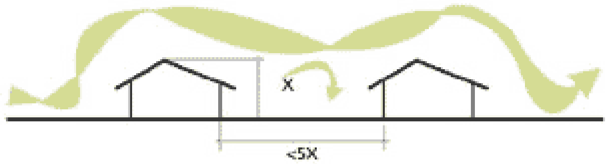
- surrounding, shape and orientation,
- landscape strategies that may change air movements within the surrounding,
- location and size of the windows and openings,
- interior openings between different areas of the building.

Rectangular, permeable, narrow or segregated building shapes, oriented on a certain angle to the dominant wind, and with the shorter sides to the east and west if possible, are the optimal dispositions to gain benefits from wind driven ventilation.



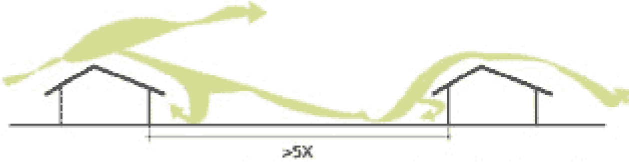
Optimal disposition to a certain dominant wind

Source: Field Guide for Energy Performance, Confort and Value in Hawai Home



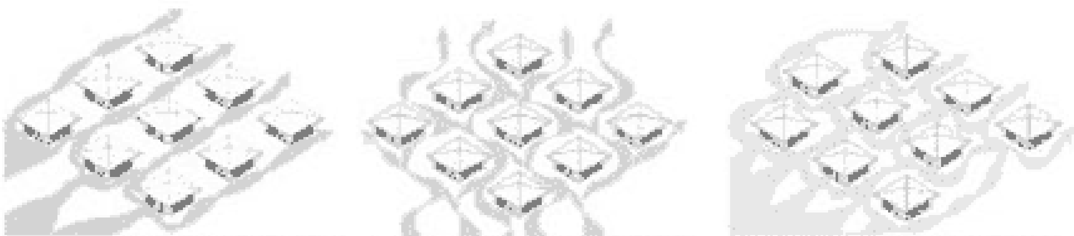
Insufficient distance to allow ventilation
Source: Field Guide for Energy Performance, Confort and Value in Hawai Home

Distance between buildings should be at least 5 times the height of the first exposed building to allow wind flow to the second building.



Optimal distance to allow wind driven ventilation
Source: Field Guide for Energy Performance, Confort and Value in Hawai Home

The air flow around a building creates an overpressured area on its front and an underpressured area on the other side. When buildings are aligned on the wind direction they may create "wind shadows" causing a detriment of their ventilation. If the same buildings are oriented on a certain angle to the wind, ventilation may have a better performance.

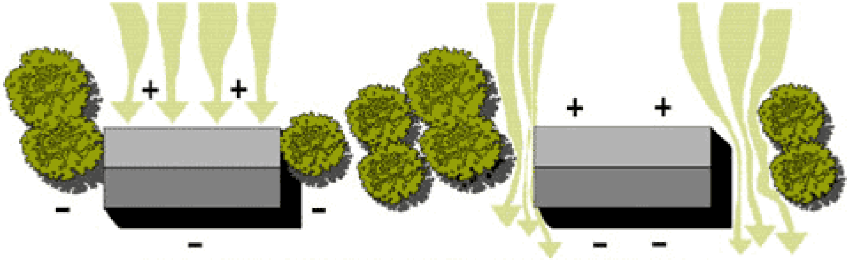


1 2 3

1. "wind shadows" on aligned buildings
2. Better performance on a different orientation
3. Good performance for different wind directions due to a not aligned disposition

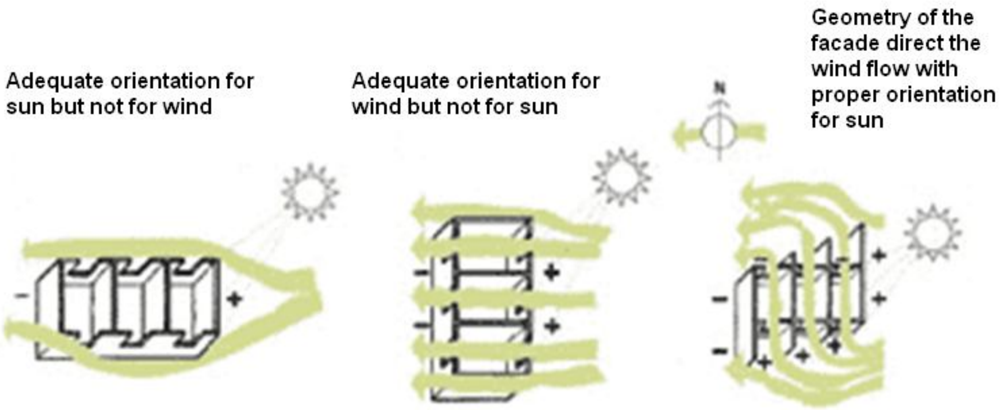
Source: Field Guide for Energy Performance, Confort and Value in Hawai Home

On many occasions the optimal wind orientation is not the best solar orientation. On these cases landscaping may be useful to model the wind performance.



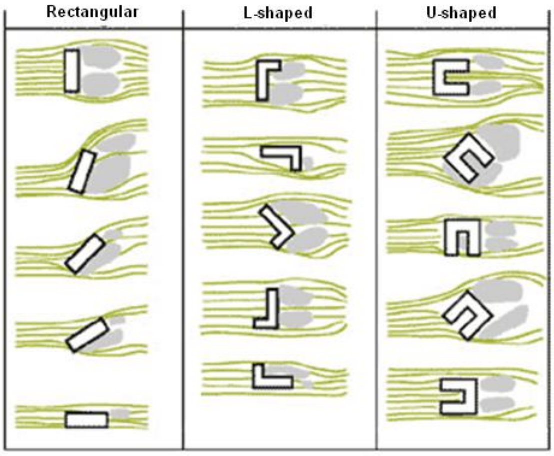
Vegetation can be used to favour natural ventilation
Source: based on Poler, M. (Clima y Arquitectura)

The location of vegetation, the election of the species and the proper maintenance may be useful to gain benefit from wind driven ventilation and solar orientation.
When the optimal wind orientation is controversial with the solar orientation, a specific modelling of the façade surfaces may be used to direct the wind flow. This may be especially useful on certain climatic conditions.



Design to conceal sun and win orientation (from Hawaii and Design)
Source: based on Poler, M. (Clima y Arquitectura)

The building exterior can be modelled to reinforce the difference of pressures and at the same time the building envelope may be design with different permeability to introduce the wind inside.
The stronger the diversion of the wind's path is, the bigger the wind "shadow" caused becomes. The opposition caused to the wind path depends on the high, the angle and the length of the surface opposed to the wind flow.



Wind shadows for different geometries (from Poler, M. Clima y Arquitectura)
Source: based on Poler, M. (Clima y Arquitectura)

A wall erected between two building enclosing oriented against the wind may cause increased pressures. At the end of a façade oriented 45° to the wind direction if a projected wall or volume is designed, pressures may duplicate over the envelope. If the same projected object is placed in the middle of the façade or before an opening, pressures may reduce even a 50%.
The slope and orientation of a roof may be used to diverse the wind path, in order to use wind driven ventilation.

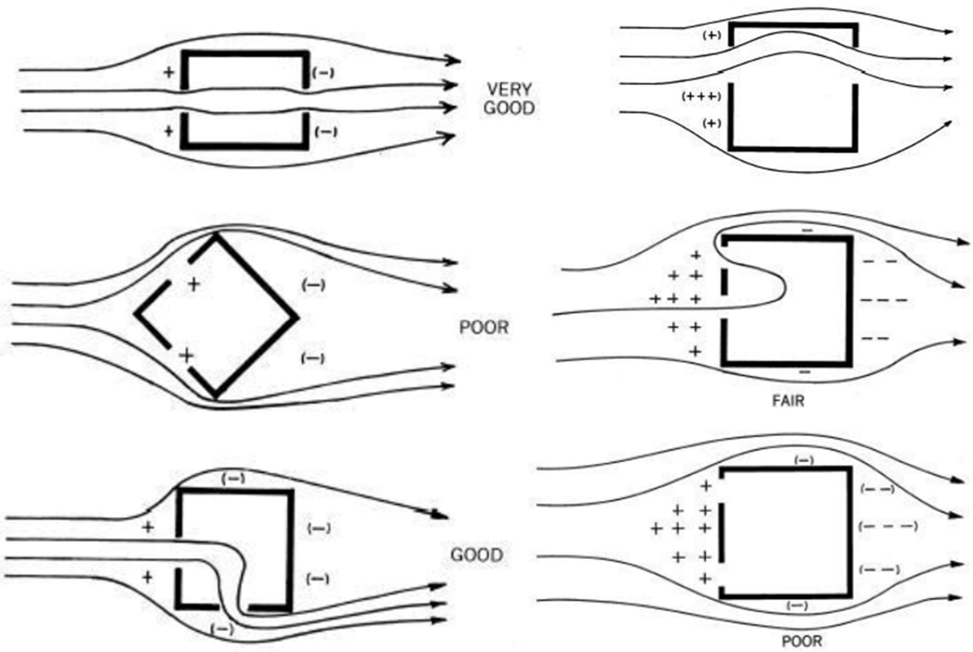
A pitched roof produces bigger pressures on the façade below and bigger subpressures on the other side than a flat roof. This phenomenon increases with bigger slopes on the roof. Pitched roofs perpendicular to the wind direction (offering the gable ends to the wind) may cause smaller underpressures as the wind path soon recovers its way. Smaller slopes cause a little disturbance on the wind path and consequently smaller pressures and subpressures. The disturbance caused by a hip roof is even smaller.

Wind pressure reduces near the ground due to the friction. The use of wind driven ventilation may need the elevation of the building over pilotis to get a bigger exposure to the wind.

Comfort ventilation
In case of comfort ventilation convenient thermal conditions are achieved by moving the air helping the evaporation of the body (i.e. the comfort zone is expanded). There are several methods to induce natural ventilation and most of them can also be used to help other cooling strategies.

Cross ventilation

The simplest direct way of comfort ventilation is cross ventilation. Its effect depends on the pressure distribution around the building, the direction of the air-flow getting through the openings, the sizes, positions and details of the openings and the positions of shadings.

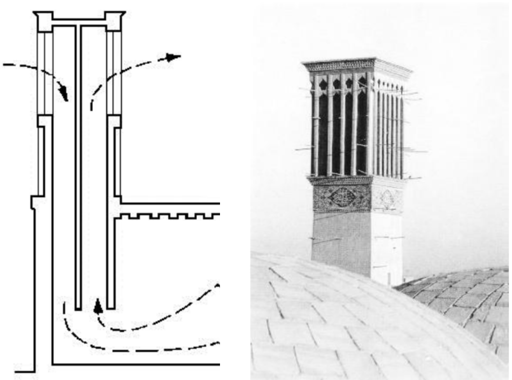


Cross ventilation depending on the position of windows
Source: Ref. [16]

In addition to cross ventilation, other used natural ventilation tools are: wind deflector walls, wind towers, ventilation shafts and solar chimneys.

Wind tower

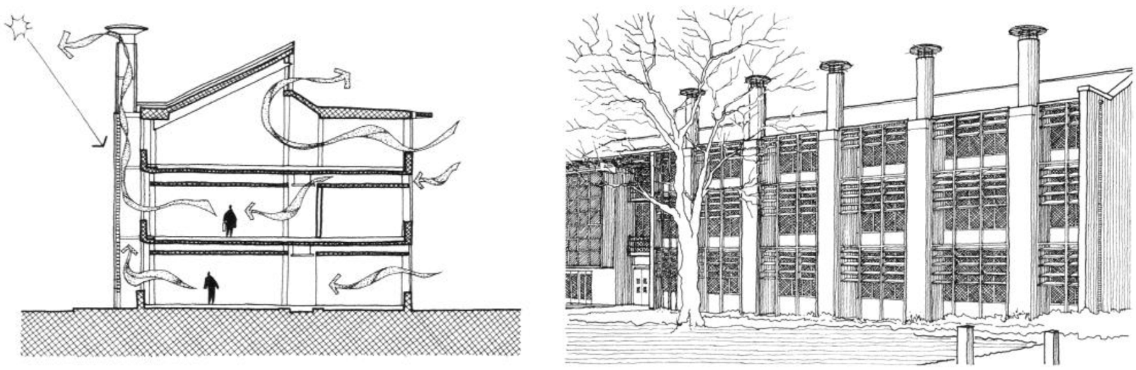
Wind towers look like a chimney shaft and their openings face the dominant wind direction and lead the air-flow into the building. Originally they are used in the Mediterranean and Arab area where the climate is very hot and windy. However, they might also be useful in recently created wind channels of towns.



Example of a wind tower
Source: Ref. [17]

Ventilation shaft
In case of a ventilation shaft the main aim is the shaft effect, i.e. take advantage of the natural upward air-flow. This phenomenon occurs when the temperature difference of an internal space between two vertical openings is higher than the external temperature difference.

Solar chimney
The solar chimney is basically a special ventilation shaft where the natural upward air-flow limited in summer is increased by the effect of the sun.



Solar chimney: BRE Office Building, Garston, UK
Source: Ref. [18]

Possibility to use and recommendations

The ventilation tools mentioned above can also be used partly in existing buildings if there is a possibility to make an extensions to the existing building.

POSSIBILITY TO USE		new	existing
natural ventilation	cross ventilation	**	*
	ventilation tower	**	-
	ventilation shaft	**	**
	solar chimney	**	*

** high possibility to use
* possibility to use
- not real possibility to use

These ventilation methods are highly recommended in the southern climate for all building function.

RECOMMENDATIONS		South		North	
		residential	office	residential	office
natural ventilation	cross ventilation	**	**	**	**
	ventilation tower	**	**	*	*
	ventilation shaft	**	**	*	*
	solar chimney	**	**	*	*

** highly recommended
* recommended
- not recommended

Unfortunately these natural ventilation systems are not sufficient in big towns warmed up by the city thermal island effect. In crowded city centres the lack of cross ventilation and the paved areas make the temperature 4-5°C higher compared to the countryside and the lower temperature during the night cannot give enough freshness either.

In case of a high rise building strategies taking advantages of the big height seem promising. The higher the building, the higher the wind speed and most of the natural ventilation methods can be applied.

5.3.3 Shading against overheating

Sun shading, or the process of controlling the sunlight entering a building through the glazing or hitting the external surface of an opaque structure, can be accomplished through a number of methods. The techniques employed generally depend on the climate and the use of the space. For instance, in climates with a high cooling load, sun entering the space or heating the external envelope can increase cooling energy use, whereas in heating climates, the excess sun may be desirable, but glare and high contrast ratios may make it difficult for occupants to work. In either case, properly designed sun shading can enhance day-lighting while reducing uncomfortable glare and unwanted solar gain.

Shading can be accomplished by exterior or interior shading devices, roof overhangs, landscaping or special glazing. Although each has its benefits, a combination of strategies usually works best, because different strategies may be appropriate for each orientation of the building. Effective sun shading is dependent on an understanding of sun angles and solar geometry as described in section 3.1.

Regarding the special glazing, there are several theoretical options including glazing with constant, changing or changeable characteristics. Absorbent, reflective and coated glazing have constant characteristics. Light transmittance properties of photo and thermo sensitive glass depends on the environmental conditions. For changeable glazing, electricity is used to control and change the characteristics of the glass.

When considering shading strategies, simply copying designs from one project to another should be avoided. Careful attention should be paid to use of the space, location of the building, and orientation. There are two main directions to be considered, the south side and the east and west sides. As a rule of thumb, horizontal shading devices are suited to southern exposures, and where sun is hitting the façade from an east or west direction vertical devices can be used effectively.

General rules for good design include:

- The east and west glazing of the building should be minimised as the east and west elevations are both difficult to shade “architecturally”.
- Projections and/or reveals should be designed for the south façade.
- If no exterior shading devices are to be used, specify windows with low solar heat gain factors should be specified.
- For occupant comfort, light-coloured venetian blinds or light-coloured translucent shades should be provided on all windows in occupied areas.

Shading properties at:

South windows

Easiest to shade, overhangs very effective
Fins may be needed for early morning, late afternoon
Trees typically not much help to the south

East/west windows

Difficult to shade due to low altitude angles
Fins (slanted) more effective or eggcrates
Trees best on the east, west, southeast, and southwest (northern hemisphere)

North windows

Little shading required
Desirable and even diffuse daylight
Fins typically enough, if needed at all

Skylights

possible problems

Potential for leaks is greater

Solar/light gain maximized at wrong time of year (summer)

Can be more difficult to shade

The real orientations of the building may require combination of solutions.

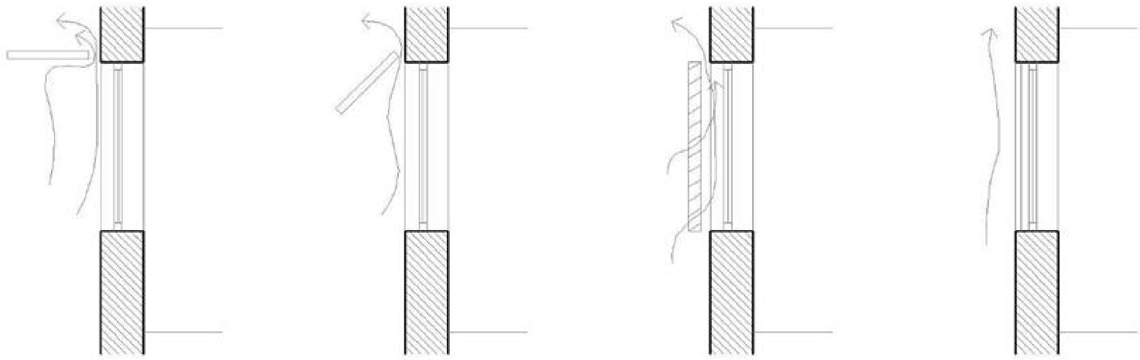
Groups of shading devices:

- Natural or constructed
- Fixed or variable (trees of differing types, movable shades, etc.)
- Opaque or somewhat transparent
- Indoor or outdoor
- Overhang - panels or louvers, can be rotated
- Fins/wings - panel(s), slanted or rotating
- “Eggcrate” - reduced depth combined overhang/fin, slanted or rotating
- Roller shades/awnings
- Trees/vines - free standing, trellis, “attached”

The simplest way of reducing summer heat load is to block the direct sunshine by using fix or movable shading devices. The efficiency of a shading device depends on its position relative to the window; it can be either on the external or internal side or in the cavity of the double glazing. From the point view of heat protection, ventilated external shading devices are more efficient as they absorb a significant part of the radiation in the summer. The efficiency is expressed by the solar heat gain factor, which indicates the amount of heat got through the structure investigated compared to a 3 mm thick normal glass as an etalon. The lower the factor, the better the protection will be.

Exterior Shading Devices

In general, fixed shading devices are less expensive than movable devices. Exterior shading is more effective at reducing unwanted solar gain than interior shades because exterior shades stop the sun from striking the building. Exterior devices can be both fixed and operable or moveable (or removable), each with its own advantages and disadvantages. Fixed devises can work well, but it must be noted that the symmetry of sun angles throughout the year often does not align with the climate or heating and cooling cycles for a building. For example, mid-April and mid-August have similar solar geometries, yet often quite different comfort demands.



0,1 0,1 0,1 0,2

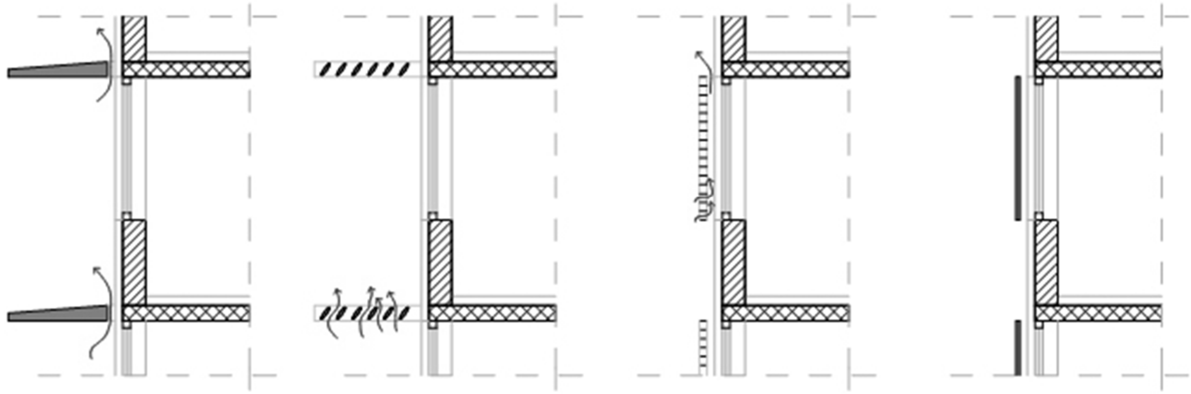
Exterior shading systems with the solar heat gain factors
Source: Gábor Becker Dr

Typical types of exterior shading devices include:

- Solar screens
- Roll-down blinds
- Shutters
- Vertical louvers/fins
- Horizontal louvers/fins
- Canvas awnings (fixed or moveable)

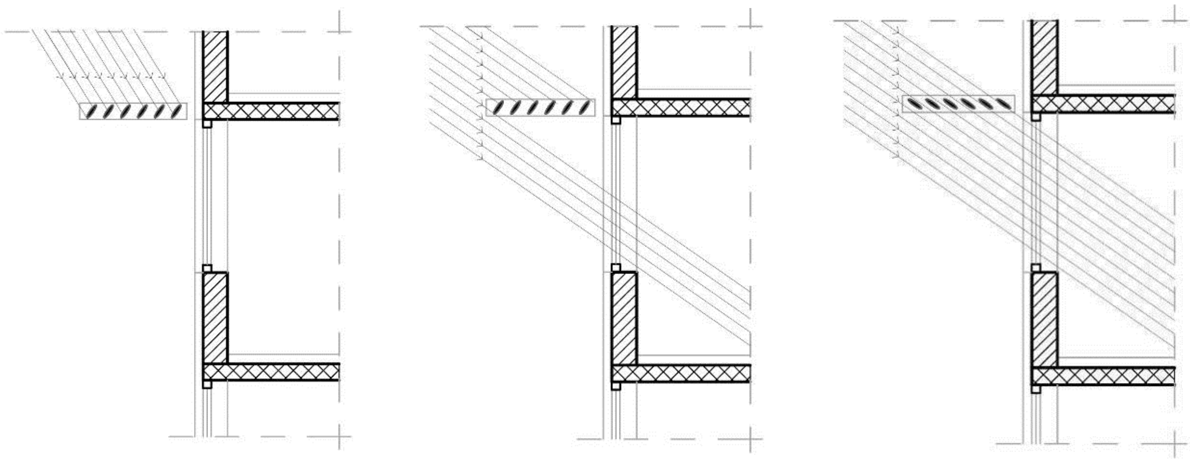
Shading with a horizontal main plane is recommended on the south façade. These devices can be solid or consist of fins or louvers. It is important that ventilation is possible near the shading device so that the heat absorbed by the shading device can be removed from the building.

Horizontal shading options:



Horizontal solid cantilever louver blades fins in vertical plane and solid boards
Source: Sára Horváth

Shading devices with controllable and movable louver blades, compared to fix solid boards, are most suitable for changing sunlight conditions. Louver blades can be rotated electronically by a central building management system so more solar radiation can be entered into the building in the winter to increase passive solar gain.



Solar radiation in summer Solar radiation in winter Light transmission in winter

Source: Sára Horváth

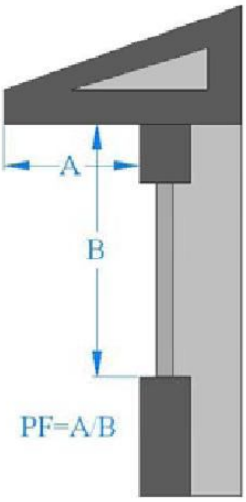
Shading devices with a horizontal main plane can also be placed in a vertical plane on the south elevation, which are movable in most cases. By changing the size of the louver blades, and their number and distance from the facade, proper shading can be achieved without inhibiting the outlook from the building.

Textile shading and fix horizontal louvers

Roof Overhangs

Because overhangs are part of the building shell, they tend to be less expensive and more reliable forms of shading than those techniques that require occupant participation, such as shades and movable awnings. Overhangs must be carefully designed so that they do not block the sun in winter in heating climates if the sun is being counted on to provide heat.

When considering using roof overhangs for sun shading, they should be specifically designed for each orientation and for the critical month and time when temperatures are higher and the sun is lower in the sky. For instance, roof overhangs on the south façade can be designed to provide 100 percent of the shading at noon on June 21st or on August 1st when the days are hotter.
Using roof overhangs to provide sufficient shading on east and west façades can result in an overhang that is undesirably large. In this case, a porch could be considered. This would provide the overhang depth necessary while providing a pleasing architectural component, along with usable outdoor space for the occupants.



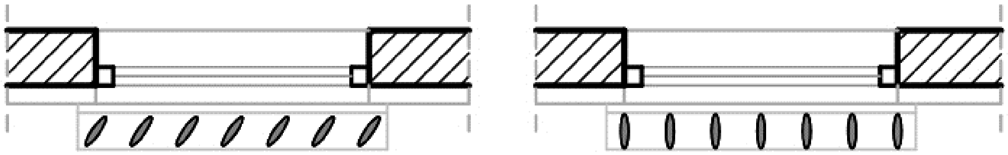
The projection factor (PF) is the overhang projection (A) divided by the distance (B) between the bottom of the window and the bottom of the overhang.

Shading devices can also be used for energy production if their surfaces are covered with solar cells, or vacuum tube solar collectors can directly be used as shading.

Solar cells on horizontal fins
Source: Sára Horvath

Solar collectors as a canopy
Source: Sára Horvath

On the east and west elevation shadings with a vertical main plane and with vertical louver blades are the most efficient devices. The blades can be rotated electronically around their vertical axis by the central building management system.

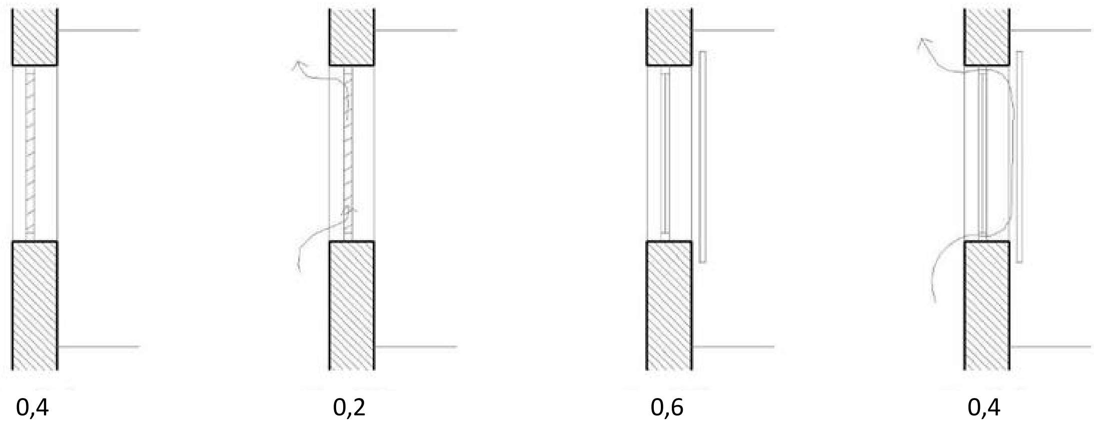


Shading in the vertical plane with vertical fins
Source: Sára Horváth

The vertical and horizontal components can also be combined, for example they are integrated into a complex grid.

Interior Shading Devices
With the exception of awnings, most devices used on the exterior of the building can be used on the interior. They tend to be less effective at reducing the cooling load because they allow the sun to enter the building, trapping the heat between the window and the shading device. The benefits are that such interior devices are low cost and easy to operate.

Also, interior shading can be especially effective if designed to provide both sun control and insulation during the day in the cooling season and at night in the heating season.

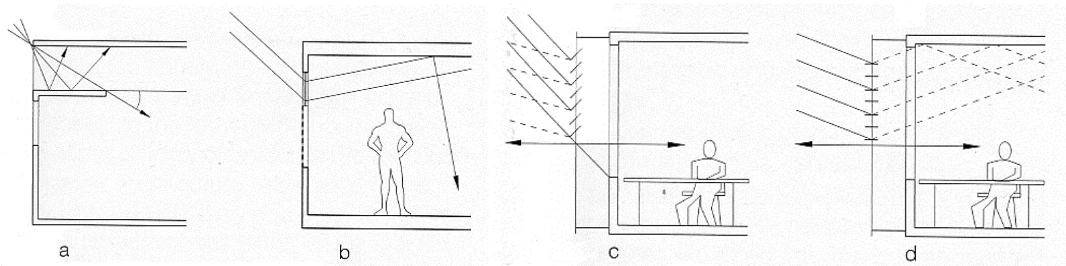


Shading in the cavity of double glazing and internal shadings with the solar heat gain factors
Source: Gábor Becker Dr

Light diverting structures
For offices, it is an essential requirement to keep away the direct sunshine, admit natural daylight and provide a proper outlook at the same time. Too much shading can result in dark places in the building which increases the electricity demand as the occupants switch the light on.

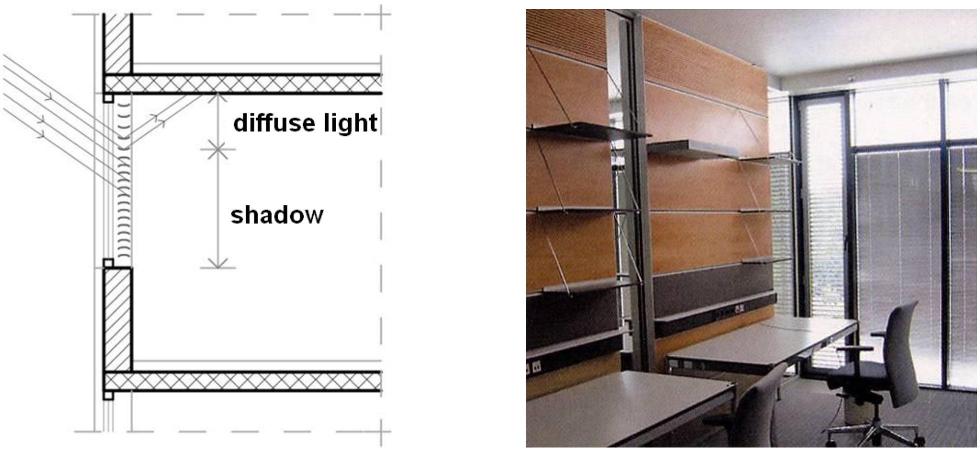
To fulfil all of these requirements, using light diverting structure could be a solution. This structure can be

- a light diverting ledge (a)
- a holographic optical unit (b)
- rotating fins (c and d).



Light diverting alternatives
Source: Ref. [3]

At the top one-third or one-fourth part of the shading the movable fins reflect the light to the white ceiling providing diffuse lighting in the whole office area, whereas sunlight cannot get through at the bottom part of the shading.



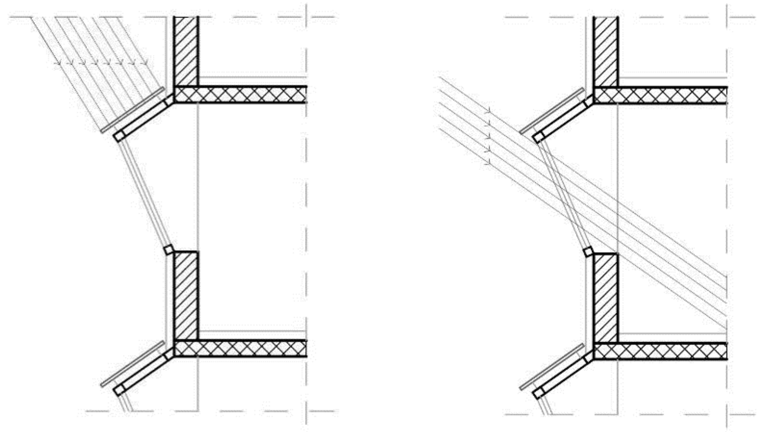
Operation of internal light diverting shading
Source: Ref. [3]

Slanted glazing on the facade

The main advantage of slanted glazing, with a typical angle of 35° from vertical, that direct sunlight can be blocked in summer time when the sun is at high in the sky, whereas sunlight can enter into the building in winter time when the angle of sunshine is low.

On the top of the slanted glazing solar cells can be installed where they can work more efficiently compared to a vertical installation.

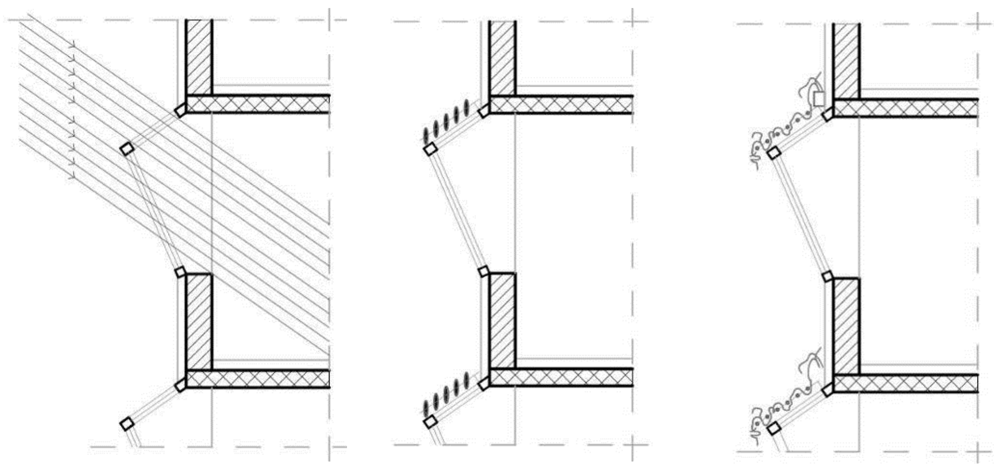
The adequate angle depends on the geographical location and should be determined from the sun path diagrams. One disadvantage of this solution is that the increased cooling surface can cause additional heat loss.



Sunlight in summer Sunlight in winter

Source: Ref. [3]

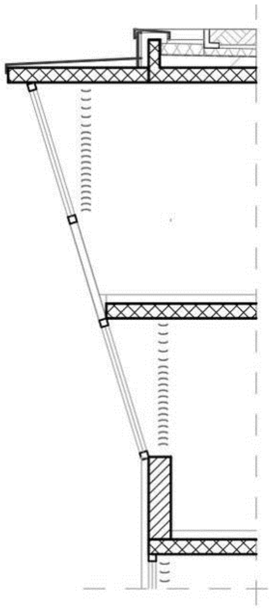
The system can be improved by using glazing at the upper part which is covered by a shading device.
It is recommended using electronically rotatable fins or deciduous vegetation so that the shading effect does not work in winter months.



Without shading With louver blades shading With vegetation shading

Source: Ref. [3]

The same shading effect can be achieved on the elevation if larger slanted curtain walls are used. In this way even the floor area of the building can be increased.



Slanted glass façade
Source: Ref. [3]

Possibility to use and recommendations

Post-installation of shading devices is usually possible. However, some hidden types of shading devices cannot be installed afterwards (e.g. built-in window blinds). Internal blinds can be placed easily, however their ventilation can cause problems which cannot be solved without replacing the windows. Slanted façade glazing or double skin glass façade can be applied for new buildings only.

POSSIBILITY TO USE		new	existing
exterior shading devices	solar screens	**	**
	roll-down blinds	**	**
	shutters	**	**
	vertical louvers/fins	**	**
	horizontal louvers/fins	**	**
	canvas awnings (fixed or moveable)	**	**
interior shading devices	between glazing, with ventilation	**	*
	between glazing, without ventilation	**	*
	behind glazing, with ventilation	**	*
	behind glazing, without ventilation	**	**
slanted glazing on the facade		**	-

** high possibility to use
* possibility to use
- not real possibility to use

During the design of shading devices it is highly recommended using external, more efficient tools for hot, southern climates. For shading devices with lamellas the direction of the lamellas (vertical or horizontal) depends on the orientation of the window (see more above). In case of high rise buildings external shading devices in front of the windows get quite big wind loads, which should be considered when the type of the device is chosen.
The slanted glazing, due to aesthetic reasons, is recommended mainly for office or commercial buildings.

RECOMMENDATIONS		South		North	
		residential	office	residential	office
exterior shading devices	solar screens	**	**	*	*
	roll-down blinds	**	**	*	*
	shutters	**	**	*	*
	vertical louvers/fins	**	**	*	*
	horizontal louvers/fins	**	**	*	*
	canvas awnings (fixed or moveable)	**	**	*	*
interior shading devices	between glazing, with ventilation	*	*	*	*
	between glazing, without ventilation	*	*	*	*
	behind glazing, with ventilation	*	*	*	*
	behind glazing, without ventilation	-	-	*	*
slanted glazing on the facade		*	**	-	-

** highly recommended
* recommended
- not recommended

For office buildings light-diverting internal blinds mentioned above are recommended to provide enough light needed for the work.

5.3.4 Vegetation, water surfaces

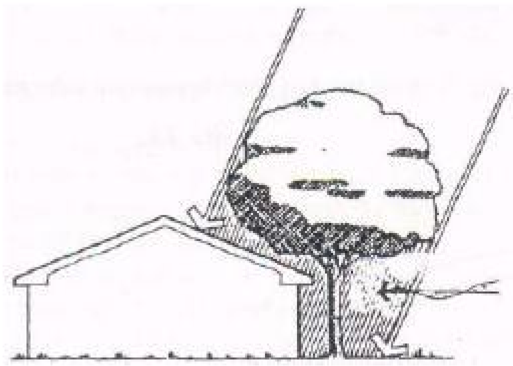
Vegetation and water surfaces have a positive effect in many ways on the building interior and the microclimate of the adjacent surroundings. This positive effect is caused by the shading of vegetation and the evaporation of letters and roots. Shading by a tree is always better than an artificial shading device since the letters of a tree follows the sun and the tree does not warm up and radiate heat downwards. A significant amount of the sun energy is transferred into latent heat by the evaporation of the letters of the tree.

Vegetation around the building

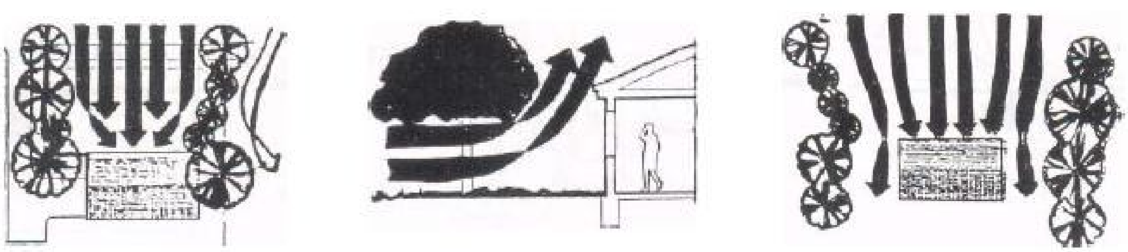
The local natural environment can significantly affect the performance of the building. The vegetation, which changes with the season and the daytime, can help to improve the comfort of the users of the building. Without vegetation, a site loses its natural capacity for stormwater management, filtration, and groundwater recharge. Reduced vegetative cover also affects soil health, because vegetation maintains soil structure, contributes to soil organic matter, and prevents erosion. Through evaporation, transpiration, and the uptake and storage of carbon, trees and other vegetation moderate the climate of the world and provide a breathable atmosphere.

To reduce urban heat island effects, trees, green roofs, or vegetated structures (e.g., trellises) to cover non-vegetated surfaces such as walkways, roofs, or parking lots should be used, and vegetation-based methods should be selected to achieve stormwater management goals for the site.

Trees and bushes can naturally provide shading for the building. This can be an advantage in hot summers, however in winter this effect is lowered, letting in the sunshine and decreasing the energy need for heating and lighting. The latter effect is even better in case of snow cover due to its higher light reflection. As mostly the vegetation - especially in summer - lets through scattered light, it can be applied to moderate direct light, which can cause unnecessarily bright indoor enlightment.



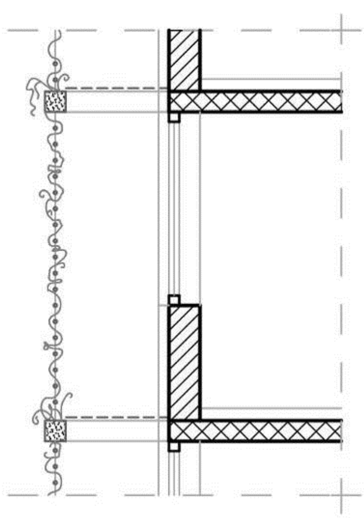
Also trees and bushes can be arranged in a way around the building that leads to an improved natural ventilation due to directed wind.

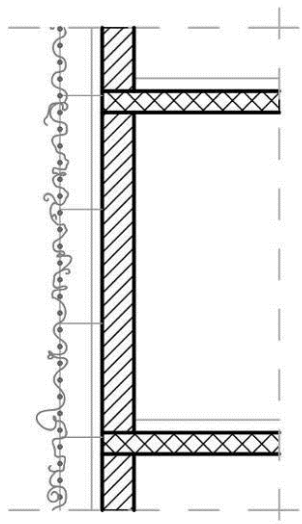


A natural or artificial lake or pond near the building moderates the surrounding region's temperature and climate, because water has a very high specific heat capacity (4,186 $J \cdot kg^{-1} \cdot K^{-1}$). In summer it lowers the temperature surrounding it by 1-2 °C partly due to the evaporation of the large water surface and the heat storage effect. However in winter the evaporation is decreased and the stored thermal energy of warmer seasons provides a slight heating effect for the environment, which depends mainly on the mass of water. In the daytime or warm weather a lake can cool the land beside it with local winds, resulting in a sea breeze; in the night or cold weather it can warm it with a land breeze. Also large water surfaces have a special mirror effect for photons, providing reflected direct and scattered light for the surrounding objects. Furthermore this also means an additional heat energy by thermal radiation in daylight conditions, which have to be considered during the design of the building.

Green facades

The advantage of the deciduous green facades is that they provide proper shading in summer, while in autumn and winter they let through the necessary light and heat of the sun. In summer the vegetation decreases the temperature of the local environment by 1-2°C due to their evaporation, and it also improves the quality of the air by the oxygen emission. The leafage also acts as a dust filter, protects the facade from the effects of the weather and also the painting of graffities. The disadvantage of the green facade is the significant requirement of maintenance, and the proliferating of insects. The beneficial effects can be improved, if a ’corridor’ is formed between the vegetation and the facade.

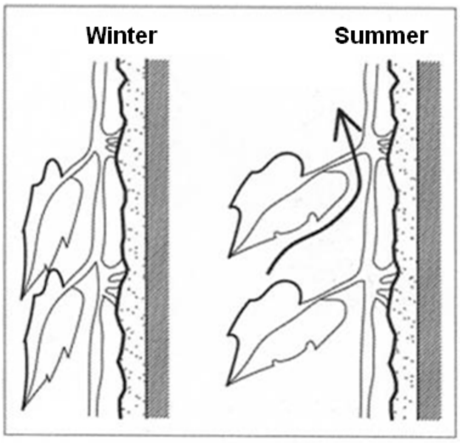




Ventilated double skin green façade   Vegetation on a frame in front of the building

Source: Ref. [3]

The plants can be different in various climates, e.g. in Hungary these can be ivy, spindle-berry, virginia creeper, rose, blackberry, wisteria, trumpet tree etc. On the northern side it is advised to grow evergreen plants due to their lower need of light, while on the southern side rather deciduous plants are recommended.



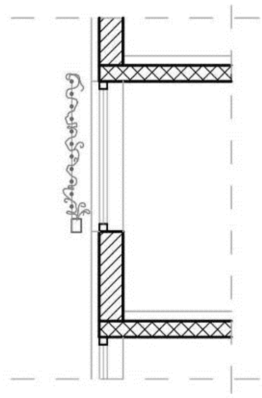
The role of the vegetation in winter and summer
Source: Ref. [14]

The plants can run either directly on the external or on a supporting frame. The supporting frame can be a timber grid appr. 10-20 cm in front of the façade, a tensioned wire from the ground level to the eave, steel mesh on spacers, or wattle, etc.

Source: Ref. [3]

Green facades
Source: http://sustainablecitiescollective.com/ and http://www.plataformaarquitectura.cl/

The leaves of deciduous plants fall in autumn so the background and the branches of the plants become visible. Some people might not like it, however this disadvantage can be reduced significantly by using a characteristic and aesthetic background structure.
In case of green facades starting from the ground level, the maintenance can be done easily by the building operator from outside. In case of supporting frames with larger distance from the external wall, a maintenance walkway is recommended at each 1 or 2 floor level.
Unfortunately the positive effects of green facades cannot be considered in energy calculations due to their heterogeneity.
Green surfaces can also be applied on smaller surfaces. 'Green boards' can be used for shading in front of windows, which can be slid in the horizontal or vertical plane. A box containing the soil for the plants is attached to the bottom of the frame so they can be moved without any problems. The maintenance can be done from inside the building in that case.



'Green board' shading
Source: Sára Horváth

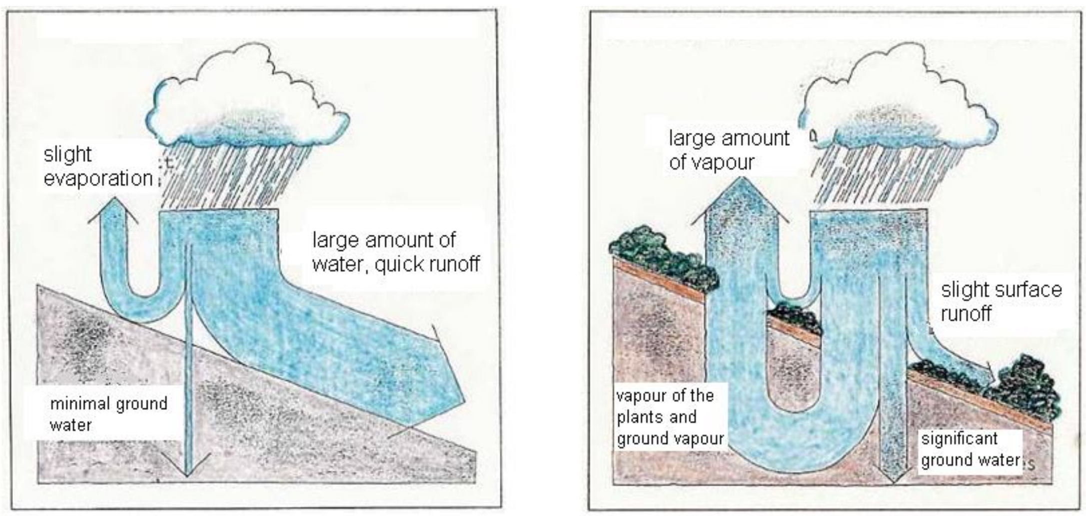
Green roofs
Green roofs, also known as vegetated roof covers or eco-roofs, are thin layers of living vegetation installed on top of conventional flat or pitched roofs. Green roofs protect conventional roof waterproofing systems while adding a wide range of ecological and aesthetic benefits.

In case of simple flat roofs without access the temperature under them can be unbearable. On the contrary, green roofs provide significant heat attenuation due to their large mass. In addition, the evaporation of the wet soil and plants decrease the local temperature of the building environment further. Green roofs have been shown to out-perform white or reflective roof surfaces at reducing the ambient air temperature.

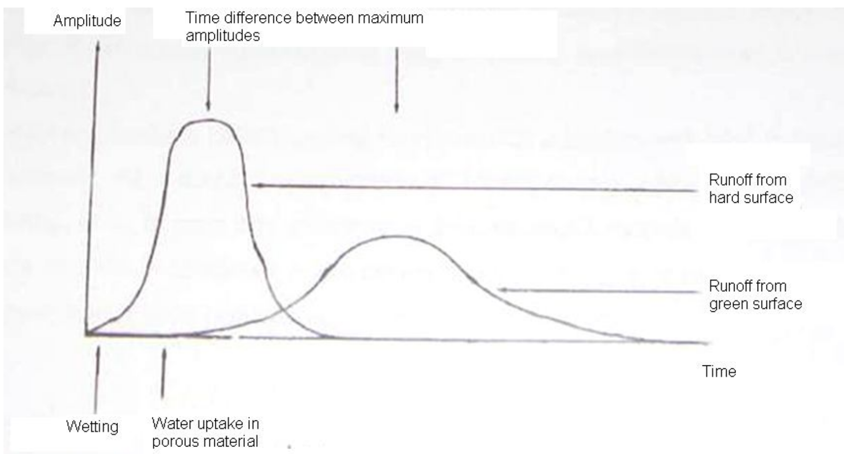
Basically there are two types of green roof structures: intensive and extensive.
Intensive green roofs are roof gardens aiming to be a place for recreation, which need continuous maintenance. Extensive green roofs are covered with draught-resistant herbaceous perennial plants and gramineous set in a thin, maximum 10-15 cm thick planter

medium. They are not designed for long staying of people, however they need minimal maintenance.

In case of a green roof the runoff of the rainwater has a significant time delay. Green roofs can be designed to achieve specified levels of storm water runoff control, including reductions in both total annual runoff volume (reductions of 50 to 60 percent are common) and peak runoff rates for storms. Reliable techniques for predicting the rate and quantity of runoff from vegetated roof covers have been used successfully to design integrated storm water management measures in Germany, where large zero-discharge developments that rely heavily on green roofs are already operating. Green roofs also bind the dust and contamination, produce oxygen and decrease the noise. A simple 8-10 cm deep vegetative cover can be expected to reduce sound transmission by a minimum of 5 decibels. Sound abatement of up to 46 decibels has been measured on thicker roofs. However, green roofs (especially intensive ones) usually need continuous maintenance and watering.



Rainwater distribution on hard surface and green roof
Source: Sándor Horváth



Intensity of runoff vs. time
Source: Ref. [3]

Intensive green roof

Extensive green roof

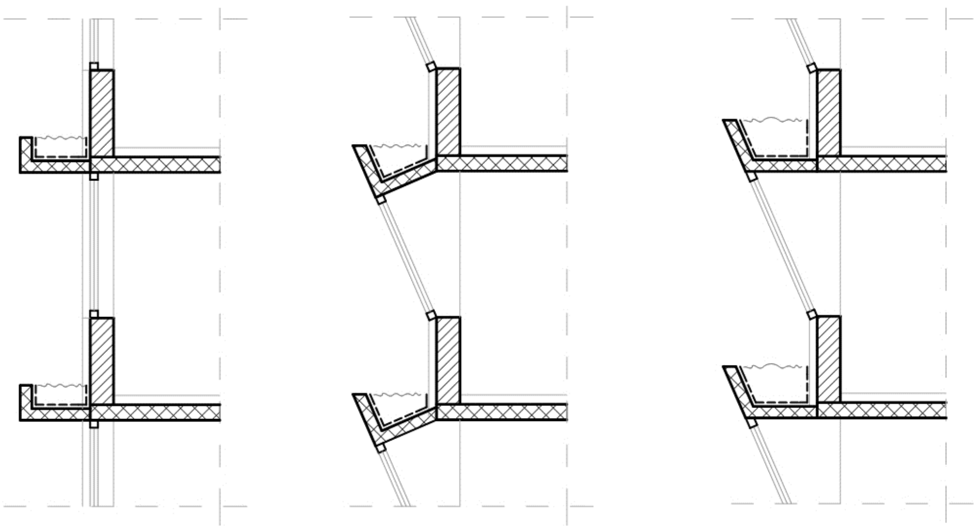
Source: Sándor Horváth

Water surfaces around the building

The operation of water surfaces, small ponds and fountains placed into or adjacent to buildings is, as opposed to artificial evaporation, that we make the dry air contact with large water surfaces. Of course the efficiency of such systems are much worse than an artificial evaporation cooling system, they can, however, provide enough cooling in case of suitable climate conditions without the use external energy supply. Water surfaces around the building due to their evaporative heat absorption can reduce the air temperature by 2-4°C improving the micro climate in the summer. In addition to the cooling of effect, large water surfaces have positive environmental-psychological effect as well.

Water surfaces on the facade

Water surfaces can also be formed on the elevation or flat roof of the building.



Water surfaces on the facade
Source: Sára Horváth

It should be noted that water surfaces require additional maintenance and investment costs and they should be properly designed and constructed at a very high level.

Possibility to use and recommendations

Vegetation around buildings has a significant environmental-psychological role, however they provide real effects from energy consumption point of view in case of small buildings only. Vegetation can be planted any time, however trees grow quite slow and it takes quite a long time when they are high enough to provide sufficient shading. Green facades can usually be made on existing buildings, however making an extensive green roof, which can provide more significant cooling, could be a problem due to its heavy weight and the load-bearing capacity of the existing top floor.

POSSIBILITY TO USE		new	existing
vegetation around the building		**	**
green facade		**	*
green roof		**	-
water surfaces	around the building	**	*
	on the facade	*	-

** high possibility to use
* possibility to use
- not real possibility to use

In northern climates with cooler summer the vegetation, if it is deciduous, can shade the glazed surfaces significantly, which reduces the solar gain in winter. Therefore, it is not recommended using vegetation from the point of view of cooling. The big thermal mass of a green roof can play a big role in reducing the winter heat loss as well, therefore it is recommended applying in all climates. Water surfaces cooling the façade wall is recommended in southern countries, however their design and execution requires high attention and professional skills.

RECOMMENDATIONS		South		North	
		residential	office	residential	office
vegetation around the building		**	*	-	-
green facade		**	**	-	-
green roof		**	**	**	**
water surfaces	around the building	**	**	-	-
	on the facade	-	*	-	-

** highly recommended
* recommended
- not recommended

5.4 Day-lighting

Daylight use may be the crucial factor to bioclimatic lighting design. The use and opening hours of the building, as well as the orientation and the glazing areas, the building and interior spaces dimensions (depth versus façade) should be considered. When the problem is caused by the depth of a certain room, daylight conductors may be applied.

Daylight may not provide the sufficient luminance at any time it is needed, though it is not excuse not to use it as much as possible, its use may suppose important energy consumption reductions. It must always be combined with artificial lighting.

There are three main criteria on lighting design:
- Obtain a correct luminance on the surface where it is needed for certain activities.
- Avoid the reflections which may cause dazzle.
- Relate interior to exterior luminance.

The following table describes the correspondence between luminance (lux) and visibility (dVis), referred to typical environments to develop different activities comfortably.

Lux	dVis	Environment	Activity
100000	70	Full sun	Near to painful excess
30000	65	Sunny day	Exterior daylight, walking.
10000	60	Partly clouded	Exceptional activities (operating theatres)
3000	55	Transitional areas	Very high demand Task. Punctual lighting.
1000	50	High interior	High demand Task (kitchen, restroom), Lighting a certain area
300	45	Medium interior	Medium demand Task, general daytime lighting
100	40	Low interior	Low demand task. Resting. General nocturne lighting.
30	35	High street light	Interior distribution areas and exterior street high traffic.
10	30	Medium street light	Medium traffic and medium density
3	25	Low street light	Low traffic street, low density
1	20	Minimum street light	Parking and others, only direction.
0,1	10	Moon light	Need adaptation to keep direction
0,01	0	Star light	Almost complete darkness

Night time lighting has normally a lower intensity since vision is normally adapted to inferior luminance. Different intensity between a close-up and its surroundings may vary around 1/3. The following table shows adequate luminance levels for interiors.

Lux	dVis	Daytime interior activity	Night time interior activity
1000	50	Close-up, high demand task	(light exceeding)
300	45	Middle distance and medium demand task	Close-up, high demand task
100	30	Surroundings low demand task	Middle distance and medium demand task
30	25	(insufficient light)	Surroundings low demand task

The sun is the source of natural day light, its effect depends on the location, luminance characteristic are determinates by altitude, latitude and climatic conditions. Light is the visible portion from the electromagnetic radiation spectrum, from 380 to 780 nm. Light is received directly on the exposed façades and as diffuse light on the rest.

A correct use of day light requires transmittance and reflection models:

- Transmittance:
  Opaque objects are those that as being exposed to daylight, light does not go through them and they produce shadows. Other objects transmit most of the light they receive and they are called transparent or translucent.
- Transmission: Light is distributed on three ways reflectivity (r), absorbance (a) and transmittance (t).
  $r + a + t = 1$
  For opaque objects:
  $t = 0 ; \; r + a = 1$

Translucent objects transmit most of the light that they receive, but they may cause diffuse light by reflections.

- Reflection: It is the property by which light is reflected by a surface in the way a mirror does. If parallel rays are reflected as parallel it is called specular (the mirror effect), when reflection is not parallel it is called diffuse reflection. On many occasions both types of reflections appear together.

Selection of materials should take into account the reflection properties to make a good use of daylight and an efficient lighting design. Specular materials can be used to redistribute or redirect daylight as used on light tubes and light shelves.

A proper use of daylight use should be based on:

- The election of orientation and the use of shadings, shutters, blinds, or any kind of sun protection.
- The use of advanced glazing reducing heat transmission and controlling solar gains.
- The design should consider the location and size of windows according to the use and proportion of the interior spaces.
- The use of light colours and reflective materials.
- The use of reflection to redistribute day light.
- Glare control both interior and exterior areas.

In case of offices, it is an essential requirement to keep away the direct sunshine, admit natural daylight and provide a proper outlook at the same time. Too much shading can result in dark places in the building which increases the electricity demand as the occupants switch the light on. The possible solutions were showed in 5.3.3. section.

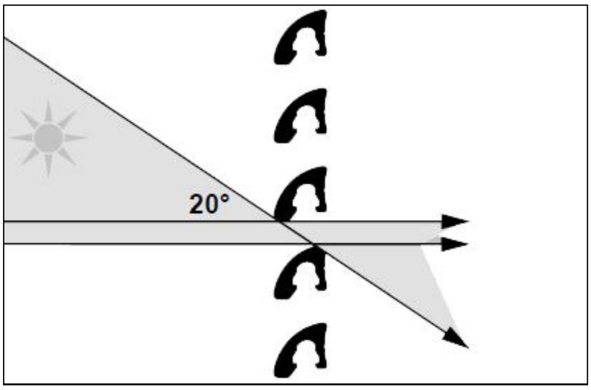
5.5 Innovative solutions

Schüco Energy^2 „Breathable" glass facade with shading

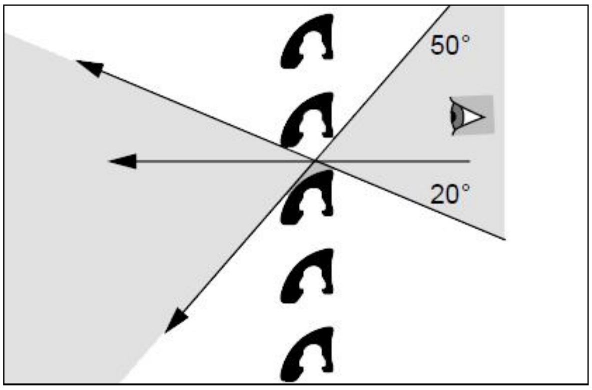
Schüco Energy^2 curtain wall systems consist of openable parts so the ventilation of the rooms behind the curtain wall is possible through the facade. Further components of the system in addition to the conventional parts of the curtain wall system are openable elements, innovative shading elements, integrated solar collectors and solar cells and decentralised mechanical ventilation. The operation and moving of all of the parts is computer controlled.

Although external shading devices are exposed to weather, they work in the most effective way. Wind is the most dangerous factor, which gives a limitation of the application of aluminium louvers.
The main advantage of Schüco CTB (Concealed Toughened Blind) external aluminium micro louver system is that it can withstand a wind speed of 30 m/s (110 km/h). The shading, of which area of one element is maximum 9m^2, can be integrated into to Energy^2 curtain wall system.

The micro louvers reflect the sunlight with an angle of greater than 20°, whereas it still provides proper outlook even when the shading is rolled down.



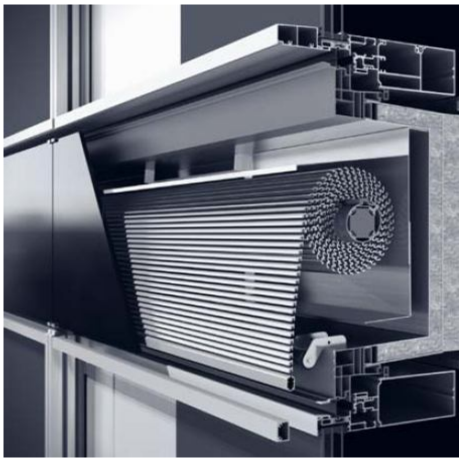
Shading (sun angle > 20°)



Outlook

Source: www.schueco.hu

E^2 curtain wall



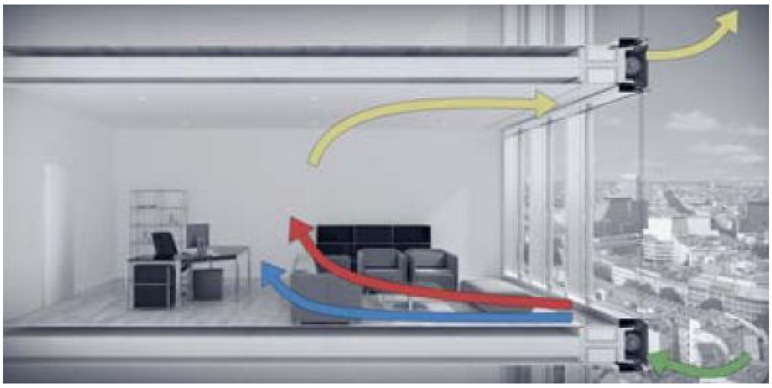
Integrated shading

Source: www.schueco.hu

Energy[2] facade system is breathable due to the ventilation devices integrated into the curtain wall. These integrated devices are situated in front of the intermediate floors and each unit can be controlled individually. They can also be installed with heat recovery devices. They are 115 cm wide, 40 cm deep and have a height of 13-25 cm, depending on their type.

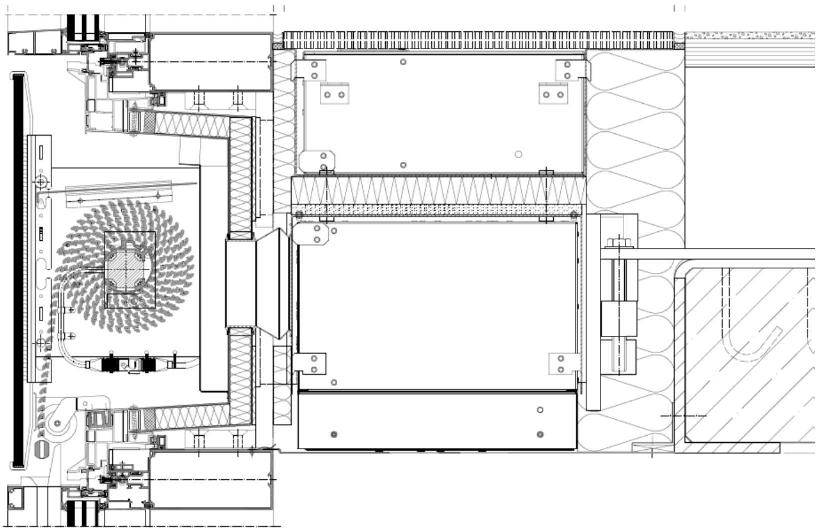
There are 5 different ventilation concepts depending on the location of the air inlets and outlets. E.g. in the figure below, fresh air is admitted at the floor, whereas used air leaves the room at the ceiling through the curtain wall.

Ventilation device



Ventilation concept

Source: www.schueco.hu



General floor connection detail

Source: www.schueco.hu

SCHÜCO 2° concept

Schüco 2° concept is flexible facade employing several different mobile layers. The first layer from outside is a Schüco PV solar cell, which acts as a shading on sunny days if it is slid in front of the window or in extreme weather conditions (wind speed greater than 110 km/h) can provide protection to Schüco CTB micro louvers. Using the two shading systems gives higher protection against the summer heat load. The next layer is a mobile thermal insulation, which looks like ground glass. The inner layer is double or triple glazing. The four layers can be controlled by the building management system using computer software.

The facade also has fix parts, which is a special thermo active wall containing phase-changing material. This material melts at 22°C and cools the adjacent environment.

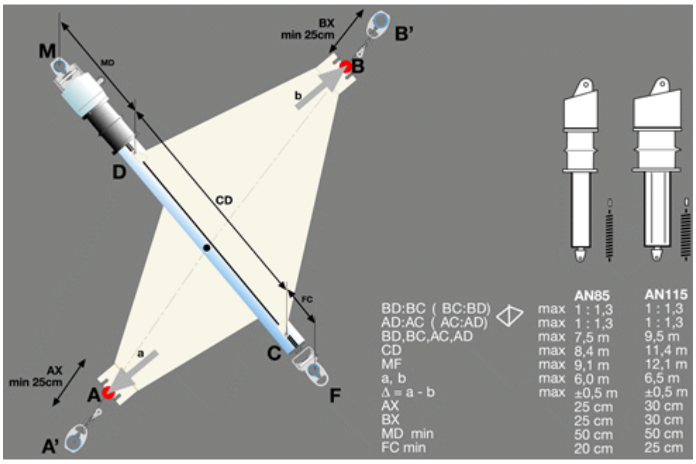
Applying the Schüco 2° Concept with its 4 computer controlled mobile layers and thermo active parts, the heating and cooling energy demand of the building can be reduced significantly.

SCHÜCO 2° Concept
Source: www.schueco.hu

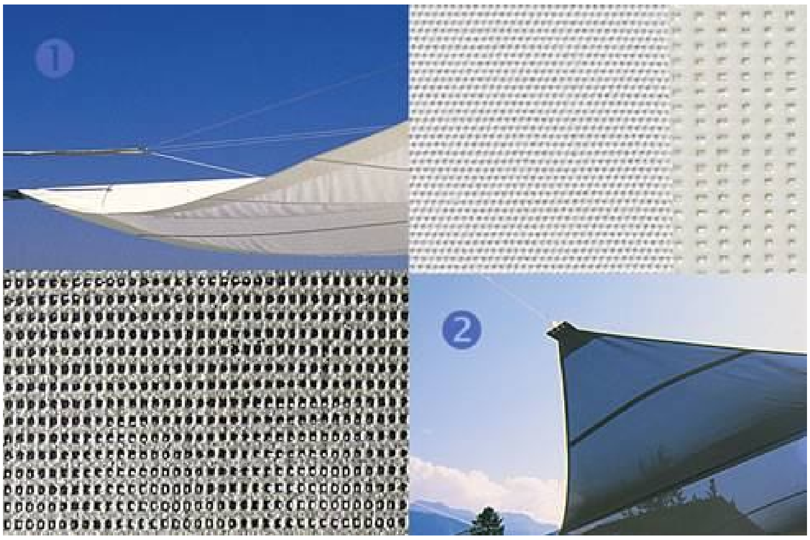
Sun Sail Shades

Sun sails can protect and shade patios, balconies, yards, swimming pools, etc. They are not only shadings, but can make an attractive addition to any property, and with the right design, they can enhance the existing property with artistic or architectural flair and style.

The material of the sail is UVA and UVB resistant special canvas and it has a triangle shape. An adequate ratio of the edge sizes is important so that the sail can be rolled up properly. The maximum surface area of the sail is 50 m^2 and when the wind speed exceeds 40 km/h it is rolled up automatically.

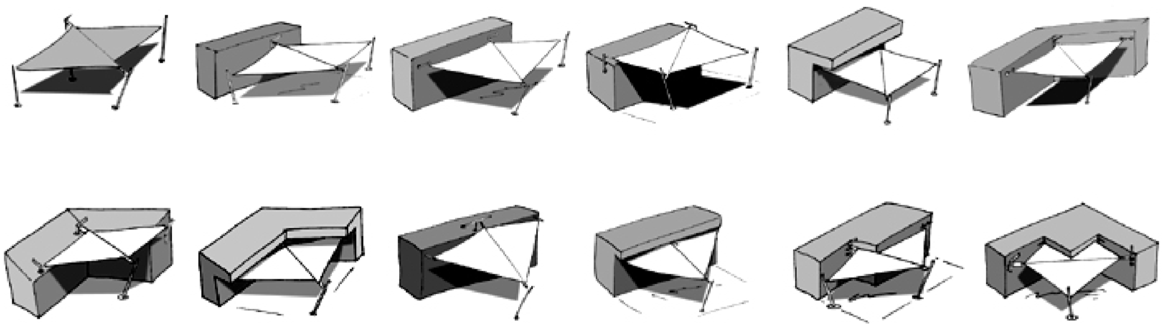


The operation of sun sail
Source: www.napvitorla.hu



Source: www.napvitorla.hu

The gap between the wall and the sail is maximum 60 cm in all cases. This gap provides ventilation preventing overheating below the sail.



Sun sail types
Source: www.napvitorla.hu

The sails can be attached to walls, directly or with spacers, or to concrete or metal containers filled with water place on the ground.

Existing examples
Source: www.napvitorla.hu

6 Examples

6.1 House for elderly people, Domat (Germany)

(source: www.minergie.ch, and DETAIL 6/2007)

Architect: Dieter Schwarz
Construction date: 2003-2004
Building cost: 130.000 EUR / residential unit
Total energy demand: 16 kWh/m^2a

The building, which consists of 20 pcs residential unit 57 m^2 each, was the one of the first buildings where phase-changing glazing was used. The south elevation is fully transparent of which 150 m^2 is GlassXCrystal type glazing, whereas the north facade has very small windows only. See more details about GlassXCrystal glazing in section 5.2.1.

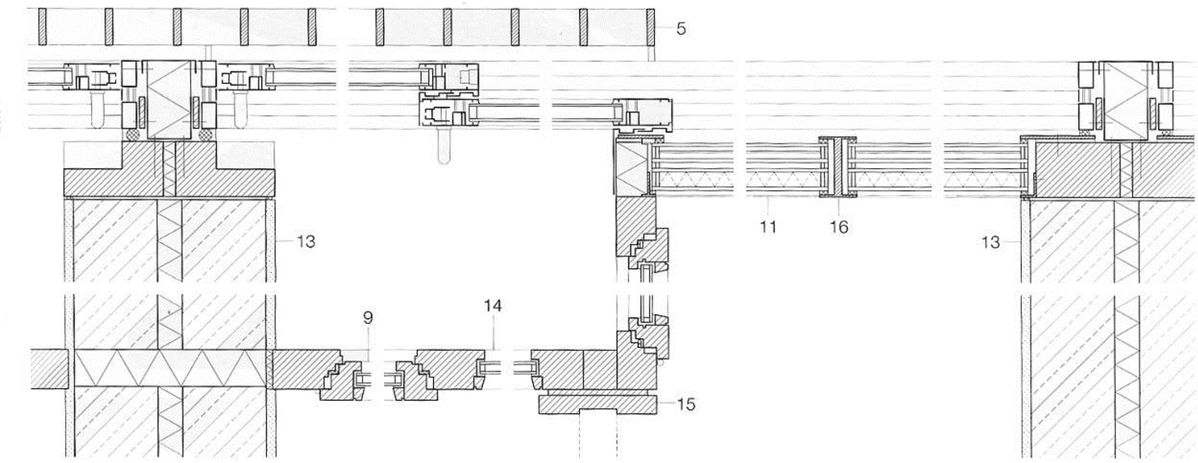
Thermal storage of passive solar energy is provided by the reinforced concrete slabs. The external walls are covered by thermal insulation with a thickness of 20 cm. There are solar cells installed as well with a surface area of 22,5 m^2 providing 14.000 kWh electricity.

The glazed balconies function as sunspaces in winter. The glazing with an aluminium frame can be slid away in summer and it can also be protected from the sun by textile shading.

Ground floor layout


South elevation


GlassXCrystal glazing – view from inside



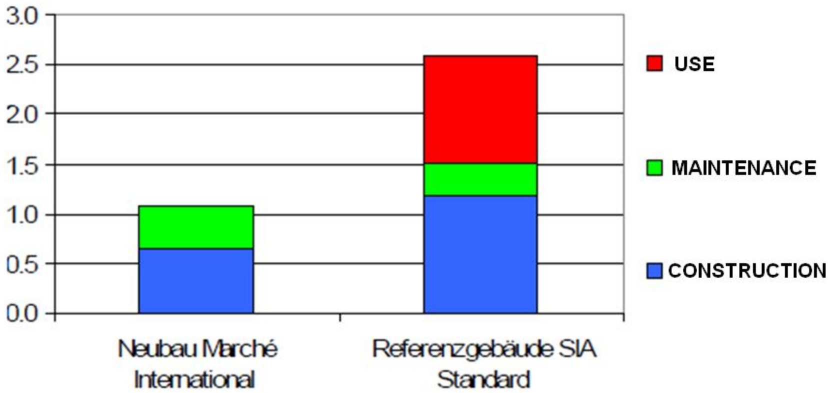
Horizontal section (details of conservatory and phase-changing glazing)

6.2 Marché 0 Energy Office Building, Kepmtthall (Switzerland)

(source: DETAIL 1/2009 and DETAIL Green 01/09)

Architect: Beat Kämpfen
Construction date: 2007
Net surface area: 1.200 m^2
Building cost: 2.2.35.- CHF /m^2 (total: 3,25 million CHF)
Heating energy demand: 7,8 kWh/m2a

The office building, which is a light-weight structure and owned by Marché international restaurant chain, was the first 0 energy building in Switzerland, which won the „Schweizer Solarpreis" prize in 2007. During design an LCA assessment was carried out considering the whole life cycle of the building for 50 years including phases of construction, maintenance, use and demolition. The calculation showed a 60% reduction in negative environmental impacts, such as CO_2 equivalent emission, compared to an office building designed in accordance with normal Swiss standards.



Environmental impacts, comparison of Marché building and a standard Swiss office building

Energetic concept:

Improved thermal insulation and air-tightness
On the ground floor glass wool thermal insulation with a thickness of 28 cm was used (U = 0,095 W/m^{2}K), in the roof 16 cm thick glasswool and 28 cm thick cellulose were applied (U = 0,084 W/m^{2}K), on the external walls 34 cm thick glasswool was installed (U = 0,104 W/m^{2}K). Some of the timber window frames were installed with GlassXCrystal glazing (U = 0,46 W/m^{2}K).

Effective shading
The conventional glazed surfaces were shaded by external, ventilated textile shadings (type Soltis 92) and the balconies on the south side function as fix shadings as well.

Renewable energy use
Solar cells with a surface area of 485 m^2 and an annual peak output of 44.600 kWh were installed on the southern pitched roof surface with a slope of 12°. The annual electricity demand of the building is about 40.000 kWh. The heating and cooling of the building are provided by heat pumps.

Heat recovery ventilation
The fresh air demand of the offices is provided by heat recovery ventilation, the efficieny is about 90 %.

Green surfaces
A „green wall" with a surface area of 12 m^2 was built on the staircase wall at each floor level to achieve a pleasant internal climate.

Water storage
A rainwater storage tank with a volume of 100 m^3 was placed below the ground.

South elevation of the building

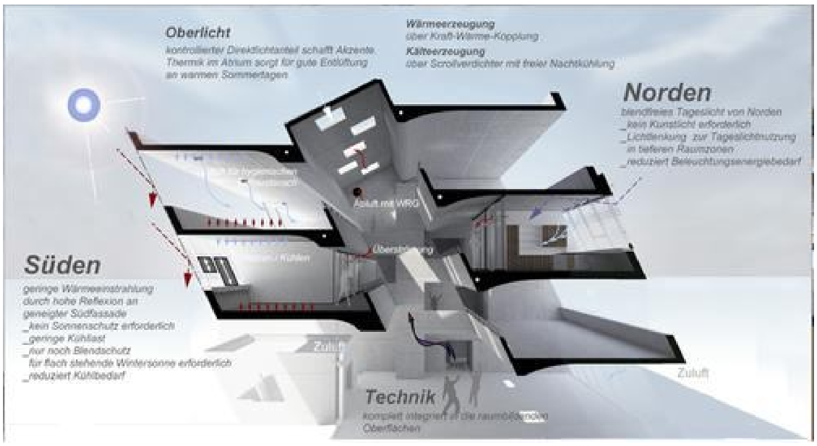
Glass facade with GlassXCrystal glazing from outside

Glass facade with GlassXCrystal glazing from inside

6.3 e-on Office building, Zolling (Németország)
(source: http://www.boesel-benkert-hohberg.de/press/ZOL-EFM2008.pdf and DETAIL Green 01/09)

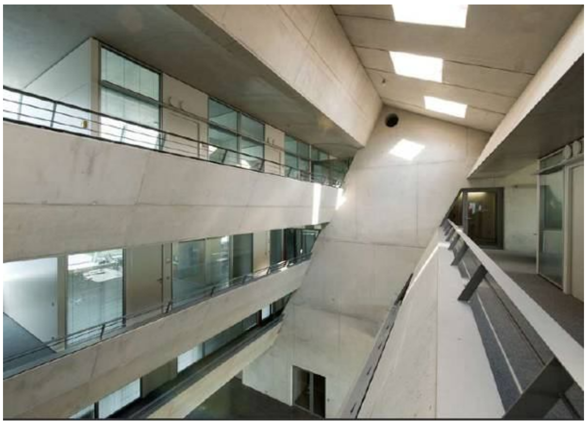
Architect: Boesel Benkert Hohberg Architecten
Construction date: 2007-2008
Surface area: 2.500m^2
Construction cost: 4,5 M EUR

The new headquarter of e-on in Zolling is another example of slanted glazed facing. During the design the designers slanted the whole building by 26° in south direction to get an optimal balance between solar gain and shading. In this way offices on the southern side avoided the direct summer sunshine, whereas offices on the northern side received more sunshine than those located in conventionally shaped building.



The theory


South elevation

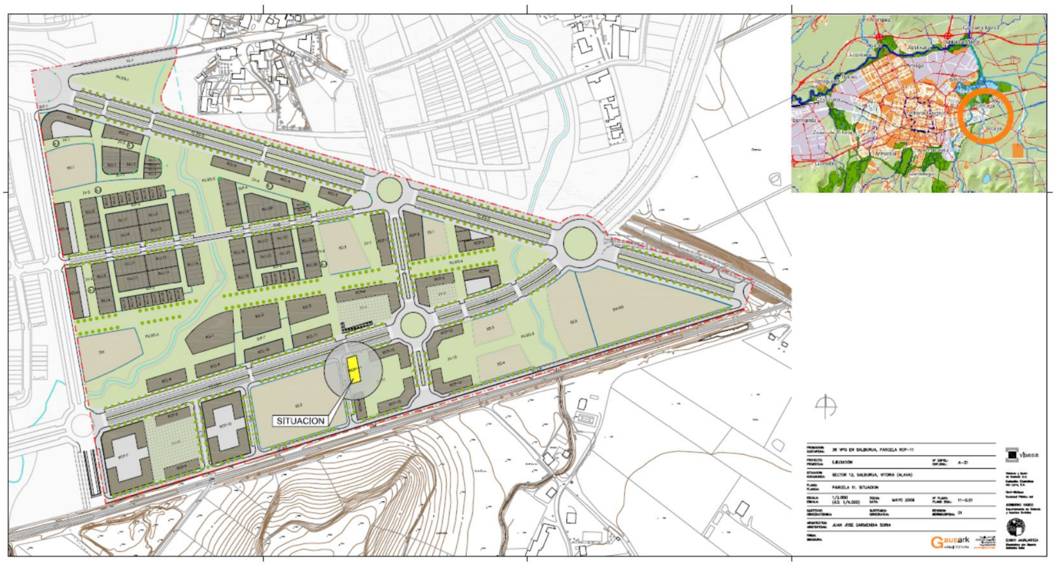

Internal corridor

7 Case studies

7.1 Case study of Salburúa (Vitoria- Spain)

7.1.1 Location

The Salburúa CONCERTO Community is to be built close to the Green Ring that surrounds the City of VITORIA-GASTEIZ. Vitoria-Gasteiz is a 240580 population city located in the Basque Country in the Northeast of Spain. 42.84N,-2.65W. Altitude is about 520m. Salburúa is a new urban development at the east part of the city. The new neighborhood is close to a wetland area also called Salburúa. Its limits at the south are the railways Madrid-Irún, in Vitoria-Gasteiz.



Source: VISESA

The site has a rhomboid shape, its longest dimension on the East-West direction. Its surface is 2.903,08 m2. The site has a light descending slope from North to South. Its boundaries are a new road at the north, the site identified as RCP-7-B at the south, a public garden at the East and the railway at West. It has almost no slope; the streets on its limits have 0.5% descending to the east and 1.50% slope descending to the north.

7.1.2 Climate data

CLIMATE ZONE D1 (Vitoria)

Spanish building regulation establishes different climatic zones. These zones will be considered on different parameters as insulation or solar protections. Victoria is considered as part of the D1 climatic zone according to this regulation.

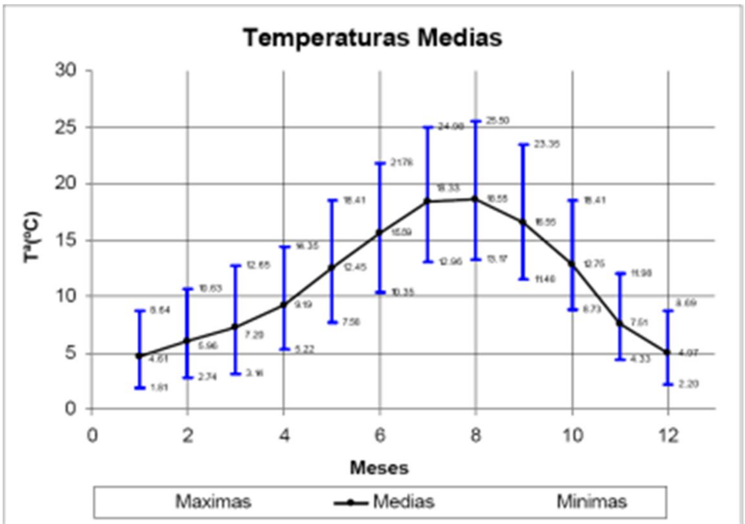
The National Meteorological Institute has a weather station located in Foronda airport near to Vitoria city centre. Next table shows the month averages of the most representative climatic parameters registered from 1971 to 2000 by this weather station.

VITORIA (AEROPUERTO DE FORONDA)														
Periodo: 1973-2000 Altitud (m): 508 Latitud: 42 53 02 Longitud: 2 43 22														
MES	T	TM	Tm	R	H	DR	DN	DT	DF	DH	DD	I	N	HDD	CDD
ENE	4.7	8.3	1	76	83	10	3	0	5	12	2	82	31	412.3	0
FEB	5.9	10.5	1.4	65	79	10	3	0	4	10	2	106	28	338.8	0
MAR	7.9	13.3	2.4	61	73	9	2	0	3	7	2	145	31	313.1	0
ABR	9.2	14.5	3.9	86	72	12	2	1	3	4	2	154	30	264	0
MAY	12.9	18.7	7.1	70	71	10	0	4	3	1	2	182	31	158.1	0
JUN	15.9	22	9.8	51	71	6	0	3	4	0	3	207	30	63	0
JUL	18.7	25.3	12.1	43	71	5	0	4	4	0	4	239	31	0	0
AGO	19.1	25.7	12.5	45	71	5	0	4	6	0	3	221	31	0	0
SEP	16.6	23.2	10.1	42	71	6	0	2	6	0	4	178	30	42	0
OCT	12.4	17.5	7.2	74	77	9	0	1	6	0	2	137	31	173.6	0
NOV	7.9	12.1	3.6	89	82	10	1	0	6	6	2	95	30	303	0
DIC	5.6	9	2.2	80	84	11	1	0	4	9	2	73	31	384.4	0
AÑO	**11.5**	**16.8**	**6.1**	**779**	**75**	**103**	**11**	**21**	**54**	**49**	**28**	**1830**		**2452.3**	**0**

T Mean temperature (ºC); TM Mean highest day temperature ºC); Tm Mean minimum day temperature (ºC); R Mean precipitation (mm); H Mean relative humidity (%); DR Mean days with more than 1mm precipitation; DN Mean days of snow; DT Mean days of storms; DF Mean days of mist or fog; DH Mean days of frost; DD Mean sunny days; I mean number of hours of sunlight; N number of days per month; HDD Heating degree day; CDD cooling degree day.

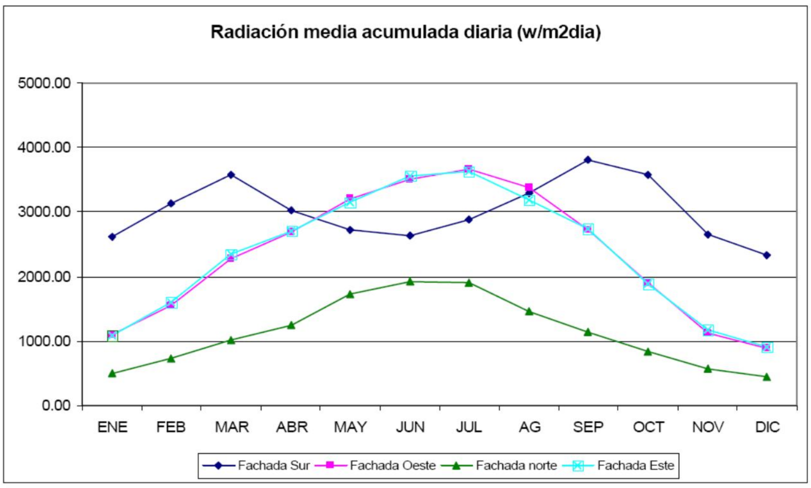
Temperature

Mean temperatures in Vitoria are those of cold winters (2ºC) and moderate summer (24ºC). Daily temperature fluctuation is not high, around 10-12ºC all year about.



Sunshine

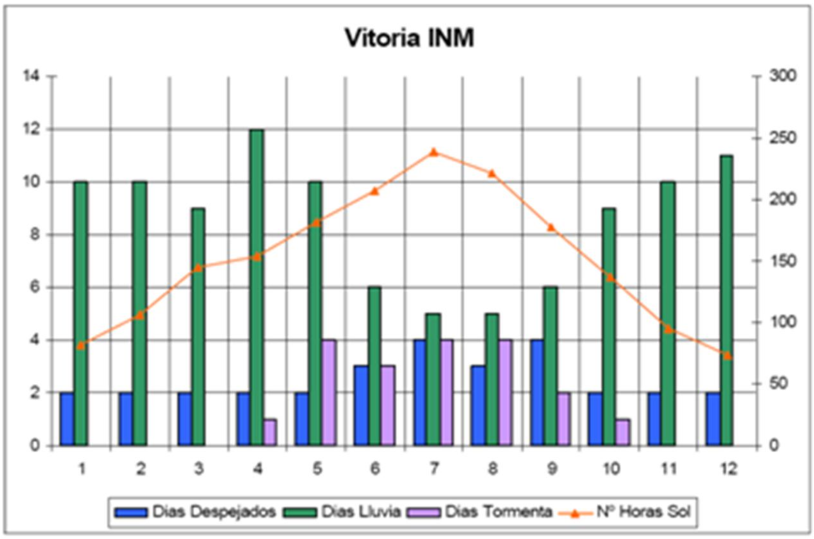
Next figure shows solar radiation on the different façades. East and west façade receive much more radiation during the summer period. This is not strongly detriment on a moderate climate as the one in Vitoria. Solar radiation on the south façade shows a significant reduction from March to September, receiving less radiation during the summer period.



In dark blue, South façade; in pink, West façade; in green, North façade; in turquoise, East façade.

Rain (Precipitations)

In this graphic of the National Meteorological Institute for Vitoria, in blue there are sunny days, rainy days in green and stormy days in purple. Number of daylight hours per day and month correspond to the red line. Sunny days in Vitoria are few all year around, from two days during the winter to 4 during the summer months. Rain is abundant, with about 10 rainy days per month during winter, spring and autumn, and shows a reduction during the summer with only 5 or 6 days per month. Summer has the highest number of stormy weather days per month.



Relative humidity

Humidity is almost constant during the different seasons varying from 50 to 60% from winter to summer period.

Wind

The data from the National Meteorological Institute is used as the main source in the case of wind regime, though it must be taken into account that the results may change significantly for the real location.

Summer period is windier with a northeast direction. This direction is predominant also during spring and September; in those cases the Southwest direction is also important. During the winter and the end of autumn southwest is predominant.

7.1.3 Building description

General

Salburúa is a promotion of subsidized dwellings whose design will take into account criteria of energy efficiency, harnessing of renewable energy and sustainability and continuity over time, making people feel proud and encouraging them to participate in the improvement of the quality of life and reduction of the environmental impact.

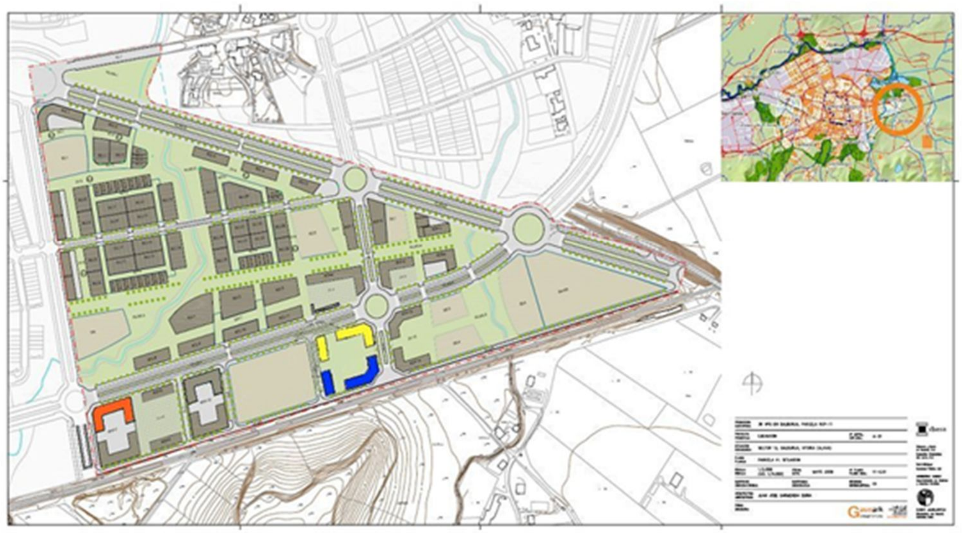
Salburúa community buildings have the compromise to reduce energy consumption by implementing their thermal insulation and the use of RES technologies. Microgrid will be also developed from the generated energy.

Main goals are:

- Constructive improvements to gain a higher energetic efficiency including:
    - 30% Reduction of the total energy consumption estimated by CTE (considering mechanical ventilation of 1.00 renov/hour)
    - Façade thermal transmission < 0´35 W/m²K
    - Roof thermal transmission < 0´24 W/m²K
    - Floor on slab over the ground thermal transmission < 0´30 W/m²K
    - Window frame and glazing thermal transmission < 2´00 W/m²K
    - Shading elements covering >90% of the openings surface
- Electric and Thermal energy production (for heating and hot water), using cost effective RES technologies using a microgrid. Solar thermal and photovoltaic installations will be used.
- Other particular improvements will be also considered such as:
    - Low temperature heating
    - Low emissive glazing
    - Buffer spaces on the south which will be acting as a green house.
    - Systems to reduce lighting consumptions.
    - Passive thermal storage and reduction of the thermal bridges.
- Energetic management by the ESCO set up by EVE and VISESA will control the energy distribution and the internal consumption or the energy sold out to the grid.
- Improvements will be verified by the monitorization of the buildings during their first year in use.

NOTE: The nomenclature for the buildings projects are: A-31/A-43 and A-32

buildings	A-32 (176 flats)	A-31-N (128 flats)	A-31-S (128 flats)
Plots	1	2 (A-31-N, A-31-S)	2 (A-31-N, A-31-S)
Buildings	1	3	3
Profile	2PS+PB+8P+BC	2PS+PB+8P+BC	2PS+PB+8P+BC
Dwellings	176	128	128
Gross floor area	15,079 m²	13,421 m²	13,421 m²
Garages	184	135	135
Storages	176	128	128
Inhabitants	502 inhab.	506 inhab.	506 inhab.



The energy demands of the buildings

	A-32 (176 flats)	A-31-N (128 flats)	A-31-S (128 flats)
Total conditioned area	12,417 m²	11,268 m²	11,268 m²
Total CTE heating demand	780,484 kWh/year	758,309 kWh/year	758,309 kWh/year
Total PIME's heating demand	486,134 kWh/year	462,246,50 kWh/year	462,246.50 kWh/year
Heating demand reduction	38.7 %	39 %	39 %
CTE demand per square meter	63 kWh/(m² year)	67.4 kWh/(m² year)	67.4 kWh/(m² year)
PIME´s demand per square meter	39 kWh/(m² year)	41 kWh/(m² year)	41 kWh/(m² year)

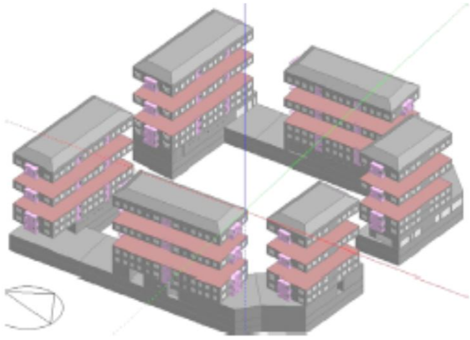
The energy facilities

Energy facilities	A-32 (176 flats)	A-31-N (128 flats)	A-31-S (128 flats)
system	Micro-CHP PV panels Mini wind mills High performance boiler	Geothermal exchange system and heat pumps Micro-CHP Thermal solar collectors and seasonal storage High performance boilers	

SYSTEM	A-32 (176 flats)	A-31-N (128 flats)	A-31-S (128 flats)
Cogeneration (CHP)	12,5 kW (thermal) x2	27 kW (thermal)	27 kW (thermal)
Geothermal exchange system (GE), heat pumps	--	218 kW (thermal)	218 kW (thermal)
PV panels	58.7 kWp (430 m^2)	--	--
High performance boilers	420 kW (thermal) x2	774 kW (thermal)	774 kW (thermal)
Thermal solar collectors	--	700 m^2	700 m^2
Mini wind mills	50 kW (electric)	--	--

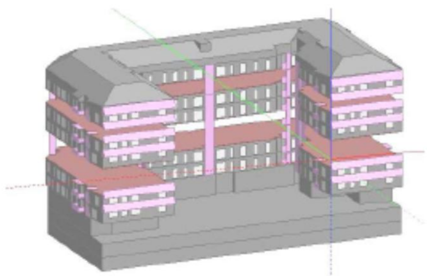
Layout

A-31/A-43 → 256 SOCIAL FLATS



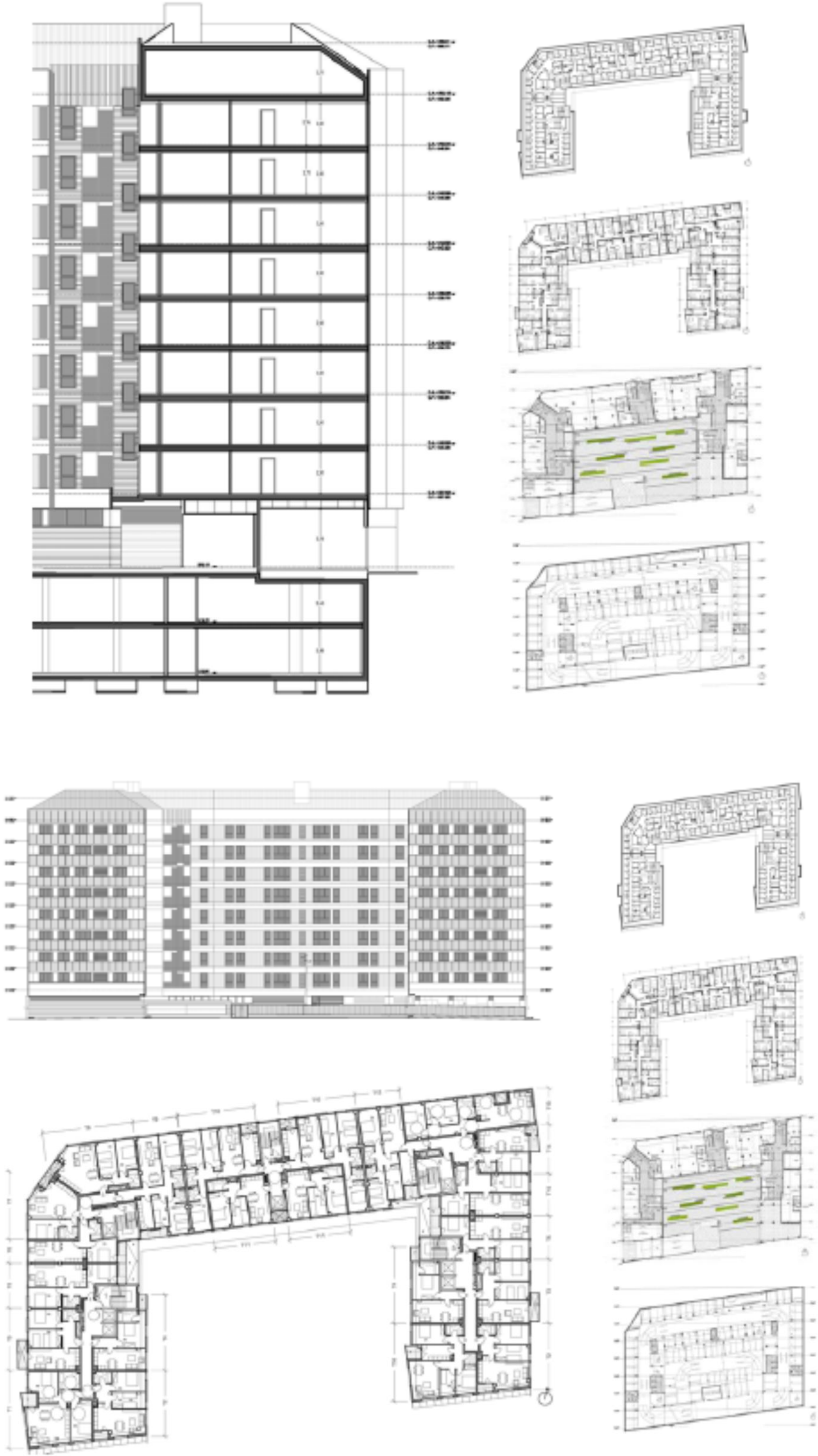
	A-31 promotion
Total conditioned area	22,536 m²
Total CTE heating demand	1,518,618 kWh/year
Total PIME's heating demand	924,493 kWh/year
Heating demand reduction	39 %
CTE demand per square meter	67.4 kWh/(m² year)
PIME´s demand per square meter	41 kWh/(m² year)

A-32 → 176 SOCIAL FLATS



	A-32 promotion
No of dwellings	176 social dwellings
Plots	RCP 7-A
Buildings	1
Profile	2Bts+GF+8+Attics
Garages	184 (8 free sale)
Dwellings (m²)	14,260 m² (md 81)
Surface area of green and open spaces	1,069 m²

Source: VISESA



Source: VISESA

Desing principles

Bioclimatic strategies in Salburúa includes:

- Compact volumes
- Optimum orientation: South faced
- Overhanging elements in South façade to shade openings during summer season
- Natural cross ventilation
- Lumber rooms under roofing
- Low transmittance enclosure. High insulation thickness
- Low emissivity glazing
- Air tight, thermal break window frames

Next factors are considered in order to achieve the best behavior of the building:

- Orientation: To harvest the maximum radiation during winter and the less during summer. Considering dominant winds.
- Shape factor: Relation between the outer surface and the volume contained inside it. It has influence on the energy exchange between the building and the exterior.
- Space distribution: It is advisable to fix less occupied rooms in most exposed zones in order to perform as "thermal buffer spaces".
- Volumetric: Stepped volumes to shade façades in order to avoid direct radiation during summer time and allowing it during winter.
- Surroundings: Influence of buildings, green zones and asphalted zones is also studied.

Solar exposure and protection has a special influence on the building energy performance:

- Analysis of the stereographic solar chart to make a correct façade design for each orientation.
- Projecting elements designed considering solar height both in summer and winter to have and effective use of solar radiation.
    - Summer: Avoid solar radiation.
    - Winter: Harvest solar radiation.
- Consideration of the influence of other buildings, parks, trees, asphalted zones… of the surroundings.
- Geographical determining factors and microclimates are also considered under this study.

The correct design of the building itself is essential in order to achieve a good energy efficiency, receiving less solar heating gains during summer and having less winter heat losses as possible. As Vitoria-Gasteiz has a cold long winter, the main passive strategies to be adopted are pointed to reduce energy losses while harvesting the most quantity of solar radiation, storing it in order to be released when the solar gains are over. Considering the plan, a compact building shape reduces heat losses.

To prevent heat losses, a good and thick thermal insulation will be used in all the opaque enclosures, while especial glazing will be used in all the windows attending to the needs of the different orientations, being, at least, the North facing glazing of low emissivity (Low E). Windows, following the national legislation, are thermal break framed in all the façades. Air tightness will be reinforced to avoid at maximum the uncontrolled infiltration. Insulation of the roof will be made by VIP: Vacuum Insulation Panel in order to achieve a lower energy exchange as the roof is the most exposed construction element in the building both in summer and winter. This kind of insulation has a very low thermal conductivity coefficient of 0.005 W/m.K. A VIP of 20 mm has a U-value of 0.25 $W/m^2.K$ equivalent to 16 cm of a usual mineral wool. This insulation element permits to reduce the U-value of the roof to 0.17 $W/m^2.K$.

Special attention has been paid to thermal bridges in the whole envelope and in the insulation between non-conditioned and conditioned spaces. The thermal bridges will be studied thanks to a CDF software called Fluent to calculate the exact thermal exchange. Special care will be also paid to those elements liable to suffer condensations.

From the point of view of the bioclimatic design, with the aim of achieving a solar radiation crop it would be a good practice to construct green houses, conservatories or other buffer spaces in the South side of the building to heat and store incoming ventilation air. The hinged windows let the natural ventilation controlled by the occupants. On the solar path area of the floor, a material with high inertia should be placed to capture the heat from the sun and release it into the room.

Cross ventilation should be the way to air condition the inner spaces using special vents in the façade to avoid or lessen the thermal break effect. Incoming air will be treated during summer by a dehumidifier supplied by solar energy.

The use of deciduous trees would be helpful to shade the building during summer whilst allowing penetration by winter sun in the first floor and the pedestrian zone in the neighbourhood.

PASSIVE SYSTEMS. ENCLOSURE DESIGN

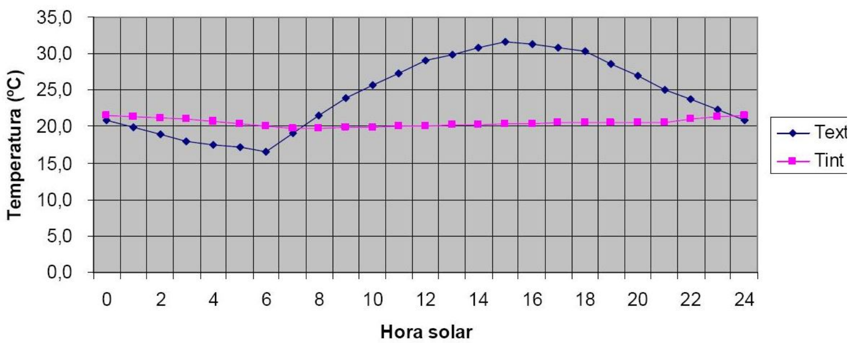
SEASON:	WINTER:	SUMMER:
OBJECTIVE:	**Conservation:** Avoiding heat losses	**Reduction:** Avoiding overheating
Façades:		
Openings:		
- Orientation	- Facing South to harvest heat Avoiding North to minimize heat losses	- Western orientation receives the biggest heat gains.
- Shading	- Allowing solar direct radiation	- Protection against direct radiation
- Specific glazing	- Low-E glazings	- Low solar factor glazings
Walls:		
- Coatings and claddings colour.	- Dark colours absorb heat.	- Light colours reflect radiation
- Insulation	- Better overinsulated than misinsulated	- Better overinsulated than misinsulated
- Ventilated façade		- Prevents from overheating
Roofings:		
Green roofs: Vegetation acts like a thermal and humidity regulator. It also avoids the running-off during storms	- Minimizes losses and avoids the running-off during storms	- Avoids overheating not only by thermal mass of ground but also because of photosynthesis.
Ventilated roofs		- Prevents from overheating

Thermal mass

Thermal inertia *= Resistance materials oppose to change their temperature.*
Thermal mass = Mass of the building that has thermal inertia.

Indoor temperature will keep constant despite of outdoor fluctuations.

- **Summer**: Absorbs heat
- **Winter:** Releases heat



INDOOR TEMPERATURE EVOLUTION

Thermal insulation

Depending on the use of the zone, thermal insulation should be at:

- Outer part of the wall: Thermal mass
- Inner part of the wall: No thermal mass

There are several kinds of insulation:

- VIPs.
- Closed cell insulation.
- Mineral wools.
- Wood chip insulation.
- Ecologic insulation.
- Reflective insulation.

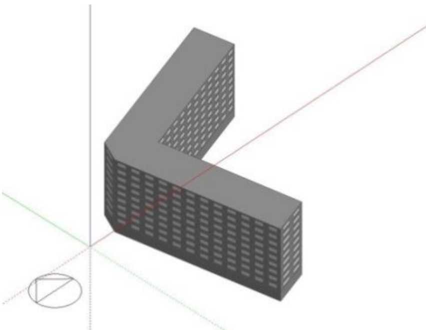
Glazing

- Analysis of heat gains/ losses through glazing.
- Indoor cooling/ heating requirements
    - Thermal transmission
    - Solar factor
    - Transparency
- Different kind of glasses are selected, they are affordable and do with the properties required for the project.

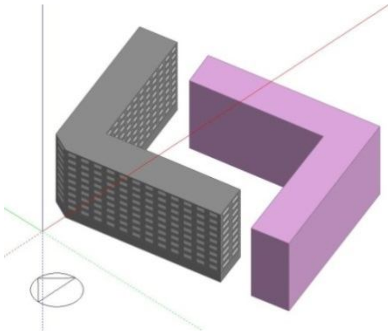
Construction

To define the optimum solutions as well as for bioclimatic design simulation will be used to simulate the behaviour of the building in terms of energy demand, consumption and of thermal comfort. Each building will be optimized separately to take into account the different orientations and the shadings of urban elements and other buildings.

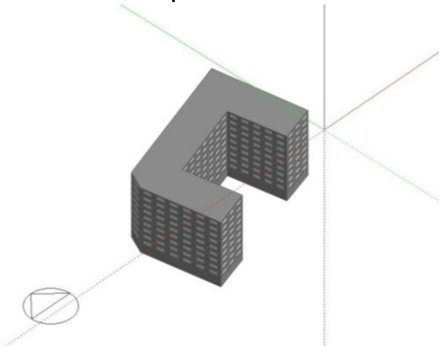
Two different volumes have been simulated L and U shaped, with and without a second building in the site. Next figures show the different models.



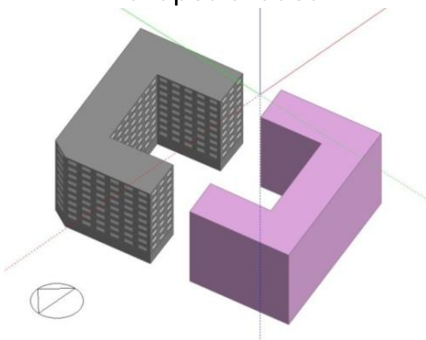
L shaped isolated



L shaped shaded



U shaped isolated



U shaped shaded

The second building on the site (violet on the figures) will not be constructed during the PIME´S project, thought it will suppose an important shading element it is important to consider its future influence on the buildings.

This simulation has been developed at the beginning of the project when no architectural design had been made yet. For the energetic performance simulations next data sources and hypothesis have been considered:

- Vitoria climatic data
- Typical residential use
- Heating and cooling temperatures: 20 – 24 ºC
- A 30 % glazing envelope
  Glazing properties:
    U = 1,97 W/m2K
    g = 0,69
- Envelope:
    Façade: U = 0,35 W/m2K
    Roof: U = 0,25 W/m2K
- Air renovation due to infiltration: 0,35 ren/h
- Air renovation through mechanical and natural ventilation: 1 ren/h

RESULTS

The energetic demands for heating and cooling were obtained for each building (4 different models). Comparison should be made on the consumptions by surface.

U Shaped	(1937 m2 per floor)					
	HEATING		COOLING		TOTAL	
	(kWh)	(kWh/m2)	(kWh)	(kWh/m2)	(kWh)	(kWh/m2)
Isolated	679180	35,06	245820	12,69	925000	47,75
With a second building	710610	36,68	228960	11,82	939570	48,50

L Shaped	(1861 m2 per floor)					
	HEATING		COOLING		TOTAL	
	(kWh)	(kWh/m2)	(kWh)	(kWh/m2)	(kWh)	(kWh/m2)
Isolated	631180	33,90	275100	14,78	906280	48,68
With a second building	689130	37,02	240700	12,93	929830	49,95

CONCLUSIONS

Results when considered the consumptions per surface are similar on both cases.

The construction of a second building supposes a light increase on the total demand. This is due to the heating demands increased by shading which are higher than cooling demand reductions.

Total energetic demand is similar in both models L and U. U shape has higher heating demands while L shape needs higher cooling demands.
To conclude, none of the proposed models, considering a similar size and same orientation, is energetically better performing than the other. Both have approximately the same façade surfaces on each orientation, and none of them presents a higher solar gain on the south orientation.

Once the architectural design and materials are defined, energetic performance of the different buildings is obtained through simulations. The material properties on the same geometrical models will be modified to define the energetic improvements.

Simulation process is based on some data hypothesis since the reality of the buildings daily use is still unknown. These hypotheses are coherent to the final use of the building and based on previous experience. Some of the basic hypotheses are:

- The only conditioned areas in the buildings are the dwellings.
- Heating will be considered but not cooling.
- Heating temperature will be considered 22ºc.
- Heating will be working only from 07:00 to 23:00, and from October 15th to may 15th.
- Air renovation due to infiltration is considered as 0,25 ren/h.
- Air renovation through mechanical ventilation is 0,75 ren/h.
- Dwelling occupancy average is 3 person and distributed daily:
  - 00:00 – 08:00: 100%
  - 08:00 – 13:00: 30%
  - 13:00 – 15:00: 100%
  - 15:00 – 20:00: 30%
  - 20:00 – 24:00: 100%
- Internal thermal gain is considered 12 W/m2 and distributed daily:
  - 00:00 – 08:00: 10%
  - 08:00 – 13:00: 100%
  - 13:00 – 22:00: 25%
  - 22:00 – 24:00: 10%
- Thermal gains due to lighting are considered 5 W/m2 and distributed daily:
  - 00:00 – 08:00: 0%
  - 08:00 – 13:00: 100%
  - 10:00 – 15:00: 0%
  - 13:00 – 20:00: 25%
  - 22:00 – 24:00: 100%

ENERGY EFFICIENCY CERTIFICATION

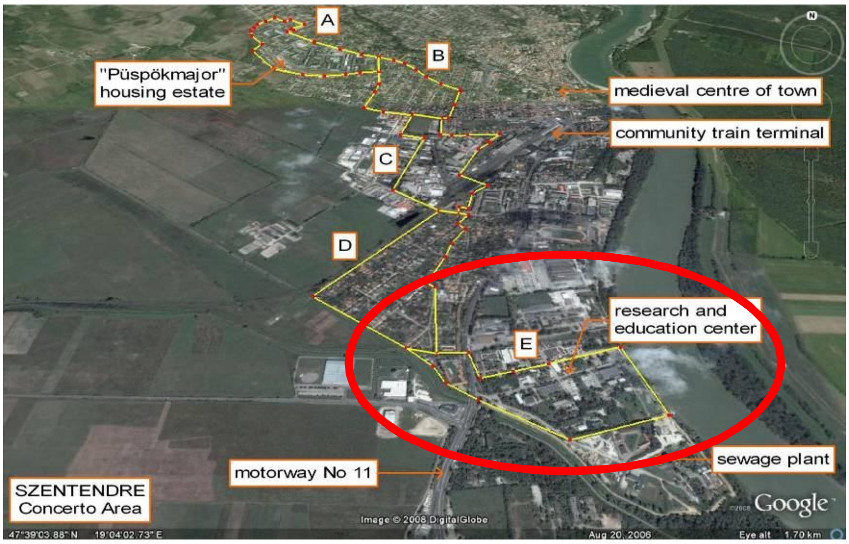
The three buildings' projects have achieved the best certification label: A (calculations have been made with the CALENER software, which is the Spanish official tool for certification).

Energy certification	A-32 (176 flats)	A-31-N (128 flats)	A-31-S (128 flats)
Annual energy consumption			
kWh/year	1,042,696.3	606,970.8	575,995.1
kWh/m²	68.1	45.2	43.5
Annual CO2 emissions			
$kgCO_2$/year	76,182.4	130,316.7	124,438.5
kgCO2/m2	5.0	9.7	9.4
Energy certification	A	A	A
			

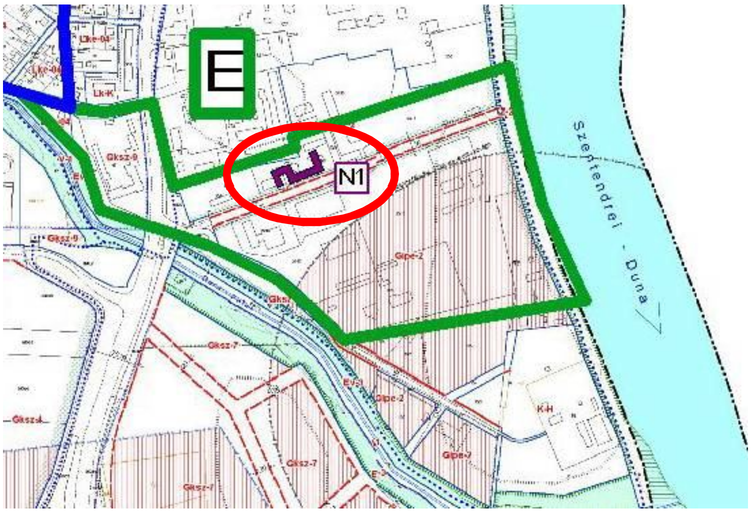
7.2 Szentendre case study - ÉMI new Office Building, Szentendre

7.2.1 Location

The Industrial Park of EMI is situated in the southern area of Szentendre between river Danube and main road 11, close to the waste water treatment plant. The planned building can be reached from the road which runs along the southern edge of the L shaped corner plot.



Szentendre Concerto area Source: EMI



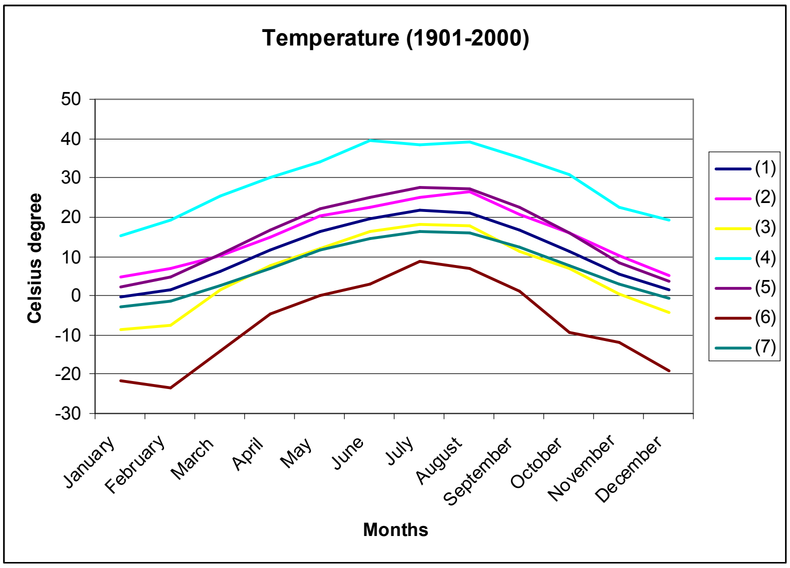
EMI Industrial Park, Source: EMI

7.2.2 Climate data

Climate data (except RH data) for Budapest, which is about 20 kilometres far from Szentendre, has been collected from the National Meteorological Service (OMSZ) of Hungary.

Temperature

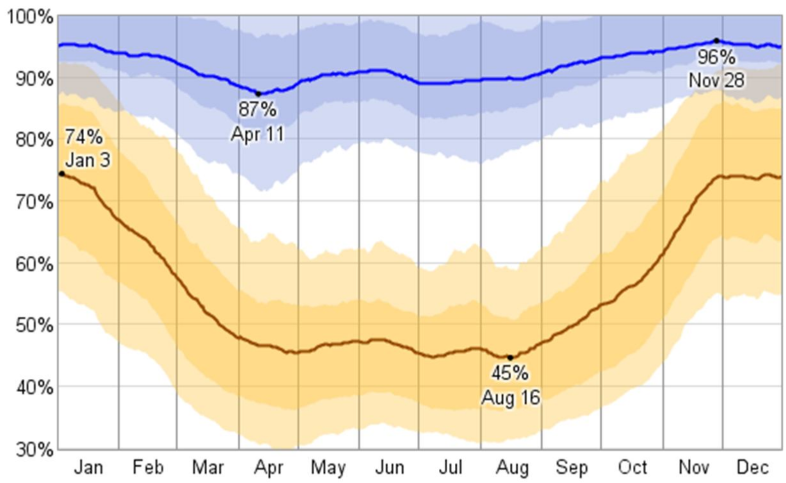
Monthly mean, maximum and minimum temperatures are shown in the chart below (source: OMSZ).



(1) 100-year average of monthly mean temperatures
(2) the highest monthly mean temperature between 1901 and 2000
(3) the lowest monthly mean temperature between 1901 and 2000
(4) the highest maximum temperature between 1901 and 2000
(5) 100-year average of the maximum temperatures
(6) the lowest minimum temperature between 1901 and 2000
(7) 100-year average of the minimum temperatures

Relative humidity

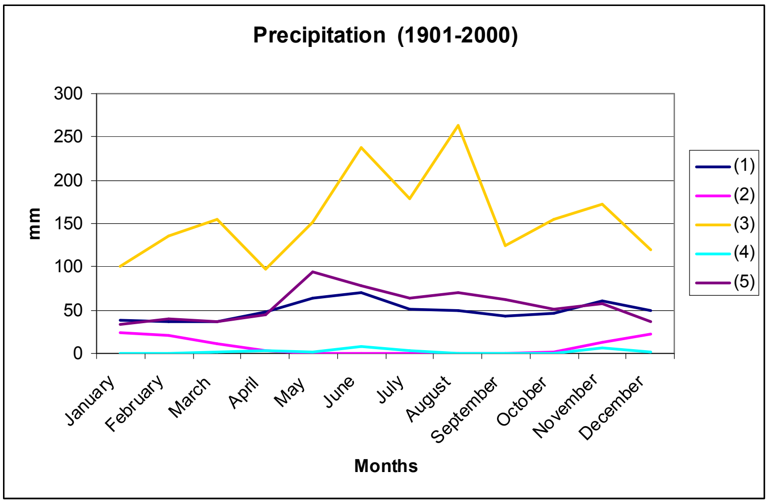
The average daily high (blue) and low (brown) relative humidity is shown in the figure below (Liszt Ferenc International Airport, Budapest, timeframe 1974 – 2011).



Source: www.weatherspark.com

<u>Precipitation</u>

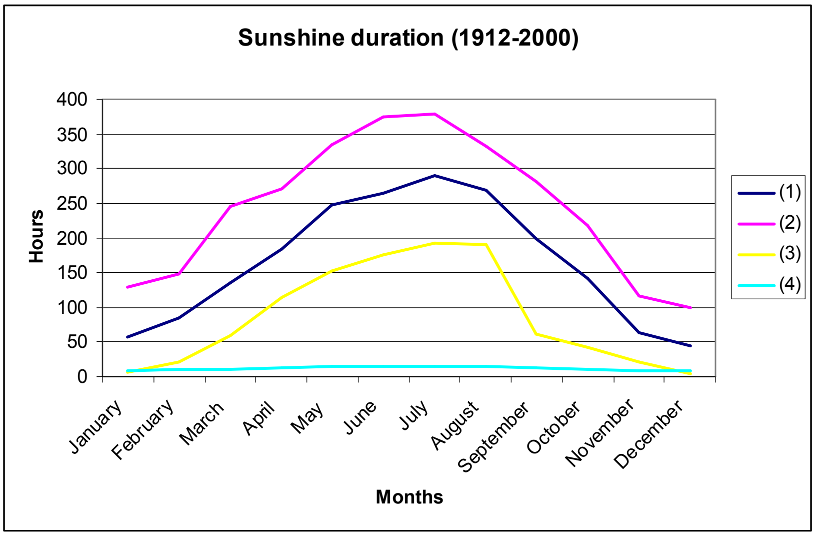
Monthly mean, maximum and minimum precipitation are shown in the chart below (source: OMSZ).



(1) 100-year average of monthly precipitation
(2) 100-year average of monthly precipitation from snow
(3) the highest monthly precipitation between 1901 and 2000
(4) the lowest monthly precipitation between 1901 and 2000
(5) the highest daily precipitation for each month between 1901 and 2000

<u>Sunshine duration</u>

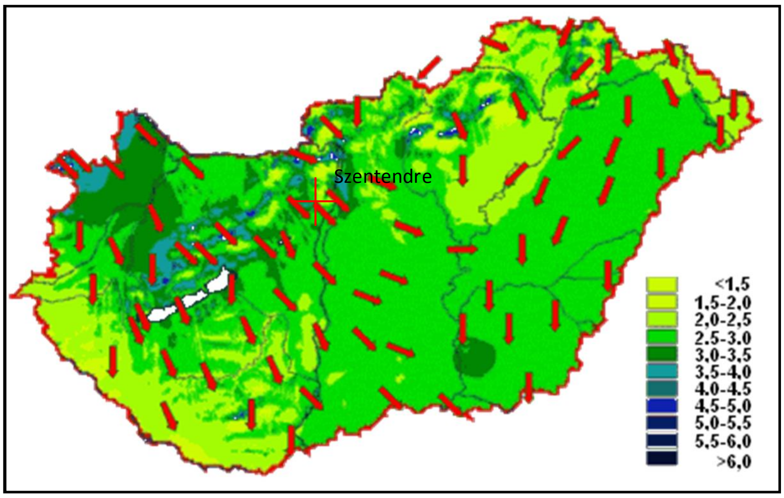
Monthly mean, maximum and minimum sunshine duration are shown in the table and chart below (source: OMSZ).



(1) 89-year monthly average of sunshine duration (1912-2000)
(2) highest monthly sunshine duration (1912-2000)
(3) lowest monthly sunshine duration (1912-2000)
(4) the highest daily sunshine duration for each month between 1912 and 2000

Wind

The dominant wind direction in Hungary and the yearly average wind speeds in m/s are shown in the figure below.



(Source: OMSZ)

7.2.3 Building description

General

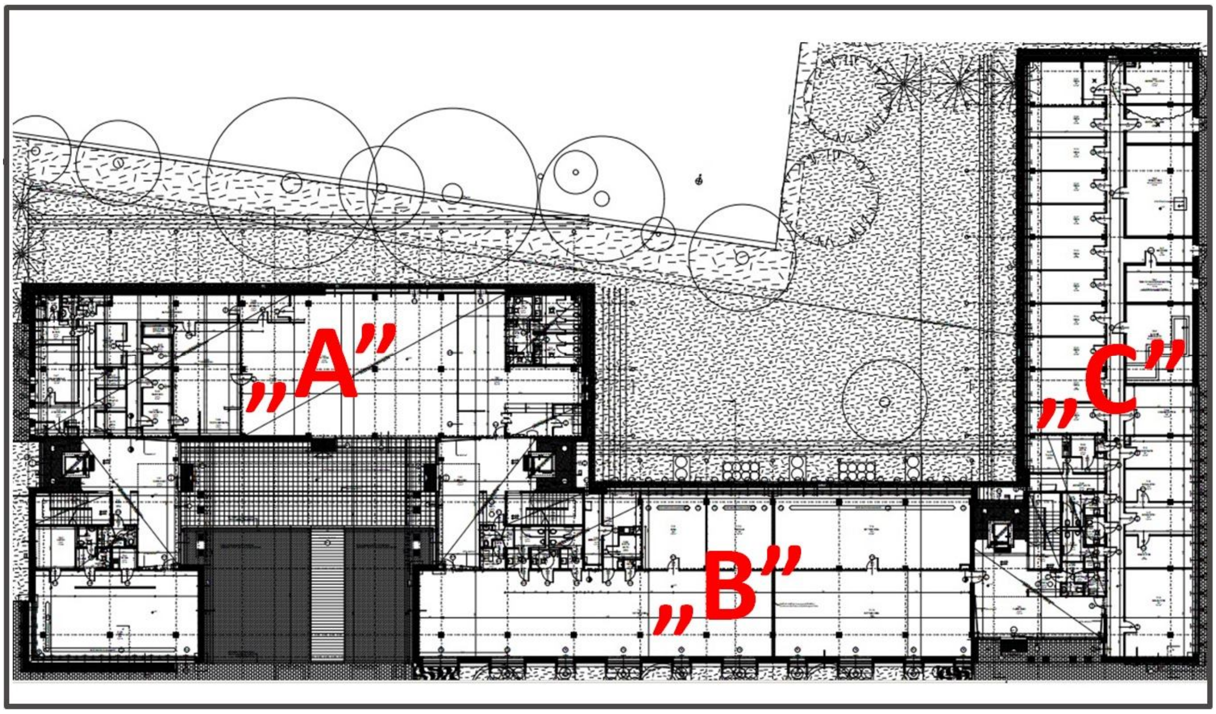
The 3-storey office building, which might also be used for educational purposes, has a gross built-in area of appr. 2200 m^2. The layout is split into three separated office sections (and three wings), each of them has a separated entrance, reception and staircase. Layout of the offices on the ground floor and upstairs can be varied, either open plan or cells can be formed. On the ground floor there is also a restaurant for 120 people.
The building has an in-situ concrete load-bearing column and beam frame. The concrete frame is filled with clay masonry units which are externally covered by rockwool thermal insulation and pre-cast concrete or steel cladding with a ventilated airspace. Windows in the external wall have thermal insulated glazing in aluminium profiles with thermal breaks and in some facade areas curtain wall has been installed. On the roof of the “A” wing there is an

extensive green roof. Plasterboard suspended ceiling has installed above the corridors and some of the office areas.

After the preparatory works and design the construction work of the building has been completed in March 2013 at the Industrial Park of Szentendre. The new office building called ÉMI Knowledge Centre has 5680 m2 net floor area.

Layout

Layout sketch showing the atrium and the different wings, Source: EMI



Ground floor layout, Source: EMI

Design principles

Buildings with a low-energy consumption label in Europe have a consumption of 5-50 kWh/m^2/year (in case of „passive houses” this is less than 15 kWh/m^2/year).

Energy consumption of buildings significantly depends on the climate. Hungary has a continental climate, so normally the most energy is used in winter for heating. However, due to global warming, protection against summer heat is becoming an important issue as well. In accordance with energy calculations and experience, it can be shown that modern office buildings equipped with air-conditioning systems consume more energy in summer for cooling than in winter for heating. In case of well insulated office buildings the internal heat load from lighting, computer equipments and people working inside the building is so high

that it can significantly reduce the length of the heating season while extend the cooling period.
The main conceptions of a low-energy consumption building for a given layout are:
- intensive thermal insulation of the building envelope (with no thermal bridges, i.e. nearly zero heat losses at the junctions),
- adequate air-tightness,
- maximum solar gain and thermal storage mass,
- mechanical ventilation with heat recovery system,
- proper shading,
- using of renewable energy sources and low energy electrical equipments.

This case study deals with the building envelope only from architectural and constructional point of view. However, it should be noted, that the heating and cooling of the building will be provided by the heat pumps installed at the nearby waste water treatment plant.

Bioclimatic design elements
- increased thermal insulation and air-tightness of the building envelope;
- efficient shading (external and internal light diverting blinds, shading of the atrium);
- slanted facade glazing;
- double skin glazed facade;
- water surfaces around the building;
- green facade;
- green roof;
- programmable building management system.

Increased thermal insulation and air-tightness of the building envelope

The building envelope was designed with the following thermal insulation thicknesses:

External wall, cladding with ventilated air-space:

- 20 cm in situ reinforced concrete
- 25 cm thermal insulation (recycled rockwool insulation)
- air-space
- horizontal metal strip cladding or pre-cast concrete panel cladding

U-value:0,13 W/m^2K

Flat roof, extensive green roof:

- extensive green roof
- 22-32 cm thermal insulation (recycled polystyrene insulation)
- 20 cm in-situ concrete slab

U-value:0,13 W/m^2K

Slab-on-ground floor:

- Floor finish
- 20 cm reinforced concrete screed
- 40 cm thermal insulation (recycled polystyrene insulation)

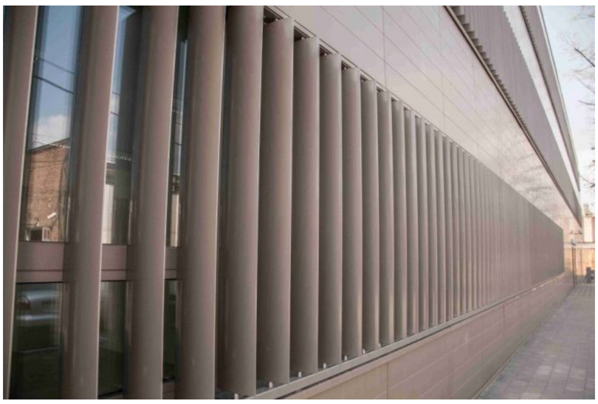
U-value:0,19 W/m^2K

Windows: triple-glazed windows; $U_w \leq 0{,}8\ W/m^2K$ (on the East and on the North facades)

Shading

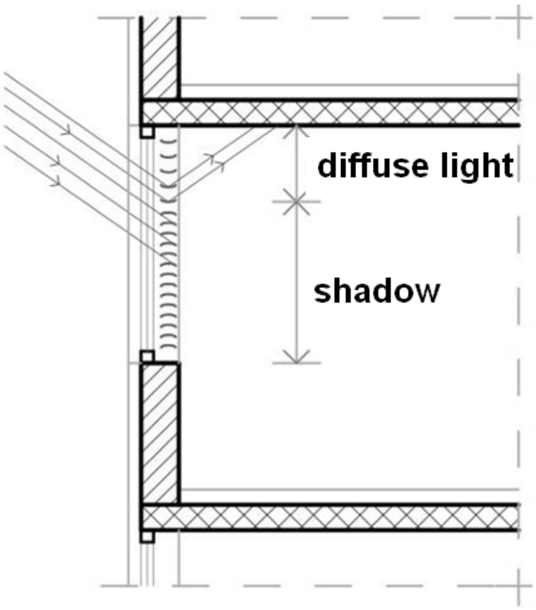
External movable louver blades

On the east and west facade of the building large aluminium louver blades rotating around a vertical axis were designed in front of the windows and the curtain wall in the plane of the cladding. The aluminium louver blades in front of the windows with a size of 130/180 cm on the wing “C” of the building have a height of 160 cm and a width of 150 mm. The blades are 3,10 m high and 225 mm wide on the western facade of wing “A” in front of the curtain wall.
The shading devices are operated manually or by the building management system in accordance with the actual weather and sunlight conditions. This centralised operation can be overruled by the users of the offices.

Internal light diverting louver blind

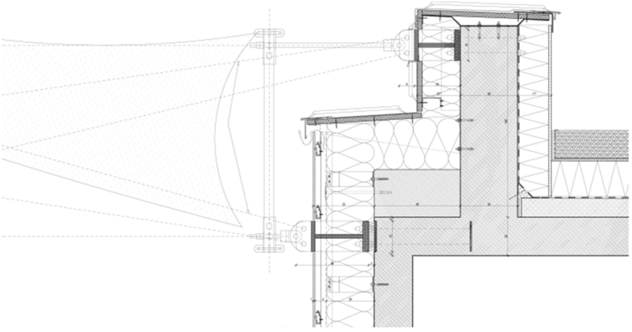
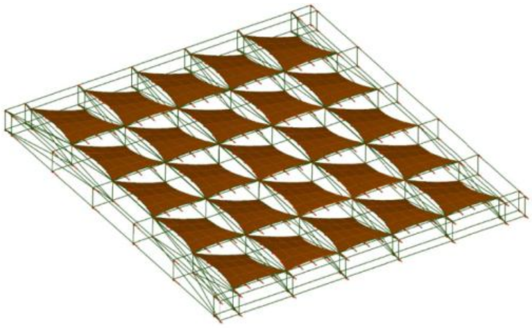
All of the office rooms, independently from the external shading, are equipped with an internal louver blind. The internal blind consists of 50 mm wide “C” shaped strips made of hard-elastic aluminium alloy. The upper one-third part of the blind can be moved separately, so it can divert the sunlight to the ceiling providing diffuse lighting in the offices. It can be operated directly from the offices or from the boardroom and auditorium.



Shading above the atrium by sun sails

The U-shape atrium at the main entrance of the building is shaded by sun sails. The main load-bearing structure of the shading is a double-layer tensioned net made of galvanised steel tendons with a mesh size of 3,30 x 2,80 m. The distance between the net layers is 100 cm. The tendons are attached to the reinforced concrete parapet walls and lintels with galvanised steel connectors.

The material of the sun sails is PTFE coated polyester yarn in white colour or other light colour determined by the architects. The sun sails are attached at three points to the upper and at one point to the lower steel net.

The section of the sun shading of the atrium
Source: EMI


Slanted glazing

On the south facade of the building window boxes are built with slanted glazing. The substructure is a reinforced concrete wall with a parapet section and small openings. The window boxes are in two types; single with a size of 135/170 cm and double with a size of 270/170 cm. The boxes are made from coated aluminium curtain wall profiles with thermal breaks. The profiles and the thermal glazing are designed by the manufacturer. There is a tilting sash at the lower part of the boxes and the bigger upper part is fixed glazing. Since the slanted glazing is positioned above head level and due to safety reasons, the external layer of the glazing must be 2 x 4 mm laminated tempered safety glass.

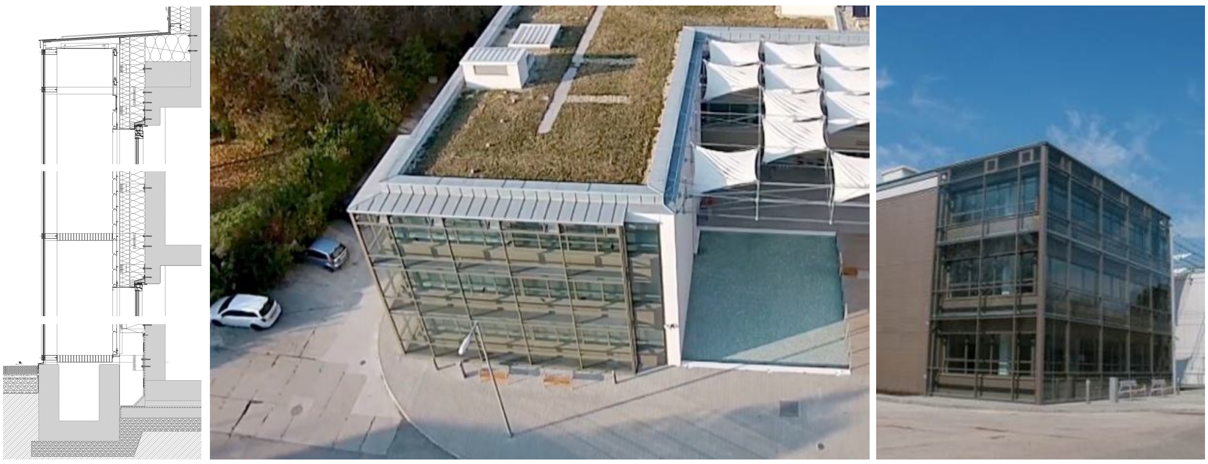
The tilted surface window boxes ensure the natural illumination and the shading simultaneously. Because of the reduced thickness (15 cm) mineral wool insulation around the tilted windows, it was made with special care.

The external cladding of the window boxes are made from 3 mm thick semi-hard coated aluminium sheet folded in accordance with the geometry required and attached to the reinforced concrete substructure in an air-tight and water-tight way.

The slanted glazing on the façade
Source: EMI

Double skin glazed facade

At the south-west corner of the building a double skin glazed structure is constructed. This is a closed space in front of the plane the facade with a width of 55 cm, which is enclosed from the exterior on each side.
The frame of the external skin is made from curtain wall profiles without thermal breaks. The external glazing is a single layer, 8 mm thick tempered glass. The frame, which is made from vertical members, is a suspended structure. The connector brackets are positioned at the level of the walking grids at each floor level, and the vertical aluminium members are elongated at this height as well.

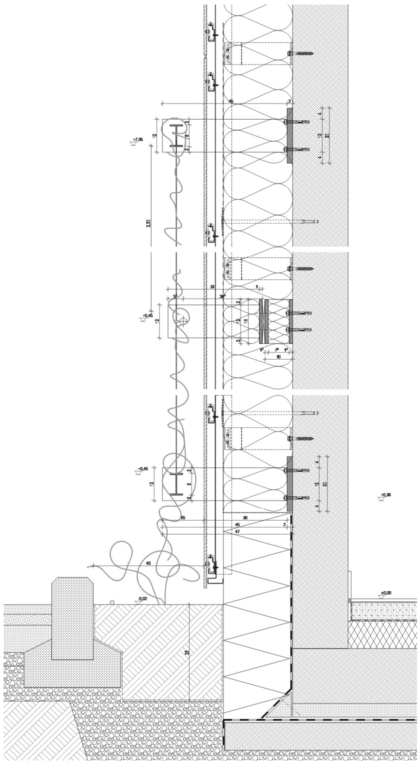


Double skin glazed façade
Source: EMI

The upper metal capping is similar to the adjacent facade sections. At the ground level the curtain wall is not supported by the reinforced concrete air-duct, it is attached with brackets to the reinforced concrete wall in the same way as at the upper levels.

Green facade

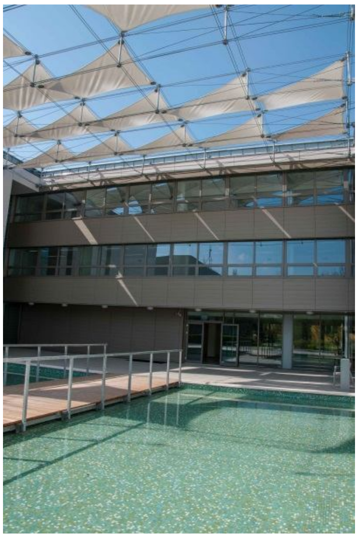
At the south-east corner of the building a green facade is formed with a size of 7,20 x 7,50 m (54,0 m^2). Wisteria plants will climb on a supporting frame in front of the ventilated pre-cast concrete panel cladding. The frame is made from a stainless steel wire mesh 10 cm apart from the plane of the cladding and it is attached with stainless steel brackets through the panel joints.



Wisteria is planted at every 40 cm. The plants require careful and continuous maintenance and they had to be cut to a proper shape every year. Continuous water supply of the soil is provided by a drop irrigation system.

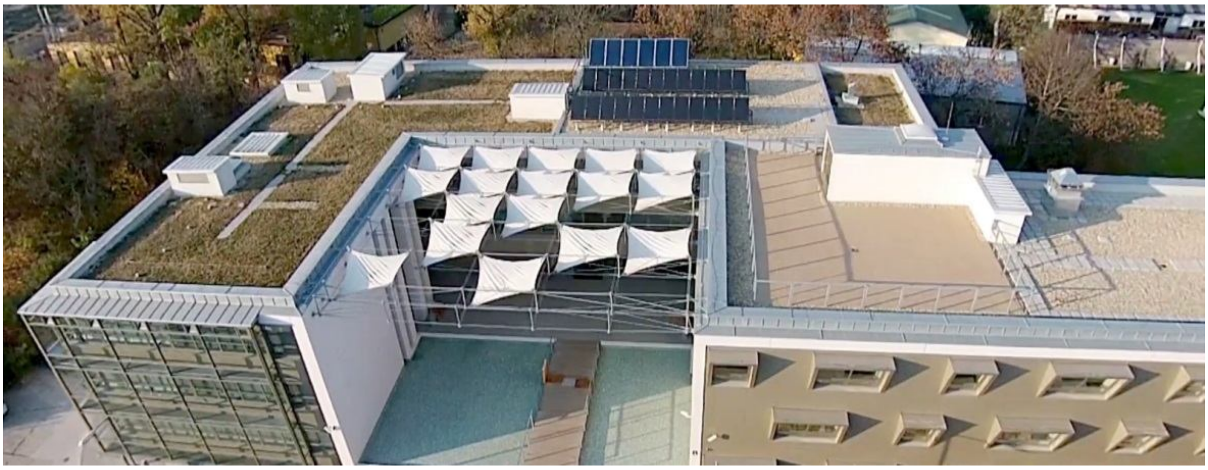
Water surfaces

Water surfaces surrounding the building cool the air temperature in a passive way by 2-4°C due to evaporation improving the microclimate significantly in the hot summer period. The total planned water surface in the atrium and directly in front of the southern elevation is 190 m^2. The water is supplied from a drilled well and fed into the grey water system of the building through the external water ponds for flushing toilets. In this way the continuous fresh water supply and water change is automatically provided without any additional water pump or water cleaning equipment.



Green roof

As opposed to simple flat roofs without access under which the summer heat is the most unbearable, green roofs have significant cooling effect due to their big mass, so they can keep the room temperature under themselves lower. In addition, due to the plants and the evaporation of the wet soil surface, the temperature around the building can decrease further. Because of the maximum allowed building height required by building regulations, only extensive type green roof can be executed.



Heating-cooling

The highly efficient surface heating-cooling suspended ceilings and the heating-cooling surfaces have been installed in the office building adjusting to the heat pump system.


The building has four pipe system included separated heating and cooling pipeline pairs. On the first and 2 floor of the east wing there are tempered structure slabs, the plumbing was directly incorporated into the reinforced concrete structure. The rest of the building the cooling and heating panels provided proper thermal comfort placed afterwards to the reinforced concrete slabs. Downstairs in the restaurant and in the board and conference rooms located upstairs the air comfort provided by the air ventilation system.
The finishing works of the control system have been completed. The test run of the heating system was done, and the results were show a successfully installed and appropriately working system.

In summary the progressive elements of the new office building are the followings:

- recycled PS insulation on the roof
- recycled thermal insulation on the façade
- extensive green roof
- internal courtyard shading by canopy structure
- water surface for summer cooling at the entrance
- climatic façade with double glazed skin
- green façade
- tilted windows
- façade orientation optimized glazing
- external vertical flexible shading and internal venetian blinds
- highly efficient surface heating and cooling
- During the construction a photo documentation system was set up based on hourly taken pictures.

The building will be qualified by a BREEAM (in use) certification procedure.

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