DEBATES: MORE about LESS [emissions]

TOPIC 6

ENVIRONMENTAL CONTROL

Passive Systems in Collective Housing

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HISTORY

Designs around us are determined by the control of energy, and both our experience and the observation of living creatures, their behaviour and their design warn us about the importance of the energy factor. Living creatures are machines which exchange energy with the environment. Each design follows the different strategies that they have developed in order to optimize the exchange of energy with the environment.

There are many mechanisms where nature uses its energy-focused designs. Mammals, for example, produce energy from food. Their nature allows them to accumulate energy in their bodies; they get an adequate size to optimize their surface-to-volume ratio and to conserve the accumulated energy. They develop a skin, an adequate envelope to conserve or give off heat, and they adapt their shape to the conditions in which they live. The way in which they generate waste products that will be incorporated to the biological cycle seems to be part of a planned strategy.

We can accept a parallelism between our buildings and biological designs because we try to imitate nature to make possible the optimization of the building's energy exchange with the environment.

The approach to the building as an energy exchange system has always been present in architecture. All cultures have been aware of their dependence on the balance between consumption and resources. This consumption has always been regulated through design and, in a second place, through energy production.

Last century's technology boom brought about such big changes that their consequences were not easily foreseen. The result was a completely new construction strategy, characterized by the loss of massivity and the increase of the glazed area, what altered the shape and the behaviour of buildings.

In general, Rationalism or many of its dimensions were aware that a new energy design strategy, in line with the new construction methods, had to be found, taking into account the importance of orientation, landscaping, natural ventilation and lighting, materials selection, etc.

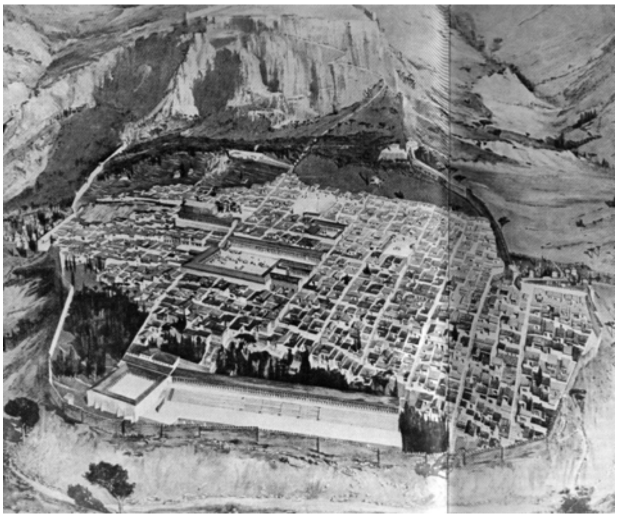
Other approaches and especially the most commercial architecture, decided to use active conditioning systems, forgetting to a great extent traditional design strategies.

Nowadays, the attention to bioclimatic problems is bringing back to the forefront the problem of energy. The objective would be to achieve a type of architecture capable of satisfying our needs using our resources in a rational way and focused in the reduction of energy consumption and pollution.

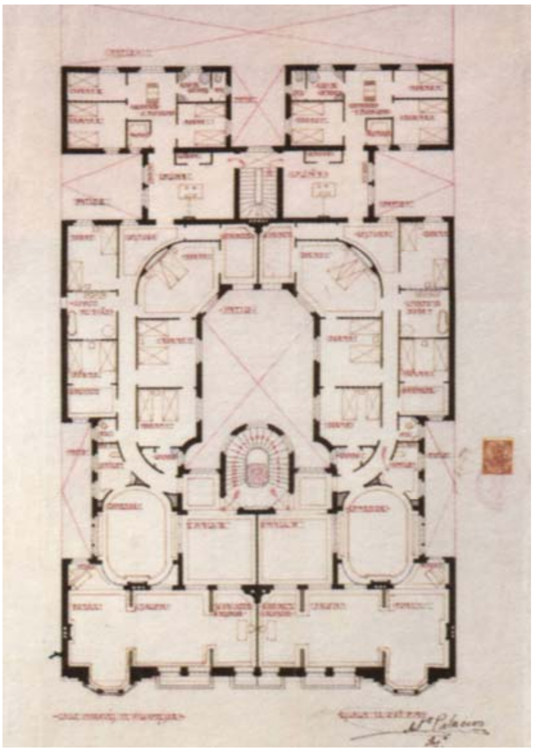
In this change process there is a main problem: the huge intervention in our present environment, the metropolis. Passive energy control systems that were crucial in the ancient world are not so obvious with certain sizes and even less in an "unnatural" environment, the city.

The energy consumption of a building has multiple variables that we can mainly divide in energy used for the construction (materials and constructive elements manufacture, transport and use in the construction site) and the energy consumed for the operation of the building. A problem derived from both is the pollution produced by those consumptions.

Pre-modern societies were necessarily aware of these implications of construction. We can find evidence of that in tribal architecture, where cabins are a clear expression of the control of the resources both for the construction, adopting minimum consumption shapes in their construction and using many materials; and for the consumption, choosing shapes adapted to the climate that minimize the energy consumption.

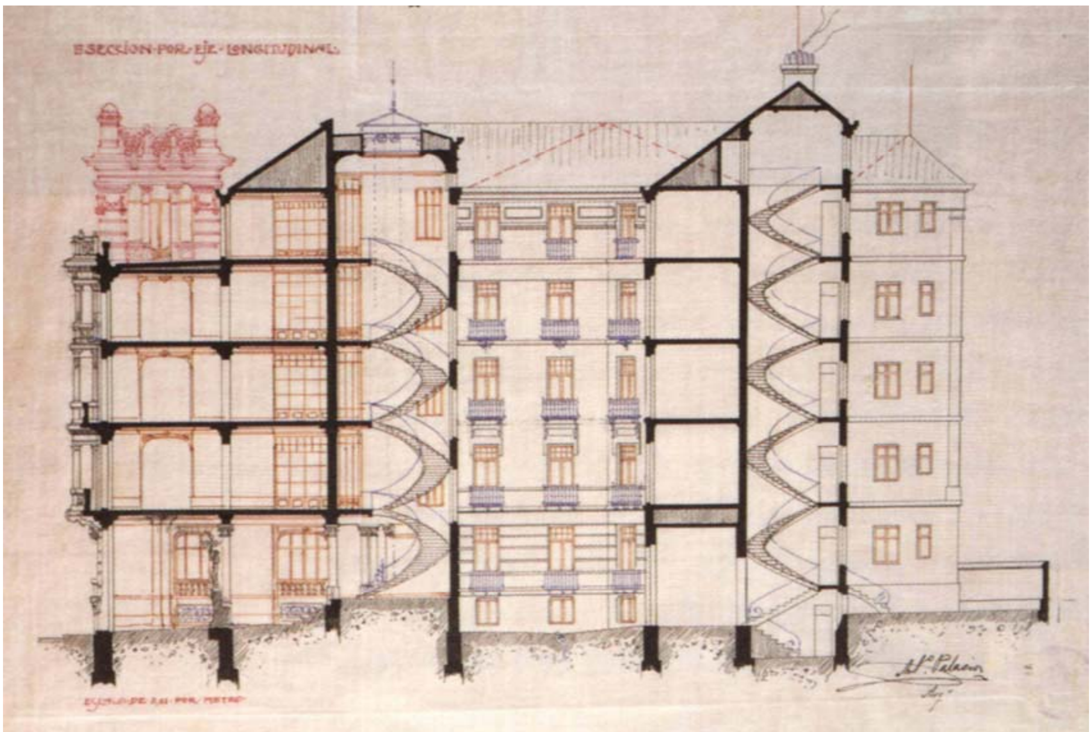


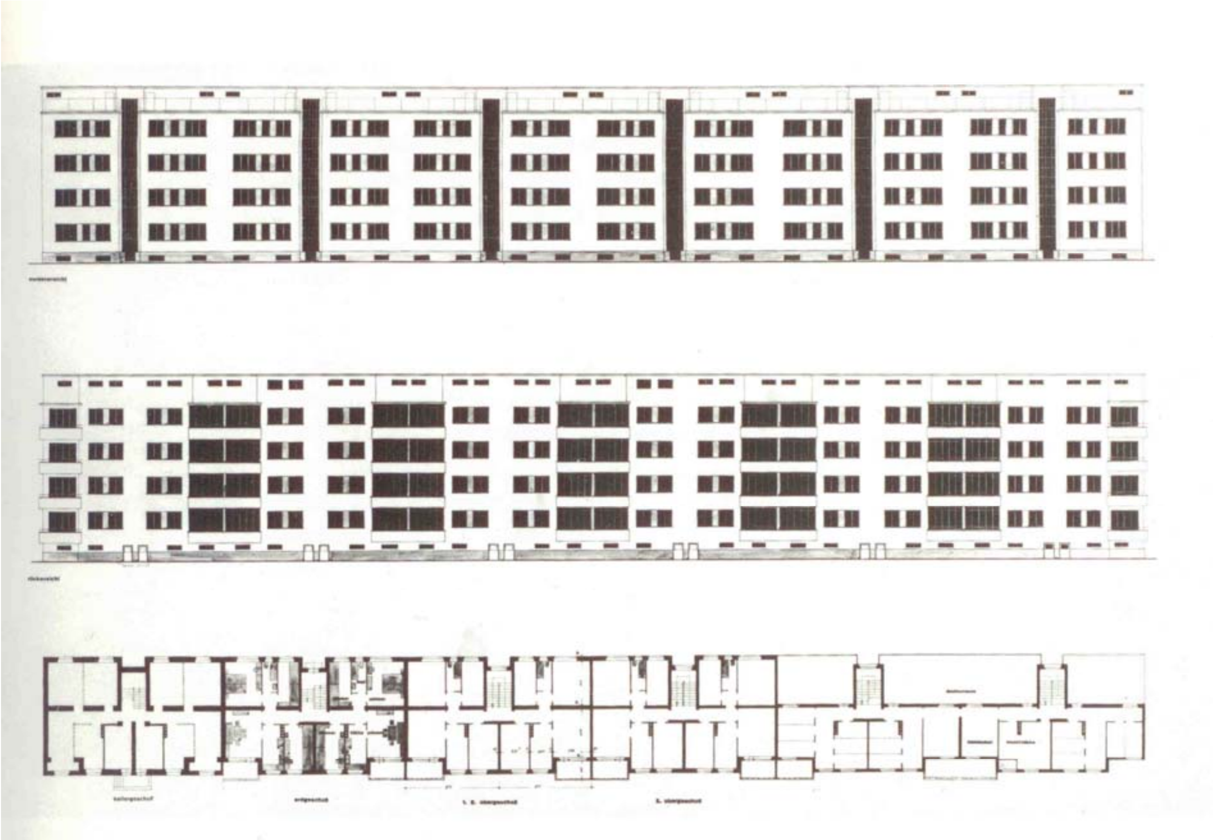
Graeco-Latin and Arabic cities retained the same spirit, with their patio houses grouped on the hillside and facing south. Patio houses are a great example of energy control. Their passive control systems are well-known: thermal inertia of the wall mass, roof ventilation, cross ventilation from façades to courtyards, sun exposure control (with few exterior holes, eaves and porches, vegetation, etc).



Medieval cities were formed by residential type buildings between two walls, a very conservative type: a low enclosure surface-area-to-volume ratio, shapes and materials that store heat, urban planning adapted to the climate, eaves and porches, etc.

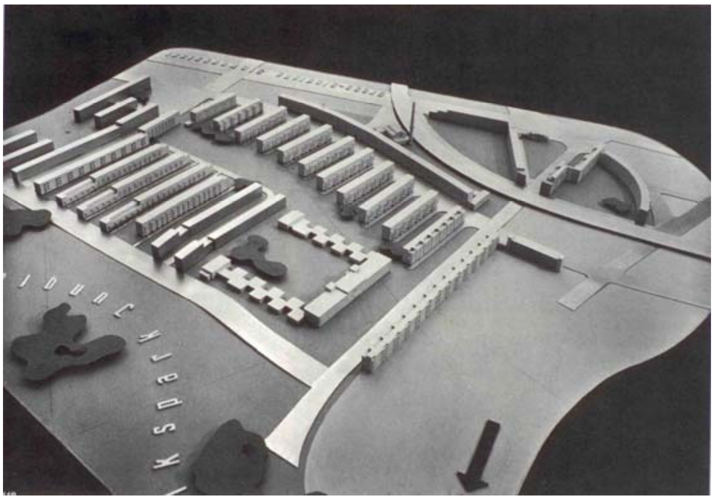
Buildings in the Ensanche can be analyzed in this way too. They are organized with two houses in each floor. Those houses have always two orientations with an inner courtyard. Very thick brick walls dimensioned both for mechanical resistance and thermal insulation purposes become widespread. Decorative elements act as climate defenses. The design of the hole serves both load transmission mechanisms and solar and thermal control mechanisms. The building is vertically organized, devaluing the elements that can be most easily harmed by the environment (ground floor and attic). New elements appear, such as inner courtyards, which bring light to the center of the building, make possible the natural ventilation of wet rooms and help with the cooling during the summer, and other singular elements, such as the balcony and the window's walk (exterior space, winter thermal gains, more light without conduction losses, etc.)





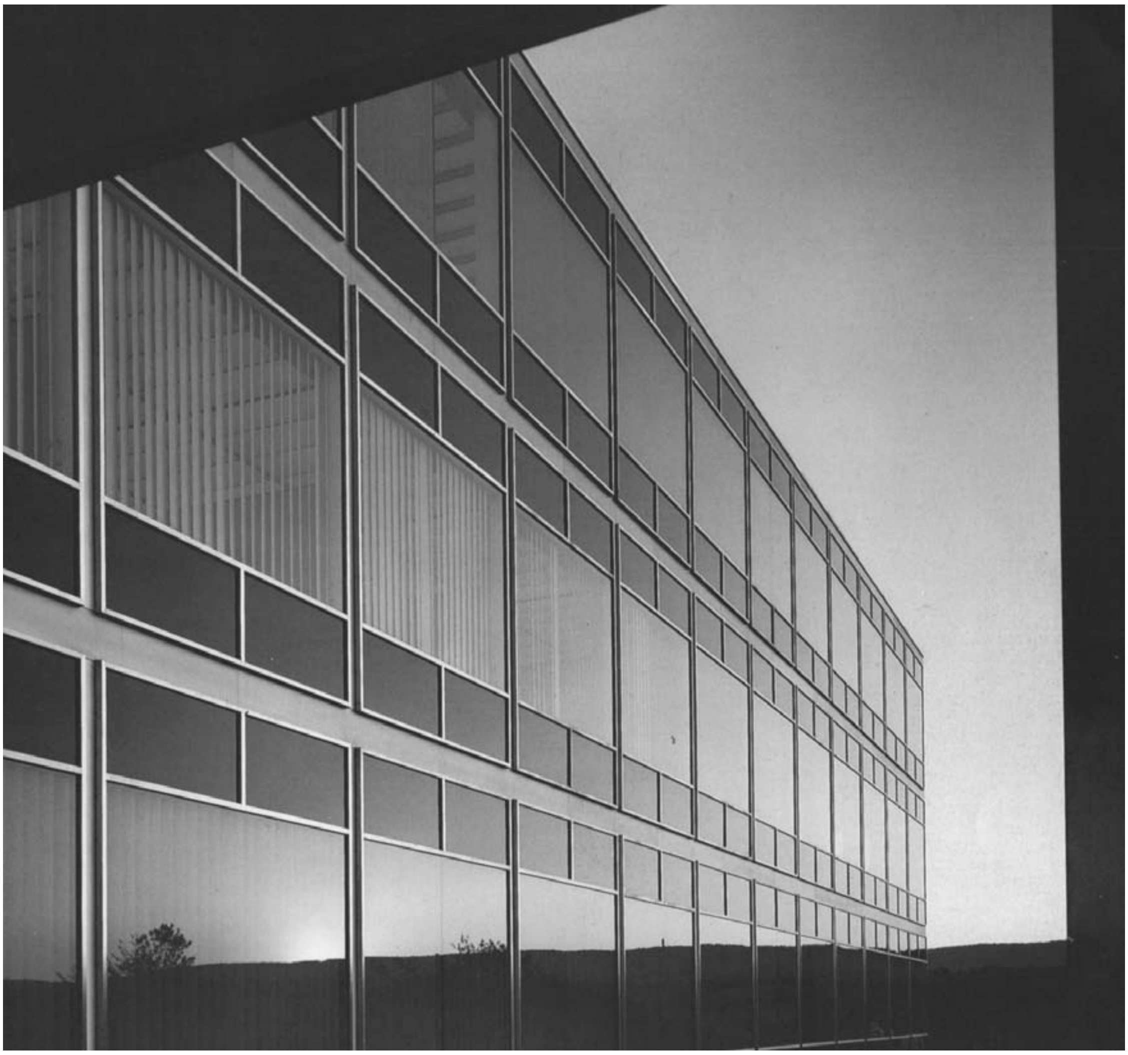
The Modern Movement and particularly CIAM's experience defined the house in strictly rational and scientific terms, trying to find the most efficient organization for the grouping process and the house in all senses: functional, economic, environmental, urban planning, technical, etc. Different solutions are studied. One of the most outstanding is the row houses typology with two orientations, with galleries at both sides or with shared cores and one or two-storey houses.

The size is optimized, what is the first step for the control of resources. The inner courtyard is replaced by the double orientation to open spaces: linear block with length determined by natural lighting and height determined by the lift and the exposure to the sun. The construction is optimized. The flat roof is a constructive rationalization.



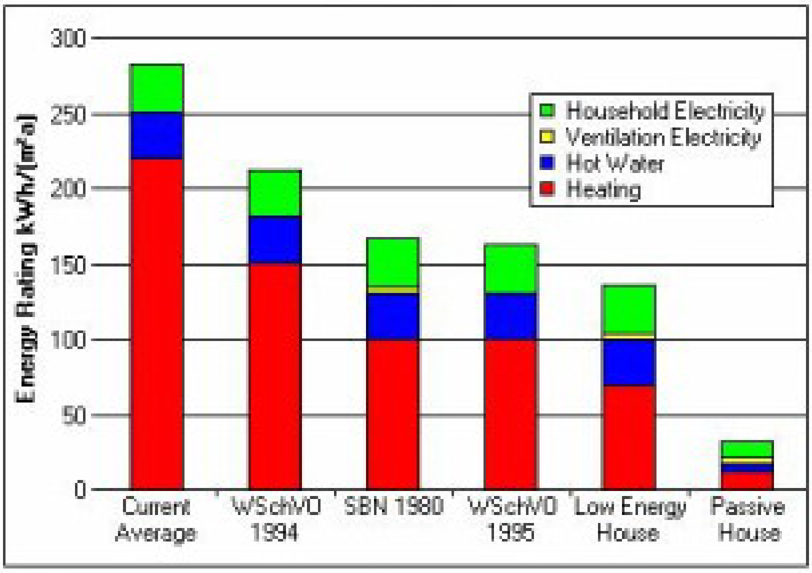
Light frame construction becomes widespread. The structure is always optimized with compensated span systems and the lack of mass is prevented with new materials and solutions: enclosures with air gap, insulation and waterproof elements, sealing materials, etc.

Modern proposals were determined by the solar cycle and ventilation. Even the new constructive rationalization will be a more than advanced solution to the environmental problems we have started to face nowadays.



The progressive lightening, the spread of the use of big glazing and the abandonment of many traditional solutions generated an energy behaviour that has not been known or dominated. The new constructive system does not present a new energy strategy that replaces the traditional one; instead it opts more and more for the production of energy. The drastic change introduced by new typologies, materials, technical systems and industrial processes could not be controlled and have not been controlled yet. In the middle of the last century, architecture permanently broke its relation with traditional culture. The idea of the almighty technique and infinite resources is introduced.

NEW OBJECTIVES



A general objective of present housing policies is to reduce significantly the current annual energy consumption standards. If the usual consumption average estimated is 250 Kwh/m^2year, low consumption houses reduce it to 150-120 Kwh/m^2year or even below 50. Some of the most used strategies for the design of houses nowadays are:

A. ***To reduce the energy cost and the emissions of the building as a construction:***

Promoting materials with low energy of production, certificated and with low emission during the manufacturing; promoting recycled materials and re-used constructive elements and reducing the waste products generated during the construction process.

B. ***To minimize the impact of the building on the site:***

Controlling the construction's pollution and overflow, promoting locations with appropriate infrastructures (public transport, common facilities, etc.) and restoring the site after the works.

C. ***Create buildings with high thermal insulation:***

Promoting compact shapes and construction without thermal bridges, high insulation doors and windows and special glazing.

D. ***To make a good use of solar gains thanks to the south orientation:***

Meeting a significant part of the heating needs (about 40%), to control the sun exposure during the summer and to store heat in the slab and enclosure mass.

E. To achieve air tightness:

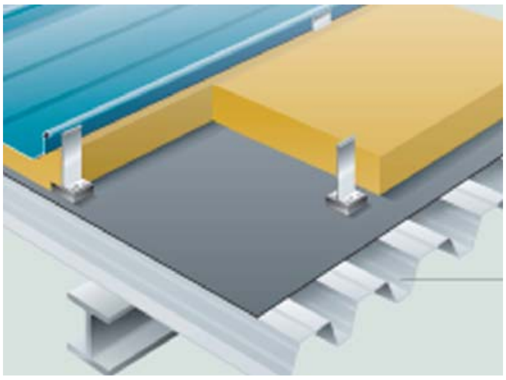
Infiltrations below 0.6 times the volume of air per hour.

F. To reduce pollution:

Implied in the previous sections, storage and waste recycling, etc.

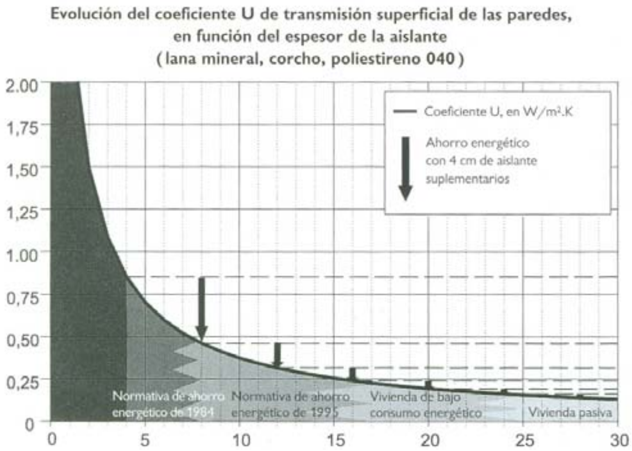
THERMAL INSULATION

The first strategy to reduce heat losses is to insulate the building from the environment choosing the appropriate shape and an insulating envelope.



For wall construction in antiquity they opted for an increase of the thickness. Nowadays mass insulation is being reconsidered, using too its storage capacity. However, in our constructions we use light enclosures that insulate thanks to air gaps and specific insulating materials.

'Superinsulation' is nowadays becoming widespread in Central Europe, with 15-20 cm thickness to reduce transmission to 0.2-0.3 W/m^{2o}C. Insulating glazing is used as well (double and triple glazing, with low emission layers and noble gases, transmission coefficients of almost 1) and thermal bridges are avoided.



We have to remind that the efficiency of the insulation decreases as the thickness increases, since by doubling it we cut by half the thermal losses. Consequently, with small thickness, we obtain big improvements, but the successive increases are less efficient.

It is also important to avoid losses caused by infiltration and air renewal. Infiltration is produced especially through doors, windows and other gaskets. The objective is to achieve a quality in construction that limits losses to the necessary air renewal for habitability.

All those things need to be adapted to the different climate zones, because they can be quite contradictory with our tradition of a half-opened architecture. It is important to bear in mind that a great part of the present development of these strategies belongs to cold climates, so the importance of thermal bridges or the necessity of insulation should be evaluated in each case.

THERMAL STORAGE

The heat storage in the construction materials (thermal inertia) has been traditionally used as a thermal control mechanism.

Systems with a lot of inertia are difficult to regulate: in a high mass construction the heat that we produce is used to heat that mass and to compensate the losses caused by transmission and renewal. The heating will have a very slow response.

During the summer, air is overheated. That mass acts as a heat drain and enables the drop of the temperature of the air. The temperature of the mass envelope needs to drop during the night so that this mechanism can work.

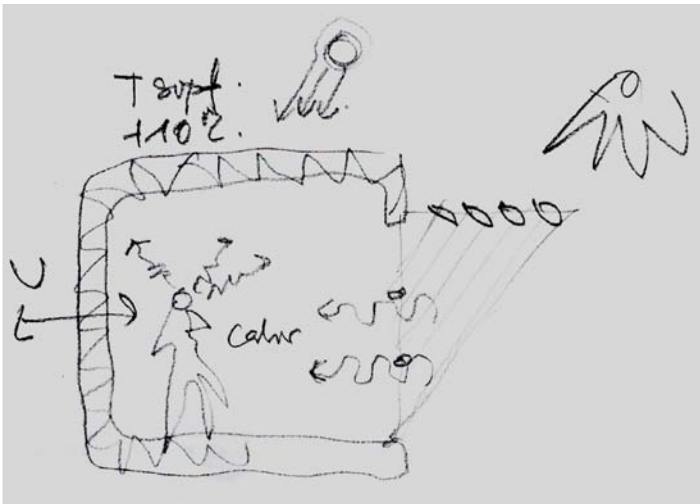
In a light and insulated building the heat generated is used to heat the air and the response is immediate. We do not have thermal inertia and the heat is not stored. We cannot store either the heat generated by direct solar radiation. During the summer the air is overheated because of the lack of a thermal drain.

The problem is to quantify the appropriate inertia and decide where it is placed.

SOLAR THERMAL RADIATION

The intensity of the direct solar radiation on a plane changes depending on the solar height and the angle of incidence. Insolation thermal gains are considerable and the direct ones are around ten times higher than the diffused ones (surface in the shade).

The rise in the temperature of the envelope caused by insolation is favourable in some climates; heat can come through opaque elements (winter) heating the enclosure or the air in the gap. We can also cool buildings by radiation: during the night the environment, especially the sky, acts as a heat drain and the building gives off heat through radiation, cooling itself.



But solar radiation is the cause of many overheating problems, especially in roofs. The sun rises significantly the temperature of the enclosure and the thermal difference between it and the interior is much higher than the one between the temperatures of the air, drastically increasing the conduction heat gains.

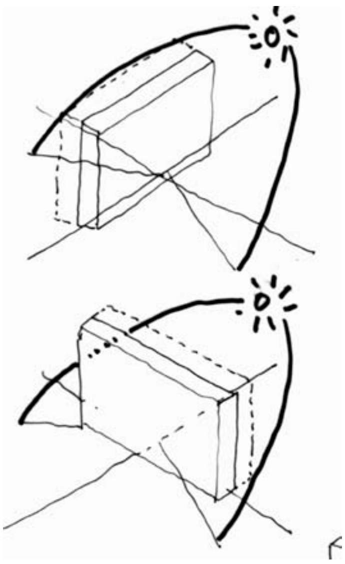
The most important effect of solar radiation is produced when it acts on glass surfaces. Simple glass is transparent to solar radiations, both visible and thermal, but opaque to thermal radiations that come from the interior (greenhouse effect).

Different kinds of glass can reduce the radiation transmission but reducing too visible radiation. The reduction of the overheating produced by solar radiation is only achieved by keeping this in the shade, so that just diffused radiation is transmitted. It is the historical solution of galleries, balconies, mouldings, retracted holes, awnings, blinds, etc.

Many times (winter) the objective is to make use of the radiated heat, since its power is important. The solar radiation that goes through the glass falls on the constructive elements (floor and walls) rising their temperature, so the construction stores some heat that will be radiated inside the space. To that end, constructive elements need some mass. Its storage effect can be improved too with a surface treatment to increase its absorption.

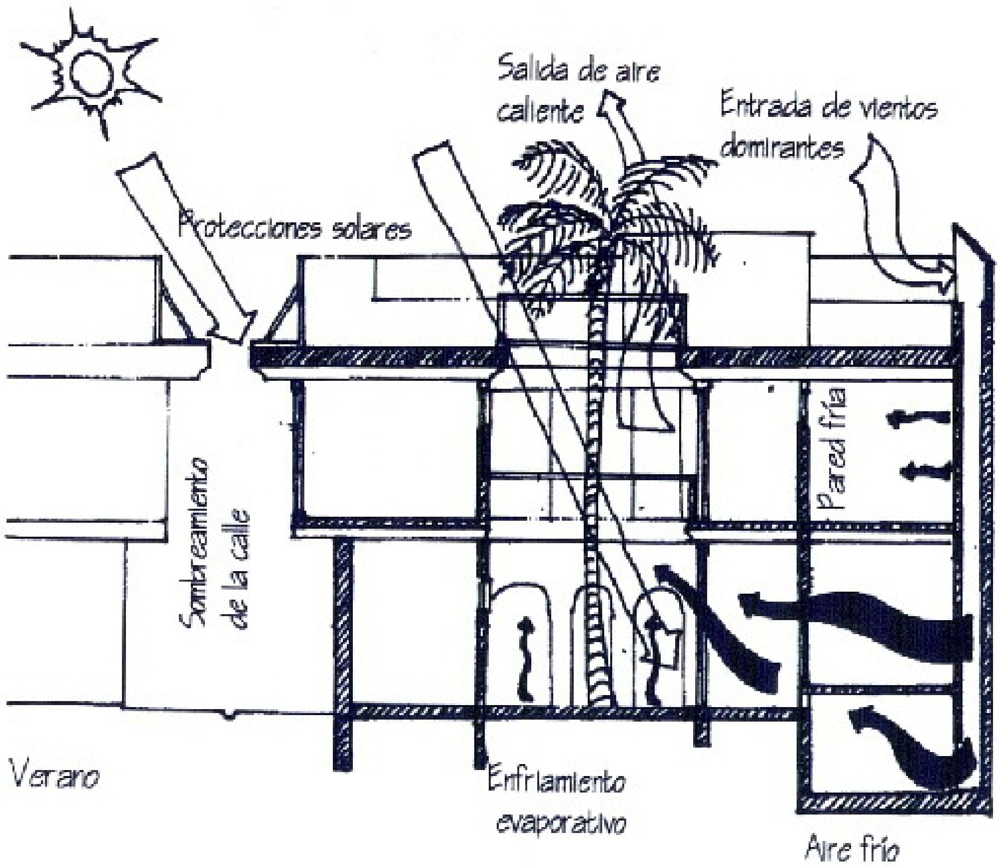
We can generate heat with a Trombe wall system or a glass balcony where solar radiation heats its enclosures. Then we recover that heat with doors and windows in the interior face. When we do not want that heat, we cover the system or we open it to release the heat stored.

The orientation of the façades is an essential aspect, since there are big energy differences depending on the orientations. South orientation has obvious advantages with simple designs, because thermal gains through façades are maximum in winter and minimum in summer due to the angle of incidence. With simple solar protection systems summer radiation can be prevented. East and especially west are more difficult to deal with, since gains are higher during the summer than during the winter (the arc described by the sun is bigger) and it is difficult to avoid insolation when the sun is low. On the west we also have the disadvantage that solar radiation is received too when the temperature of the environment is the highest of the day.



The form factor (S/V) is essential for that, since radiation gains can be not very significant in a building with a not too developed envelop but can transform a space with a small volume and many glass into a solar oven.

VENTILATION AND HEAT

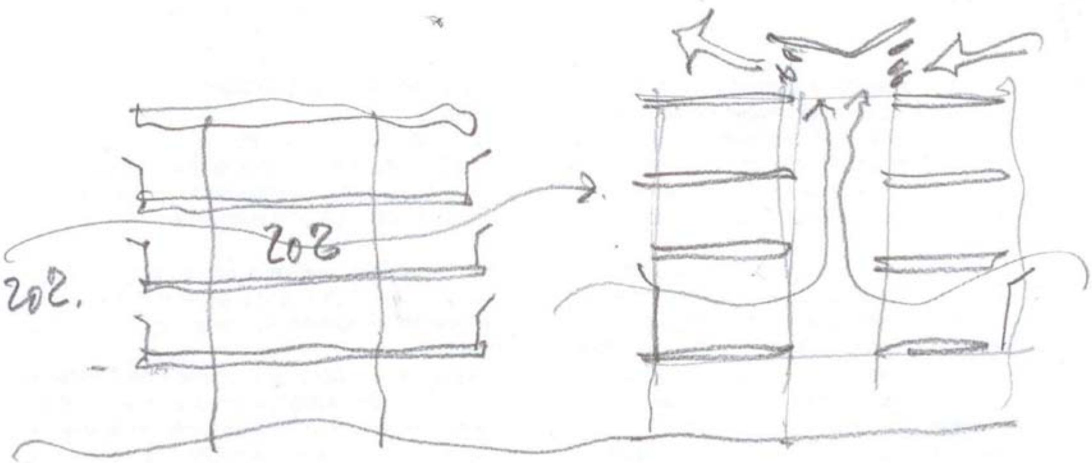


Air can move due to a difference of pressure (the action of the wind) or to a difference of temperature or humidity (hot air is less dense than cold air and humid air less dense than dry air, so they tend to go up).

We are familiarized with natural convective phenomena and with their use in traditional architecture in courtyards, chimneys, ventilated roofs, opposite openings, etc.

We renew the air in the houses to prevent its pollution, mixing it with external air. We try to limit this renewal, because the new air has to be conditioned again. Acting on the humidity of the air will be more difficult.

Air renewal in houses is solved ventilating the space through different kinds of openings, even designing specific holes that control the admission air. We have also seen that a better construction, which reduces infiltrations, makes possible the reduction of the necessary consumption to condition renewal air.



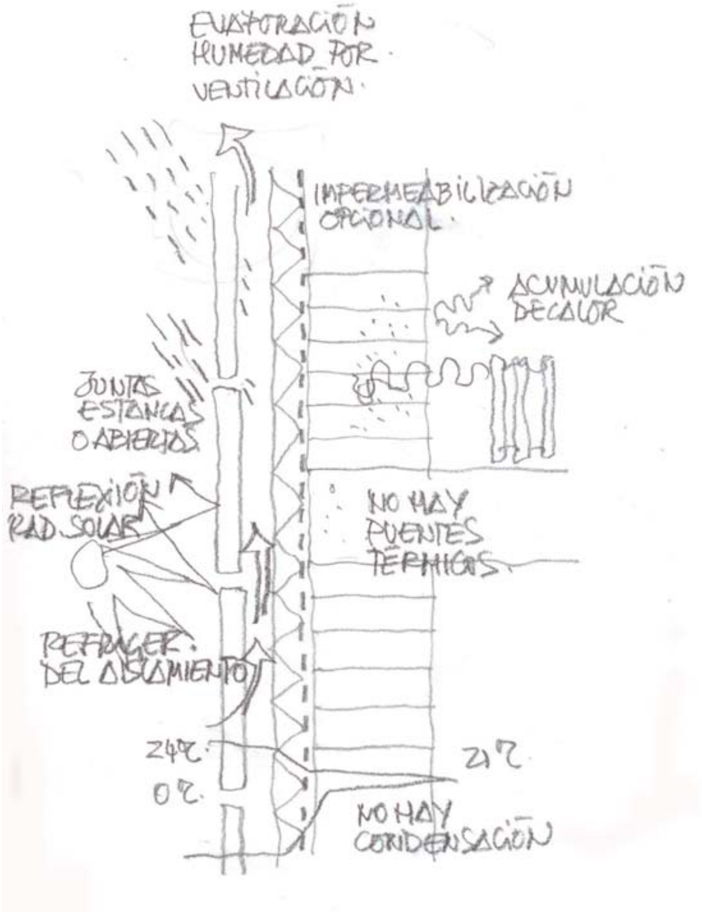
We also use ventilation in conditioning to cool, producing air currents to lower the temperature of a surface. This effect is especially interesting during the night, when temperatures drop and we can release through ventilation the heat stored inside the envelope.

The convection move to cool can be simply generated including some openings in the envelope, so that the pressure of the wind moves the air. Currents can be favoured designing the holes properly and choosing the appropriate shape.

Chimneys are a special case of the use of the shape to produce the movement of the air, but if they are activated in winter when cool air from outside enters into the space and goes up when it is heated, during the summer they have to be activated (with a ventilator, heating the air and increasing its humidity content). Through an underground chimney we receive the admission air after it has run under the ground at a temperature that is lower than the temperature of the environment in summer and higher in winter.

Another option is to include inner courtyards, if they have the appropriate design. During the summer, the temperature of the air in the courtyard goes down and the external air is heated, acting as a barrier for the courtyard, which keeps a lower temperature than the temperature in the rest of the building.

We can also use convection, creating currents inside the enclosure, with air gaps. The air gap can be used to create an air current with which we will lower the temperature of the interior face of the enclosure. If the air gap's openings are at a different height, ventilation will be more efficient, since there will be convection due to the tendency of the air to go up when it is hot. During the winter the ventilation of the air gap can produce more heat losses.



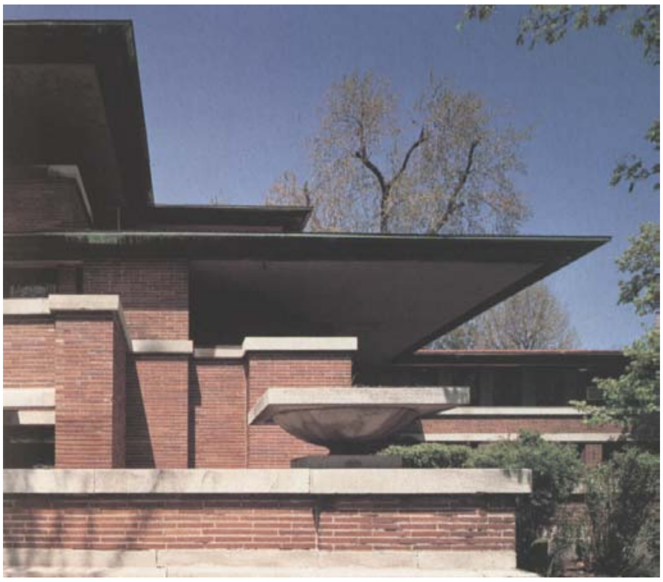
In conventional double glazing the air gap is an insulation technique through conduction, but nowadays thicker glass surfaces with two sheets, open or closed, and with solar control elements are being used. During the winter this air gap acts as an insulation element, especially if it is closed. During the summer its efficiency is more questionable, because the air in the gap has been overheated and it will be unlikely that a convection effect is produced, so heat will not be released.

LIGHT

An average cloudy day has an illuminance of 5,000 lux and we need just 500 for most of the activities that we carry out. However, the energy consumption in electric lighting is very significant and it usually generates 20% of the total consumption in office buildings.

The main problem to achieve a good natural lighting in buildings is the place where it comes from, usually through a wall. Usually the light intensity is very high (excessive with direct radiation) near it and it is lower and even insufficient at a distance of around twice the height of the window.

Besides that, solar radiation transmits both visible and thermal radiation. As a consequence, a lot of light means a lot of heat, especially if radiation is direct.



We can improve the lighting in order to make it more uniform and reduce its thermal contributions applying some basic strategies: the selection of the type of glass, the design of solar protection and the design of the hole (the higher it is, the further the light goes, the longer it is, the more homogeneous it is). Some horizontal reflectors will help to spread the light, which will be reflected. In combination with the materials and colours selection in the interior we can achieve a more regular distribution.

Once again the ideal orientations will be south and north, the second one will offer a less intense but uniform lighting and the first one will be easily controlled with horizontal reflectors.

Obviously, the crucial aspect is the depth of the bay, which has increased progressively for years, leaving many habitable spaces without the possibility of having natural lighting.

WATER AND VEGETATION

Since running water was implemented in buildings we have not been too worried about controlling its consumption and pollution, until it has become a major problem.

Limiting its consumption depends on our habits, but the design has too its consequences on the water cycle. Maybe rain water collection and control is the topic that falls on us, in the first place suggesting its re-use for wet rooms and watering, etc. and in the second place controlling the overflow. Constructions are more and more waterproof, with not too absorbing materials. Drainage is sudden. Some solutions such as landscaped roofs are interesting.

Including vegetation in the constructed space was already done in traditional construction, especially in exterior spaces such as courtyards and balconies. In modern architecture that has become a very important aspect, in relation to the search of the green city. Landscaping has many potential for climate control and consumption and the interest to promote landscaped spaces around buildings is clear and will be the best response for thermal conditioning in climates like ours.

The balcony offers a landscaped space that can be hardly bet, but we can see everyday how 'heat traps' are built where wonderful balconies had been planned. The introduction of vegetal elements in those spaces has clear positive consequences for conditioning: solar control, air cleaning, air humidity increase, etc. In roofs that effect is even more favourable and it offers a determining increase of thermal insulation, especially in summer.

Many topics can be mentioned in that respect. For example, some domestic architecture solutions can have a significant influence in consumption, like hanging out clothes. Now that European certificates give priority to their implementation, we should reconsider the drying places that we architects so hated. We could also question whether eliminating natural lighting in wet rooms and kitchens is so clear. And we should also think about waste control through appropriate spaces, which are being spread in Central Europe.

EXAMPLES

As we already mentioned, traditional architecture and many residential buildings of antiquity are full of all kinds of interesting solutions, since they were planned thinking in the control of resources.

We can also find many interesting solutions in modern architecture. Many of its designs are equally determined by energy. Some examples can be some buildings by Le Corbusier, who paid attention to solar control problems, etc. and many others.

In the last few years many house groups have been constructed considering the energy control problem, in general row houses or not too high linear blocks facing south, creating sometimes complete neighbourhoods.

Their philosophy complies quite literally with the philosophy defended by the 'energy saving certificates', centering their innovations in the reduction of heating consumption (through passive solar heat passive gains, insulation, form factor, etc.), the use of traditional materials (brick, wood, etc.), the introduction of renewable energy systems (solar panels to support the heating, PV panels, methane or cogeneration stations, geothermal energy, etc.) and advanced systems (heat recovery in ventilation, water recovery and treatment, low consumption appliances, etc.)

In Germany many houses like those are being constructed, what reminds us of the first residential neighbourhoods of the Modern Movement in Central Europe. Some characteristic buildings may be the houses built in Freiburg.

Actually, this big group of buildings has derived from the experimentation with the 70s and 80s solar detached houses, of which we can find many interesting examples. I mention that because it is important to bear in mind that the solutions considerated are efficient on this scale. For that reason, for collective housing, where row housing with one orientation is more arguable, there are not significant examples.

REFERENCES

I include here just some works that, in my opinion, have a simple global approach to the topic ‘energy and design’, since the bibliography about the different aspects of the subject is very vast. Internet references make reference to some of the main current energy saving certificates.

Araujo, R -El edificio como intercambiador de energía. Tectónica nº 28. Marzo 2009.

Banham.R- La Arquitectura del Entorno Bien Climatizado. Infinito. Buenos Aires, 1975.

Daniels.K- The technology of Ecological Building. Birkhäuser Verlag. Basel, Boston, Berlín 1994

Gauzin-Müller.D- Arquitectura ecológica. G.G. Barcelona 2002

Lechner.N- Heating, cooling, lighting. John Wiley 2001.

Smith, P.F- Architecture in a climate of change. Elsevier 2005.

Thomas, R- Enviromental Design. E&FN SPON. London-N.York 1999.

http://www.passive-on.org/es/index.php

http://www.minergie.com/home_en.html

http://www.cepheus.de/eng/

http://www.breeam.org/index.jsp

http://www.leed.net/