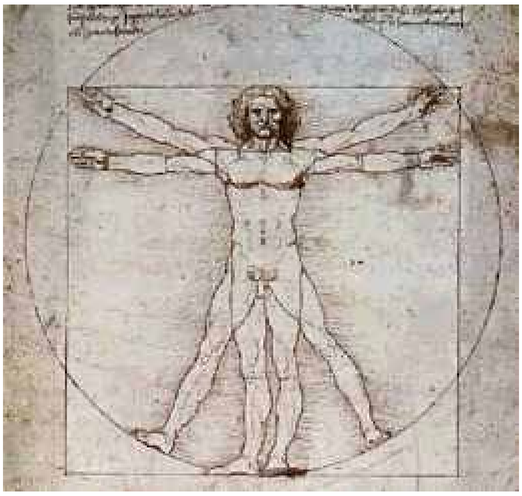
TECHNOLOGICAL EDUCATION INSTITUTE OF PIRAEUS

UNIVERSITAT POLITECNICA DE CATALUNYA

A Study of Energy Efficiency on Agriculture School Building of UPC Placed in Castelldefels Campus



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THESIS

March 2009

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March 2009

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PART ONE

1. CLIMATE CONDITIONS

Sustainable urban design can only succeed on the climate-appropriate planning, which – as the name indicates – must be adapted to local microclimate conditions. The etymological meaning of the word ‘’climate’’ is ‘’slope’’ or ‘’incline’’, in reference to the angle of altitude of solar radiation. This ‘’incline’’ varies both over the course of a day and throughout the year and influences the entire spectrum of climate parameters. However, only those weather factors that directly influence people of the utility of a building are relevant to the architect. These factors are, broadly speaking, temperature, wind and solar radiation.

The heat losses of a building are largely determined by external temperature. In this context, transmittance heat losses are dependent on three equally important factors: the heat-transmitting surface, its insulating properties and the difference between internal and external temperature. While the first two factors translate into measures related to design (compactness) and construction (insulating properties), the third factor is a characteristic of the local climate that cannot be influenced. The more extreme are the external temperatures, the more important is the optimization of the first two aspects.

Glasshouses, the so-called ‘’house-in-a-house’’ principle, or enclosed atria and courtyards, create a buffer zone between interior and exterior.

Warmed by solar radiation, these spaces achieve higher temperatures on average than the temperature of the external air. Consequently, they contribute to energy conservation and provide comfortable interior spaces for a variety of activities. Although the concept opens the door onto attractive architectural expressions, the constructional effort of most realized examples is disproportionate to the energy savings achieved. Overheating in summer is often unavoidable without expending additional energy.

Daily fluctuations in external temperatures can also be significant in summer. Carefully designed ventilation overnight can cool the building mass, enabling it to absorb temperature peaks or the internal heat load during the day.

Wind effects, the energy balance of a building in two ways: first, by increasing the transmittance heat loses through the convective cooling of the building skin, and secondly by increasing the ventilation heat losses through leaks in the building skin. Energy efficient building is therefore based on creating impervious building skins.

The influence of wind is a significant factor in the design of open spaces. Local conditions, above all topography and vegetation, orientation and shape of the built volume or the positioning of buildings in relation to one another, determine the wind conditions in the interstitial spaces and hence their quality as useable outdoor areas. Dense groups of buildings and open spaces or streetscapes with directional breaks prevent a wind tunnel effect. Ancillary buildings (warehouses, sheds, garages, etc.), as well as earth walls or planted wind barriers (trees, hedges, etc.), can fulfill a protective function for the built environment.

For energy-efficient architecture, solar radiation is the most important climate factor. This design concept is therefore known in simplified fashion as ‘’solar architecture’’. We must understand the solar geometry, both in cold climates where its utilization can contribute greatly to heating, and in warm zones, where the focus is on avoiding solar incidence in summer.

Dependent on cloud cover, global radiation is composed of a direct and a diffuse component. The diffuse component of solar radiation is non-directional. Hence, even north facades will receive a certain amount of solar radiation, although it is much lower than in all other cardinal directions. Measures for the passive utilization of solar energy are chiefly based on direct solar radiation. It influences the orientation and distance between buildings as well as the conditions for solar incidence in street- scapes and open areas.

In warm climates, protection from the sun is a more important urban design task. The close arrangement of houses that is typical of Mediterranean regions prevents the heating of the building mass by providing mutual shading. Narrow lanes and courtyards are also protected from direct sun by this means.

In addition to the climate factors we have already explored, location, orientation, topography and vegetation are important in the context of defining the local conditions.

The characteristics of the site are vital for the choice of ecological measures. In an urban setting buildings sites tend to be smaller and more influenced by the surroundings than in rural settings. The topography influences the orientation of the buildings to the sun (slope orientation) or the influence of wind (exposed or sheltered location). A summit location, for example, offers ideal conditions for the utilization of solar energy, while at the same time causing higher heat losses as a result of the greater exposure to wind. A location on a south facing slope, by contrast, makes it possible to decrease the distance between building arranged one behind another, thus enabling higher building density.

Planting vegetation around the building can improve the climate conditions (solar incidence, wind conditions) for the building skill and open spaces. Deciduous trees provide shade in summer and allow solar incidence in winter. Rows of trees can also form wind barriers or act as wind channels for natural ventilation where needed. As a result of evaporation which extracts heat from the environment, ventilation can also be used to cool the outside in summer and hence promote the effect of natural ventilation.

The context in which a building is located determines the degree of potential solar incidence and hence of potentional energy gains. Two urban design factors play a role:
-building orientation and
-distance between buildings (density).
Furthermore, these two aspects are linked to additional factors I urban planning for energy efficient architecture. These are:
-access (external and internal)
-parking and
-open spaces.

2. ENVIRONMENT

The range of impacts of buildings on the environment is diverse. Problems which result from construction-related processes, such as global warming, ozone depletion, loss of natural habitat and biodiversity, soil erosion and release of toxic pollutants are now well known. It is useful to think of the proposed building as a new, living, healthy entity. The building is an integral part of the site. The two diagrams illustrate the linear, open systems of conventional buildings and the closed, cyclical sustainable systems which represent the alternative.

A building is a physical structure composed of different elements and also a kind of “living machine”; a place where people go about their lives, appliances use electricity; temperature must be regulated, and so on. There are two main headings under which the environmental impact of the building must be analyzed:

As a physical structure, a building is dead, the mere “sum of its parts”. These parts are individually extracted, manufactured, assembled, maintained, demolished, and finally disposed of. Each part has a set of effects associated with these processes, and the total environmental impact of the building is the sum of these effects.
As a “living machine” the cost to the environment is that of running the building during its lifetime: the inputs that will be required, such as energy and services, and the outputs, such as CO_2 and wastes.

To establish the true environmental impact of a building, the analysis may be carried out in a way that reflects the relative importance of different building elements and processes, and the priorities for reducing environmental impacts. This is called life cycle analysis. The information required to carry out this task impractical to undertake in most circumstances. It is possible, however, to analyze selected building elements or components. While the idea of cradle-to-grave, analysis may be out of reach for all but the specialist, understanding the concept will help rationalize choices.

While various factors exert their influence upon the different stages of a building's lifetime, it is during planning and construction that almost all of them are fundamentally fixed. Decisions at this time determine the extent of resource and energy consumption during future stages, such as maintenance, renovation, conversion and restructuring.

Issues which need to be considered fall into five mail categories:

- control of energy consumption
- use of materials
- water waste
- waste management
- noise control

Energy

The use of energy in conventional buildings impacts on the environment through the consumption of non-renewable resources and by contributing to global pollution through CO_2, NO_x and SO_2 emissions.

Design for sustainability means that one of the clear design objectives is to minimize the effect of pollution from energy use in three ways:

- Use passive design principles to ensure that the building needs less energy.
- Supplement conventional energy sources with renewable ones such as solar, biomass, wind, etc.
- Where conventional systems are employed specify the most efficient and least polluting types.

In a conventional building, the amount of energy consumed in use (and where that energy comes from) is still the single most important consideration from an environmental point of view. However this situation is changing as buildings become more energy-efficient. The UK Building Research Establishment has noted that in some new, well-insulated buildings, the energy embodied in their fabric could amount to as much as 50% of the energy used to run them over a 25 year period.

Materials

Criteria for the selection of materials and components include cost, aesthetics performance and availability. Environmentally –responsible specification of building materials and components, and of the manner in which they are assembled, means that consideration of embodied energy and local and global environmental impacts must be added. Effects on the building interior and the broader environmental impacts of various categories of materials are covered in HEALTH; materials above.

Materials and their embodied energy value (kWh/m^3)	A	B	C	Variation between sources
Lightweight blocks	417	600	(-)	144%
Lightweight concrete	833	(-)	480	174%
Concrete	625	600-800	368	217%
Timber (imported)	694	754	(-)	108%
Timber (local)	(-)	110-220	53	415%
Bricks	1222	1462	(assumed local)	172%
Plaster	1806	900	2100	247%
Plastics	9300	47000	730	500%
Glass	23000	15000	12000	153%
Steel	63000	103000	15000	163%
Aluminum	195000	75600	78330	258%
A – The Architects	Journal,	8.6.97	151200	
B – BSRIA, Env.	Code of	Practice 1994		
C – Environmental	Science	Handbook 1980		

Embodied energy of common building materials

The choice of materials and components has an important role in determining energy performance. The embodied energy in a concrete structure may be high, but if it is designed to use passive solar heating and cooling, it can easily produce an equal reduction in energy consumption over a few years of use. Other components, such as low-emissivity, windows and efficient heating and lighting installations, are as important to energy efficiency as to greatly outweigh any increased impact from their manufacture and disposal.

2.3 Water

The careless use of water causes a variety of environmental problems. This covers both the supply of water for use in buildings and handling of surface and waste water in built-up areas.

Under most building codes almost all water used in buildings must be of drinkable quality. This is drawn from the natural environment, often reducing groundwater levels and water levels in streams, lakes and marshlands. Its treatment requires the construction and running of water treatment plants, with all the use of materials and energy that that implies.

After use, waste water must be routed through sewers to be treated again before being released, more or less purified, back into the natural environment.

Even where water is not a scarce resource, effects on natural habitats and bio-diversity can be widespread and long-lasting.

2.4 Waste

Household and commercial refuse street litter, construction debris, industrial process, and other wastes together with sewage sludge present environmental problems. Even though existing waste handling systems in most European countries tent to minimize local impacts, eventual disposal has significant effects, including contamination of land, air and water sources, at the regional and global scale. The EU Waste Management Strategy lists a four-stranded waste management system:

- Reduce waste at source
- Sort wastes
- Re-use or re-cycle
- Dispose of water safely

The design team can contribute to sustainable practices on the part of building owners and users by planning safe and adequate storage for different categories of waste. This is the preliminary to recycling or to safe and efficient disposal.

The only time at which the design team has direct influence on the generation of wastes is during the construction phase. Waste reduction through careful handling of materials, and sorting of waste for re-use or re-cycling is within the contractors area of control. In Sweden it has been calculated that the construction of a ten-storey building generates waste equivalent to one full storey. However, the development of more sustainable practices for constructions and demolition wastes is heavily dependent on the existence of handling facilities and of a market for recycled materials.

2.5 Noise

The increase in high-density schemes together with mechanization and urbanization means that noise is a serious problem in most human settlements throughout the world. The effects are local rather than global, but do have a significant impact on the quality of life in affect areas.

2.6 Objectives

i. Use renewable energy sources

Renewable energy sources can be integrated as design features in most new or existing buildings. This leads to a reduction of fossil fuel consumption for heating and air conditioning, minimizing the environmental impact of buildings and contributing to the reduction of the CO_2 emissions.

- Minimize the energy demand of buildings for heating, cooling and lighting purposes, by making use of passive solar systems and technologies (atria, sun spaces, solar walls, solar chimneys, ventilated roofs and walls, day lighting, etc.).
- Use air solar systems and collectors for providing adequate ventilation exchange rates to the indoor environment.
- Make use of water solar systems and collectors for basic hot sanitary water requirements and low temperature space heating of building settlements.
- Integrate photovoltaic modules and cells within roofs and southern-oriented facades, appropriate in size and peak power, for electricity production and load management.
- Integrate low emission wood-chip furnaces and other biomass for local district heating, incorporating low cost electrostatic filters.

ii. Specify low energy systems and appliances

The successful application and implementation of innovate measures in energy technologies calls for cooperation with energy suppliers at the building design stage; design should incorporate energy conscious solutions at the building and district level. This can result from an accurate integration of different technologies and design concepts at the early design phase.

- Time shifting of electricity peaks should be introduced wherever practicable, using suitable thermal properties of building and equipment technologies.
- Equipment design should include load management systems with control devices that optimize the electricity tariff.
- Heating and cooling systems should incorporate building energy management systems.
- Artificial lighting should use energy-efficient lamps and ballasts, and automatic lighting control systems.
- Spot radiant systems can reduce the energy consumption of large spaces at low occupancy.
- Low temperature local district heating/cooling systems can be integrated with renewable energies of waste energy cascading from technological equipment.
- Air equipment design should incorporate heat exchange and recovery on exhaust air extractors.

iii. Use materials wisely

Building design should consider the choice of materials, and the deconstruction and dismantling of the building at the end of its life cycle, as key design issues. This will minimize the use of resources and the generation of emissions, and facilitate re-use and recycling.

- Select materials with their environmental effects in mind.
- Design for durability of materials and components.
- Design for flexibility, allowing for change in building use over time.
- Facades and internal partitioning should permit removal and replacement without structural disturbance.
- Incorporate a methodology for dismantling buildings, re-using or recycling building components through their easy separation into constituent elements at the end of their lifespan.

- Design should focus an easy maintenance of components and systems for long life and low emissions.
- Require contractor to use eco-friendly cleaning materials during construction and at final clean-up.

iv. Provide sufficient clean water

In EU Member States, between 40-97% of the rural population is connected to a good quality water supply system, and 30% to a sewerage system. In urban areas 95-99% is connected to a satisfactory water supply system and 70-75% to a sewerage system.

The qualitative aspects of water supplies are also important. Toxic products can pollute water supplies, making it unfit for consumption. Control measures at this level are of paramount importance to public health and to the safety of our environment.

- In new developments water supply, water distribution, waste water disposal, drainage and sewerage should form an integral part of a master development plan.
- Piped water supplies need to be protected against contamination from harmful bacteria or chemicals in the ground.
- External or internal water storage tanks should always be covered to discourage algae growth due to its exposure to sunlight and to prevent the entry of rodents, while facilitating regular cleaning operation.
- Materials used for water services should not present a source of bacterial or chemical contamination to supplies.

v. Provide for water conservation and re-use

Design should minimize the consumption of water, and reduce the environmental impact of new and existing settlements, by using water saving technologies and other measures.

- Install water meters to facilitate measurement and control of water use.
- Incorporate water savings technologies for WC, showers and other water using appliances, to reduce water consumption.
- The principle of grey water usage should be planned at the design stage.
- Landscapes should be designed for minimum irrigation.
- Site planning and building design should incorporate provisions for storage of rainwater for exterior use.

vi. Provide sanitary means of waste and surface water disposal

Adequate water disposal contributes to health and environmental improvement. Inadequate surface-water drainage can cause periodic flooding of roads, wells and housing, creating safety and environmental hazards.

- Design and construction of drainage systems should conform with health principles. Ensure that effluent does not leak into surrounding ground, contaminating water supplies.
- Specify preference for enclosed pipes protected with access points for maintenance. Ensure that open rainwater-drainage channels are regularly checked for blockage.
- Plumbing should be easily accessible for maintenance and avoid back pressure that might lead to contamination of the water supply system.
- Materials for plumbing systems should be selected for strength, durability, and the ability to resist to the corrosive action of wastes.

vii. Provide for reduction, sorting, storage, collection and disposal of waste

Careful design and management can reduce construction wastes. Facilities for storages, collection and disposal of domestic waste after the building is occupied are essential. Methods of disposal depend largely upon the availability of suitable sites, cost of transport, socio-economic factors and local conditions.

- Design for standard sizes to reduce on-site cutting and require contractor to use off-cuts to feasible maximum.
- Enforce specification requirements for handling, storage and protection of materials.
- Require contractors to plan careful estimating and ordering of materials.
- Specify separation, storage and collection on re-use of recyclable materials, including packaging.
- Facilities for handling waste should provide adequate space for on-site treatment, combined with convenience for the occupier and waste collector and high standards of hygiene, safety and amenity.
- Provide spaces for individual storage containers for each dwelling in residential developments.
- Provide designated access routes to all containers for the waste collector, without passing through any part of the building.
- Consider the refuse shelter as a properly designed integral part of the building complex.

viii. Control outdoor noise

3. Industrial buildings should be insulated to prevent noise transmission at source.
4. Urban main streets should be widened with protective belts of greenery to separate different zones.
5. Vehicular traffic should be prohibited or reduced in residential areas, particularly at night.
6. Avoid paving and other hard surfaces where possible so as to minimize ground reflection. Use vegetation and grass areas to absorb noise.

3. ENERGY BALANCE

The goal of energy-efficient planning is to achieve a balance between energy gains and energy losses. Imbalances mean the loss of thermal comfort in the interior space and the need for additional regulatory measures (e.g. sun protection, more effective thermal insulation). If these do not suffice, then the balance must be achieved at the cost of additional energy (heating or cooling). The energy balance can be influenced through planning, construction and technology. The sequence in this enumeration reflects the complexity and effort required for solutions in each of these fields: planning solutions are often the simplest and technological solutions the most elaborate with a view to achieving the same effect. The compactness and thermal insulation quality of the building skin determines the level of heat transmission losses.

Commercial buildings tend to be compact for economic reasons. However, the possibility for an even distribution of natural lighting in summer and natural ventilation must be taken in consideration. Differentiated zoning of internal spaces according to lighting requirements does allow for deep, compact volumes.
In comparison to housing, the work conditions in commercial buildings or the concentration of occupants tend to call for much higher air change frequency and hence greater ventilation heat losses. In compact buildings with good thermal insulation, the heat losses resulting from ventilation are higher than those resulting from transmission.

Natural ventilation can lead extremely high heat losses and also includes the risk of improper use, for example, windows that are left open or, conversely, insufficient ventilation and therefore an unhealthy concentration of toxins or vapor.

Controlled air change offers an efficient solution and makes it possible to utilize the heat from the ventilated air to preheat the supply air. Overheating as a result of internal heat loads (people, machines…) or external influence (solar heat) is thus compensated because the heat can be distributed more effectively across the entire building.

A well-designed airtight building skin is prerequisite for a ventilation system. The following constructional design aspects should also be taken into consideration in the interest of optimizing the design of ventilation systems:

- problems arising from air circulation across several stories;
- internal division of rooms that require mechanical ventilation in summer;
- functional integration with the heating system;
- options for natural or summer ventilation.

Traffic noise and emissions diminish the quality of the work environment. To avoid these problems, windows are often kept close which makes natural ventilation in summer more difficult.

Double-skin glass facades were developed as a structural response to this challenge. By staggering the openings in the two layers, noise levels are diminished and natural ventilation is nevertheless made possible. In a similar way and despite strong wind impact, operable windows can also be provided in high rises. The cavity in the double-layer façade can serve as an access area from maintenance and accommodate various control mechanisms, such as sun and glare protection as well as light deflecting systems in a weather-protected space. Similar to conservatories, double-skin facades have a buffet effect as a temperature-controlling interstitial space and generate heat exchange during ventilation.

This approach is by no means new. Its predecessor is the box-type window, which was developed to improve the poor thermal properties of single glazing and the permeability of windows and window frames.

However, the construction effort required to build a double-skin glass facade is too expensive to justify this approach on the basis of its influence on the energy balance alone, without taking the influence of other factors such as noise or wind pressure into consideration. Similar to glass-enclosed buffer spaces, the thermal processes in this system require careful regulation. Increasingly employed for aesthetic reasons alone, these systems failed to achieve the anticipated effect. On the contrary, overheating, expensive maintenance costs and increased energy requirements are the more likely and frequent outcome.

Commercial buildings have a very high internal heat load. They are more densely occupied and are subject to considerable internal heat gains, chiefly from artificial lighting but also from machines and equipment. The ratio of window area to solid wall required for natural lighting can furthermore increase the heat load through incident solar radiation. And finally, these buildings are used during daytime hours when outside temperatures are higher. In summer, especially, the combination of all these factors can lead to very poor comfort conditions, ultimately resulting in a need for energy-inefficient air condition systems. The negative influences can be overcome, however, through relevant planning strategies. These can be divided into two categories:

Strategies to avoid overheating, for example sun protection in summer (and frequently also in winter) and optimizing natural and artificial lighting;

Strategies to extract excess heat, mainly through various forms of natural ventilation but also through a temperature-regulating building mass.

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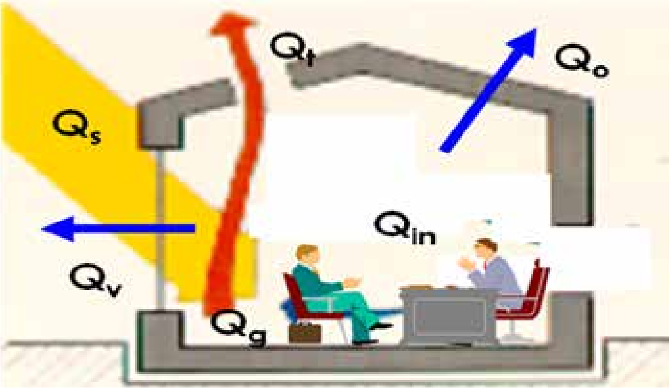
Buildings are characterized by thermal gains and losses.

The thermal balance is a function of various terms
where :+ QS+Qin - Qt - Qo - Qv - Qg

- Qs are the solar gains
- Qin are the internal gains
- Qv are the ventilation losses,
- Qo the losses through
- the opaque elements,
- Qt the losses through
- the transparent elements
- Qg the losses to the ground.



4. SURROUNDINGS AND OPEN AREAS

Determining the necessary distances between buildings must always be seen in the context of how these interstitial spaces are designed and used. As sites for a variety of activities –from hobbies to gardening to communal celebrations – layout and design of the open areas is as important as the access solution. Differentiating between public and private spaces is essential if one wishes to ensure unimpeded use of the private zones. Single-sided access to building rows results in interstitial spaces with adjacent access and open areas. When distances between rows are small, it is especially important to clearly separate these areas from the public zone. When access is combined for two rows, the result is the formation of groupings and an alternating provision of access and open areas in the interstitial spaces. Differing building heights require different distances for solar incidence, thus contributing even further to the differentiation of the interstitial spaces. The monotonous repetitiveness in row housing, a typical characteristic of developments from the 1950s and 1960s, can be alleviated by this means. Mixing building types (row houses, multi-story buildings) is also possible through this approach. Since living areas should preferably face south, the access conditions change for the individual rows and this factor must be taken into consideration in the development plan.

The usefulness of private open spaces as well as the protection of privacy in the living areas of building rows with access from the south is especially affected by this. If this protection is no provided, the glazed area is closed off from visual contact (curtains, etc.) and the desired heat gain from sunshine is eliminated. Decisions made in urban development thus influence even the user’s behavior with regard to passive use of solar energy. This situation deserves particular attention in environments with increasing density. The closer the buildings are, the more important privacy becomes interns of visual contact into private open spaces. The effect of the sun should not be studied exclusively from the perspective of the energy it can provide. Architecture is the result of the definition of space within space, that is, the dialogue between the interior and the exterior. In this relationship between the interior and the exterior space, there are intermediate spaces, transitional elements, which we call threshold. The sun allows the outside and the inside to enter into an exciting dialogue, thereby initiating different possibilities of perception, which this relationship communicates to us.

The use of the open space and the sunshine it receives should therefore be given the same degree of attention as that accorded to enclosed living spaces. Ultimately, the scope of the problems we have just enumerated is an issue of scale in urban development. Priorities differ according to the context of a specific project, depending on whether we are dealing with a new urban quarter, an isolated settlement, development on the periphery or an inner-city situation. The sun can play a determining role in low-density developments. In inner-city locations, other factors such as conditions at the site, property costs and the related economic density, population structures, etc., will largely determine building structure and placement. Although improving solar incidence can be a goal, the results will be rarely be ideal.

Nevertheless, densification is the more sensible path in the city with regard to energy savings since it achieves better results on a global perspective, than developments designed for optimized solar use on the urban periphery. A sunlit environment offers the ideal framework for individual and communal activities to flourish. This is where the life in the city takes place and as an extension of the living space in the open area, its quality is directly linked to the quality of the apartment. The urge to flee from the urban environment into “nature” is diminished, which translates into yet more energy savings. Living in the city should recapture the charm of times gone by, the public space should be characterized by a rich and varied social dimension. And urban space should be understood as space for public life.

5. BUILDING PLANNING AND DESIGN

5.1 Form

The orientation of a building may be fixed but if choice is possible it should face south to take advantage of the sun’s energy. Total volume, too, is likely to be prescribed and so, often, the first major design decisions are allocating volumes to various activities and developing the form of a building.

- Form is governed by a number of functional considerations:
- The use of the sun’s energy and daylight
- Provision of views for occupants
- Heat loss through the building envelope
- The need for ventilation
- Acoustic attention if required

5.2 The building body

An important consideration is how quickly a building responds to heat inputs (internal and external), and this is related to the thermal conductivity of its materials, the thermal mass (or heat capacity), and related to these, the admittances of the elements of the construction.

The admittance, Y, of a constructional element, put simply, is the amount of energy entering the surface of the element for each degree of temperature charge just outside the surface and, as such, has the same units as the U-value ($W/m^2 K$). The admittance of a material depends on its thickness, conductivity, density, specific heat and the frequency at which heat is put into it. (In addition to the admittance, the response of building elements to energy cycles depends on the decrement factor and the surface factor, put simply; once again these factors are associated with time lags in energy flows, with the decrement factor representing the ‘damping’ effect of an element’s response to an energy gain).

5.3 The building skin

Development of the building envelope, or ‘skin’, is likely to be rapid in the next decade or so. Technological innovation in glass will allow window systems to respond to environmental conditions in ways not previously commercially viable for buildings. Sun-glasses which react to different light conditions are but a hint of the potential of glass.

Building envelopes obviously need to be durable, economical, aesthetically pleasing, weather tight, structurally sound and secure. Psychologically, views out are very important. Environmentally, the questions that need to be addressed are: how they respond to solar radiation (both for the sun’s heat and light), how ventilation is made possible, how heat loss is minimized and how noise is controlled. The envelope will, to a large extent, determine how the internal environment is affected by the external one.

6. BUILDING ORIENTATION

In low-density settlements corresponding to the situation present in developments in rural environments on the urban periphery, requirements such as good orientation or sufficient distance between buildings are easier to fulfill. In the urban context, on the other hand, considerations related to energy conservation take on a different dimension. Complex contexts, for example access and traffic volume, noise, urban integration, density, neighboring developments, heat supply, etc., must be taken into consideration. This differing factor should be treated within the scope of the overarching situation and never be optimized in a mono-causal, that is, isolated fashion.

This does not mean, however, that the utilization of solar energy cannot be achieved given the complex conditions presented by urban situations. On the one hand, optimal orientation of the buildings toward the sun is simply not possible in all cases and limited solar incidence in winter has to be accepted in more cases. On the other hand, urban situations are characterized by greater density and more compact building forms, both of which reduce energy losses in the first place. Measures for passive solar use must then be developed in response to the conditions of the specific site and scaled accordingly. In addition to structural passive measures, active systems are a sensible complement (water heating, supplementary heating).

These are most effective if they are not employed for individual buildings but for ensembles as a whole. They are usually installed on the roof, since roofs tend to be exposed to the sun even in dense developments. Optimal orientation of the solar systems, independent on building orientation, is also facilitated in this situation. Choosing the appropriate type and dimension of the system is dependent, however, on the overall supply concept. Regional energy concepts and supply structures should also be taken into consideration.

6.1 Density

The achievable density is largely dependent on the necessary distance between buildings. In row development with south orientation, all units can benefit from the same conditions for solar incidence provided the necessary distance in maintained between the rows for winter conditions. For a 48° latitude (Munich, Freiburg), this distance equals three times the building height. Based on this prerequisite, the maximum sectional density that can be achieved in multi-storey developments is roughly 1.0.

If the goal is to achieve greater density, these distances cannot be maintained. Roof shape also has a considerable influence on the determination of distances. Even if the goal is to create a fully insolated façade, maisonette units in developments to roughly 1.3- maintaining the distance of 1 H, which is typical for housing. Greater density can only be achieved through a combination of buildings with differing orientations (countryard, block structure). Shadows cast by one building onto another and the various qualities of the location must be studied on a case-by-case basis.

For uses other than habitations, solar gain tends to play a subordinate role. Allocating the lower parts of a building, which receive little or no sun, to commercial uses makes it possible to reduce the necessary distances.

Developments on the periphery should also aim for high density in areas with excellent public access. Savings in traffic and infrastructure are usually much greater than any energy savings achieved by the buildings themselves.

6.2 Access

In addition to density, the access system and the differentiated use of open spaces – both public and private – are important aspects for the study of distances between buildings. As urban planning and design evolved, the differing views have divided the planners of modernism into two camps: those who favor E-W orientation and those who advocate N-S orientation.

The internal access or circulation within the building is subject to a variety of condition, depending on the orientation of the access side. In a building with access from the north, the following options are available:

- Direct access (row house, direct access via external stairs),
- Covered walkway, and
- Common access per block or building slab.

In a building with access from the south, there are some restrictions, which must be taken into consideration:

- Direct access: here on the sunny side, where a private outdoor space would be desirable. This conflict must be avoided through appropriate measures.
- Covered walkway: on the south side, the walkway interferes in the sunshine penetrating into the rooms behind or below the walkway. Privacy must be ensured between the walkway and the adjacent interiors. If the walkway is located on the north side, it does not interfere with solar incidence but causes a change in the access side. This arrangement means that residents walk through the building to the rear side, which nullifies the clear separation between public access and private spaces. Once again, visual contact into private areas is an irritant.
- Common access per block or building slab: this type of access causes few problems with regard to solar incidence. To ensure that a south-facing outdoor space can be allocated to units on the ground floor, the distance between stairwells should be sufficiently generous. On the other hand, when stairwells are spaced farther apart, one can only build fairly large apartments. A combination of block or slab access and short individual walkways offers an advantageous alternative.

6.3 Orientation

- § The classic rule of solar architecture is that living rooms should be placed on the south side and ancillary rooms on the north side in a building with north/south orientation. Although this results in a diminished building depth and hence less compact volume, it does improve the use of solar energy.
- § Houses with east/west orientation, on the other hand, should feature deeper plans because the potential solar gain is lower by comparison to south orientation. Greater compactness and minimized heat transmission losses then compensate for the diminished solar incidence.
- § This orientation fundamentally allows solar radiation to penetrate the house from both sides. Hence the living areas can be oriented to two sides, with ancillary rooms

arranged along the middle. This translates into a tremendous building depth, that is, highly compact volume. The qualitative difference between the morning and evening sun should, however, be taken into consideration in the allocation of the living areas.

- § A careful study of floor plans shows that a third internal zone that faces north is quite feasible when combined with north/south orientation. This zone could accommodate rooms that do not necessarily require direct sunshine or others that are spatially linked to the south facing zone. As regards the south-facing rooms, deep, narrow layouts are preferable. This allows for generously glazed facades without running the risk of overheating.
- § This approach to planning creates greater openness in the floor plan design. Lighting from two sides and contact with outside are also made possible, greatly enhancing the spatial quality of a living unit.
- § In other words, the south orientation of a building has no adverse effect on designer deeper, more compact buildings. Small deviations from an orientation that is due south also result in interesting planning questions without having any noticeable impact on solar gain. By rotating the principle alignment to the southwest, the sun can penetrate into the building on this side to the evening hours in summer. This has an influence not only on the quality of the exterior space that precedes it. The north facade is correspondingly rotated to the northeast with the result that the rooms on this side benefit from the morning sun in the summer and during the transitional seasons.
- § Different concepts are frequently mixed up in the context of working with orientation. It is important here to distinguish clearly between lighting, solar use for heating and solar incidence in relationship to spatial quality. Lighting from all four cardinal directions is possible. In some cases (work areas, artist’s studio), a northern orientation is preferable because its offers an even distribution of natural light without the risk of overheating or glare resulting from direct solar incidence.
- § A differentiation is made between diffuse and direct solar radiation with regard to the use of solar energy. The diffuse component is evenly distributed across all cardinal directions, resulting in a small amount of solar gain also being achieved on the north side. When it comes to the passive use of solar energy for heating, direct radiation is the most significant variable, because of its intensity, and generates the highest value on the south side. This value quickly drops with any deviation towards the east or the west.
- § The availability of solar energy in cases with east/west orientation should also be studied in conjunction with the temperature curves.

§ Both sides receive approximately the same intensity of radiation. However, outside temperatures are lower before noon and this stands in direct correlation to the utilization factor of the solar energy potential. Despite these variables, a west orientation is preferred for living areas because the quality of this orientation offers and the time of occupation by the inhabitants (usually in the afternoons).

§ Another factor should be taken into consideration when studying solar incidence as a contribution to improving the spatial quality: this is the solar altitude over the course of day. In winter the sun rises in the southeast, reaches its highest altitude (and hence its highest intensity radiation) in the south at noon and sets in the southwest. In other words, the solar radiation will fall onto an east/west facade at an angle that grows increasingly more shallow as noon approaches, which means that sunshine cannot penetrate as deeply into the interior. If this angle is less than 15^o, the bulk of the solar radiation is reflected off the glass pane. The greater the distance in time is from the noon hour, the larger the angle of incidence and the lower the solar altitude. Shading from parallel rows of buildings is then increased.

7. BUILDING ENVEPOPE

7.1 Material

To design a building detail is to test a hypothesis but the difference between idea, intention, and the actuality of the full-scale artifact can be immense. The infinite specificity of the real makes it difficult to anticipate exactly how materials will come together, correspond, and behave. For this reason, the conception of a project must be constantly examined throughout its development and grounded in a rigorous process and intuition about the behavior of materials. Material choice and relationships reinforce the spatial organization and the legibility of the idea and vice versa. A detail must have constructional purpose and critical content. Of primary interest is the way in which the building envelope (wall, roof, floor and openings) plays a critical role alongside mechanical systems in providing visual and thermal comfort. The conscientious and rigorous development of a detail becomes more complex as the building itself assists in mitigating the variability and extremes of weather. Material choice deals directly with the interrelated nature o structure, construction, and environmental systems in pursuit of the integration of these technologies into the architectural ideal.

7.2 Insulation

Attention to a well insulated envelope allows the designer o reduce the size of climate control systems. The exterior walls, floors and roof of a structure should be insulated to a level consistent with climate and codes. Walls, floors, roofs and fenestration of a green building should exceed code-minimum performance requirements. Infiltration must be controlled, this means air cannot move through unplanned openings in the envelope. Windows and glazed doors should be selected and specified to contribute to the goals of the project- whether this be through solar admittance, day lighting, and/or solar rejection.

A green roof can provide many advantages. It plays an aesthetic role by extending the form of the project and creating a place of refuge. Species of glasses and plants should be selected because they require minimal water and maintenance will shade the project when full grown on the summer (flowers/herbs) of use in the building. Lightweight soil can provide extra insulation and absorb water runoff. Rainwater can be used for irrigating the garden or used in a greywater system. The garden thus extends the usable living space of the project in area and in spirit.

7.3 Insulation Materials

Plastic foam board (rigid board) insulation. Comprising products such as bead board (molded expanded polystyrene-MEPS) and foam-board (extruded expanded polystyrene-XEPS), this category of materials can contain VOCs (volatile organic compounds) and is not biodegradable.

Spray-applied foam insulation (spray-in cavity-fill). Some open-cell polyurethane insulation products are produced with soy oil comprising about 40% of their “poly” components, resulting in foam that is about 25% soy and 75% petro chemically derived. Although these products do not have R-values as high as those of closed-cell polyurethane, there are three to four times as resource-efficient.

Magnesium silicate or cementitious foam (Air Krete). This product provides CFC- and HCFC-free insulation alternatives. Although it is more expensive than products that use CFCs and HCFCs, it is fire-resistant and has no indoor air quality impact. Its weakest point is its fragility-which may soon be addressed by adding plastics to the mix to reduce brittleness.

Cellulose insulation. Installed loose-fill, sprayed damp, or densely packed, cellulose insulation is made from 75-85% recycled newsprint. Embodied energy is about 150 Btu/Ib [0.09 Kw/kg]. This insulation contains non –toxic chemical additives that are within U.S. Consumer Product Safety Commission fire-retardancy requirements. There are no significant indoor air quality issues if this product is properly installed, although there are potential risks resulting from dust inhalation during installation and VOC emissions from the incorporated printing inks.

Fibrous batt and board insulation. These materials are an insulation mainstay; unfortunately many of these products use formaldehyde as a primary component. Glass fiber products usually use phenol formaldehyde as a binder, which is less likely to emit harmful pollutants than urea formaldehyde. Some major manufacturers have elected not to use formaldehyde binders in their fibrous insulation products.

Loose-fill fiber. Loose-fill glass fiber or blowing wool that does not contain formaldehyde is readily available in applications with R-values ranging from 11 to 60.

Mineral wool. Often used for fire protection of building structural elements, this material is made from iron ore blast-furnace slag (an industrial waste product from steel production that has been classified by the U.S. Environmental Protection Agency as hazardous) or from rock such as basalt.

Cotton insulation. Batt insulation that is made from recycled denim scraps. Some products use 85% recycled fiber saturated with a borate flame retardant or a combination of borate and ammonium sulfate flame retardants.

Radiant barriers (bubble-backed, foil-faced polyethylene foam, foil-faced paperboard sheathing, foil-faced OSB). These are thin, reflective foil sheets (available in a range of configurations) that reduce the flow of heat by radiant transfer. They are effective only if the reflective surface of the barrier faces an airspace. Proper installation is a key to the success of this type of insulation. Recycled polyethylene products containing 20-40% post-consumer recycled content are available.

Perlite. This is a siliceous rock that forms glass-like fibers. Perlite is usually poured into cavities in concrete masonry units (or similar assemblies). It is non-flammable, lightweight, and chemically inert. Perlite generates very little pollution during manufacturing and poses a minor threat for dust irritation. Its main drawback is its limited range of applications due to its “fluid” character.

Structural insulated panels (SIPs). Comprising “structural” and insulation materials in one assembly, SIPs generally outperform other insulation /construction compositions in terms of R-value per assembly thickness. Building envelopes constructed with SIPs are also virtually airtight when properly installed.

7.4 Climate control systems

Basic advantages of green heating and cooling systems over conventional heating and cooling technologies include using natural ambient conditions to the fullest extent to provide heating and cooling for a building. These ambient energies are typically renewable and non-polluting. Passive strategies have the capacity to deliver heating and cooling strictly from environmental resources on site. A climate control system should be designed to be simple, both in operation and in installation.

7.5 Envelope

Building envelope considerations begin with the sitting of the building and the placement of windows and skylights. Orienting a building on an east-west axis while placing the bulk of window openings on the north and south elevations makes solar control and day lighting easier to achieve.

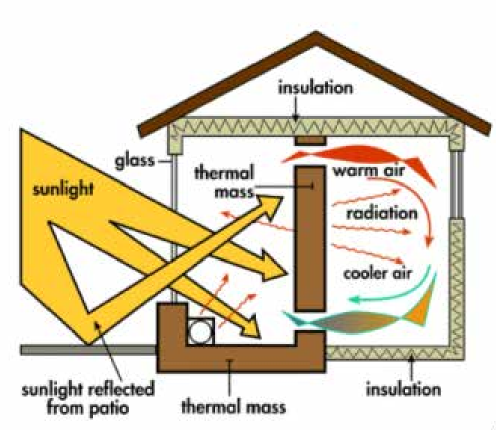
Insulation is a crucial part of any green building project. Because reducing energy use is a high priority in a green building, a thick layer of a not-quite-green insulation is almost always preferable to an inadequate thickness of a green insulation. That said, presuming adequate insulation values and quality of installation can be achieved, choose a green insulation over a non-green one.

When selecting materials for structure and envelope, less is often more. Using materials more efficiently conserves resources, reduces wastes, and help reduce construction costs. If using wood framing, make sure spacing and detailing are optimized for resource efficiency. If using concrete, design for efficient use of the material and reduce cement content by incorporating fly ash. For steel, develop insulation details that avoid thermal bridging.

During schematic design, consider the benefits of admitting or rejecting solar heat and begin to glazing with a solar heat gain coefficient (SHGC) to best address solar concerns. Glazing selection is shaped by many factors. A wise choice for one project may not be appropriate in another. Overhangs and shading devices can reduce or eliminate the need for solar control glazing.

Consider alternative materials- such as straw bales for commercial or residential buildings in appropriate climates. Roofing presents several options. A green roof offers many benefits, reducing the urban heat island effect, potentially providing high insulation values, reducing rainwater runoff, and possibly offering habitat for local flora and fauna. If a green roof is not an option, cool roofing materials are preferable in cooling dominated climates. Cool roofing can lessen solar loads on the building and extend the life of the roof by reducing expansion and contraction of materials.

Materials that last longer will reduce the demand for resources and in many cases involve lower embodied energy. They also reduce maintenance costs and thus may be cheaper from a life-cycle perspective even if they involve higher first costs.



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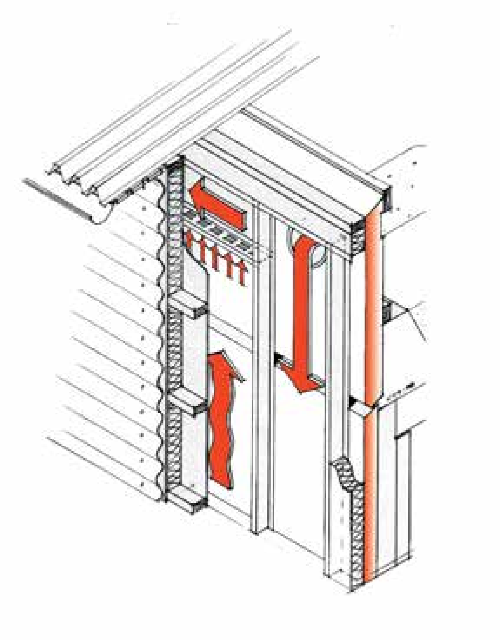
7.5.1 **Strawbale construction** is a strategy for building energy-efficient, low environmental impact buildings. Dry strawbale are set upon a moisture-protected foundation, stacked in a running bond, and secured with rebar or bamboo sticks. The bale wall is then post tensioned with cables or rope to prevent extreme settling. Wire mesh is applied to the constructed bale walls and the resulting assembly is finished with several layers of plaster, spray-applied concrete, or stucco.

Straw is a renewable agricultural waste product that is abundantly available, inexpensive, and simple to work with. Bales may be used as a structural component on a building or coupled with wood, metal or concrete framing. Strawbale walls lend themselves to passive solar structures. With R-values generally between R-35 and R-50 the interest insulating value of straw is a valuable tool in passive heating and cooling design. With a wall thickness of 0.16 in. (400mm) or greater providing a substantially massive envelope, strawbale construction can also serve as an effective sound barrier.

7.5.2 Double Envelopes

As described in this strategy, are multiple leaf assemblies used in transparent or largely transparent portions of a building façade. They range, in configurations, from the time-honored storm window to a recurring modernist ideal, the all-glass façade. Double envelopes consist of an outer façade, an intermediate space, and an inner façade. The outer leaf provides weather protection and a first line of acoustic isolation. The intermediate space is used to buffer thermal impacts on the interior. Through the use of open slots and operable elements in the glass planes it is possible to ventilate the interstitial space on warm days and admit partially conditioned air to adjacent rooms on cool days. In most cases sunshades are placed in the intermediate zone where they can operate freely, but with reasonable access for maintenance. Double glazing of the inner façade provides an optimum thermal barrier (for most climates), while single glazing of the outer façade is sufficient to create the buffer space.



Double envelopes present the building designer with an extraordinary array of options. The selection of an appropriate system proceeds through the following considerations:

- Relationship of the glazing to the overall façade
- Performance objectives of the transparencies
- Construction strategies
- Maintenance requirements

The primary architectural issue related to double envelope construction is the fact that building appearance and thermal and lighting performance are essentially defined by the success of the façade. It is imperative that the designer have clear design intent, explicit design criteria, and a sense that the intended envelope façade is a very complex system that may not behave totally intuitively.

The effectiveness of double envelope systems is widely debated and difficult to summarize. A simple comparison of façade costs has little meaning without also comparing the floor space available for use, the cost of compatible structural system, the size and complexity of the mechanical plant, total building energy flows, and the cost of long-term maintenance. One must also examine the qualitative benefits to building occupants and the ecological impacts of the materials required. Some of the most effective double envelope applications are "re-wraps" of existing building envelopes that are poor energy performers.

Generally, double envelopes should not be the first green strategy adopted. They should be considered when and if they complement others steps taken in pursuit of overall environmental quality and energy efficiency. Many of the benefits associated with double envelopes can be achieved through means that have far less design and cost impact. Passive ventilation, for instance, can be integrated using trickle vents through a single leaf skin. Operating in a façade should be designed to optimize the harvesting of daylight and provide meaningful connections to the outdoor environment. Too often double envelopes are used to control gain and losses through areas of glass that are much larger than can be justified by these fundamental performance considerations.

7.5.3 Structural Insulated Panels

SIPs consist of an insulating core element sandwiched between two skins. In this structural assembly, the skins act in tension and compression while the core handles shears and buckling forces. SIPs are commonly composed of an expanded polystyrene (EPS) core with adhesive-attached oriented-strand board (OSB) facings. Alternatives to EPS as a core include extruded polystyrene (XPS), polyurethane, polyisocyanurate, and straw.

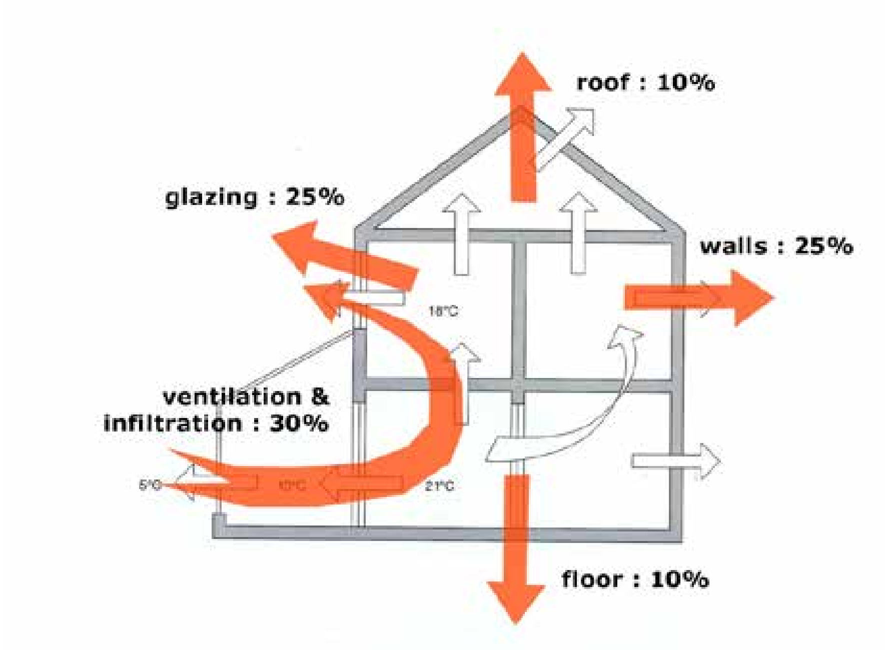
Building with structural insulated panels has proven to be an energy-efficient alternative to stick-frame construction primarily because of the limited need for heat-conducting (thermal bridging) studs. The structural strength of this construction method is also superior. A benefit of structural insulated panels is resource efficiency. Wood for OSB typically originates from tree farms and EPS is produced without ozone-damaging CFCs or HCFCs. A quiet interior in a building that is solidly built is valuable, through often overlooked, asset that fits with green design intent. Due to their potential for rapid assembly, SIPs are a good choice for a project on a tight schedule. Because manufacturers work with the designer and contractor in the production of panels, customization is not difficult as long as it falls within the capacity of manufacturer's machinery.

From a disassembly and recycling perspective, the EPS and polyurethane components of SIPs are generally recyclable, but foam and adhesive residue on the OSB panels will probably prevent their beneficial reuse. The amount and type of VOCs emitted by SIPs can vary from manufacturer to manufacturer. Some data suggest that SIPs emit lower levels of formaldehyde than standard wooden residential construction (some SIPs may not emit any) but may emit higher levels of other chemicals.

To reduce field costs and resource wastage, a building designer using SIPs must consider the modular nature of these panels and work with the dimensions to minimize field cutting. To simplify construction, site access for a crane to unload, raise and place the panels is necessary. When using SIPs in long span floors or roofs, creep may cause the SIPs facings to pull away from the core. To avoid this problem, confirm the viability of intended applications with the panel manufacturer and/or project structural engineer.

Drywall facings may be required in order to meet fire code ratings. Verify requirements with the local jurisdiction. A pest control barrier should be provided to prevent carpenter ants and termites from nesting in the insulating core of the SIPs. The use of stick framing behind kitchen sinks and similar locations, will simplify plumbing installation.

Because SIPs construction can greatly reduce infiltration, ensure that adequate ventilation (active or passive) is provided for acceptable indoor air quality.



Increased envelope heat loss

7.6 **Green Roofs** can be used to provide for rainwater detention or retention, to increase the thermal resistance and capacitance of a building roof, to reduce the urban heat island effect, and to provide green space for animals and people on what would otherwise be a hard-surfaced area. Green roofs are two basic types: extensive and intensive.

Extensive green roofs have a relatively shallow soil base, making them lighter, less expensive, and easier to maintain than intensive green roofs. Extensive roofs usually have limited plant diversity, typically consisting of sedum (succulents), grasses, mosses, and herbs. They are often not accessible by building tenants, but may provide for “natural” views from adjacent or neighboring buildings.

Extensive green roofs can work at slopes of up to 35°, although slopes above 20° require a baffle system to prevent soil plump. These can be used in both urban and rural settings, are applicable to a wide variety of building types, and can be used in both new and existing construction.

From 2 to 6 in. [50-150mm] of some kind of lightweight growing material (often a mineral-based mixture of sand, gravel and organic matter) is required for an extensive green roof. In addition to the growing medium, a drainage system for excess rainwater and a protective barrier for the roof membrane are required. Because plant roots bond to underlayment fabrics to create a unified whole, there is no need to provide additional ballast against roof uplift unless the roof is located in an unusually high wind area, such as on a high-rise building or in a coastal area.

Intensive green roofs have a deeper soil base than extensive green roofs. They are not limited in terms of plant diversity (as are shallower extensive green roofs) and often feature the same kinds of landscaping as local gardens. Intensive green roofs can provide park- like accessible open spaces, and often include larger plants and trees as well as walk- ways, water features, and irrigation systems. The deeper soil base required for these roofs and the weight of the plants combined with the weight of water that may saturate the soil make them much heavier than extensive green roofs or conventional roofs. This extra weight requires a substantial building structure, and results in a roof that is more expensive to build. Intensive green roofs are feasible only on flat-roofed buildings.

While intensive green roofs involve more cost, design time, and attention than other roofs, this approach provides the broadest palette by which the roof can become an exciting and vibrant environment. A great diversity of habitats can be created, including those with trees. These types of roofs are often accessible to people for recreation, for open space, even for growing food. Intensive green roofs are more energy- efficient than extensive green roofs, and their roof membranes are typically and more protected and last longer. The deeper soil base provides greater storm water retention capacity. Growing media depth for intensive green roofs is typically 24 in. (600 mm).

The layers of a green roof can vary depending upon the specific type of green roof selected. Generally, insulation will be placed on top of the roof deck. Above this will be a waterproof membrane, a root barrier, a drainable layer, a filter membrane, and finally growing media for the plants. Drainable insulation planes are also commonly used, where the waterproofing is located at the structural surface. Depending upon the weight of the soil base and plants, additional structure may be needed on top of the insulation layer. Careful attention should be given to vapor retarder location.

Key architectural issues

Successful green roofs require a building massing that provides appropriate solar exposure for the intended types of vegetation. Shading from adjacent buildings or trees can have a big impact of the success of rooftop plantings. Building massing can also be used to create rooftop surfaces that are relatively protected from wind. Building form will also determine how building occupants can interact with a green roof. A green roof is a user amenity only if it is at least visible to occupants. If it is also accessible to building occupants, greater integration of the green roof with appropriate interior spaces is desirable. Structural system design, careful detailing of drainage systems, irrigation systems, and penetrations of the roof membrane are key concerns.

8. SOLAR FACADES

Early low-energy houses were distinguished from conventional buildings by the largest possible opening of the facade facing the sun. Since energy requirements were still relatively high in these buildings, the solar energy gained from large window areas could be utilized with a high content of efficiency. Energy requirements decreased as the constructional and ventilation properties of buildings improved, and the effective window area diminished accordingly. From an energy perspective, fully glazed facades are rarely ideal. Full glazing also goes hand in hand with the risk of overheating in summer. The rule of thumb proposed in the relevant literature is that the maximum glazing ratio on a south facade should not exceed 50 percent of the total area.

The decisive factor for the success of passive solar energy strategies is less the size than the harmony in design and function with the architectural concept of the building. The strategies in their entirety should never restrict the utility of living areas, but send a clear message as a result of their visible effect. This increases acceptance among users and promotes energy-conscious behavior.

The energy exchange between a building and its environment is characterized by a continual crossing of the thermal boundaries between interior and exterior. This unique interior-exterior relationship occurs in various ways. Most of which are barely noticeable.

While the cold air drafts from an open ventilation flap renters the heat exchange is resulting from ventilation perceptible, it does not make users aware of the overall affect on the energy balance. A cold glass pane, for example, is a tangible manifestation of the energy transfer through the building skin. However, a sensory experience of the totality of this process - rendered visible in a infrared image, for example - is not possible.

When sun flows into an interior, we recognize the influence of energy in a more conscious manner.

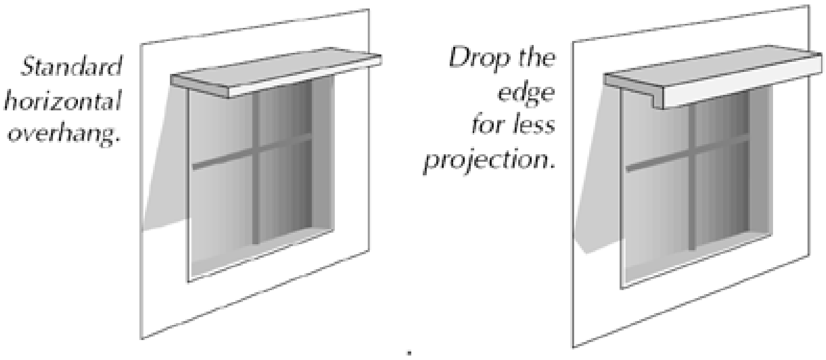
This energy is more than warmth and can be perceived in a variety of ways: simply looking at a surface bathed in sun reveals the presence of this flow of energy. Conversely, the coolness provided by shade in summer is intensified as a pleasure experience in contrast to the heat of the sun. Incident sunlight penetrates a room and connects it to the outside world. Solar incidence thus expands our range of perception because it mediates between inside and outside. Different elements, not just the building skin, but also others that lie in front of or behind the diving line we call facade, articulate the relation between interior and exterior. When we look at the principles of passive solar use from this perspective, it is surprising how complex a window is, although it is widely regarded as the simplest system employed for solar energy gain. The different requirements which a window is meant to fulfill, (light, air, sun, all manner of visual contact - from the outside in, the inside out and across the length or breath – as well as the ability to accentuate a space) give this element an infinite variety. A window can fulfill one or several of these requirements. It can be a simple, modest element or a complex configuration of parts, the totality of which meets different demands. The window is more than simply a surface. In the form of multi-layered facades or in combination with control features (shading, light-deflection etc.) it can extend toward the inside or the outside. Thus the window adapts to the changing conditions the interior or the exterior. A differentiated treatment of windows is possible and necessary inhabitants are to understand and experience their functions (also with regard to energy management). The perception of the transition between inside and outside is more difficult on solar walls. The warmth of the sun flows through the transparent or translucent exterior surface and is captured on the wall behind it. This process cannot be tracked from the inside nor can it be coupled with a specific spatial effect. By virtue of the glazing on the outside, solar walls are similar to windows in appearance. This impression is contradicted on the inside, however, because the wall merges with the other, closed areas. Ultimately, its function as a solar element is entirely a matter of thermodynamic principles.

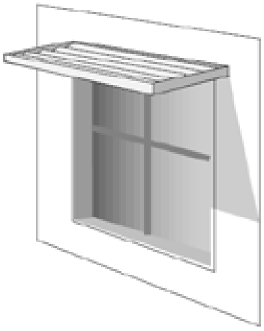
9. SUN PROTECTION

Incident solar radiation in summer is one of the prime causes of overheating. Sun protection measures are employed to prevent this. The type of sun protection is chiefly dependent on the direction in which the openings face. South-facing windows are most easily protected against the high-altitude summer sun. Skylights as well as glass areas in flat or shallow-incline roofs deserve particular attention because of the high solar altitude in summer. East-west orientation also presents a problem due to the morning and evening sun, which stands perpendicular to the windows.

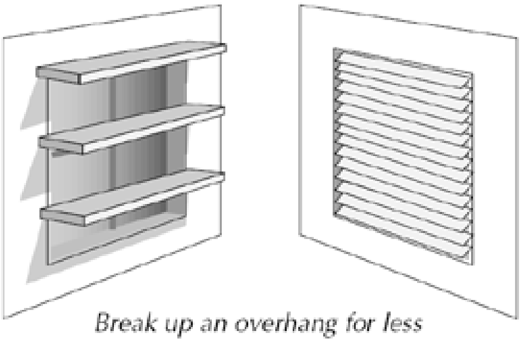
Depending on window orientation, light incidence and sun protection must be harmonized. Sun protection systems must not interfere with natural lighting. Rather, sun protection measures can block direct sunlight, offer efficient glare protection and simultaneously provide better lighting in the depth of the interior space by means of daylight deflection. The position of the suns changes over the course of the seasons and the day. The influence of the sun also differs according to weather. A correct response to these conditions is only possible with sun protection systems that are adaptable to the requirements at any given time. Adjustable systems are not only more elaborate; they also require additional solutions with regard to control and operation (automatic or manual). By contrast, rigid systems call for a precise definition of the times when the sun protection system is needed and must be designed accordingly.

Utilizing the benefits from natural protection provided by trellises, pergolas or trees is usually insufficient; these “systems” can moreover not be regulated in a flexible manner when the need arises.

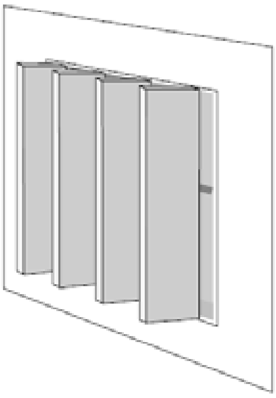




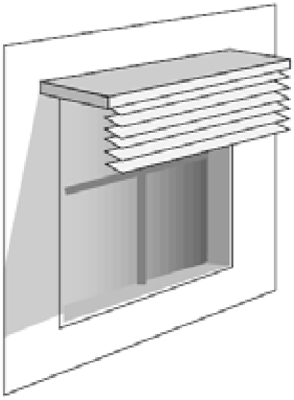
Use louvers in place of solid overhang for more diffuse light while still shading.



Break up an overhang for less projection.



Vertical louvers or fins for east and especially west facades.



Substitute louvers for the solid dropped edge to let in more light.

10. LIGHTING

10.1 Day lighting

Most people prefer daylight. The contact with changing natural light is psychologically physiologically and architecturally important. Daylight availability varies enormously and is a key design issue. Temperature variations, on the other hand, are more seasonal and are therefore easier to control; noise level variability depends very much on the site.

The lighting level in the space is very important. One aspect of this daylight factor, which is defined as the illuminance received at a point, indoors, from a sky of known or assumed luminance distribution, expressed as a percentage of the horizontal illuminance outdoors from an unobstructed hemisphere of the same sky; direct sunlight is excluded from both values of illuminance.

Recommended daylight factors exist but need to be treated with caution, because they are not in fact high enough if the optimum use of daylight is to be made. The best guidance is probably to say that daylight should be maximized subject to the constraints of glare, increased solar gains and possible greater heat loss.

The amount of light that enters a space obviously depends on the areas and disposition of glazing. To a large extend the amount of daylight at a point in a room depends on the area of the sky that can be seen through the window. Thus, there tend to be wide disparities in natural light levels between areas close to windows and those some distance of them.

It is common to apply the daylight factor to what is known as the standard overcast sky illuminance of 5000 lux. This value is exceeded about 85% of the standard working year. Thus, under a standard overcast sky a daylight factor of 10% at a point near a glazed wall would give an illuminance of 500 lux. These indicates that if you had a desk at that position in a general office the light level would normally be sufficient, but for 15% of the working hours you would need to turn some lights on to maintain the recommended lighting level. We also show why it is “recommended” daylight factors are too low.

Although the main reason to make effective use of daylight is to reduce artificial energy consumption there are also potentially useful heat gains available. A rule of thumb is that an illumination level of about 1000 lux outside would correspond to total radiation of about 10 W/m^2 on a horizontal surface.

Making effective use of daylight depends very much on planning the building. Highly articulated spaces with a greater perimeter length will normally offer more potential daylight (and natural ventilation) but at the possible cost of greater heat loss. The art lies in finding the right balance – one key element of which is reducing the heat loss at night.

The more glazing at the perimeter wall, the higher the daylight factor.

A key point for all these examples, and for many of the more innovate day-lighting systems, is that ceiling reflectances must be kept high by using very light colours; another consideration is that the ceiling should not be encumbered by bulky artificial lighting systems. High ceilings with windows running up to them, as in Victorian schools and hospitals, help to increase light level.

Obviously, wherever possible, activities that need great deal of light should be placed near the perimeter. Similarly, a variety of spaces that need lighting only occasionally (such as store-rooms), or that have lower lighting requirements (such as circulation spaces) should be moved towards the interior.

One standard reference suggests that when the average daylight factor exceeds 5% on the horizontal plane an interior will look cheerfully bright, and when the factor is below 2% the interior will not be perceived as having adequate daylight and electric lighting may be in constant use. Achieving 5% (and often, ideally more than 5%) is by no means easy in many situations and requires careful design.

The quality of lighting and the perceived need to switch on artificial lighting depends much on the range of light levels from the front to the back of the space. Too great a range can give predominantly gloomy character of the space. One criterion for acceptable uniformity in spaces with windows on one wall is that (d/w + d/h) shall not exceed 2/ (1 - R_b)
Where 'd' is the depth of the room, 'w' is the width of the room, 'h' is the height of the window head above floor level and R_b is the area weighted average reflectance of the half of the interior remote from the window. For single-storey buildings, or the uppermost floor of multi-store buildings, roof lights can provide additional lighting away from the perimeter.

On a standard overcast day the approximate lighting levels just outside a vertical window and outside a horizontal skylight are about 2000 lux and 5000 lux, respectively. Thus, it makes sense to consider the use of skylights where possible, always keeping in mind that solar gain needs to be kept under control. Though, also needs to be given to the effects of top-lighting because some people find that this gives objects a duller appearance owing to a lack of modeling. Another consideration is that roof-light on a clear night can be greater than that of a window because the roof-light "sees" more of the cold sky than the window and so the radiation loss is greater; losses due to conduction/ convection can also be somewhat greater with roof lights.

In more common applications where only side lighting is possible, one way of attempting to improve uniformity has been the use of light shelves and other reflective mechanisms such as prismatic glass.

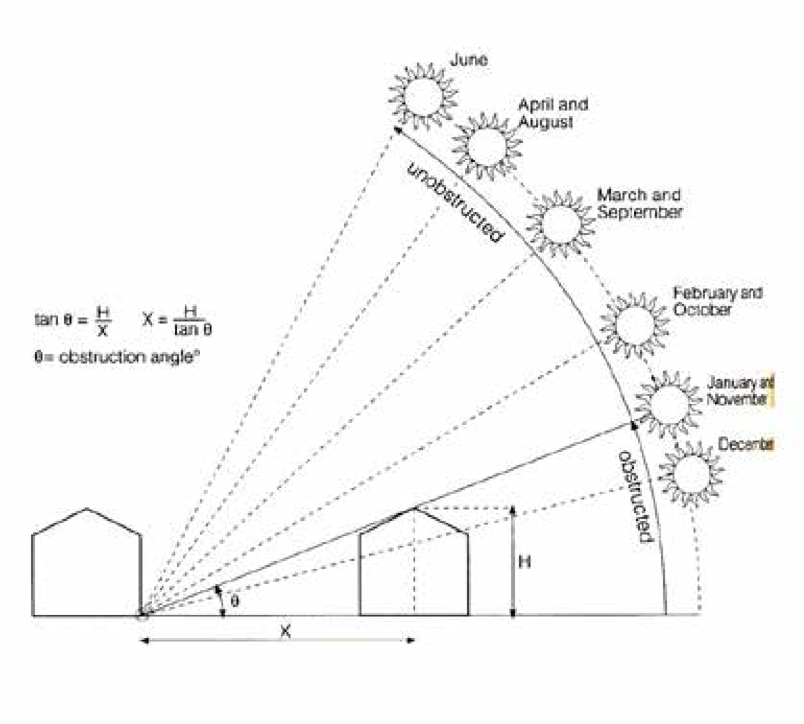
The BRE has carried out extensive tests on light shelves in south facing walls and found that in sunny conditions they had the advantage of shading an area of the room close to the windows from direct sunlight but resulted in some light loss and provided relatively small direction of light. In overcast skies light levels are reduced by 5-30% depending on the position in the room with the 5% loss being at the back of the room. This pattern of some light loss and some redistribution in sunny conditions and light loss in overcast conditions was also found to be valid in the same study for similar techniques such as mirrored louvers and prismatic films.

One point to kept on mind when evaluating such systems is the relative proportion of times when it is overcast and when it is sunny. There may be other ways of looking at light shelves that make them services. Another is to have an adjustable light self similar to e Venetian blind. In sunny conditions the blind would be closed to reflect light up to the ceiling; under overcast skies it would be allowing more light to the zone near the window.

If we now look at attempting to provide daylight or sunlight from rooftop level to floors lower down we find it is not easy. In atria with large glazed areas and few obstructions it is not a problem but shafts are much less effective.

Larger shafts have the disadvantage of requiring more space for openings on intermediate floors. A common problem with all shafts is that with time the surface becomes less clean and less reflective. Additionally, the light that eventually reaches the space may have a curiously dead quality even on sunny days because the direct sunlight is effectively transformed into diffuse light by reflections.

More highly technological systems of light pipes or piped sunlight with slow-tracking lenses or mirror exist and others are being developed. However, it must noted that in many areas of the world , including much of northern Europe, systems designed particularly for direct sunlight are not likely to be appropriate as sunlight is often in short supply. Furthermore, the systems cannot enhance the diffuse light and, indeed, reduce it. It would seem, therefore, that these solutions with their higher costs are destined for a minority of buildings in sunnier climates.



10.2 Artificial lighting

Lighting is a significant energy consumer in non-domestic buildings. In offices it can account for as much as 50% of electricity consumption, and in deep-plan buildings lighting costs can exceed heating costs. In factories the proportion of energy used for lighting is typically around 15% and in schools 10-15%.

The amount of energy consumed in lighting depends on the power consumption of lighting equipment and the time for which is switched on.

A reduction in either of these will reduce the energy consumption. There is considerable potential for energy and costs savings in existing buildings, with many examples of savings in the range 30-50% having been achieved. In new building designs, the optimum use of day lighting can reduce the amount of time during which electric lighting is required.

Electric lighting contributes internal heat gain to the building. This reduces the heating load in winter, but it is undesirable in summer, since its adds to cooling needs and costs. An improvement in the energy efficiency of electric lighting will be offset in winter by the corresponding increase in the heating load, though heating is usually provided by a source of lower cost and higher efficiency, there will be a net gain in both money and primary energy terms. In summer, savings on both lighting costs and cooling needs are achieved.

The luminous efficacy of a light source is the light output per unit of power input. Its units are lumens per watt (lm/W). typical luminous efficacies for different lamp types are shown here

Lamp type	Efficiency (lm/W)
Incandescent bulb	10-15
Tungsten halogen	20-30
Compact fluorescent	50-75
Fluorescent (triphosphor)	80-100
Metal halide	70-90
High-pressure sodium	70-120

Typical luminous efficacies

Efficacy tends to rise with lumen output, that is bigger lamps are more efficient than smaller ones.

Gas discharge lamps require ballast, which will consume power in addition to the power consumed by the lamp itself. Thus the luminous efficacy of lamp plus ballast will be lower than that of the lamp alone.

The use of electronic high-frequency ballasts with fluorescent lighting, rather than magnetic ballasts, improves the luminous efficacy of the lamp/ballast combination by 10-20%. Electronic ballasts also provide for smoother starting of lamps, thus extending their operating lives and reducing relamping costs. Furthermore, the high frequency reduces flicker (there is an evidence that the flickering light output from older ballasts is associated with eye strain and headaches).

A measure of the efficiency of a luminaire is the luminous flux emitted by the lamps it contains. The directional distributions of the emitted light, and the luminance of the luminaire, are also important design consideration.

Light-colored room surfaces will reflect more light than dark ones. If surfaces of high reflectance can be assumed at the design stage, required electric lighting capacity, and thus capital costs, will be reduced.

The provision of localized lighting on work surfaces, with a lower level of general lighting in other parts of the room, is more energy-efficient than general lighting only, since not all of the space needs to be lit to the high level required at workplaces.

At times of peak overheating, electric lighting will generally contribute less to internal heat gains than day lighting. This is because the distribution of light and the illuminance levels from electric lighting can be controlled to match user requirements more precisely than with daylight. This applies despite the fact that the ratio of luminous flux to energy content of daylight, is higher than the luminous efficacy of modern fluorescent lamps.

10.3 Controls

In many buildings there is considerable potential for energy savings through switching off lamps when they are not needed. Since occupants cannot in many cases be relied upon to switch off or dim as required, automatic controls have an important role to play in energy efficient lighting.

Time control can be used to switch lights of automatically when the building is normally unoccupied. Occupancy control involves the use of sensors which detect movement, and which lamps off if no movement is detected during a preset time interval, for example 15 minutes. Daylight linking controls may be used to dim or switch off lamps in response to daylight levels. Such controls are in many cases necessary if significant daylight savings are to be achieved.

Localized switching involves the provision of opportunities to control lighting in small areas independently by means of switches which are close at hand. Lamps controlled by a single switch should be rationally related to daylight penetration and occupancy, e.g. lamps providing general lighting in an open-plan office could be controlled in rows parallel to the window wall, while lamps over each work place could be controlled individually.

The control strategy most suitable to a particular building or room will depend on the circumstances, in particular the occupancy patterns. In many cases, the best strategy is for the controls to switch lights off only, leaving occupants to switch them on as required.

11. COOLING

11.1 Natural cooling

Natural cooling systems have the potential to maintain comfortable conditions in summer in a wide range of buildings and climates. If natural cooling alone is not adequate, then ventilation rates may be increased mechanically. If this is not sufficient, artificial cooling will be required.

However, before ruling out natural cooling as an option, all means of reducing internal and solar gains and enhancing natural ventilation during peak temperature conditions should be assessed. Naturally cooled buildings tend to have lower capital and operating costs, and, provided they can meet thermal comfort requirements, many occupants prefer them. Furthermore, effective management is critical for air conditioning systems. Without it, efficiency falls and discomfort increases. Natural cooling systems do not normally require such a commitment in terms of operation and maintenance.

If mechanical ventilation or artificial cooling is required, consideration should be given to combining it with natural ventilation in a ‘mixed-mode’ system. This may involve the provision of natural cooling in some parts of the building, and mechanical ventilation/cooling in others (zonal mixed-mode). Alternatively, both natural and mechanical systems may be installed in the same zone, with the mechanical system being used only when the natural cooling system is unable to meet requirements (seasonal mixed-mode).

Ceiling fans

The air movement generated by a ceiling fan may produce the same cooling effect as a temperature reduction of 2-3^{o}C, and at only a fraction of the energy consumption of a typical air conditioning system. Air speeds below such fans should remain within acceptable limits.

11.2 Artificial cooling

Air-conditioning is energy-intensive. A fully air-conditioned building may consume two to three times the energy used by a similar naturally ventilated one. If air-conditioning must be used, it should be specified only for those parts of the building where it is essential.

If artificial cooling is unavoidable, factors which can minimize the required capacity and operating hours include a shallow plan, a well-insulated building shell, an air-tight construction (Refer STRATEGIES; Envelope), energy-efficient and well-control lighting and equipment to minimize internal gains, and solar control. Excessive amounts of glazing on facades exposed to the summer sun should be avoided.

Many artificial cooling systems use refrigerants containing ozone-depleting chemicals. HCFC (hydro chloro fluo rocatbon), refrigerants are not as bad as the now banned CFCs (chlorofluorocarbons), but are still damaging to the ozone layer but are powerful greenhouse gases, so still give rise to concern. Alternative refrigerants, which do not deplete ozone and which are not gases, include ammonia propane, and water, though the market for these is not as well-developed as for the fluorocarbon types above.

The efficiency of an artificial cooling system may be expressed in terms of the ratio of the heat removed from occupied spaces to the electricity consumed by the complete system. Seasonal average values in the region of 2 kW of heat removal per kW of power consumption are common in existing systems. A layout which minimizes the lengths of ductwork and pipe work required so as to minimize resistance to flow increases system efficiency. Locating plant rooms close to the areas of greatest cooling load may be useful in this regard.

Most of the chillers in use in artificial cooling systems are of the vapor compression type, and the comments above refer to these. Another type is the absorption chillers. Applications with significant future potential are the use of absorption chillers for space cooling driven either by waste heat from combined heat and power plant or by active solar thermal systems. The economics of such projects will be favored by a demand for heat throughout the year e.g. space heating in winter, space cooling in summer and hot water during all seasons.

12. HEATING

In heating schematically about heating a building, an understanding of the extent of the heating loads tend to be larger than cooling loads (except in very mild or hot climates). Larger (internal load dominated) buildings tend to have significant cooling loads due to occupancy, lighting, and equipment- along with a low surface-to-volume ratio. It is not unusual for a large office building to be in permanent cooling mode at the building core, with heating required only at the perimeter- and with a high performance façade it is possible to virtually eliminate perimeter heating. Thus, the heating strategies covered in this book are most appropriate for residential or small-scale commercial/institutional buildings.

The simplest way to heat a building is with direct solar gain, admitting solar radiation during the heating season and storing it in thermally massive materials. Direct gain is very effective in a well insulated building with good windows. It can bring glare, however and cause deterioration of interior finishes and furnishings. It is best suited where occupants can move about as conditions change over the course of the day, such as in a residence or library reading room. Direct gain heating is problematic in offices, where workers typically are not free to move to another workspace.

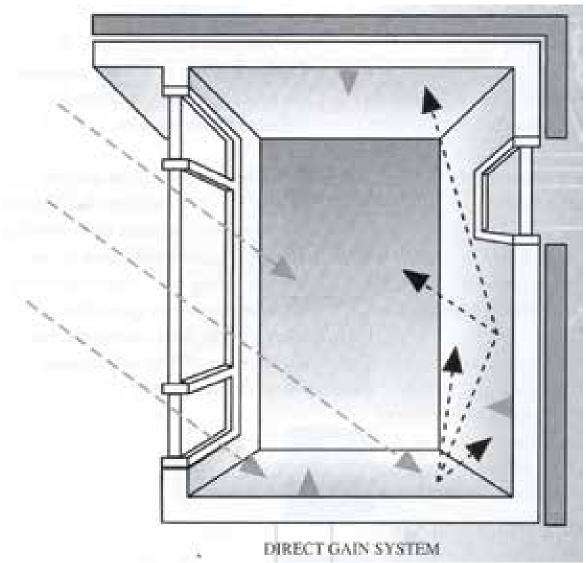
With indirect gain, a massive assembly (such as a Trombe wall or roof pond) absorbs solar radiation without directly admitting the sun into the occupied space. The collected heat gradually conducts through the thermal mass and radiates, and convects to the occupied spaces later in the day. Indirect gain to balance heating over the course of the day.

A sunspace adsorbs and stores solar heat that can be drawn off for use in occupied spaces as needed. Usually the thermal storage space is not occupied, so temperatures need not be maintained in the comfort zone. In fact, the sunspace may be most effective in providing heat if temperatures rise (and drop) well beyond the comfort zone.

Ground source heat pumps are an active strategy using the refrigeration cycle to move heat from one location to another. A ground source heat pump uses the soil as a source of heat during the heating season and as a heat sink during the cooling season. Because the ground temperature is warmer than the outside air during the winter (and cooler during the summer) a ground source heat pump is more efficient than an air source heat pump (which is turn is more efficient than most other active alternatives).

12.1 Direct gain

Direct gain systems are generally considered to be the most basic, simple, and cost-effective means of passive solar heating. During the heating season, solar radiation enters south-facing glazing and is then absorbed by and heats interior mass. Properly sized storage mass can provide steady and reliable heating performance. During the cooling season, solar radiation can be blocked by with appropriate shading devices (including landscaping). The defining design and operational feature of a direct gain system is the fact that occupants inhabit the building heating system.



Although direct gain systems perform surprisingly well in a variety of climates and building types, cloudless winters and smaller, skin-load dominated buildings make for an ideal application of this strategy.

The building axis for a direct gain system should run generally east-west to maximize solar exposure on the south-facing aperture is within 15^{o} of true south (or north, in the southern hemisphere), the building will receive within 90% of optimal winter solar heat gains. Shifting the aperture to the east or west will somewhat shift the timing of these heat gains.

The distribution of functional spaces in a direct gain building is an important consideration. South-facing rooms will benefit from direct solar heating, while north-facing ones will not. Those areas with direct gain aperture will also receive more daylight than rooms with primarily opaque walls. Placing lesser-used spaces (i.e. closets, bathrooms, circulation, service spaces) along the north wall can provide a buffer on the under-heated northern façade, and reduce the need to transfer heat from the southern spaces.

Night ventilation of mass for passive cooling in the summer is a logical complement to a direct gain passive heating system. Coordination of prevailing summer (cooling) wind directions with the elongated southern solar exposure is necessary if this combination of systems is to succeed.

It is important to recognize that a direct gain system will have large glazing areas, therefore it is also important to take steps to mitigate glare and reduce nighttime heat losses. Using light-colored surfaces and furnishings near windows can help reduce glare potential by reducing contrast. The use of some type of movable insulation or high performance glazing can help reduce nighttime heat losses. Furniture and carpets in the path of direct sunlight may fade if not selected with this exposure in mind they will also interfere with the absorption and storage of solar energy.

Implementation Considerations

Sloped glazing is often considered as a way to maximize solar exposure. Left unshaded, however, this solution may increase unwanted summer gains. Shading tiled glazing is more difficult than shading vertical glazing. Remember that even bare trees provide some shading effect that may reduce system performance.

The color of the absorber surface/thermal mass is an important consideration. Dark colors (with an absorptance of 0.5-0.8) work best. Most unpainted masonry materials will perform reasonably well. Because even reflected radiation can contribute to heating, low thermal-mass surfaces (ceilings, partitions) should be painted a light color in order to reflect radiation onto the identified thermal storage surfaces.

MATERIAL	SPECIFIC HEAT		DENSITY		HEAT CAPACITY	
	Btu/Ib ^{o}F	kJ/kg k	Ib/ft^{3}	Kg/m^{3}	Btu/ft^{3} ^{o}F	KJ/m^{3}K
Water	1.0	4.18	62.4	998	62.4	4172
Brick	0.22	0.92	120	1920	26.4	1766
Concrete	0.19	0.79	150	2400	28.5	1896
Air	0.24	1.00	0.075	1.2	0.018	1.2

As the simplest passive solar heating approach, direct gain systems have certain limitations. Sunnier than average conditions, for example, can lead to overheating-as the heat storage capacity of the building is exceeded. The opposite can occur during cloudy periods. Because of this, it is important to include a certain degree of occupant control (i.e. movable shades or operable exhausts to temper overheating). A backup active (mechanical) heating is commonly required-both to provide for heating loads that cannot be met passively with a reasonably sized system and for use during periods of extreme (cold or cloudy) weather.

Thermal storage mass should generally not exceed a thickness of 4-5 in. [100-125mm]. Any additional mass required to provide adequate storage should be provided by additional surfaces. Increasing thickness is progressively less effective and distributed storage can help keep a room evenly heated. Because the absorber surface is also the top of the thermal storage in most direct gain systems, locating storage mass is constrained by solar exposure. Secondary storage (not receiving direct solar radiation) is much less effective in controlling overheating. Any mass should be exposed as much as possible, so limit the use of rugs or carpets (which act as insulators).

South glazing should have an SHGC (solar heat gain coefficient) of 0.60 or higher (the higher the better, as shading is best provided by other means) and U-factor of 0.35 [2.0] or less. Non-solar glazing should be selected to optimize building envelope performance. To help keep heat from migrating out of windows at night, use insulating shades or panels to cover the glazing at night.

In a building subdivided into rooms (most buildings), the direct gain heating system only heats the rooms with a solar aperture-unless serious efforts are made to ensure the distribution of heat to adjacent or distant non-aperture rooms. This can place severe limitations on the applicability of direct gain systems in larger buildings or where there are complex room arrangements.

12.2 Indirect gain

An indirect gain system is passive solar heating system that collects and stores energy from the sun in an element that also acts to buffer the occupied spaces of the building from the solar collection process. Heating effect occurs as natural radiation, conduction, and/or convection redistributes the collected energy from the storage element to the building spaces. Conceptually speaking, occupants reside right next to an indirect gain system-whereas they reside in a direct gain system and near an isolated gain system. As in the case with most passive systems, an indirect gain system will exert substantial influence on the form of the building as a whole.

There are three basic types of indirect gain passive solar heating systems: thermal storage walls using masonry (also called Trombe walls), thermal storage walls using water storage (sometimes called water walls), and thermal storage roofs (roof ponds).

A thermal storage wall is a south-facing glazed wall with an appropriate storage medium (such as heavy masonry or substantial water) located immediately behind the glass. Solar radiation passes through the glass and is absorbed by the storage element. The collected heat is conducted slowly through the masonry or water to the interior face of the element and then into the occupied spaces. Vents are often placed in the top and bottom of a Trombe wall to permit additional heat transfer through convection (tapping into a mini stack effect). In water walls, convective currents in the water wall enable heat transfer to the interior, improving the efficiency of heat transfer into and through the storage element.

A thermal storage roof is similar in concept to a thermal storage wall, except that the storage mass is located on the roof. The thermal mass is either masonry (rare), water in bags, or a shallow pond of water. Movable insulation is opened and closed diurnally, exposing the storage mass to solar radiation during the day and insulating it at night to reduce heat losses. The same roof system can provide passive cooling during the summer by tapping into the cooling potential of the night sky.

The designer must consider site climate, building orientation, and solar access potential when considering a passive solar heating system. The form of a solar building will tend to strongly reflect its role as a solar collector and heat distributor. An indirect gain heating system must be integrated with plan and section decision making. The placement of glazing and absorber/storage elements must be considered in concert with decisions regarding the building envelope.

There is no substantial performance penalty if the solar glazing faces within 5^o of true south. Glazing facing 45^o from true south, however incurs a reduction in performance of more than 30%. Direct gain systems are sometimes intentionally shifted in orientation to give preference to morning or afternoon warm-up; such shifts make less sense in an isolated gain system where there is an inherent time delay built into the entry of solar effect into the space.

The design of solar glazing must include provision for shading as a means of seasonal performance control. The building design as a whole should consider ventilation in summer, both for general comfort cooling and for mitigation of potential overheating from the solar system. Design to provide for easy operations and maintenance, especially for the cleaning of glazing.

Adequate space/volume and structural support must be provided for thermal mass (masonry or water). This is especially true for a roof-based indirect gain system. Structural solutions that minimize additional costs are ideal. A backup or auxiliary heating system will be required in many projects to meet design intent.

Implementation considerations

Early in the design process, determine the most applicable system type (thermal storage wall, water wall, or thermal storage roof) and its general impact upon the plan and section of the building. An appropriate system type will much the climate, program, and schedule of use of the building. In addition, the system type will be seen as working with (even complementing) the intended form and aesthetic of the building.

Anticipated needs for day lighting and cooling should be coordinated with the selection of the passive solar heating system type. Consider the provision of adequate shading and ventilation to prevent and/or mitigate summertime overheating.

A backup heating system will be required in most climates. Space must be allocated for this equipment.

The following issues are worthy of consideration during schematic design:

- Overheating: inadequate thermal storage capacity will cause overheating. Match thermal storage capacity with system type and the proposed collector area.
- Lag time: excessive thermal storage capacity will cause overly long lag times in system response, impeding system performance. Appropriate lag time depends upon building type, diurnal weather patterns, and design intent.
- Leakage/storage failure: absorber surfaces and storage media are subject to large, daily shifts in temperature, increasing opportunities for failure. Routine, preventive maintenance can prevent a catastrophic failure-especially critical when water is the storage medium. Provide adequate space and access for maintenance and repair during schematic design, including provisions for normal and emergency drainage.

- Maintenance: in addition to maintenance access for water storage elements, provide adequate space and access for periodic cleaning of glazing and absorber surfaces.

12.3 Isolated gain

An isolated gain system is a passive solar heating system that collects and stores energy from the sun in a building element thermally separated from the occupied spaces of the building. A sunspace (attached greenhouse) is the most common example, although there are other configurations, including convective loops. Heating effect occurs as solar energy captured in the collector element is redistributed from a storage component to the occupied building spaces through natural radiation, conduction, and/or convection. As opposed to a direct or indirect gain system, where occupants reside in or right next to the passive heating system, an isolated gain system provides thermal and spatial separation between the occupancy and heat collection functions. An isolated gain system will substantially influence the form of the building as a whole.

A sunspace can fit into the overall building floor plan in many ways-including adjacency with the main building along one side of the sunspace, adjacency with the main building along two sides, or adjacency along three sides (where the building embraces the sunspace). A sunspace could also be an internal element, such as an atrium, but solar access and heat distribution would be more difficult in such a configuration. Convective loop systems employ a collector element located below the elevation of the building proper; heat flows to the occupied building by air circulating in a connective loop via the stack effect. Thermal storage components of an isolated gain system include masonry floors and/or walls, water tubes or barrels, or a rock bed when using a convective loop.

A key issue to consider relative to sunspace systems is that thermal functions dictate the role of the space; functioning as comfortably occupiable space is a secondary role. During the course of heat collection and discharge, a sunspace will likely reach temperatures substantially above and below the comfort zone. This is both natural and necessary. Use of the space (for people or plants) must accommodate these temperature swings. A working sunspace will generally make a bad dining room or conservatory.

The designer must consider site climate, building orientation, and solar access potential when considering a passive solar heating system. The form of a passive solar building will tend to reflect strongly its role as a solar collector and heat distributor. This is especially true of isolated gain systems, which involve substantial areas of glazing that are not quite part of the building proper.

Solar glazing should generally face within 5o of true south. Glazing facing 45o from true south incurs a substantial reduction in performance. As with direct gain systems, isolated gain apertures can be intentionally oriented to give preference to morning or afternoon warm-up, although the lag of storage and thermal separation make implementation less simple.

The design of solar glazing must include provision for shading as a means of seasonal performance control. This is especially true for sunspaces, which tend to include substantial glazing, often tilted from the vertical. Shading is fundamental to system success on a year-round basis. Natural ventilation often mitigates summer overheating in a sunspace. Design to provide for easy operation and maintenance, especially for the cleaning of sloped glazing.

Implementation considerations

Determine the most applicable system type (sunspace or convective loop) early in the design process. Convective loop systems work best when there is a natural elevation change on site that can be used to advantage. Establish how the collector element will integrate with the main building. An isolated gain heating system can drive the aesthetics of a small building.

The distribution of heat from the isolated gain collector area to the occupied spaces in a major design challenge. By its very nature an isolated gain system removes the heating function from the vicinity of the occupied spaces. Natural heat transfer must convey the heat from its collection point to where it is needed.
Two fundamental options exist with an attached greenhouse (sunspace) system: (1) the connecting wall between the collector and the occupied building is insulated and all heat transfer occurs by convection (this is a truly isolated gain system), or (2) the connecting wall is uninsulated and provides both heat storage and transfer functions (like an oversized Trombe wall arrangement). This is a decision that can be deferred until design development and detailed simulations.

A backup heating system for the occupied building will be required in most climates. It is important to allocate space for this equipment.

12.4 Active solar thermal energy systems

Active solar thermal energy systems utilize energy from the sun for domestic water heating, pool heating, preheating of ventilation air, and/or space heating. The most common application for active solar thermal energy systems is heating water for domestic use. The major components of an active solar thermal system include a collector, a circulation system that moves a fluid from the collectors to storage, a storage tank (or equivalent), and a control system. A backup heating system is typically included.

There are four basic types of active solar thermal systems: thermosiphon systems, direct circulation systems, indirect circulation systems, and air-water systems.

In a thermosiphon system, the collector heats water (or an antifreeze fluid), which causes the fluid to rise by convection to a storage tank. Pumping is not required, but fluid movement and heat transfer are dependent upon the temperature of the fluid. A thermosiphon system is a good option for climates with good solar radiation resources and little chance of low outdoor air temperatures.

A direct circulation system pumps water from a storage tank to collectors during hours of adequate solar radiation. Freeze protection is addressed either by recirculating hot water from the storage tank through the collectors or by draining the water from the collectors when freezing conditions occur.

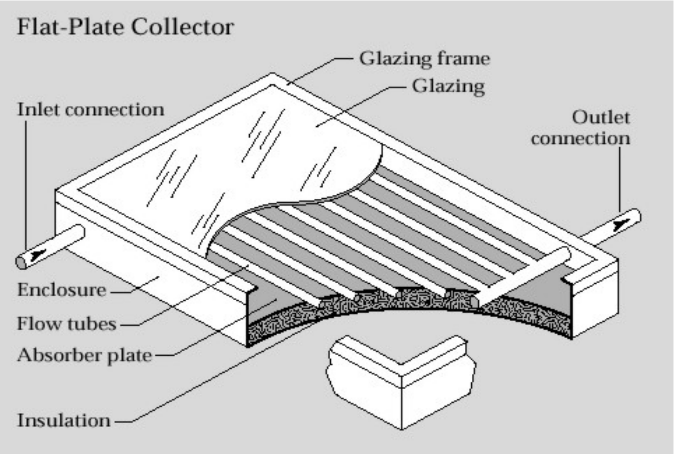
An indirect circulation system circulates an antifreeze fluid through a closed loop. A heat exchanger transfers heat from this closed collector loop to an open potable water circuit. Freeze protection is achieved either by specification of an antifreeze fluid or by draining the collectors when freezing conditions occur. Glycol-based solutions are the most commonly used fluids for closed loop freeze protection.

The collectors in an air-water system heats air. A fan moves the heated air through an air-to-water heat exchange. The efficiency of to an air-to-water heat exchanger is generally in the range of 50-60 %. Air based solar systems while not as efficient as water systems, are an option if the inherent freeze protection provided by air is a key point of interest .Solar heated air can also directly heat a space, with heat storage occurring in a rock bed storage bin.

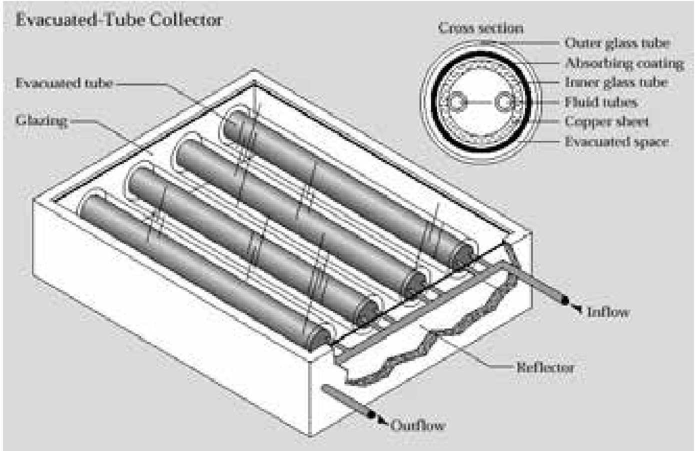
There are four common types of solar collectors: batch collectors, flat plate collectors, evacuated tubes collectors, and transpired collectors.

A batch collector includes an insulated storage tank, lined with glass on the inside and painted black on the outside. The collector is mounted on a roof in a sunny location. Cold inlet water comes from the building’s potable water system. The breadbox is the collector, absorbing and retaining heat from the sun. An outlet at the top of the insulated storage tank supplies the building with heated water. Direct and thermosiphon systems often employ batch collectors.

The flat plate collector is the most common collector plate. It is thin rectangular box with a transparent or translucent cover, usually installed on a building’s roof. Small tubes run through the box carrying either water or an antifreeze solution to a black absorber plate. The absorber plate absorbs solar radiation and quickly heats up; the heat is transferred to the circulating fluid. A small pump (or gravity) moves the fluid into the building. Direct, indirect, and thermosiphon systems commonly use flat plate collectors.



Evacuated tube collectors consist of parallel rows of transparent glass tubes each containing an absorber tube with a selective surface coating (high absorbtivity, low emissivity). Solar radiation enters the tube, strikes the absorber, and heats a freeze-protected liquid flowing through the absorber. The tubes are vacuum-sealed, which helps them achieve extremely high temperatures with reasonably high efficiencies (due to reduced heat losses). Such collectors can provide solar heat on days with limited amounts of solar radiation. Evacuated tube collectors are used only with indirect circulation systems.



A transpired collector is a south-facing exterior wall covered by a dark sheet metal collector. The collector heats outdoor air, which is drawn into the building through perforations in the collector. The heated air can heat a space or be used to precondition ventilation air.

12.5 <u>Ground source heat pumps</u>

Ground source heat pumps use the mass of the earth to improve the performance of a vapor compression refrigeration cycle- which can heat in winter and cool in summer. Ground temperature fluctuates less than air temperature. The enormous mass of soil at even moderate depths also contributes to a seasonal temperature lag, such that when air temperatures are extreme (summer and winter), the ground temperature is comparatively mild. The price of the improved efficiency of a ground source heat pump is higher equipment cost.

A basic ground source heat pump system includes a vapor compression cycle that produces the basic heating/cooling effect, air or water distribution of the heating/cooling effect, and a pump/tubing subsystem to obtain or reject heat to the soil or groundwater. The heat exchange fluid in the tubing (usually water) is circulated through a pipe field (or well) that is located outside of the building. The tubes-usually made of a high density 3/ 4 in [20mm] polyethylene-allow the fluid to absorb heat from the surrounding soil during winter months, or dump heat to the soil during summer months. The amount/length of tubing depends upon the configuration of the system, the soil conditions, and the heating/cooling capacity required. A heat exchanger is used to transfer heat from the refrigerant in the heat pump cycle to air or water that is then circulated throughout the building for climate control. A deep well may substitute for horizontally buried tubing.

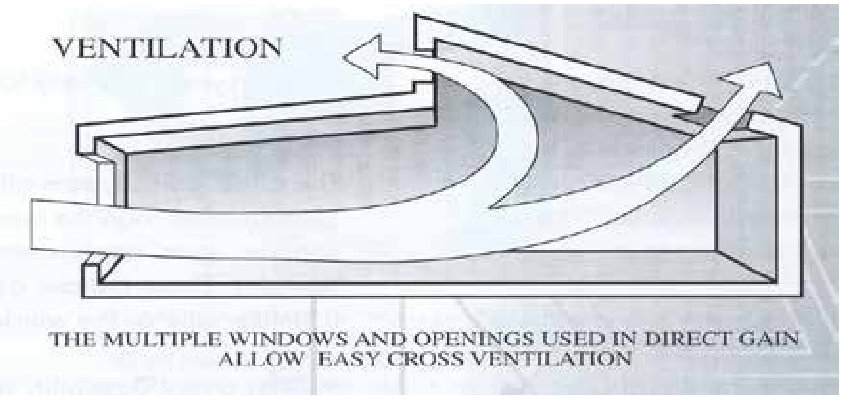
Because of the thermal advantage provided by the more benign below-ground environment, this strategy presents an energy-efficient alternative to conventional heat pumps- and a great advantage over electric resistance heating systems.

Ground source heat pumps can be used in many types of buildings in virtually any climatic condition. The cost of a ground source heat pump system is dependent upon the depth of the frost line; the deeper the frost line, the deeper the tubing needs to be buried to benefit from a buffered ground temperature.

Various configurations have been used for the ground source component-closed horizontal loops are very common (these are pipe fields running parallel to the plane of the ground a few feet below the surface that require minimum excavation), closed vertical loops (similar to an enclosed well) can overcome deep frost lines and the constraints of small sites, open loop systems (such as an open well) can reduce costs in areas where acceptable groundwater is plentiful and connection to the aquifer is permitted.

13. VENTILATION

As levels of thermal insulation improve, and as occupants' expectations regarding air quality rise, the proportion of total heat loss from buildings accounted for by ventilation has become increasingly important. Though not as straightforward as controlling fabric heat loss, much can be done to control ventilation heat loss.



Required ventilation rates depend on various factors including occupant activity and type of accommodation. For example, in non-smoking offices a ventilation rates 5-8 liters per second per person is sometimes recommended. Ventilation rates above those required give rise to an energy penalty. Since both the driving forces for infiltration (wind pressure and internal/external temperature differences) and the internal ventilation requirements vary, a relatively airtight building envelope and controllable ventilation rates are required to meet occupants' needs without wastage.

A basic level of ventilation is required to provide occupants with oxygen, and to dilute and remove carbon dioxide and odors. However, ventilation must also remove other pollutants (water, vapor, formaldehyde, etc), thus higher ventilation rates will be required if these are present in significant quantities. An important element in any energy-efficient ventilation strategy is to minimize required ventilation rate by avoiding the emission of pollutants in the building.

Where the emission of pollutants within the building is unavoidable, it is more energy-efficient to remove these at source than to increase whole-building ventilation rates. Sources of such pollutants in office buildings include some photocopying machines and printers which emit ozone, and tea-rooms and canteens which emit water vapor. Pollutants may be removed at source either through local extract or by locating the source close to a window through which air would normally leave the building.

If natural ventilation is unable to fully meet ventilation needs in particular circumstances, extract fans may be used to increase ventilation rates. These fans should be controlled to ensure that they are not switched on when not needed.

13.1 Mechanical Ventilation

Mechanical extract fans may be used to enhance natural ventilation. For example, in an atrium designed for stack-effect ventilation, an extract fan may be installed in the roof, and activated when internal temperatures rise above a pre-set level.

Ducted mechanical ventilation systems may also be used for cooling. However, because of the relatively high flow rates which may be required for cooling, pressure drops in the system will be correspondingly high, and additional fan power will therefore be required to drive these air flows.

Mechanical ventilation systems may be categorized as supply, extract or balanced. In mechanical supply systems, air leaves the building through exfiltration and therefore heat recovery is not feasible. Mechanical extract and balanced systems provide opportunities for heat recovery. In extract systems, heat may be recovered from the stale air leaving the building by means of a heat pump, and used for water heating. On balanced systems, heat recovered may be used to heat replacement fresh air via a plate heat exchanger or thermal wheel. The economics of heat recovery in balanced systems improve with the severity of the heating season.

Heat exchangers can have seasonal efficiencies of about 70%. However, they can only recover heat from the air leaving through them. If a building with balanced mechanical ventilation system is leaky, much air will leave by exfiltration through the building fabric. Furthermore, infiltration will increase ventilation air supply rates above requires levels. Thus, particularly in balanced ventilation systems, air tight construction is required for effective operation.

The ventilation system should be designed to facilitate maintenance, e.g. parts that need regular cleaning should be easily accessible. Once in operation, the systems should be properly maintained, with filter changed and heat exchange surfaces cleaned regularly, otherwise efficiency will fall and air quality will deteriorate. A failure to adequately maintain mechanical ventilation (and air conditioning) systems will result not only in poor air quality, but possibly also health concerns due to the growth of micro-organisms. A useful measure of the energy efficiency of a mechanical ventilation system is the electricity consumed per unit of air supplied, expressed either in Joules per liter (J/l) or more commonly in watts per liter-per-second (W/ (l/sec)). Typical values range from 1-3 W/ (l/sec), with energy efficient systems near the lower end of this range.

Ventilation air may be supplied by natural or mechanical means, or a hybrid system containing elements of both. Natural ventilation is driven by wind or buoyancy forces caused by temperature differences between the inside and outside air. To encourage cross-ventilation, there should be vents or openable windows on opposite sides of the building, without major obstructions to airflow in between. An open-palm layout is good in this regard.

13.2 Design internal temperatures

Many air-conditioning systems are designed for the worst case scenario, and are therefore oversized for most of their working life. Where comfort temperatures are expressed as a range, for a example 24-25^{o}Cf, the system should be sized for the upper end of his range rather than the midpoint. Allowing temperatures to rise above considerably.

Design internal temperatures for summer and winter are often based on data provided in ISO 7730, which is derived from laboratory-based assessments of comfort perceptions. However, as outlined in Section 2 ISSUES, field research has shown that methods and those observed in practice. In many cases people are satisfied with higher temperatures in hot weather and lower temperatures in cold weather, than those suggested by ISO 7730. Particularly if opportunities for adaptive comfort are provided, the selection of design temperatures need not be as stringent as ISO 7730 would suggest.

Opportunities for adaptation tend to be more numerous in naturally cooled rather air-conditioned buildings. Examples of design features allowing occupant control of the internal environment include adjustable thermostats, trickle vents and blinds, openable windows and flexible layout which allows occupants to arrange the position of desks and seating to suit themselves.

14. HVAC SYSTEMS

Heating, ventilating and air-conditioning (HVAC) systems can play several roles to reduce the environmental impact of buildings. The primary function of HVAC systems is to provide healthy and comfortable interior conditions for occupants; well-designed, efficient systems do this with minimal non-renewable energy and air and water pollutant emissions. Cooling equipment that avoids chlorofluorocarbons and hydrochlorofluorocarbons (CFCs and HCFCs) eliminates a major cause of damage to the ozone layer.

However, even the best HVAC equipment and systems cannot compensate for a building design with inherently high cooling and heating needs. The greatest opportunities to conserve non-renewable energy are through architectural design that controls solar gain, while taking advantage of passive heating, day lighting, natural ventilation and cooling opportunities. The critical factors in mechanical systems' energy consumption – and capital cost – are reducing the cooling and heating loads they must handle.

14.1 Indoor Air Quality

Indoor air quality is a central concern for mechanical designers and contractors, requiring careful design, installation and site review for good results. The first step is to reduce contaminant sources through careful material selection practices, as recommended in the Materials and Construction Management chapters. Conditioning large amounts of outdoor air to deal with indoor pollutants that could have been avoided is a waste of energy – and money.

Bio-contaminants – microbial diseases, fungi and molds – are some of the most potentially dangerous indoor air pollutants. These typically grow best in warm, dark, moist environments, which have a ready source of nutrients such as dust and dirt. Standing water in contact with ventilation air supplied to occupied spaces can harbor these organisms. Of particular concern is legionella, which can be fatal to exposed occupants. Potential legionella sources include cooling tower drift, direct evaporative coolers, and standing water in coil drain pans or in humidifiers.

Combustion equipment for heating, such as furnaces and boilers, is another potential source of indoor air pollutants, such as carbon monoxide and nitrogen oxides. Natural gas and propane equipment, if operating properly, emit little carbon monoxide; their major air emissions are carbon dioxide and water vapor. However, they still emit trace pollutants, including sulfur oxides, polyaromatic hydro-carbons and nitrogen oxides, which have been shown to affect health with chronic, low-level exposures. Designers can reduce or eliminate occupant exposure to combustion products by isolating combustion chambers from occupied spaces, providing excess combustion air under all operating circumstances, and ensuring that equipment operators have complete manuals and training in maintenance procedures to keep the equipment properly tuned.

Man-made mineral fibers (MMMFs) are another potential indoor air pollutant from mechanical systems, causing nasal, throat and eye irritation. These typically come from damaged fibrous duct liners used to reduce noise, or from insulation and ceiling tiles exposed in air return plenums. These fibrous materials can become greater hazards if they become damp, as they form an ideal growth medium for biocontaminants – especially since they tend to trap and retain dust.

Some indoor air pollutants are difficult to eliminate. In these cases, isolation and local exhaust helps control occupant exposure. This strategy works best with photocopiers and laser printers, storage areas for toxics such as cleaners and pesticides, areas for gluing and solvent use, and other local “point sources.”

A crucial element in pollutant source control is ensuring that outdoor air intakes do not bring pollutants into the building. Santa Monica has some of the best outdoor air quality in the entire Los Angeles basin, largely due to steady on-shore winds, so treatment of outdoor air is usually necessary only near local sources of air pollution. However, the location of outdoor air intakes and operable windows must be carefully separated from building pollution sources such as cooling towers, combustion appliance vents, vehicle exhausts, plumbing vents and air exhausted from buildings.

Once pollutant source controls are addressed, efficiently filtering supply air and providing generous amounts of outdoor air will help ensure indoor air quality. An HVAC system that is capable of providing more outdoor air than the minimums required by ASHRAE standards helps ensure flexibility and occupant health in future, as building uses and furnishings change.

These efforts can aid the marketability of buildings, with growing awareness and concern about indoor air quality by buyers and lessors. They can also reduce the liability exposure of building developers, designers, builders and managers.

14.2 Energy- Efficient HVAC Equipment

Climate-responsive building design reduces heating and cooling loads, and thus the size of HVAC systems and equipment. The cost of smaller equipment often more than offsets the cost of envelope and electrical upgrades aimed at saving energy. Selection of more efficient HVAC equipment can further conserve non-renewable energy, and reduce air pollution from electricity generation and on-site combustion. The efficiency of heating and cooling equipment has improved significantly since the introduction of minimum efficiency regulations such as Title 24 and federal requirements. As demand for better equipment has increased, the cost of energy-efficient HVAC equipment has dropped. However, equipment that exceeds regulated minimums often bears a capital cost premium. This can be balanced by other factors which reduce capital and life-cycle cost, and enhance marketability of the building:

- Smaller heating and cooling loads allow smaller, less expensive HVAC equipment and ductwork.
- Reduced energy costs can pay for HVAC equipment investment within two to three years.
- High-efficiency equipment tends to be of higher quality, with longer service lives and warranties.

14.3 Cooling Equipment and Ozone Layer Protection

Chlorofluorocarbon refrigerant production has been banned in most nations, and its use is declining as recycled CFC costs continue to rise dramatically. Hydrochlorofluorocarbon refrigerants are currently permitted, but new production is scheduled to end in 2010, within the lifetime of most of the smaller HVAC equipment typical in Santa Monica buildings. HCFC costs are likely to rise quickly when production ends, just as CFC costs have.

CFC-free chillers, air conditioners and heat pumps are now in widespread use, with excellent efficiencies, and capital costs comparable to those before the end of CFC production. However, HCFC-free equipment is currently not available in a full range of equipment sizes and models. Building design for the long term must consider how HCFC equipment will be replaced in future.

15. PHOTOVOLTAICS (PV)

Photovoltaics (PV) are the field of technology and research related to the application of solar cells for energy by converting sunlight directly into electricity. Due to the growing demand for clean sources of energy, the manufacture of solar cells and photovoltaic arrays has expanded dramatically in recent years.

Photovoltaic production has been doubling every two years, increasing by an average of 48 percent each year since 2002, making it the world’s fastest-growing energy technology. At the end of 2007, according to preliminary data, cumulative global production was 12,400 megawatts. Roughly 90% of this generating capacity consists of grid-tied electrical systems. Such installations may be ground-mounted (and sometimes integrated with farming and grazing) or built into the roof or walls of a building, known as Building Integrated Photovoltaic or BIPV for short.

Photovoltaics are best known as a method for generating electric power by using solar cells packaged in photovoltaic modules, often electrically connected in multiples as solar photovoltaic arrays to convert energy from the sun into electricity. To explain the photovoltaic solar panel more simply, photons from sunlight knock electrons into a higher state of energy, creating electricity. The term photovoltaic denotes the unbiased operating mode of a photodiode in which current through the device is entirely due to the transuded light energy. Virtually all photovoltaic devices are some type of photodiode.

Solar cells produce direct current electricity from light, which can be used to power equipment or to recharge a battery. The first practical application of photovoltaics was to power orbiting satellites and other spacecraft, but today the majority of photovoltaic modules are used for grid connected power generation. In this case an inverter is required to convert the DC to AC. There is a smaller market for off grid power for remote dwellings, roadside emergency telephones, remote sensing, and cathodic protection of pipelines.

Cells require protection from the environment and are packaged usually behind a glass sheet. When more power is required than a single cell can deliver, cells are electrically connected together to form photovoltaic modules, or solar panels. A single module is enough to power an emergency telephone, but for a house or a power plant the modules must be arranged in arrays. Although the selling price of modules is still too high to compete with grid electricity in most places, significant financial incentives in Japan and then Germany triggered a huge growth in demand, followed quickly by production.

Perhaps not unexpectedly, a significant market has emerged in urban or grid-proximate locations for solar-power-charged storage-battery based solutions. These are deployed as stand-by systems in energy deficient countries like India and as supplementary systems in developed markets. In a vast majority of situations such solutions make neither economic nor environmental sense, any green credentials being largely offset by the lead-acid storage systems typically deployed. For some serious issues see Lead Acid Battery recycling.

The EPIA/Greenpeace Advanced Scenario shows that by the year 2030, PV systems could be generating approximately 2,600 TWh of electricity around the world. This means that, assuming a serious commitment is made to energy efficiency, enough solar power would be produced globally in twenty-five years' time to satisfy the electricity needs of almost 14% of the world's population.

15.1 Current development

The most important issue with solar panels is capital cost (installation and materials). Newer alternatives to standard crystalline silicon modules including casting wafers instead of sawing, thin film (CdTe, CIGS, amorphous Si, microcrystalline Si), concentrator modules, 'Sliver' cells, and continuous printing processes. Due to economies of scale solar panels get less costly as people use and buy more — as manufacturers increase production to meet demand, the cost and price is expected to drop in the years to come. By early 2006, the average cost per installed watt for a residential sized system was about USD 7.50 to USD 9.50, including panels, inverters, mounts, and electrical items.

In 2006 investors began offering free solar panel installation in return for a 25 year contract, or Power Purchase Agreement, to purchase electricity at a fixed price, normally set at or below current electric rates. It is expected that by 2009 over 90% of commercial photovoltaics installed in the United States will be installed using a power purchase agreement. An innovative financing arrangement is being tested in Berkeley, California, which adds an amount to the property assessment to allow the city to pay for the installed panels up front, which the homeowner pays for over a 20 year period at a rate equal to the annual electric bill savings, thus allowing free installation for the homeowner at no cost to the city.

The current market leader in solar panel efficiency (measured by energy conversion ratio) is Sun Power, a San Jose based company. Sun power's cells have a conversion ratio of 23.4%, well above the market average of 12-18%. However, advances past this efficiency mark are being innovated by engineers at MIT and the California Institute of Technology, and efficiencies of 42% have been achieved at the University of Delaware.

15.2 In buildings

Building-integrated photovoltaics (BIPV) are increasingly incorporated into new domestic and industrial buildings as a principal or ancillary source of electrical power and are one of the fastest growing segments of the photovoltaic industry. Typically, an array is incorporated into the roof or walls of a building, and roof tiles with integrated PV cells can now be purchased. Arrays can also be retrofitted into existing buildings; in this case they are usually fitted on top of the existing roof structure. Alternatively, an array can be located separately from the building but connected by cable to supply power for the building.

Photovoltaic solar panels on a house roof

Where a building is at a considerable distance from the public electricity supply (or grid) - in remote or mountainous areas – PV may be the preferred possibility for generating electricity, or PV may be used together with wind, diesel generators and/or hydroelectric power. In such off-grid circumstances batteries are usually used to store the electric power.

In locations near the grid, however, feeding the grid using PV panels is more practical, and leads to optimum use of the investment in the photovoltaic system. This requires both regulatory and commercial preparation, including net-metering and feed-in agreements. To provide for possible power failure, some grid tied systems are set up to allow local use disconnected from the grid. Most photovoltaics are grid connected. In the event the grid fails, the local system must not feed the grid to prevent the possible creation of dangerous islanding.

The power output of photovoltaic systems for installation in buildings is usually described in kilowatt-peak units (kWp).

15.3 Power costs

The PV industry is beginning to adopt levelized cost of energy (LCOE) as the unit of cost. The results of a sample calculation can be found on pp. 52, 53 of the 2007 DOE report describing the plans for solar power 2007-2011. For a 10 MW plant in Phoenix, AZ, the LCOE is estimated at $0.15 to 0.22/kWh.

The table below is a pure mathematical calculation. It illustrates the calculated total cost in US cents per kilowatt-hour of electricity generated by a photovoltaic system as function of the investment cost and the efficiency, assuming some accounting parameters such as cost of capital and depreciation period. The row headings on the left show the total cost, per peak kilowatt (kWp), of a photovoltaic installation. The column headings across the top refer to the annual energy output in kilowatt-hours expected from each installed peak kilowatt. This varies by geographic region because the average isolation depends on the average cloudiness and the thickness of atmosphere traversed by the sunlight. It also depends on the path of the sun relative to the panel and the horizon.

Panels can be mounted at an angle based on latitude, which can add to total energy output. Solar tracking can also be utilized to access even more perpendicular sunlight, thereby raising the total energy output. The calculated values in the table reflect the total cost in cents per kilowatt-hour produced. They assume a 10% total capital cost (for instance 4% interest rate, 1% operating and maintenance cost, and depreciation of the capital outlay over 20 years). Physicists have claimed that recent technological developments bring the cost of solar energy more in parity with that of fossil fuels. In 2007, David Faiman, the director of the Ben-Gurion National Solar Energy Center of Israel, announced that the Center had entered into a project with Zenith Solar to create a home solar energy system that uses a 10 square meter reflector dish. In testing, the concentrated solar technology proved to be up to five times more cost effective than standard flat photovoltaic silicon panels, which would make it almost the same cost as oil and natural gas. A prototype ready for commercialization achieved a concentration of solar energy that was more than 1,000 times greater than standard flat panel.

System	Approximate Installed Cost €/m
Pv curtain walling, glass/glass crystalline	880
Pv curtain walling, thin-film amorphous	380
Double glazing	450
Stone cladding	4
Polished stone	750-1600
Pv rain-screen cladding	700
Steel rain-screen over-cladding	290
Pv roofing tiles(housing)	500
Pv modules on a pitched roof	750
Roofing tiles-clay or concrete	42
Timber roofing (larch)	44
Slate	60

16. IMPLEMENTATION OF THE EPBD IN SPAIN: STATUS MAY 2007

The existing Spanish legislation regarding energy saving in buildings dates from 1979 and the last regulation on thermal building installations from 1998. Both needed extensive reviewing and updating. The EPBD gave the Spanish Government the chance to include more stringent energy criteria into this review, not just for the fulfillment of the EU obligations but also for the implementation of other National Energy Policies such as the Energy Strategy E4 and the Renewable Energy Plan.

i. Legal context

The EPBD was transposed in Spain by means of three royal decrees:

- Royal Decree approving the 'Technical Code of Buildings (CTE)'. It was approved by the Council of Ministers on 17th of March 2006 and published in the Official Gazette on 28th March 2006.
- Royal Decree approving the review of the current 'Regulations for thermal installations on Buildings (RITE)', approved by the Council of Ministers on 20th of July 2007 and published in the official Gazette on 29th August 2007.
- Royal Decree on the Basic Procedure for Energy Performance Certification of new buildings approved by the Council of Ministers on 17th January 2007, and published in the Official Gazette on 31st January 2007.

All of these are the responsibilities of the Ministry of Housing, and the revised RITE and Energy Certification is the responsibility of the Ministry of Industry, Tourisms and Trade also.

ii. Status of the implementation

Calculation procedures

The calculation procedure for the buildings energy efficiency (named "Energy Efficiency qualification") is expressed by the estimated energy consumption necessary to satisfy the building energy demand in occupational and standard running conditions.

Requirements for new buildings

The Building Code (CTE) has set minimum energy requirements for new buildings. The requirements come into force for building permits requested after 17th September of 2006.

The type and level of performance requirements depend on the climatic zone (in total, there are 12 in all the Spanish territory) where there is building work, and they cover:

- Maximum U-values for different building elements;
- Solar factor for windows, roof lights, etc;
- Minimum Efficiency performance for thermal installations;
- Minimum Efficiency performance for lighting installations;
- Minimum natural lightning contribution;
- Minimum solar contribution to Domestic Hot Water;
- Minimum photovoltaic contribution to electric power.

The compliance with requirements on ‘Energy demand limitation’ (HE1) could be checked using a simplified procedure, (for each orientation, the real values are compared with the limit values for the roof, facade walls and floors in contact with ground) or by using a complex procedure.

The complex procedure requires the use of software tools. LIDER is the official one; it has been developed by the Government and is available for free.

More information about these two procedures are found in the Section HE1 “Limits for the Energy Demand” of the Basic Document DB-HE Energy Saving of the Building Code approved by the Royal Decree 314/2006, on 28th of March.

Requirements for existing buildings

Existing buildings must comply with the same minimum requirement as new ones when building rehabilitation, enlargement or renovation is carried out: also large buildings (floor area over 1.000 m2) where more than 25 % of the building envelope undergoes renovation. For new buildings, these requirements must also be implemented by 17th September 2006.

Inspection of boilers and air conditioning

Inspection of boilers is already covered by the Regulation on thermal installations on Buildings (RITE) since its first version was approved in 1982, revised in 1986 and currently applicable since 1998. This current RITE version has been recently revised and approved by the Council of Ministers on 20th of July 2007.

The technical procedures for HVAC systems are included in this revised version of RITE.

Certification of buildings. Provisions regarding the energy performance certification of new buildings have been adopted at national level by the Government as the ‘National Basic

Procedure for energy certification' by means of the Royal Decree 47/2007, of 17th January, published on 31st of January 2007. The fact that it is a 'Basic procedure' means that other authorities having jurisdiction, such as the Autonomous Communities, can regulate and complete the National system giving more detail provisions of the control and inspections. The cooperation between all interested parties and administrations involved will be realized through a National Advisory Commission set by the Decree.

Certification will be obligatory for new buildings for which a building permit is requested by Local Authorities after 31st October 2007. This applies to every type of building (dwellings, public, commercial…).

As for the calculation of energy demand, the 'National Basic Procedure' for energy certification foresees two possible ways: a simplified one (that includes any validated procedure approved by the Certification Commission added to the already existing simplified methodology for dwellings based in 12 tables for different climatic areas) and another complex one. The last one requires the use of a software tool, 'CALENER' being the official one.

So far, there are two different versions of CALENER: CALENER_VYP (for dwellings and small tertiary sector buildings) and CALENER_GT (for big tertiary sector buildings).

For existing buildings, another Royal Decree is under preparation. A 'Basic procedure" for the certification of existing buildings is expected to be ready and mandatory from 2009.

iii. Future planning

It is expected that the Royal Decree approving the Certification for new buildings will be approved by the Government soon.

PART TWO

Purpose

The main purpose of this research was to find the energy efficiency of the agriculture building placed in Castelldefels, Barcelona. This has been achieved through the study of a lot of parameters.

Firstly, we checked the location, the climate (winds, temperature) and the orientation of the building and of all the surroundings of it. After this, a very important parameter was to study the envelope design, the shell of the building. There we saw the four different sides of it (north, west, east, south), with different materials, different percentage of windows, some of them covered with persiennes, some other with double glaze and also the three patios (open areas) inside the building. We scannered all these things in order to find the rate of windows and massive in the whole building and understand how important is for a building like this (which is aimed at students) to gain the more daylight it can, in order to work properly.

After this, we checked what kinds of materials have been used in each side of it (inside and outside). The goal here is to choose materials that improve the indoor air quality and energy efficiency, so we have a lot of aluminum, concrete and glaze. In addition, we calculated the watts that the fluorescent lamps which are consumed and we noticed that the price was within the limits that exist for schools. Finally, we made some excel tables with all the details of each floor and each classroom, where we can see the m^2 of each classroom, the orientation, the number of windows and dimensions of them, the number of ventilations, the lighting and their watts, in order to have an aggregate table with all these information.

1. GEOGRAPGY

Barcelona as seen from space

Barcelona is located on the northeast coast of the Iberian Peninsula, facing the Mediterranean Sea to the east, on a plateau approximately 5 km (3 mi) wide limited by the mountain range of Collserola, the Llobregat river to the south-west and the Besòs river to the north. This plateau has 170 km^2 (66 sq mi), of which 101 km² (38.9 sq mi) are occupied by the city itself. It is 160 km (100 mi) south of the Pyrenees and the Catalonian border with France.

Collserola, part of the coastal mountain range, shelters the city to the north-west. Its highest point, the peak of Tibidabo, 512 m (1,680 ft) high, offers striking views over the city and is topped by the 288.4 m (946.2 ft) Torre de Collserola, a telecommunications tower that is visible from most of the city. Barcelona is peppered with small hills, most of them urbanized and that gave their name to the neighborhoods built upon them, such as Carmel (267 m), Putxet (181 m) and Rovira (261 m). The escarpment of Montjuïc (173 m), situated to the southeast, overlooks the harbour and is topped by Montjuïc castle, a fortress built in the 17–18th centuries to control the city as a replacement for the Ciutadella.

2. CLIMATE

Climate chart for Barcelona

J	F	M	A	M	J	J	A	S	O	N	D
42	29	42	45	56	45	29	59	86	92	58	49
12	14	16	18	21	25	28	28	26	22	17	13
5	5	7	9	13	16	19	20	17	13	8	6

average temperatures in °C
precipitation totals in mm
source: MSN Weather

Imperial conversion [show]

J	F	M	A	M	J	J	A	S	O	N	D
1.7	1.1	1.7	1.8	2.2	1.8	1.1	2.3	3.4	3.6	2.3	1.9
54	57	61	64	70	77	82	82	79	72	63	55

40	41	45	48	55	61	66	68	63	55	46	43

average temperatures in °F
precipitation totals in inches

Barcelona has a Mediterranean climate, with sub-mediterranean influence, which makes of it not to be the "classical mediterranean climate" with mild, humid winters and warm, dry summers. Barcelona is located in the eastern coast of the Iberian Peninsula, so, the usual west winds, especially in winters, which cause the wet climate in many places of Western Europe, arrive in Barcelona with low humidity, producing no rain. However, the proximity to the Atlantic, its latitude, and the relief, are the reasons why the summers are not as dry as in other Mediterranean Basin countries, because lows (not surface lows but high-atmospheric "cold invasions") can affect easily the area of Barcelona (and Catalonia), causing great storms, particularly in August. Some years, the beginning of June is still cool and rainy, like April and May which, together with August, September, October and November, are the wettest months of the year. The driest are July, February, March and June. So, on average, rainy seasons are spring and autumn, and the dry ones are winter and summer. The order is: AUT-SPR-WIN-SUM. We also have to take into account that the Western Mediterranean Climate is the most irregular of the world. This means that in many occasions averages are not what really happens. For instance, one year October can be very dry and July or February wet months.

As for temperatures, December, January and February are the coldest months, averaging temperatures of 9°C (48 °F) at the Airport and over 10°C in the city. July and August are the hottest months, averaging temperatures of 24°C (72°F). The highest recorded maximum temperature in the centre of the city is 38.6°C. Near the hills and the Airport annual rainfall reaches the 650 mm, and in the city centre about 600 mm.

Barcelona from Tibidabo Hill

Snowfalls and freezing nights occur almost one time yearly, though these do not normally lead to significant, if any, disruption.

Thunderstorms, which occasionally reach severe limits, are common from mid August until November. Even if Barcelona is not a "windy city" is affected by sea breezes from May/June to September and winds from the west and north-west in winter. Besides, eastern gales (also with rain) cause huge waves in the sea which cause damages to the coast. Sometimes east and NE winds can exceed 100 km/h. In the cold season Barcelona could be affected by tramontana or mistral winds as other places of the Northwestern Mediterranean Basin.

Even if it is considered a sunny city, some days of fog and series of cloudy days are not rare. Sea Fog is usual at the beginning of Spring, when the first warm African air masses overcome the cold mediterranean waters. So, cloudy days could be usual from April to October/November. Winter is more sunny than August. Not July or June.

2.1 Winds

The **tramontane** is a strong, dry cold wind from the north (on the Mediterranean) or from the northwest (in lower Languedoc, Roussillon, Catalonia and the Balearic Islands.). It is similar to the **mistral** in its causes and effects, but it follows a different corridor; the tramontane accelerates as it passes between the Pyrenees and the Massif central, while the Mistral flows down the Rhone Valley between the Alps and the Massif central.

The tramontane is an example of a katabatic wind, which is created by the difference of pressure between the cold air of a high pressure system over the Atlantic or northwest Europe. The high-pressure air flows south, gathering speed as moves downhill and is funnelled between the Pyrenees and the Massif central.

Tramontane clouds

3. ORIENTATION

Orientation is a critical component of energy efficiency and the ability of a building to properly mediate the summer and winter sun heat loads which penetrate through a building's skin (the outer shell of the building). Larger buildings like office buildings which are more dominated by internal loads like lights, business machines, and large numbers of people. This fact sheet will cover three areas: compass direction, views and other site amenities, and building configuration.

3.1 Compass Direction

Castelldefels is located in the province of Barcelona, at 41^o 20' North Latitude and 2^o 40' East Latitude. It is the last city going down south the Baix Llobregat, between the Delta of this river and El Massis de Garraf.

It limits from East to West with the coast line about 5km the Mediterranean Sea, and from North to West with the first reliefs of Garraf. The administrative limits coincide on the North and the East with the city of Gava, and on the west with Sitges. Castelldefels is part of the Catalonian community.

It has a typical Mediterranean climate this means rain in the spring and autumn with spectacular storms, which can pour 50 liters per m^2 in less than an hour. Dry summers and winters when you can feel the influence of anticyclones. The termic regulator effect of the sea provides mild winters and hot humid summers. The average temperature around the year is about 16^o C and about 300 sunny days a year. The rain rate is 600/700 liter per m^2. The extension of the area of Castelldefels is 1.274 Hectares. Half of this area is urbanized, and another 427 are dedicated to urban residential land, which represents 34% of the whole. The present population of Castelldefels is more than 40.000 inhabitants.

Here in Castelldefels and in any climate where the sun and its heat play a dominant role in human comfort, the direction is oriented (which side faces which direction) is the most effective difference you can make in keeping your cooling costs down. The optimal orientation corresponds to the cardinal directions of the compass, due north, due south, due east, and due west.

4. ENVELOPE DESIGN

The goal for the building envelope design is to optimize energy efficiency while minimizing glare. Issues to be explored include thermal mass, glazing and window framing, glare and sun shading, and insulation values. The construction of the building is shaped in this way to gain as much sunlight it can. So there are open areas-patios, in three parts of the structure that enforce with daylight the corridors and the offices that there are all around patios.

- The north side can be considered the cool side as the sun spends little time in the northern sky. In the north side of Agriculture building there is a 19.04 % of openings. This improves the gain of solar energy and also reduces the use of artificial light during the day.

Analytically, we counted the number of the windows:

$[(2.80*1.40)*59]=231.28m^2$
$[(2.80*0.70)*13]=25.48m^2$
$[(2.80*2.10)*26]=152.88m^2$
$11.20*3.80 \quad =42.56m^2$

$452.20m^2$

North surface: **$2375.00m^2$**

Percentage of windows in north side: 19.04%
Percentage of massive in north side: 80.96%

In this side, as we can see, all the windows have the **horizontal** direction. These windows exist in order to take a small percentage of sunlight, but the main reason is to have a view to the landscape. Also there are two vertical windows in the stairs in order to take light from the outside.

Also at the building there are three patios

which in the north side have totally 30 windows:

[(0.80*3.20)*30]=76.80m^2

North surface (patio): 296.40m^2

Percentage of windows in north patio side: 25.90%
Percentage of massive in north patio side: 74.10%

In front of this side of the patio there is the other building that shades it. So here we notice that the windows are vertical. This direction is better to take sunlight from the outside.

- The south side can be considered the sunny side, since during the course of the day the sun spends more time in the southern sky. As we can see agriculture consists of two separate parts. The part above is in majority covered by windows with persiennes. In summer season there is plenty of sunlight so cause of the persiennes the building receive less of this daylight. In winter season with all of these windows it takes on all the needful light in order to reduce the use of artificial light. The advantage here is that in winter, when the sun is lower in the sky, these slight overhangs allow sun penetration deep into a house to provide some passive solar heating.

Offices building

Persiennes

Analytically, we counted the number of the windows:

[(1.75*3.00)*40] =210.00 m^2

[(3.20*0.80)*30] =76.80 m^2

[(3.00*1.75)*32] =168.00m^2

[(3.80*3.80)*22] =317.68 m^2

772.48 m^2

South surface: **2375.00m^2**

Percentage of windows in south side: 32.50%

Percentage of massive in south side: 67.50%

Also at the building there are three patios

which in the south side have:

[(13*2.33)*3] =90.87 m^2
[(2*3.80*3.80)*3] =86.64 m^2

177.51 m^2

South surface patio: 296.4 m^2

Percentage of windows in south patio side: 59.80%
Percentage of massive in south patio side: 40.12%

In this side we notice that we have squared windows 3.80*3.80 (m^2) but the half of them are covered by persiennes, so they are **vertical** to gain the daylight and the ventilation for the classrooms.

- The east side oriented to the cardinal compass directions will take a lot of the sun's morning heat, since the sun spends much of its morning climbing through the east. Minimal window area on the east side is recommended, even overhangs on this east side will only work minimally because the sun is so low in the sky during the morning hours.

Analytically, we counted the number of the windows:

[(2.70*3.80)*4]=41.04 m^2

[2.70*13.25]=35.77 m^2

[(2.30*3.55)*2]=16.33 m^2

93.14 m^2

East surface: 471.20 m^2

Percentage of windows in east side: 19.76%

Percentage of massive in east side : 80.24%

Also at the building there are three **patios**

which in the east side have **100% windows**.

At the east façade of the building we see that the windows have horizontal and vertical direction. The horizontal direction is along the corridor and the vertical is sheer the stairs.

- The west side of Agriculture oriented in the cardinal compass direction will bear the brunt of the sun’s heat. In this case, minimize not only the window area, but also the total wall area facing west. Since the ambient heat of the day has built up (air temperature), the sun’s added heat will compound this. For this reason, the western exposure of the building should be devoid of all windows, or if windows are required by the dictates of the site or design, this exposure should be buffered with porches, trees, trellises, sunshades, carports, out buildings, or other means.

So **in the west surface there are no windows**.

But for the three patios in the west side:

(7.00*3.80)=26.60 m^2

(6.35*2.65)=16.82 m^2

43.42 m^2

West surface patio: 148.20 m^2

Percentage of windows in west patio side: 29.30%

Percentage of massive in west patio side : 70.70%

5. MATERIALS

The goal here is to select building materials that improve the indoor air quality and energy efficiency of the facility. Issues to be explored include the use of salvaged materials or materials with high recycled content and construction methods to reduce the quantity of materials used.

At the north side we notice that the exterior materials are aluminum, concrete and glaze. At the south side we have aluminum persiennes, glaze and concrete. At the west there is concrete and a small amount of glaze at the patios and finally at the east side occur concrete and glaze

5.1 Aluminum

Technical characteristics:

- Succeed the air flow for natural ventilation
- Hard, wear-resistant
- Good thermal conductivity
- High strength and stiffness

5.2 Concrete: It is a massive material that with its use we succeed thermal energy. In the base of our structure we use it because it is cheaper and we solve problems of humidity.

5.3 **Glaze:** We use clear glaze in order to gain thermal energy and more daylight. The technical characteristic of the windows is that they have double glaze. This protects the building from the cold in winter season and prevents the thermal to get into the building in summer season.

Double glaze

6. LICHTING

6.1 Daylight

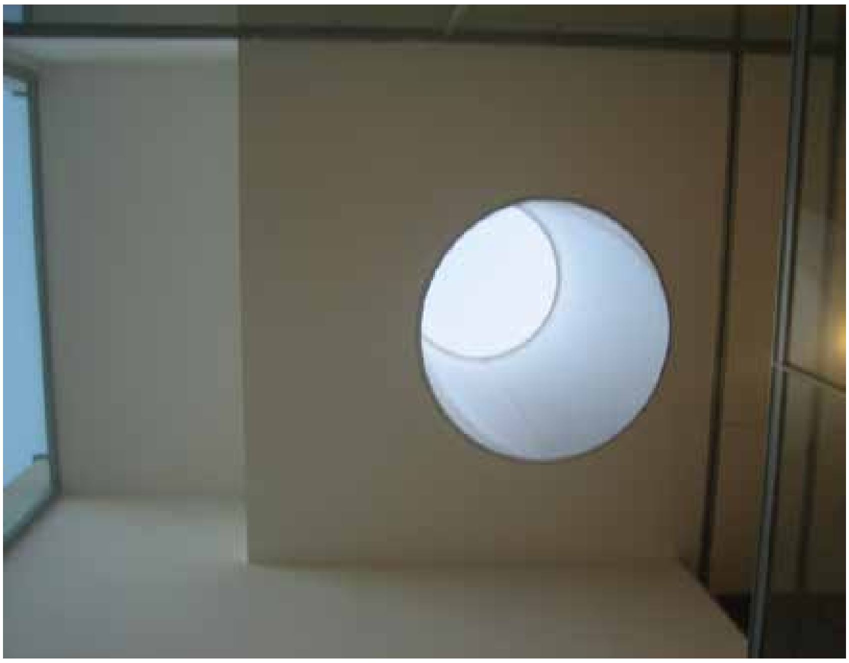
Natural light is a fluctuating source of light. It depends on the hour of the day, the season, the climate and the latitude of location. The objective of a day lighting technique consists on providing the best possible indoor luminous environment. A luminous environment should be appropriate to the function of the room. We talk about classrooms and offices so there should be enough light for reading and writing. The goal here is to optimize day lighting and reduce lighting loads. The most important thing is to gain daylight as much we can. In the agriculture building we achieve the rise of daylight with many gaps and windows. In every floor there are open areas. On third's floor roof there are windows that allow the suffusion light. With this measure we achieve the reduce of artificial light. Secondly there are open areas for the same reason (the suffusion of light).

Along the corridors of east surface there is glaze

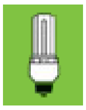
Glaze along the stairs

Gaps in the entrance of the building

Also at the separate building there are at the roof circle gaps with glaze.



6.2 Artificial lighting

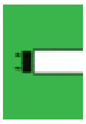


Compact fluorescent lamps/Energy saving lamps

More light, less energy and pretty to look at - three good reasons to choose compact fluorescent lamps. They consume considerably less electricity than ordinary light bulbs. They last much longer. And they can be used in place of almost any ordinary light bulb. Because they are so compact. To see how bright they can be, fit a fluorescent 23 W lamp into a luminaire designed to take a maximum of 60 W. It will give out as much light as a 120 W light bulb. That’s twice as bright.

And as for their economy, they'll last up to 15 times as long as an ordinary light bulb and consume around 80% less electricity for the same amount of light. Every fluorescent lamp will save you many times what it costs and they are also good for the environment. A fluorescent lamp of 20 W, for example, will save up to 1200 kW/h of electricity compared with an ordinary light bulb.

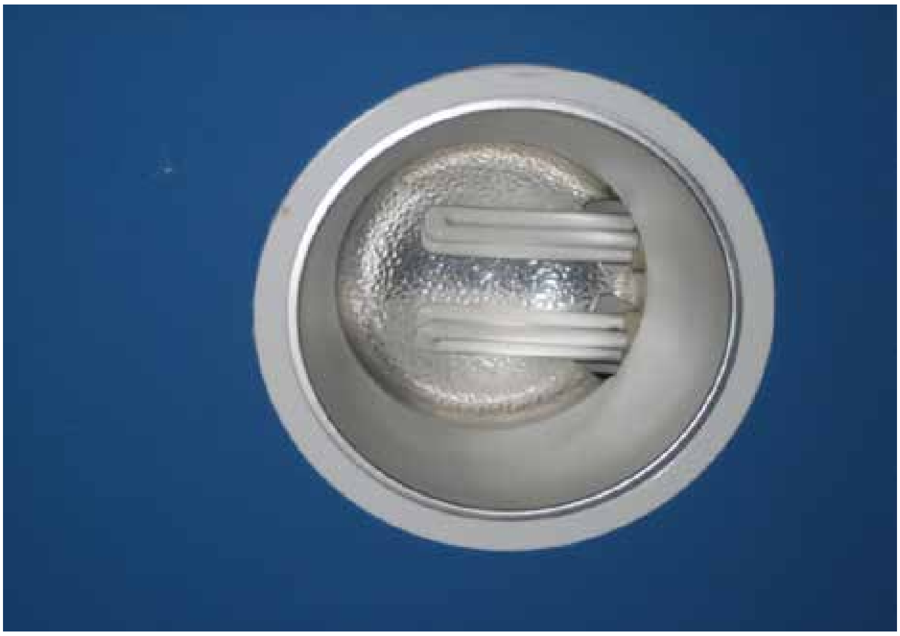
Compact fluorescent lamps are the bright and economical alternatives to ordinary light bulbs. They reduce electricity costs by as much as 80% compared with light bulbs of the same brightness, and last up to 15 times longer.
Big on economy, small in size and consumption.



Fluorescent lamps

Fluorescent lamps produce 70% of artificial light throughout the world. Their excellent economy and eco-friendly characteristics make them the first choice for many applications. Fluorescent lamps combine high luminous efficacy with low power consumption. A fluorescent lamp, for example, needs only around 15% of the electrical power that an ordinary light bulb needs. In terms of their lifespan they are also an excellent alternative. The average life of this kind of lamp is 24,000 hours- compared with just 1000 hours for an ordinary light bulb.

Low power consumption and long life mean that fluorescent lamps are kind to the environment. Their recycling quota is another plus for the environment. More than 90% of the weight of a fluorescent lamp can be reused for manufacturing lamps and 5 to 10% of the weight (e.g. metals) can be used in the manufacture of other products. First choice for durability.



Fluorescent lamp d=0.20cm, 16watt/lamp (2*16=32watt)

Fluorescent lamp l=1.50m & l=0.90m, 60watt/lamp

Fluorescent lamps along the corridor

7. COOLING

7.1 Natural Cooling

Refers to techniques which help a building stay cool in the summer but which require little to no energy. Such techniques help to reduce air-conditioning, not replace it**.**

Shading is particularly important in passive solar buildings, because the same features that collect sun light in winter we go right on collecting it in summer unless they are shaded and the building itself is designed to help cool itself.

Thermal mass performs well year round masonry materials can be effective in staying cool as well as storing heat in winter. If mass surfaces are exposed to cool night time temperatures, they will help the building stay cooler the next day. The additional insulation that increases winter performance will also work to improve summer performance by conserving the conditioned air inside the building. Sun low-e windows and other glazes with high R-values can help shield against unwanted heat gain in summer.

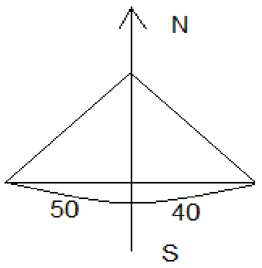
Trees are another site amenity not to be overlooked. Deciduous trees are a particularly great site asset as they can be used to shade a house in summer with their leaves and allow winter sun in when the trees lose their leaves in the fall.

Modifications of microclimate around the building can help to improve indoor comfort conditions and to reduce cooling loads, while also providing protected spaces for outdoor use.

Vegetation provides natural protection from the sun. Planting vegetation around the building can improve the climate conditions (solar incidence, wind conditions) from the building skin and open spaces. The trees provide shade in summer and allow solar incidence in winter. Around the Agriculture there are rows of trees that can also form wind barriers or act as wind channels for natural ventilation where needed. An average tree evaporates 1460 kg of water per sunny day which is the equivalent of 870 kJ cooling capacity. Evapotranspiration from one tree can save 1-2.4 MJ of electricity in A/C per year. Wet grass can lower surface temperature by 6-8^{o}C compared to exposed soil. Another landscape technique is the use of an artificial canal of water.

Wind

Middle Europe



Consider the need for shelter from prevailing winds in the heating season, and for ventilation in the cooling season. In the heating season, cold wind increase heat loss, by cooling the external fabric, and by increasing air infiltration through openings. Shelter-planting and topography can act to reduce wind speed, and hence reduce heat loss. In Castelldefels, the wind prevails from one quarter over the others, and suitable design should address this, so as to deflect or reduce wind flow without reducing solar gain. This will also improve the comfort of outdoor living spaces.

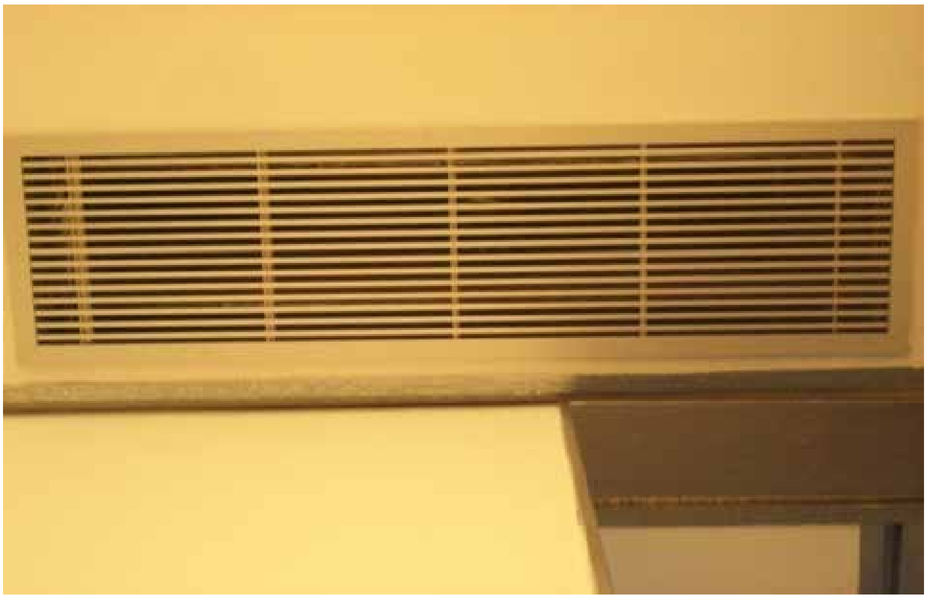
In the cooling season, it may be useful to direct the prevailing wind flow, by vegetation or topography, so as to funnel cooler breezes through the dwelling in order to reduce the cooling load.

In average, as we can see in the table below, the wind velocity in summer/spring season is 34 km/h and in winter/autumn season is 40.4 km/h.

Percentage difference 15.77%

7.2 <u>Mechanical cooling</u>

When we can’t achieve the natural cooling we replace it with mechanical cooling. In this case we use the kind of air-conditioning set on the walls.
As we can see the pictures there are in vertical and horizontal direction, up or down the wall. The dimensions of them are 0.33*1.25.



Horizontal clima on the top of the wall

Vertical clima down on the wall

This type of cooling works automatically and closes after two hours.
It is controlled to keep the temperature stable at 15 degrees during the winter and the summer.

8. VENTILATION

The goal here is to improve indoor air thermal conditions while maintaining energy efficiency and to provide thermal comfort. Natural ventilation is the process by which fresh out door air is provided to a space by means of the natural driving forces of wind and temperature difference. Natural ventilation can reduce the energy required to cool buildings by reducing or eliminating the need for chillers, fans and pumps. The type and placement of operable windows or dedicated air inlets and outlets is critical in directing air into and out of the building so they provide both ventilation and cooling of interior surfaces.

8.1 Wind natural driving force: when wind strikes a building surface it creates pressure distribution.
The pressure distribution depends on:

- Location: open country, city centre
- Wind speed and wind direction
- Shape of the building

8.2 Mechanical ventilation

Ventilation on the roof (50*50 cm)

We can see this type of ventilation on the top of the roof in some classrooms. With this way the air in classes goes straight to the atmosphere.

The same installations that used for the clima (previous photos) are working also as ventilators.

Wind driven ventilation

- The air flows through the building from areas of high surface pressure to areas of low pressure
- Wind velocity increases with height

Advantages

- Cost effective less expensive to install

- No operational costs
- No plant room space is needed
- Minimum maintenance

Disadvantages

- Inadequate for areas with severe climatic characteristics that can cause a discomfort
- Most suited to buildings located in mild to moderate climates away from inner city locations.
- No control over ventilation rate, can lead to indoor air quality problems
- Air flow rates are not constant
- Unsuited to noisy and polluted areas

9. HEATING

9.1 Natural heating

The agriculture building has high thermal mass, that means it absorbs heat during the day and releases it during the night due to the used materials. The concrete is a heavyweight material with high thermal mass, high specific heat, high density and low thermal conductivity. On the other hand glaze and aluminum are lightweight materials.

Winter consideration: thermal mass absorbs heat during the day and re-radiates it back during night.
Summer consideration: night ventilation cools down the thermal mass and draws out the stored energy. Appropriate shading during the day.

9.2 Mechanical heating

In our building we notice that it used the flat plate collector. The flat plate collector is the most common collector type. It is a thin, rectangular box with transparent or translucent cover, installed on the building’s roof. Small tubes run through the box carrying either water or an antifreeze solution to a black absorber plate. The absorber plate absorbs solar radiation and quickly heats up; the heat is transferred to the circulating fluid. A small pump moves the fluid into the building.

10. Conclusions of EXCEL Tables

Calculations
Planta 3 → 27.940 Watt
Planta 2 → 23.064 Watt
Planta 1 → 20.744 Watt
Planta 1 offices → 15.724 Watt
Baixa → 24.104 Watt
Baixa offices → 16.748 Watt
Sotterani → 7.464 Watt

Total →135.788 Watt
135.788Watt/12.098,24m^2=**11,22Watt/m^2**

Application	Lamp Style	Task illuminance/lux	Average Installed Power Density/Watt*m^{-2}
Commercial And simple Applications (schools)	fluorescent -triphosphor	750	17
	compact fluorescent	750	21

*****source: code for lighting (2002)

We notice that we have **11,22Watt/m^2** < **17,00Watt/m^2** that is the preferable price for schools.

11. Proposals – Which way to go?

In the wider area of the agriculture building there are ten foundations moreover, which operate also as independent buildings. This implies solar systems incorporated in the buildings, with high efficiency, high temperatures and some degree of storage.

- On the other hand we can go the way of centralised systems for buildings, building blocks or whole areas. This implies highly efficient solar systems, distribution networks and thermal storage facilities
- We have to keep in mind the energy needs of other societies:

This presupposes less sophisticated, partially independent applications, with systems that are inexpensive and easy to install and maintain.

New materials

Today a multitude of new materials with very interesting properties is developed. These materials contribute differently to the operation of the building.

For example:

- New kind of masonry mortar that serves as air conditioner. The coating containing plastic pellets filled with a resin mixture of paraffin. These resins are melted when the temperature exceeds 24°C so that the transition from solid to liquid state absorbs heat, and cool in this way the air inside the building.
- New paints developed for the external envelope of buildings. The new dyes absorb the exhaust gases acting sedative in cloud development and air pollution.

Advantages

- Right orientation in combination with proper construction of building envelope and materials makes it more effectual.
- Large percentage of glaze reduces the use of artificial lighting during the day and offers plenty of daylight. The glass is a highly recyclable material, but the recycling of it, leads to a second-grade material.
- The surrounding area (trees, artificial canal, lake) enforces the energy balance of the building all the seasons.
- Environment-friendly materials are used for all the building’s operations for energy saving.

Aluminum to succeed the air flow for natural ventilation

Concrete to succeed thermal energy

Glaze in order to gain thermal energy and more daylight.

Disadvantages

- The lights along the corridors switch on and off all together, that means much more energy consumption.

- In the building there are plenty of spot lights. The consumption of one spot light is 500watt, and because they are used only for decoration, the waste of energy for a bioclimatic building is huge.
- There is no green roof. A green roof is usually constructed to cover a large area in the most economical and efficient means possible with an emphasis towards improving the insulation or improving the overall energy efficiency of cooling and heating costs within a building.

PART THREE

TABLES

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