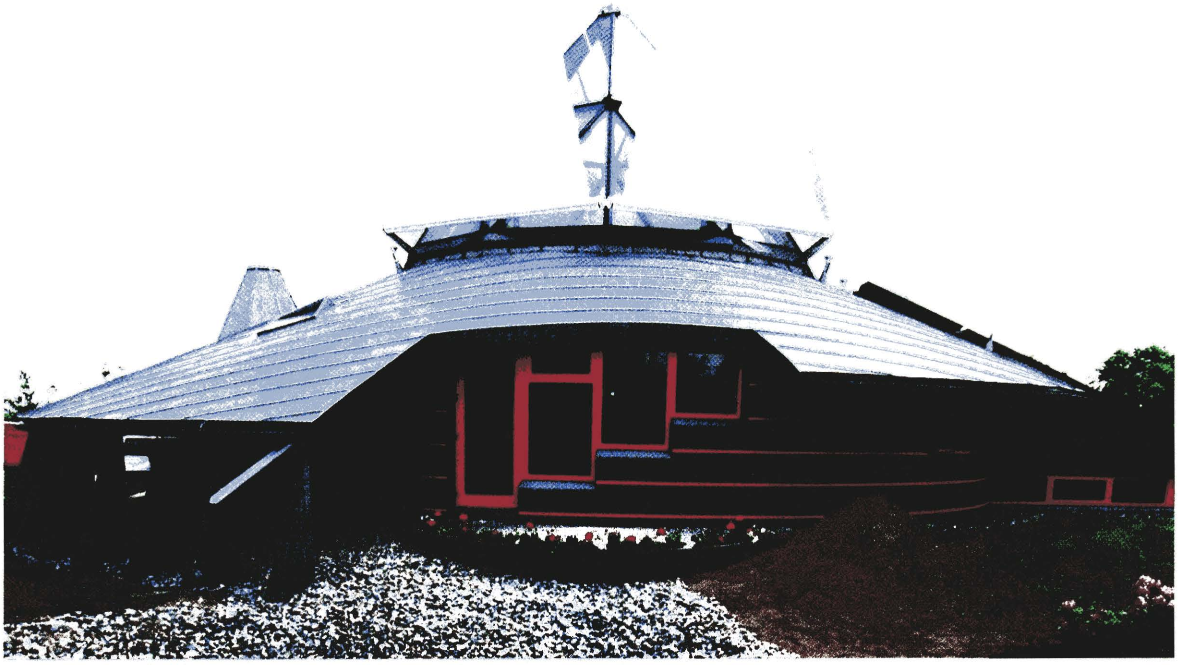
A THERMIE PROGRAMME ACTION

THERMIE

Less is More. Energy Efficient Buildings with less installations



European Commission
Directorate-General for Energy (DG XVII)

RUE

THE THERMIE (1990-1994)

This is an important European Community programme designed to promote the greater use of European energy technology. Its aim is to assist the European Union in achieving its fundamental objectives of:

- improving the energy supply prospects of the European Union;
- reducing environmental pollution by decreasing emissions, particularly those of CO_2, SO_2 and NO_X;
- strengthening the competitive position of European industry, above all small and medium-sized enterprises (SMEs);
- promoting the transfer of technology to Third Countries;
- strengthening economic and social cohesion within the European Union.

The majority of the funds of the THERMIE Programme are devoted to financial support of projects which aim to apply new and innovative energy technologies for the production, conversion and use of energy in the following areas:

- rational use of energy in buildings, industry, energy industry and transport;
- renewable energy sources such as solar energy, energy from biomass and waste, as well as geothermal, hydroelectric and wind energy;
- solid fuels, in the areas of combustion, conversion (liquefaction and gasification), use of wastes and gasification integrated in a combined cycle;
- hydrocarbons, their exploration, production, transport and storage.

THERMIE Programme (1990-1994) includes a provision for the enhanced dissemination of information to encourage a wider application and use of successful energy technologies. This information is brought together, for example, in publications such as this maxibrochure. Maxibrochures provide an invaluable source of information for those who wish to discover the state of the art of a particular technology or within a particular sector. The information they contain is drawn from all Member States and therefore provides a pan-European assessment.

To guarantee the maximum effectiveness of the funds available, the THERMIE Programme (1990-1994) includes an element for the co-ordination of promotional activities with those of similar programmes carried out in Member States and with other European Community instruments such as ALTENER, SAVE, SYNERGY, JOULE, PHARE and TACIS.

JOULE-THERMIE (1995-1998)

The first THERMIE Programme for the demonstration and promotion of new, clean and efficient technologies in the fields of rational use of energy, renewable energies, solid fuels and hydrocarbons, came to an end in December 1994. In January 1995, the programme was renewed as part of the new Non-Nuclear Energy Programme, better known as JOULE-THERMIE, within the European Community's Fourth Framework Programme for Research, Tehnological Development and Demonstration. As prescribed in the Treaty on European Union, this programme brings together for the first time the research and development aspects of JOULE (managed by the Directorate-General for Science, Research and Development, DG XII), with the demonstration and promotion activities of THERMIE (managed by the Directotate-General for Energy, DG XVII). A budget of 532 MECU has been allocated to the THERMIE component for the period 1995-1998.

Colour Coding

To enable readers to quickly identify those Maxibrochures relating to specific parts of the THERMIE Programme each Maxibrochure is colour coded with a stripe in the lower right hand corner of the front cover, i.e.:

🟩 **RATIONAL USE OF ENERGY**

🟨 **RENEWABLE ENERGY SOURCES**

🟦 **SOLID FUELS**

🟥 **HYDROCARBONS**

This maxibrochure was produced in the framework of the former THERMIE Programme (1990-1994).

Further infomation on the material contained in this publication, or on other THERMIE activities, may be obtained from one of the organisations listed inside the back cover.

Less is More. Energy Efficient Buildings with less installations

THERMIE PROGRAMME ACTION Nº B 097

Generalitat de Catalunya
Departament d'Indústria i Energia
Institut Català d'Energia

For the European Commission
Directorate-General for Energy (DG XVII)

Institut Català d'Energia
Member of the OPET NETWORK
Av. Diagonal, 453 Bis, Àtic.
Tel.: +34-3-439.28.00
Fax: +34-3-419.72.53
08036 BARCELONA
CATALUNYA-SPAIN

Directed by:
Albert Mitjà

Written by:
TOP E (European Consulting Engineering Network EEIG)

Coordinated by:
Andreu Corominas

Design and Printing:
DRIBBLING

Gener 1996

Acknowledgements

Thanks are due to the following for their contributions to this publications and to those whose material was not finally selected:

CRONE & KOCH INTERNATIONAL AS, Villa Vision, Denmark.

HOMAN O'BRIEN ASSOCIATES, Green Building, Ireland.

Professor Klaus Daniels (HL-TECHNIK AG).

Dr. Mario Costantino (INTERTECNO SpA).

NICHOLAS GRIMSHAW ASS, British Pavilion, Expo 92, Sevilla, Spain.

AGUILERA INGENIEROS, S. A.

CONTENTS

1. INTRODUCTION

When we consider future trends against the background of the major economic, ecological, social and cultural changes, it is clear that a change of mind must be brought about to save the resources which are still available now and to preserve the environment as much as possible.

This requirement must lead to new concepts in the field of the building environment, since in industrial countries about 40 % of primary energy produced is used in buildings. According to estimates, 2/3 to 3/4 of this energy may be saved through construction actions, which means that not only building services but also architectural services take on additional and exceptional importance, in which new techniques and better quality concepts must be symbiotic. Broadly speaking, the necessary change of mind has not yet taken place, particularly in the area of political and economic decision-making as there appears to be very little evidence of the necessary acceptance of construction that is environmentally friendly.

Figure 1.1 shows for the single building services the possible savings known now with their consequences and the environmental resources which are influenced.

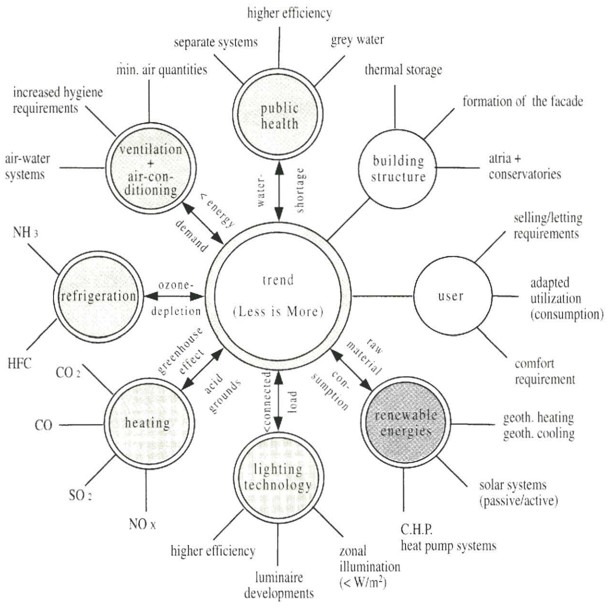


Fig. 1.1 Trends for building services-Less is More.

Besides using the possibilities in the building and building services, the user also plays, of course, a significant part. Through an adapted comfort requirement, an adapted use and a more conscious operation, the user may contribute significantly to lower investment costs and lower consumption.

The future trend "LESS IS MORE" does not mean to give away today's comfort requirement in general, but rather that with a lower implementation of building services due to better quality in construction and planning, lower quantities would be required.

"LESS IS MORE" means also that the presently known way of design thinking must come to an end, and that architects, layout planners, structural engineers, building services engineers and other members of the planning team including the owner and the user, must devise together meaningful solutions which meet the above-mentioned requirements.

Not integral but rather integrated planning is required in the future to develop integrated and meaningful solutions. These solutions should match as much as possible with the user requirements in a building and with the environmental supply in the best possible natural way with a low use of technical resources or at least only using them on a temporary basis.

"LESS IS MORE" aims thus at using as little primary energy or natural resources as possible through higher quality in the single technical and layout solutions and the most comprehensive synergy of the single building parts.

The result thereof is that a building is planned in an intelligent way so that building services are highly efficient while using minimum installation resources. It is necessary to plan the building in such a way so as to avoid problems rather than to solve them once they have been encountered.

Since buildings serve primarily the purpose of housing people, where adequate performances are to be achieved, it has to be considered under which conditions optimum performance and thermal comfort are achieved.

The relationships between thermal, health and visual comfort, the facade concept of a building, and the passive and active measures have an important meaning in the perceived overall comfort. "LESS IS MORE" from the point of view of a desired comfort level implies that buildings and their environment must be designed in such a way that they result in the least possible interference with the environment and that the environment resources are used directly as much as possible. The following will show that this is possible in numerous technological fields and that it results in numerous practical applications.

2. GENERAL

2.1 Fewer emissions, less pollution. Use of primary energy

When using primary energy it must be considered that, from the "LESS IS MORE" point of view, besides the most cost effective solution the emission of pollutants should be as small as possible. Figures 2.1. and 2.2. show examples of the evolution of emissions of nitrogen oxide (NO_x) for gas or fuel oil heating from 1979 to about 1990. The increase in emissions of nitrogen oxide was halted thanks to new regulations for a pure air and through the use of appropriate boilers as well as catalyzing technology. The cooling of exhaust gas to heat buildings (the technique of "combustion value") has also helped to reduce emissions. The financial cost of such furnaces is of course higher than for conventional systems. It must however be considered as a necessary investment for the future, to promote the protection of the environment. What must be noticed in that case is a higher use of the

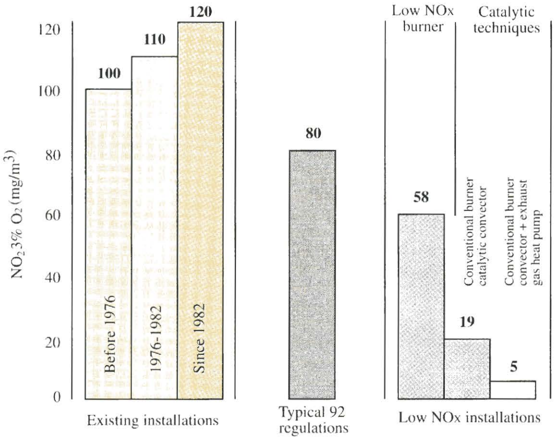


Fig. 2.1 Evolution of nitrogen emissions (NO_x) for gas heating.

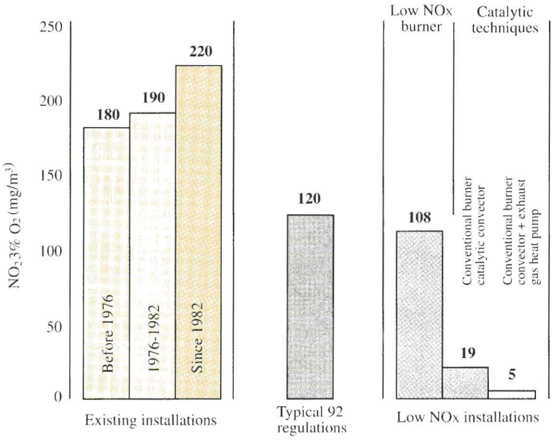


Fig. 2.2 Evolution of nitrogen emissions (NO_x) for fuel oil heating.

primary energy (fuel oil/gas) and the related higher efficiency of the installation.

The acceptability of heating production installations must be judged according to various criteria, whereby a pure air criteria must be decisive. In that case it is important to consider the primary energy consumption but also the resulting CO_2 emission. To calculate the pollutant emission of a heating production installation, the energy consumption of the installation is multiplied by an emission factor, which is as follows.

Emission factors for various heat productions

Type of installation	Fuel	NO_x (g/GJ)	CO =	CH[2] =	CO_2 =	SO_2 =	"Solids"[4] =
Gas motor[1]	natural gas	10	30	8[5]	60	0[6]	[6]
Boiler	natural gas	45	30	2[5]	60	0	0
Boiler	fuel oil	55	50	15[3]	74	94	4
Low NO_x[7] boiler	natural gas	20	30	2[5]	60	0	0
Low NO_x[7] boiler	fuel oil	30	50	15[3]	74	94	4
Gas turbine[8]	natural gas	30	50	5[5]	60	0	0

1 with a three way catalysator static operation after 3000 to 4000 hours of operation. 2 without methane. 3 also higher hydrocarbons with a higher hazardous potential. 4 "solids", hazard according to fuel. 5 only hydrocarbons to C_4H_x. 6 burnt parts of lubricant. 7 no experience on a long term basis. 8 with a "SCR"-catalysator.

Since not all emissions are equally noxious, an additional assessment is necessary:

The more NOXIOUS a pollutant is, the lower the limit level for sulphur dioxide (SO_2), nitrogen oxide (NO_x), carbon monoxide (CO) and "solids".

Various technologies can be compared to each other as to their environmental acceptability, whereby we have the present installations:

- gas condensation boiler (annual use rate 90%, with a low NO_x burner)
- fuel oil boiler (annual use rate 85%, with a low NO_x burner)
- fuel oil boiler for steam production (annual use rate 85%)
- gas motor (annual use rate 90%, three way catalysator, secondary condenser or heat pump to recover radiant heat from the motor)
- gas turbine (annual use rate 85%, secondary "denitrogenization" with ammonia or urea).

Although higher investment costs are required for gas motor operated installations than for boiler installations, it must be decided on a case -by- case basis whether in any case a higher investment cost is balanced by electrical production, a lower energy use and pollutant emissions.

According to the specific case, system combinations should be implemented for the supply of heat, cooling energy as well as electrical power, which lead to the most favourable results in the field of investment costs as well as in energy consumption and pollutant emissions.

2.2 Less conventional energy. Use of renewable energy sources

For the use of environmental energy, the location of the building plays a significant part. According to whether environmental energy is used in direct or indirect form the following is important:

- the period of sunshine
- the conditions of outside temperature (test reference year)
- the possibility of using geothermal energy (heat/cold)
- average wind speed and frequency etc.

In order to use solar energy directly, it is necessary to compare the amount of the heat gain available and the actual heat requirement. Solar energy can be used both directly and indirectly. One example of direct use of solar energy is the use of transparent insulation material. The material allows the light from the sun to go through, but keeps the heat trapped and thereby heats the facade (see also Case Study 2 for more details).

The average period of sunshine for a particular location plays a considerable role in the efficiency of the system. Figure 2.3 shows a "transparent thermal insulation" facade without water circulation (conventional construction), Figure 2.4 represents a variation thereof with water circulation. During the transition period, thermal energy from south facades may be transported to a plate heat exchanger, which makes it possible to use that thermal energy also in areas related to other facades.

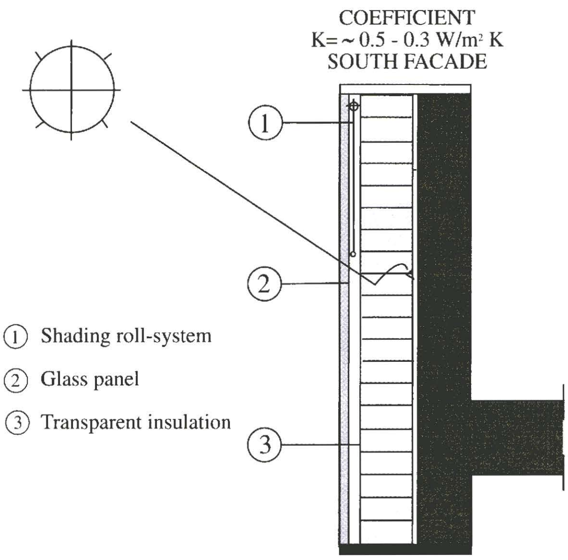


Fig. 2.3 Tansparent thermal insulation facade without water circulation (transparent wall)

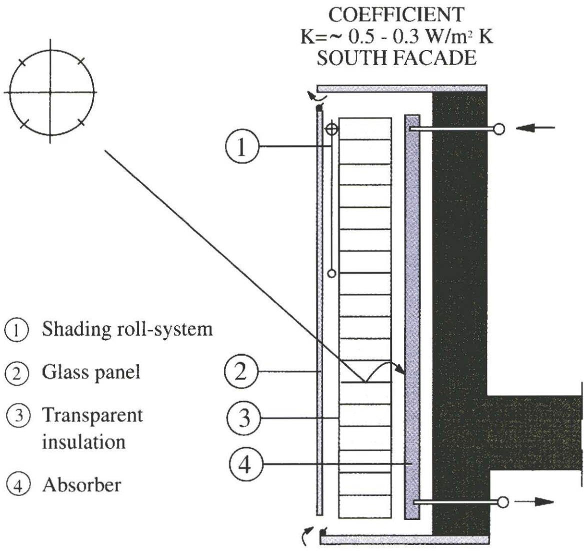


Fig. 2.4 Transparent thermal insulation facade with water circulation (transparent wall)

The maximum energy gain during the year for a south facade equals to a ratio of 100 kWh/m² (without water circulation) to 135 kWh/m² (with water circulation) for a typical Central European location (Germany).

If we wish to use facade surfaces to gain energy, we have, amongst others, absorption surfaces in combination with heat pumps. In this case cold water from the evaporator is led through absorption surfaces in the front part of the facade to gain environmental energy which is released thanks to heat pumps at a higher temperature level in the condenser. Figure 2.5 shows in a comparative way the heat requirement and the heat gain from the environment through absorption surfaces and heat pumps. The hypothesis is that in principle in the period from June to September there is a minimum heat requirement.

Contrary to "transparent thermal insulation" facades, absorption surfaces around a building may gather thermal energy, since absorption surfaces get environmental energy not only as the result of radiation but also from rain or wind.

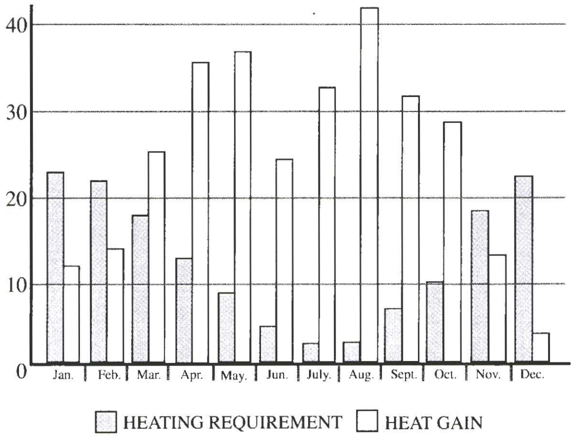


Fig. 2.5 Heat gain for a typical flat collector (south facade K-Coefficient 4.5 W/m²°K for 0.5 m² collector surface for 1 m² facade surface)*

In the example from Figure 2.5, it is only in December and January that the rate of efficiency of the absorption surfaces falls close to zero, except if the absorption surfaces are used in facades with brine, where they collect thermal energy with temperatures under 0°C. Figure 2.6 shows as an example the working principle of a relevant absorption surface, connected to a heat pump.

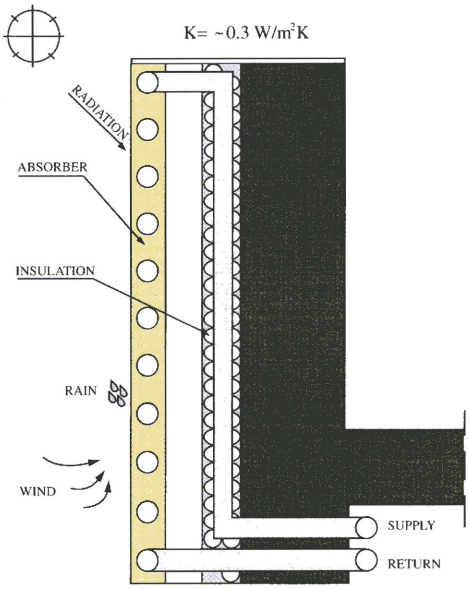


Fig. 2.6 Absorption surface in combination with heat pump

Different technical solutions are not to be balanced through pure energy cost reductions on a short-term basis and must thus be considered from the point of view of a reduction in the primary energy consumption and minimizing emissions.

Other examples based on geothermal collectors or aquifer storage and heat pump systems may provide the production of heating and cooling energy: they retrieve

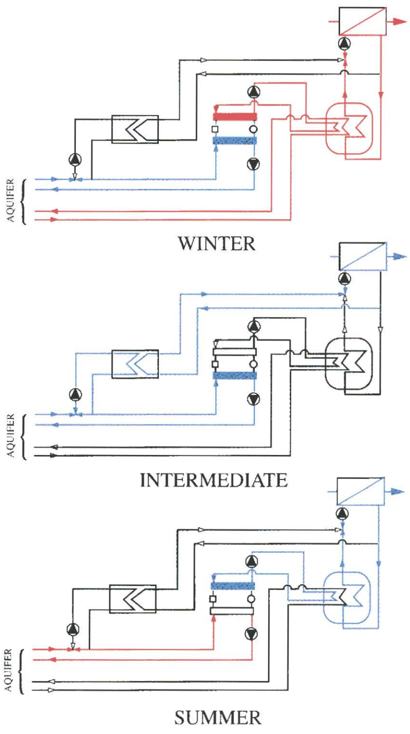


Fig. 2.7 Installation scheme for heat pump operation

heat or cold from the soil through a geothermal exchanger, whereby the heating or cooling energy stored in the aquifer can be used simultaneously. Figure 2.7 shows the schematic installation and the operation of the heat pump installation during the winter, the transition period and the summer. When using geothermal methods, to be able to use the thermal properties of the soil it has to be considered that there are soils with higher heat conductivity (>1W/mK) and better capacity to retain water (fine and medium size sand rich in quartz). To achieve the required heat conduction capacity it is also important that the soil in the areas where it is used geothermally is kept humid and saturated with water. The geothermal heat exchanger takes thermal energy from the soil during the heat period thanks to the water pumps. If the heat pumps operate in cooling mode, then the condenser heat is stored in the soil and the soil works as back and forth buffer storage.

If thermal energy is taken from the soil in the winter time and partly in the transition period, the soil becomes cooler. The cooled soil presents thus for the transition period and the summer a cold energy potential, which may be used to cool the building. During the cooling period the medium to convey heat (a brine-water mix) is pumped through the soil heat exchanger, it is cooled there, and then afterwards directly used to cool the air. If the soil has warmed up as the result of removing the cold in such a way that it is no longer possible to retrieve cooling energy, then the cold circulation of the heat pump is reversed and a standard cooling operation in the well-known form takes place. Simultaneously, the cooling unit can again provide the soil with the condenser heat, so that heat storage takes place in parallel to the cooling operation .

In the case of an artificial aquifer, the soil close to the soil heat exchanger is kept humid thanks to the water surface, but, however, care has to be taken in order that the heat storage does not warm it up too much, which would result in heavy evaporation. In that sense conveying the supplementary thermal energy to the aquifers is only possible under certain conditions.

2.3 Less resources, materials and water

2.3.1 Water supply

Fresh water is one of our most valuable supplies for which we have no equal replacement. Water supply companies produce it with much effort and supply it to the user while carefully abiding by hygienic rules. However, we are not conscious enough that a high portion of that highly valuable supply is flushed through the toilet (about 33 %). Just as a considerable quantity of water is used, without any necessity, to clean buildings, to wash cars and irrigate gardens. Figure 2.8 shows the water requirement in private houses, with a representation of the areas where potable water is necessary or rain water can be used. It shows that about 50 % of the worthy potable water may be replaced (if available) by rain water, which results in a considerable saving potential. Only 3 % of the potable water is in general used to prepare and eat food.

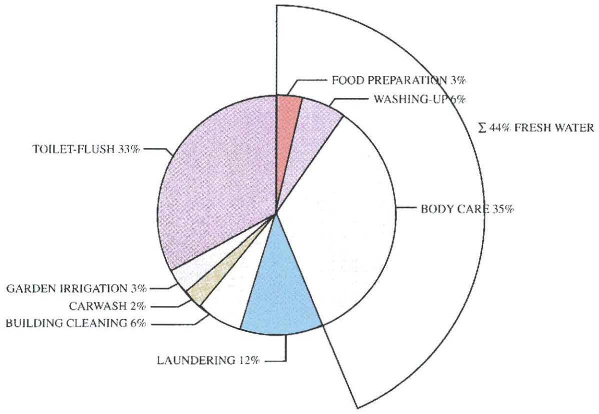


Fig. 2.8 Water requirement for private houses

2.3.2 Grey water for cleaning

The use of rain water to wash clothing is considered in general as acceptable from an hygienic point of view, while the use of rain water has the additional positive consequence that the addition of detergent can be considerably lower than with the use of potable water. Rain water is naturally softer than treated potable water. In that way potable water appears to be the necessary resource only for food preparation, washing-up and body care (a total of about 44 %) while all other water use may be covered by using rain water.

The use of rain water should in principle be only rain water from roof drainage, since this ensures that no dirty materials are introduced into the rain water system, which leads to considerable cleaning and treatment costs.

With the requirement "LESS IS MORE" it should be checked on a case by case basis if the increased investment cost is justified by the lower water cost. On a long term basis however the use of rain water is in any case to be recommended, since it results in considerable savings of the environmental resources. In the past the use of rain water was, in principle, rejected as being too expensive, but nowadays the opposite is the case and especially considering that rain water can be used not only to cover water use for cleaning and washing but also to cool a building or its surroundings.

2.3.3 Grey water for cooling

Various possibilities are available to cool a building or its environment with rain water such as:

- Cooling through evaporation around a building due to the water surface of an artificial lake or equal.
- Increased cooling through evaporation around a building through the creation of fountains in a lake, cascades of water or equal.
- Direct cooling of the outside air through evaporation of fine water mist.

When considering one of the above possible alternatives, the feasibility has to be evaluated in each specific case to avoid an excess of water consumption.

An alternative is the use of stored rain water for the direct cooling of building parts such as roofs, facades or underfloors. (See British Pavilion - Expo 92 -Seville Case Study)

The use of grey water for cooling purposes in the area around a building is further developed in Section 3.2.4.

3. LESS TRADITIONAL EQUIPMENT

3.1 Heating

3.1.1 Minimizing the heating requirement

In most of the European Member States, building regulations have been significantly improved over the last decade. There are still very big differences between the countries, but the trend is clearly going towards lower heat transfer coefficients for the external envelopes and overall maximum heat requirements. According to this trend, a building should have a maximum heating requirement of about 50 kWh/m^2, which equals a heating requirement of about 30 Watt/m^2 or about 8 Watt/m^3 for an enclosed area. If that value is applied to a building which is heated only statically, the result is an average thermal coefficient for the whole glazed and wall area of about 1.8 to 1.9 W/m^{2}K (without taking into account double to triple glazing, roof area, and floor area).

Considering a building, a house with air conditioning in winter, then the above coefficient is reduced by 50 % to about 0.9 W/m^{2}K for the wall and window surfaces. (In that case though, taking into account the heat gain resulting from occupancy, lighting, office equipment, etc). In that way, in the future, the average thermal coefficient of building surfaces (walls and windows) will be around about 0.8 to 1.0 W/m^{2}K.

Minimizing the heat requirement must thus primarily be based on a total solution, in which case during the transition period and the summer there is no over-insulation, but rather the envelope is constructed in such a way that thermal energy is kept in the building when it is necessary and released when it is not, preventing overheating in the building. The result thereof that makes sense is a variable design of the thermal coefficient, which means facade design, for which the thermal coefficient may be adjusted according to the requirement. Heat insulation blinds, adjustable window elements, the construction of air areas with appropriate front elements (for example double shell facades) etc are proper in that case. The subject shows that in that case the architect's as well as the engineer's imagination is called upon to achieve interesting architectural solutions.

Prototypes in that line have already been built and in future will become the norm in construction. The use of highly insulated window elements may under some conditions lead to the contrary, just as the obligation of minimum window surface to reduce the heating requirement, which are in contradiction to the requirement of sufficient daylight. In that way it is also necessary to draw a total energy balance to avoid false and inappropriate solutions.

3.2 Cooling

3.2.1 Mechanical refrigeration, free cooling and ground cooling

In order to cool an environment it is necessary to use an external energy source to remove the heat, thus producing cooling.

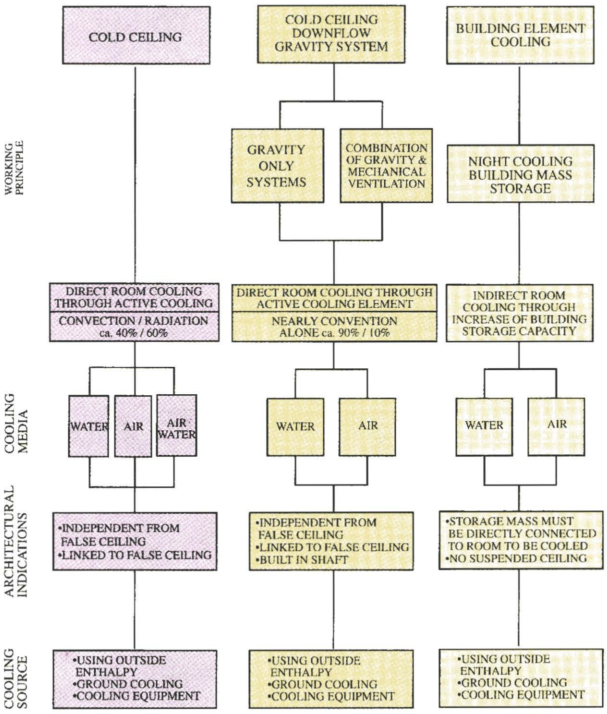


Fig. 3.1 Main groups of "static cooling"

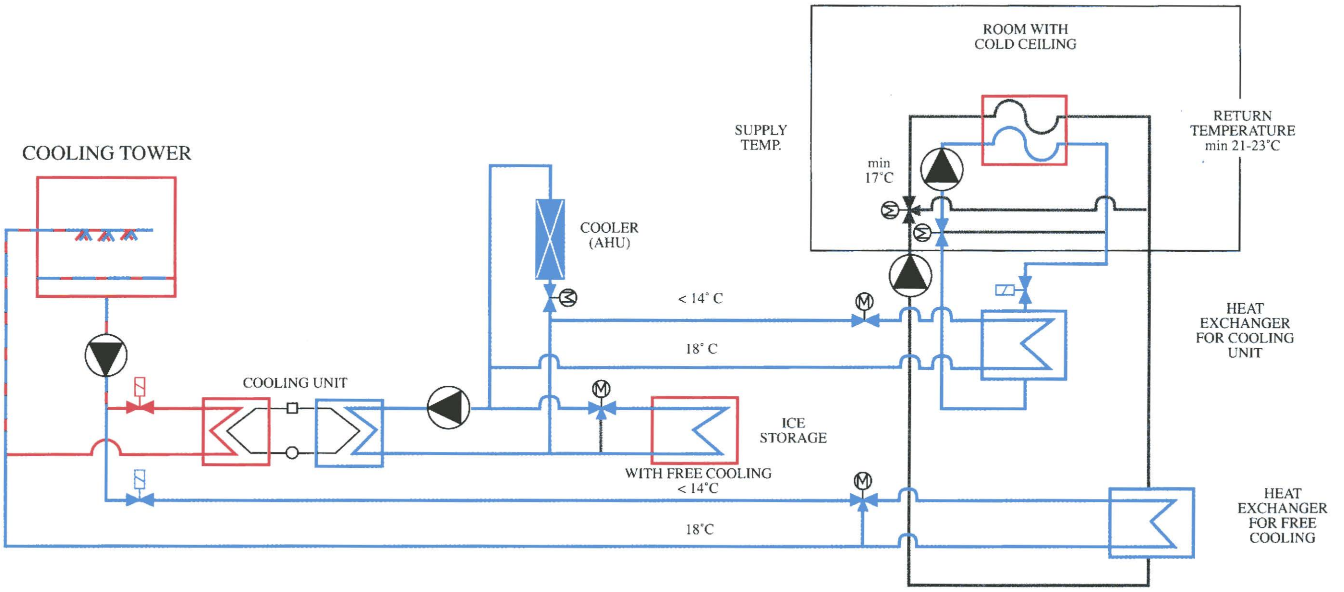


Fig. 3.2 Cold ceiling system with mechanical as well as free cooling (additional ground cooling)

This could be achieved by several methods using an external energy source (such a mechanical compression or absorption), direct air "free cooling" or a ground cooling source.

Figure 3.1 shows the main group of "quiet" or static cooling , that is to say cooling installations, which operate on the basis of gravity and which absorb thermal energy in a room due to convection and radiation. In those installations the primary cooling medium is water. The cold water is, as shown in Figure 3.2, either produced by a cooling unit, or temporarily in a cooling tower recovery installation when it is possible to obtain water at temperatures below 14°C.

To dimension refrigeration installations as small as possible and to achieve the smallest possible losses during daytime, it makes sense under certain conditions to have an ice storage installation, which is loaded overnight so as to give the total installation the stored cooling energy during daytime. This contributes to a reduction of the peak hours demand during daytime, which reduces the power load on the utility supply companies. The total combination shown in Figure 3.2 allows the reduction by about 50 % the total cooling demand installed capacity which was usual earlier (electrical connection power demand of the refrigeration units) and also to minimize simultaneously the investment cost.

Another principle for the production of cooling energy with a primary energy input as small as possible is the preparation of cold water through ground boring wherever feasible. It should be remembered that limits for water supply and return temperatures are very narrow: they should have values not significantly below + 18°C or above +22°C respectively. The use of ground cooling means that the waste heat from the building is conveyed to the ground. It should be ensured that the annual process of the energy flows is balanced, that is to say that the thermal energy supplied to the ground over the summer period is balanced over the winter period.

3.2.2 Absorption cooling units

The use of absorption cooling units has witnessed a clear development in recent years because of the effort to replace electrical energy by thermal energy in the production of cold water. A solution can be to combine absorption cooling units with solar units (line focused installations) in such a way that the necessary thermal energy for the absorption cooling units (condenser) is produced by solar units. With those installation solutions lower energy costs can be achieved, since at times of higher radiation when higher cooling loads are required, the necessary thermal energy is available for the absorption cooling units. Also higher investment costs must be considered on a case by case basis as to the justifiable amortization period.

3.2.3 Desorption process

A desorption process or air cooling with absorptive dehumidification and adiabatic cooling is an alternative system installation to produce cooling energy with the help of thermal energy.

In the case of air cooling with absorptive dehumidification and adiabatic cooling it is not required to use a refrigeration unit in the traditional sense when dehumidification is not needed. Night cooling with, for example, a gas motor operated heat pump is needed when the outside air should be cooled and in particular dehumidified. That cooling system does not need either "fluorocarbon" refrigerants or ammonia or brine circulation, but results from the fact that spraying cold water both in the exhaust and in the supply flows leads to adiabatic changes of state, which result in cooling with simultaneous humidification. The outside air is first dehumidified over a heat recovery unit through "fill material" with very low humidity and a high temperature which is thus able to take over the water moisture from the outside air flow. Finally the outside air is cooled over a heat recovery unit and the result thereof is another adiabatic cooling, through spraying cold water in the outside air flow, which evaporates and thus reduces the supply air temperature while it raises at the same time the relative humidity. Corresponding processes are used meaningfully when either overheating can be used as the result of, for example, a production process, or when heating energy is produced through collector units, since in that case it could be assumed that the largest part of the cooling energy is required, when high outside temperature are simultaneous with high heat radiations.

3.2.4 Evaporative cooling in the outside area

If a building is to be ventilated in a natural way, with high peripheral temperatures in the summer and relatively low humidity, it is then possible not to cool the building directly itself, but rather the area outside close to the building. This is possible again through adiabatic changes of state. This is thus the case when water evaporates on a static surface, or when water is sprayed. Evaporation takes place when water vapour with temperatures clearly under 100°C evaporates in the air from the water surface or the humidified surfaces. Evaporation rates depend on the water temperature, air relative humidity and temperature and the air velocity.

The following principles may be used:

- evaporation of water from a static water surface in the air
- evaporation due to water spraying
- evaporation due to compressed air water spraying
- evaporation at humidified surfaces

In the case of static or slightly running water surface an evaporation rate of about 0.1 to 0.2 Kg/m^2h can be achieved whereby evaporation heat loss is around 65 to 135 $Watt/m^2$.

If the available evaporation surface through fountains or other appropriate forms of spraying is increased, then the heat and material exchange is greater than for a static surface. The evaporation heat loss values are multiplied against the ones for static water and the corresponding cooling effect is greater.

In the case of compressed air water spraying the evaporation effect is further increased through the fact that the water evaporates quickly with practically no drops due to the spraying. For an overpressure of about 0.5 to 1.5 bar an air velocity of about 300 to 500 m/sec is obtained and water aspirated by the compressed air flow is delivered to the environment.

In the case of air cooling through evaporation of humidified surfaces, as for example in a contact humidifier, the evaporation efficiency is increased and in such a way the cooling effect, the higher the water and air temperatures and the higher the air velocity. The expected final humidity for corresponding humidified surfaces depends on the humidified surfaces itself but also the above mentioned factors and reaches a maximum of about 60 %.

3.2.5 Evaporation cooling and air improvement through green plants

In relation to the requirement for "LESS IS MORE" it would be ideal to achieve adequate room temperatures and humidity rates and also at the same time to break up pollutants using plants in the building and avoiding the use of technical means. Whether and how much this is possible is presently the subject of studies at EIDGENÖSSISCHE TECHNISCHE HOCHSCHULE - Zürich with the help of previous research projects by NASA.

The evaporation by plants and the related evaporation cooling, the production of oxygen and the break up of pollutants play an important part as to the contribution of the internal environment conditions.

B. Wolverton (NASA) conducted experiments in the break up of pollutants. Formaldehyde, benzene, and trichloroethylene were tested with various plants. It was observed that the break up of pollutants started very quickly and diminished after two hours. It is however still not clear how much the plants on the one side and the microorganisms in the soil on the other side have a cleaning function. It has not been clarified yet (since all experiments have a 24 hour duration), whether the pollutant break up is considerably reduced after a few days. Further long term experiments should be started to register the actual behaviour over a longer period.

3.3 Ventilation and indoor air quality (less indoor pollution)

Indoor air quality (IAQ) has an influence on the occurrence of the Sick Building Symptoms. According to World Health Organization definition, this term describes, "general, non-specific symptoms of malaise" that are experienced during the occupation of a building and cease shortly after leaving it.

3.3.1 Pollution sources

Nevertheless, even below the allowed levels, bad indoor air quality is not accepted by the building users. It is important to say that normally the indoor air in a building is much more polluted than the outdoor air because the origin of the pollution comes from the interior of the buildings: from the occupants, from the building construction materials and elements and from the activity being developed.

The main sources of pollution in a building are:

a) External pollution introduced into the building: dust, odours, fumes, suspension particles, etc.

b) Occupants: metabolism, breathing, body odours, tobacco smoke, bacteria, etc.

c) Building materials: man-made fibres, volatile organic compounds, cleaning agents, dust, etc.

d) Activity: odours, waste, combustion fumes, etc.

Small quantities of these different pollution elements all combined may give rise to bad indoor air quality.

The number of materials currently used in building construction has drastically increased since around 1950. In addition, we have little experience of new materials, often containing artificial substances and chemicals and thus having very high emissions of harmful or just odorous compounds.

Following the trend "Less is more" it is necessary to select carefully the building materials and reduce the pollution at the originating source in order to avoid a problem that later could only be solved with great difficulty by means of increased ventilation, resulting in an increased energy consumption.

3.3.2 Comfort and ventilation

After a careful selection of materials and the reduction of pollution at source, the remaining contamination may be easily eliminated by means of adequate ventilation.

Many research studies have been conducted in order to evaluate comfort and indoor air quality that invalidate the old theories of maintaining constant ventilation rates according to the number of persons, their activity or the air renovation rates. Until recently, ventilation has been based in the quantity of air rather than in the perceived quality of the same.

According to Prof. Ole P. Fanger ventilation quality has to be determined according to indoor contamination. Following his theory 1 olf is the average air contamination from one person and any contamination source could be referenced to the number of average persons that would produce an equivalent contamination situation.

OFFICE BUILDING (1 person/10 m^2)	OLF/m^2 LOW	OLF/m^2 MEDIUM	OLF/m^2 HIGH
CONTAMINATION	0.2	0.5	0.8
Ventilation rate (l/s*person)	10	25	40
Ventilation rate (m^3/h*person)	3.6	9.0	14.4

Table 3.1. Ventilation rate and perceived air quality.

In Figure 3.3, Prof. O. P. Fanger shows an example of an office building in Copenhagen where it is important to notice that the 17 occupants produce a contamination level of 17 Olf while the total perceived contamination is 138 which is mainly caused by tobacco smoke, building materials and the air conditioning system.

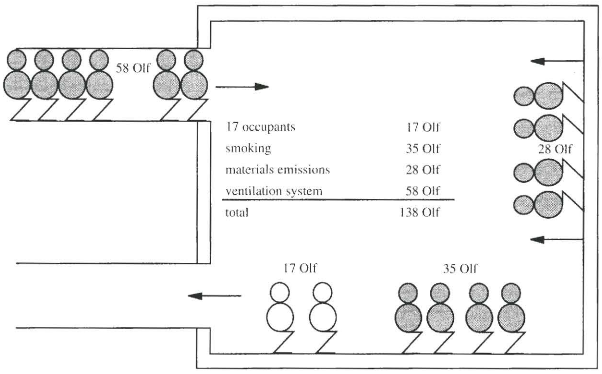


Fig. 3.3 Average contamination source in 15 offices in Copenhagen (230 m^2)

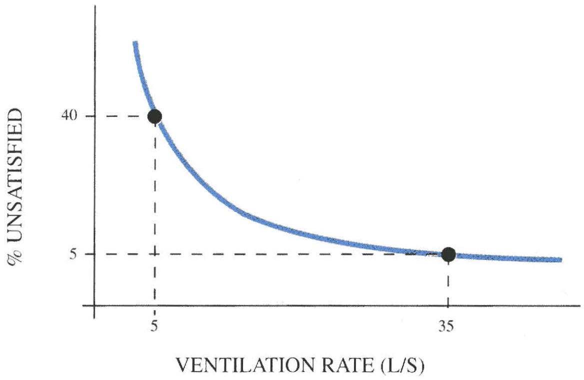


Fig. 3.4 Ventilation rate / % Unsatisfied

Taking into consideration the percentage of unsatisfied in relation with the ventilation rate, from Figure 3.4 it is observed that there is a requirement to increase up to 7 times the ventilation rate to reduce the percentage of unsatisfied from 40% to 5%. This means an important impact in energy consumption.

To reduce the impact and following the "Less is More" trend, the following aspects should be carefully considered:

a) Reduce the contamination level at the origin of the same.

b) Select carefully building materials that have a low pollution level.

c) Careful study of ventilation methods that guarantee the ventilation effectiveness such as positive displacement.

d) Dedicated zones for smokers.

e) Convenient location of air intakes and exhaust.

f) All fresh air systems with heat recovery.

3.4 Electrical power

3.4.1 Minimizing the electrical power requirement

Minimizing the electrical power requirement starts as already shown with each single user, whereby beside the efficiency rate the on-operation times also play a significant role. A room with sufficient daylight shows correspondingly low on-operation times and thus low energy use, just as equipment which stops automatically when it is not used. It should also be considered on a case by case basis whether the energy user can use other primary energy instead of electricity, to reach higher efficiency rates. We are speaking in this case in particular about large users such as kitchen installations which may be electrically and gas operated. Air conditioning installations which are not used because the building is naturally ventilated are also a step in the right direction (see Figure 3.5). Cooling installations can also produce their cooling energy from heating energy as shown previously, ice storage systems make it possible to avoid peak consumption during the day, so

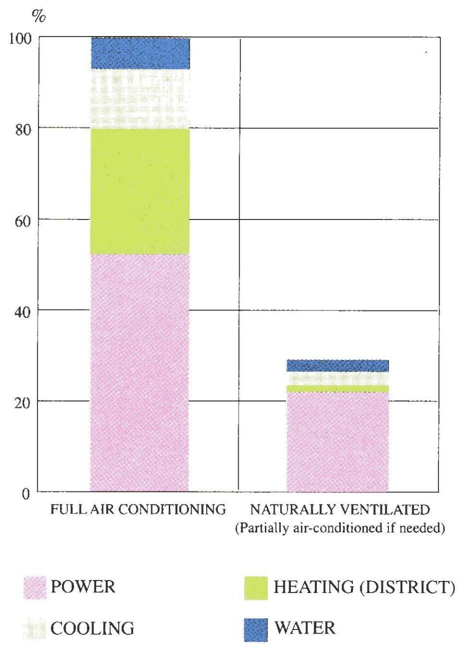


Fig. 3.5 Energy cost comparison for an entirely or partially air conditioned building

that accordingly high inertia storage can also reduce the power plant demand.

In particular installations or installation solutions should be considered, for which, thanks to the own power production, heating energy is produced, which is used for cooling or heating purposes or cooking purposes, which thus reduces considerably the total electrical power needs.

3.4.2 Alternative solutions for power supply

Combined heat power plants are often gas operated installations which release heating energy during electricity production, which supplies the heat through a high temperature distribution network the heat used in the winter and the cooling installation absorption machines in the summer. The transformation of primary energy (for example gas or fuel oil) in those combined installations is such that about 32% goes for the production of electrical energy and 54% in the form of waste heat for heating and cooling production installations. Only 14% of the used primary energy must be finally accounted as lost.

With a combination of combined heat power and absorption installations 32% electrical power is gained directly and another 12.6% indirectly out of 100% primary energy. That performance of 44.6% cannot be achieved with comparable traditional installations. For buildings with high power and cooling requirements the above installation is superior from an energy point of view to all conventional production used so far and one must notice in particular that beside the high performance through the absorber cooling of that installation solution no fluorocarbons are used.

When using photovoltaic energy we have a direct transformation of light into an electrical current, whereby the power transformation is the result of a photovoltage effect, which describes the interaction of light with the basis material of the solar cells. Solar cells achieve according to their design type and the used basic material efficiency rates of about 20% and use the global radiation which reaches a building.

Since photovoltaic installations with full solar radiation (>800W/m^2) produce an electrical output of about 1.0 W-1.5 W and each 1m^2 produces about 100 kWh electrical energy, photovoltaic installations are not in a competitive position and for the time being the amortization periods are too long, about 20 years. In this case the requirement of "LESS IS MORE" cannot be held up, since an efficiency which is too low is achieved with too much effort.

3.4.3 Optimizing lighting installations

To optimize lighting installations as one of the big electrical energy users is a very positive trend, which has been acknowledged for years.

In fact the lighting resulting from light equipment and additionally its efficiency is yet to be significantly improved to be able to light rooms more efficiently. That way energy and investment costs can be reduced, that is to say that more is achieved with less cost, which is completely in line with the "LESS IS MORE" trend.

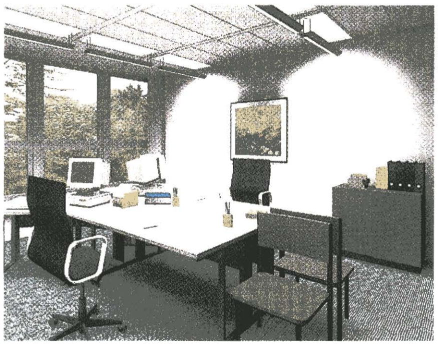
The aim of proper lighting is to consider the relationships between the individual, the room, the work and the light in a sufficient way and to create a room and workplace lighting which relaxes the individual at work and in that way increases his performance readiness and concentration capacity. An efficient lighting installation is, however, not measured only at the energy use and investment costs but rather at the light quality.

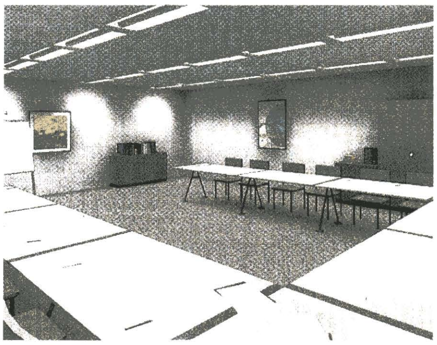
Office rooms with workstations have special requirements as to vision, since in that case illuminance must be adapted sufficiently to ensure work with no interference. In that sense it should be considered that the mental stress at a workstation is reduced when the environmental light density is a maximum of 400 Cd/m^2. Window elements with appropriate sun and glare protection measures of course play a role in meeting that requirement. Up to now, to provide at an early stage sufficient decision elements in the planning of room lighting, models were prepared, i.e. the room or rooms to be designed were reproduced as models with 1:10/1:20 scales or equal and lit accordingly.

To complete and in the future to replace the model studies, computer-assisted software has recently been developed which provides a highly worthy (with picture quality) representation of a room performance with a chosen light environment. The computer image of a room is the result of the lighting of the built room with the actual light distribution curves of the lighting devices and the actual light colours of the lighting device. The actual colours of surfaces and materials are also used so that a realistic impression of the room to be built is created.

Based on realistic framework conditions such as the right light density distributions, the lighting intensity, the surfaces etc, the lighting installations can already be optimized on the drawing board and with visualization systems. They can be presented to the future user.

Calculation and CAD programmes were used up to now in studies of theoretical lighting density models of an office room, which computed the lighting density in the room considering the reflection rate of the materials. Beside the radiation characteristic of the desired lighting devices, the various lighting installations and the various lighting intensities are also included in this innovative technique of lighting simulation.





Picts. 3.1, 3.2, 3.3, 3.4. Lighting/computer simulation. (Luxor software-HL Technik AG.)

Pictures 3.1 and 3.2 show simulations with picture true quality using different types of luminaires for the same office room with exactly the same furniture and decoration in both cases. Pictures 3.3 and 3.4 show simulations of the same room with the same size of ceiling but with different types of use, furniture, decoration, floor type and lighting devices. It is a significant improvement in the quality of representation as compared to the methods used up to now. In that way it will be possible in the future with the help of this software to make clear, not only to the architect but also to the contracting party the lighting optimization, already at the design stage, with simulation of various lights and lighting devices that can be combined with office furniture, colours and surface textures. Also the reduction of electrical energy consumption plays an important role thanks to zonal lighting of rooms. It is not the light, that is to say the lighting intensity in a room, which is often the significant characteristic of a well lit room but rather the lighting environment achieved by a specific lighting installation in combination with the colours.

4. REDUCING THE EXTERNAL AND INTERNAL LOADS

4.1 Minimizing the cooling load

The cooling load in buildings consists of in external and internal loads, which may be split as follows:

external loads:

- cooling load from direct solar radiation
- cooling load from diffuse solar radiation
- cooling load from convective thermal transmission (wall/window)

internal loads:

- cooling load from persons
- cooling load from equipment
- cooling load from lighting
- cooling load from chemical reaction
- etc

Regarding internal cooling loads, two thermal sources may be noticed which can be further minimized in the future. We are speaking here about the power consumption and heat supplied by electrical equipment (for which the equipment manufacturer is responsible) and lighting installations.

While the last years have seen rapid development in the field of lighting installations to minimize the power and energy demand, in the field of electrical equipment, in particular PC´s in offices, the necessary minimizing of power requirement is being completed only now. All mains-powered office equipment, especially in information technology systems such as PC´s, should be designed and built as if only limited power were available and should have the means to have automatic power management capability, controlled by use. Figure 4.1 shows how significant energy consumption reductions and consequently a reduction in cooling load could be achieved by means of power management capabilities between "normal use" mode, "stand-by" mode and "suspended mode".

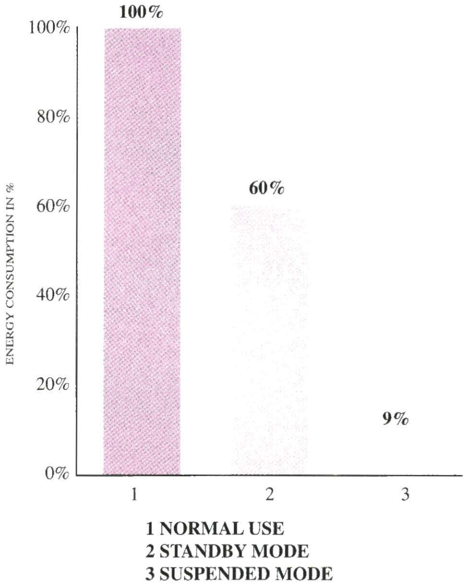


Fig. 4.1 Comparative energy consumption of an ecological PC for various operation modes

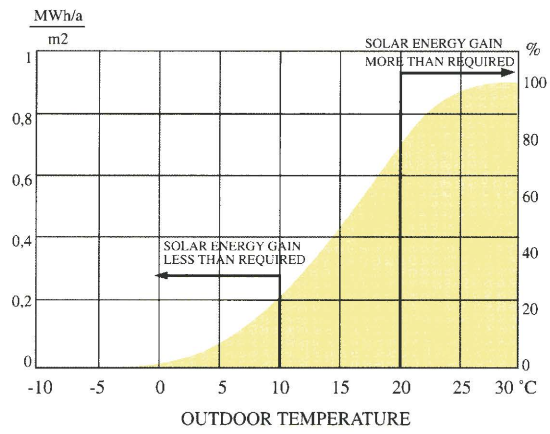


Fig. 4.2 Year profile of solar radiation on roof surfaces

In order to minimize the external cooling load the main condition is that the radiation on vertical window surfaces and roof surfaces should be reduced significantly when energy incidence is not desired. Undesired energy gains for a well insulated office building are already noticed with outside temperatures of + 5°C, or lower, since under certain conditions the internal heat sources already heat up the building sufficiently during daytime use. Figure 4.2 shows an example for the annual profile of solar radiation on roof surfaces in relation with the outside temperature and clarifies that at temperatures of + 5°C and lower, only a reduced amount of solar radiation is to be expected, while above + 5°C maximum solar radiation may be gained. Based on the annual line for solar radiation the dilemma of using high solar gains in well insulated buildings shows that only a small part of the solar radiation is actually being used directly to heat the building, while the largest part appears to be rather a disturbing factor.

To minimize the external thermal energy due to direct or diffuse radiation, the total thermal transmission coefficient (r-value) plays a significant role, as shown in Figure 4.3.

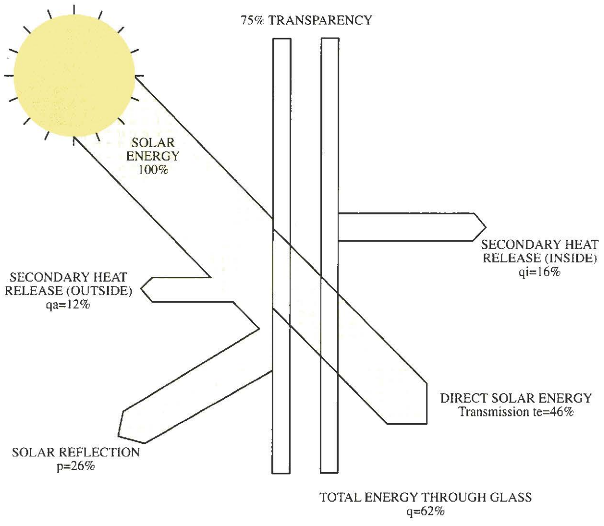


Fig. 4.3 Total energy transmission rate distribution (neutral glass)

At the same time the light transmission coefficient should be considered, which should be rather high in the case of a possible low r-value. An optimum window combination should be analyzed on a case by case basis in a very detailed way in order to minimize the cooling load but the important part played by sun shades in solar insulation should also be considered. Different forms of external and internal shading systems solar insulation are possible. These may however be improved on a case by case basis in the following way: the thermal energy absorbed in the room (secondary heat emission/convective heat flows) is removed at the place of production, in order not to increase the cooling load of the room itself.

In office buildings the specific cooling load of rooms (whatever the orientation in the facade area) should, if possible, not be higher than 50W/m².

Related specific cooling loads in levels approaching a maximum of 50W/m² office area for cooled or air-conditioned rooms based on air systems require about 4 to 5 air changes, which does not meet the "LESS IS MORE" requirement. It has to be assumed for such load conditions that about 1/3 of the cooling load is performed through air volume flows, which serve the necessary hygienic air, and 2/3 of the cooling load is as the case may be compensated through water installation. The result thereof are the well-known and standard air-water-installations, which although they result in lower operation costs, mean high investment costs. According to each particular case, the architect and engineer must look for ways to reduce the specific cooling load, so that a water-only cooling installation or an air-only installation result in the most beneficial investment and operation costs with a simultaneous improvement of the facade area. The building climate specialist intervenes in the task appropriately in that he optimizes a building from the building climate point of view as well as to its external shell and as to its building layout structure, so that the total cost for the active technical installation is kept to a minimum. The task of the building climate specialist is to develop various solution premises with the architect, and to develop them in calculations while having as a basis the dynamic load behaviour of a building to a point that the following planners (architect, building physics specialist, layout planner, etc) have a sure basis for detailed considerations.

5. BUILDING PLANNING

5.1 Concept engineering

Just as in the past, building planning is now being developed from an architectural and townplanning point of view. That is necessary and generally acknowledged and cannot be questioned. However, building planning can be done in such a way that it not only meets urban requirements but also takes into account significant single aspects, which meet the later use of the building. Building layouts which must be ventilated mainly naturally, must take into account a maximum room depth and should not as far as possible exceed it, except if the building layout itself has elements which contribute to the natural ventilation of deeper rooms. Building layouts should if possible be lit mainly by daylight not only to achieve an optimum room environment but also to minimize the use of lighting installations. This is equally possible for narrow office buildings but also for office buildings with larger internal areas with daylit interior atria.

Building layouts can also, under certain conditions, be designed with external structures which work as "buffer zones", whereby the overflow from outside air close to the building is reduced and thus in that way also the heating requirement. Halls, glazed passages or similar constructions provide not only a better and more interesting room distribution but they also reduce the cooling load or cut the heat loss by half. This thus shows that as early as the concept stage of the building layout structure the expertise of all those involved in the design must be put into action.

6. ENVELOPE

6.1 The Thermal Mass

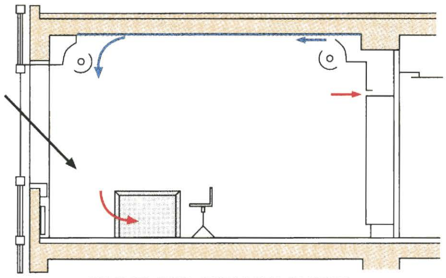
It is possible to reduce the cooling load significantly by allowing concrete to absorb heat and to store in its mass.

With the cooperation of the architect, layout planner, structural engineer and the building services consulting engineer it is possible to adopt the "Less Is More" philosophy to develop a thermal mass concept by the appropriate use of the building mass and its representation. Such a concept results in lower mechanical plant investment and particularly lower operating cost.

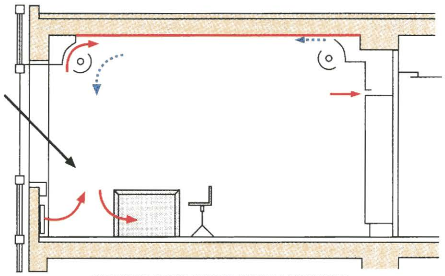
A very good example of the thermal mass of the building is Triton House (Frankfurt) where the original design was an office building with suspended ceilings and raised access floors.

Fig. 6.1. shows a section through a typical floor for the two operations.

For this building the use of a suspended ceiling was discarded to give an increase room height of 3.2 m. for a given floor to floor height of 3.6 m. The increase floorheight provides an enhanced living quality in the room due to a higher temperature gradiant. As greater area of concrete is now exposed to the air it absorbs a greater amount of heat due to the higher temperature at ceiling level and consequently reduces the cooling load which in turn leads to lower capital investment and operating cost.



SUMMER OPERATION WITH COOLING



WINTER OPERATION WITH LIGHTING

Fig. 6.1 Schematic representation - Ventilation operation (example of Triton House - Frankfurt)

With the vault lighting concept the concrete ceiling is available and is used as a thermal storage reservoir.

In the summer as well as the winter each user can open his window at his wish and the supporting ventilation installations of the room are automatically turned off. In the summer each room may be cooled additionally as needed, in the winter it may be aerated and humidified additionally, whereby the heat losses are covered by a static heating installation.

6.2 The "intelligent" facade

Facades are of course not intelligent but can however be designed in such a way that they meet all requirements from the future user and simultaneously harmonize user requirement and the environmental supply. Figure 6.2 shows the design of a glass structure according to M. Davis (Richard Rogers Partnership, London) as a polyvalent wall. This polyvalent wall must be designed in such a way that it may be used according to user requirement and season either as solar protection or heat protection, that it reflects heating energy out of the building or lets it enter the building and in that way opens up or closes. The glass industry has not been able yet to put into practice M. Davis's proposals and it is thus the task of designers to reproduce the process of a polyvalent wall with traditional means. The planning for the operation of a polyvalent wall and the requirements with which a semi intelligent facade must comply have to consider how to finally heat, aerate, light and cool a building with the lowest possible auxiliary technical means and energy cost.

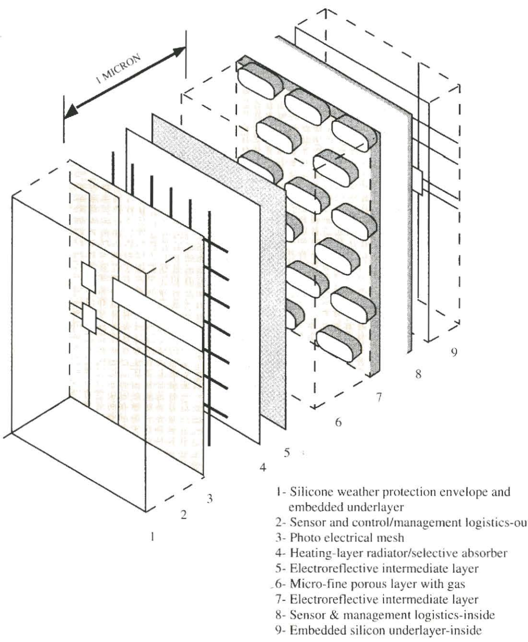


Fig. 6.2 Exploded view of polyvalent wall. Proposal by M. Davies (Rogers Partnership) for a Polyvalent Wall - 1981

7. NATURAL VENTILATION OF HIGH RISE BUILDINGS

For buildings with high atrias and shaft situations heat helps with natural ventilation thanks to the fact that it can drive flows through the building, that is to say evacuate thermal energy as well as pollutants and smells.

Natural aeration of a building thanks to thermics is in general interfered with by the outside winds through the creation of high and low pressure and a pure thermal aeration of a building happens only with no wind conditions. However, thermal aeration is particularly significant for large glazed areas, atria and glazed halls.

For the natural ventilation of high rise buildings wind pressure or low pressure plays the significant part. According to the wind direction, high or low pressure areas are established which are used to inlet or outlet outside air through windows to be opened or through facades.

The wind flow conditions for a high building and its location between other buildings play a significant part, since high wind speed rates might appear because of tight/narrow situations between the buildings, which significantly change the flow pattern at the building. It is also significant to know the air velocity in the limit layer area of the facade due to thermal uplift in the case of no wind. According to wind direction, peripheral building and wind velocity, we have at the building a stagnation point, which goes up and down the facade and directs the air flows up or down. The flow down below the stagnation point, influences the ventilation of the street area close to the building because of the circular flow patterns which are created, as shown in Figures 7.1 and 7.2.

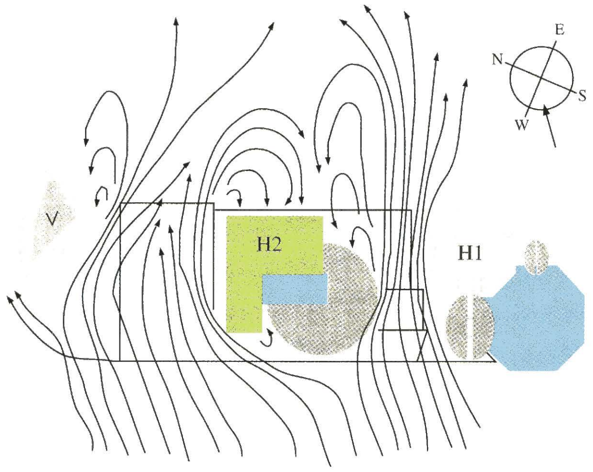


Fig. 7.1 Typical air-flow pattern, south-west wind

In principle we may notice for high rise buildings that as a rule sufficient wind pressure ensures natural ventilation of the building. The difficulty for the natural ventilation of high rise buildings is more to be found in bringing the outside air in a correct form into the building because of higher high and low pressures and to have it circulate through the building. Because of that problem the discussion lately took the way of having high rise buildings with double skin facades to reduce the pressure in the facade area and to direct it in such a way that the stagnation pressures are not fully working on the inner facade.

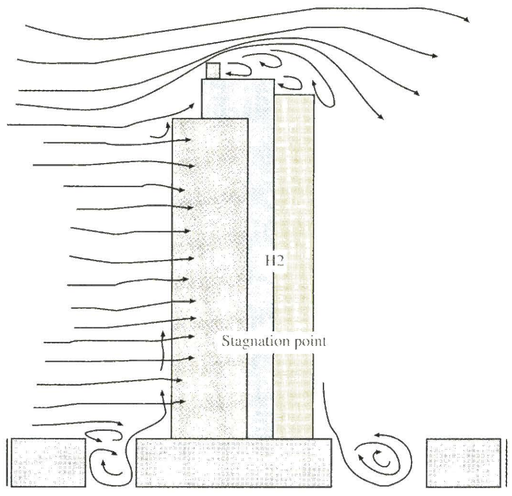
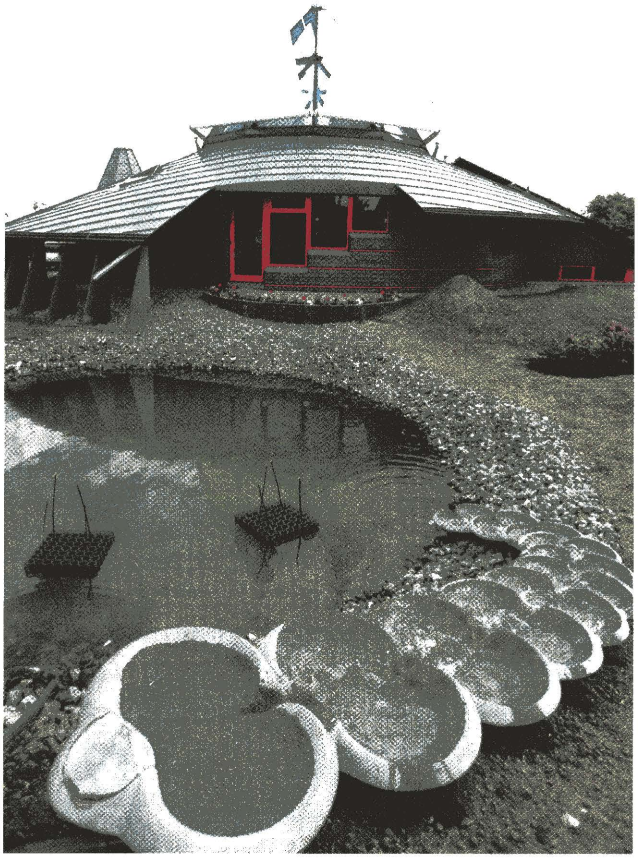


Fig. 7.2 Typical air-flow pattern, north-east wind

8 CASE STUDIES

8.1 Case Study 1.

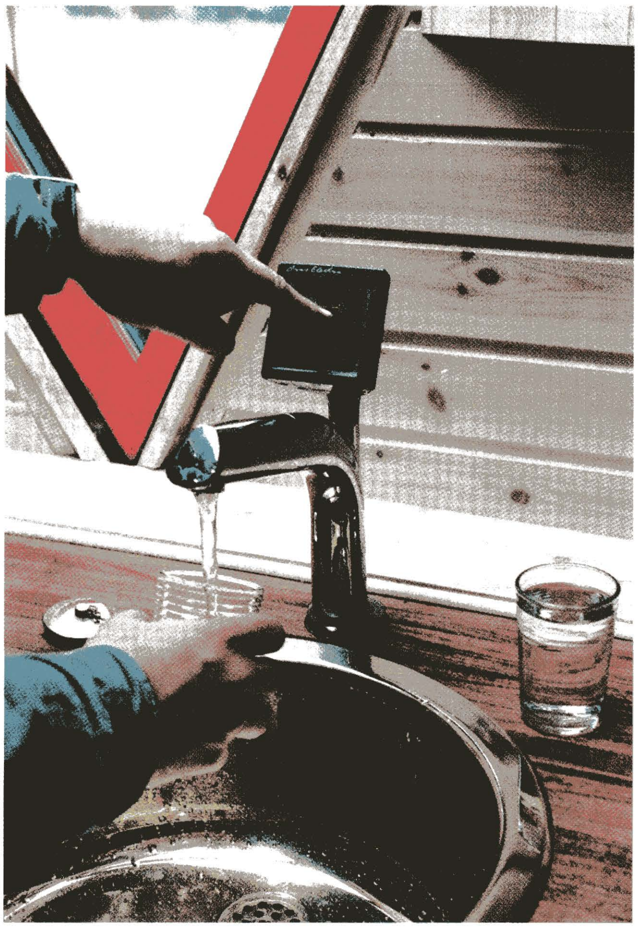
VillaVision. A high tech low energy house



Pict. 8.1 The six large sails on the roof can open and close in sunny and cloudy weather, just like a flower. The house is not connected to the public sewerage system, but has its own root zone purifying plant, which lets the water trickle down from a small hill in the garden into a pond.

The ecological and super-insulated experimental building, VillaVISION, was opened to the public in the summer of 1994.

VillaVISION is meant to blaze new trails in technological and architectural research and practice. The building presents new technology in low energy housing and should serve as an inspiration as regards function, architecture and ecology for future house owners, architects, engineers, building contractors and others to take new initiatives within the field of construction.



Pict. 8.2 The intelligent tap which can be programmed to give a pre-defined water volume with the right temperature.

The project is the result of 10 to 12 years' research at the Danish Technological Institute. With its 200 m^2 floor space the villa is meant to house one family. The comfort level of the house meets the Danish demands of today, whilst resource consumption is as low as possible.

The annual energy consumption of the house is estimated to be about 2000 kWh, i.e., five to ten per cent of the energy consumption in a normal house.

The factual energy consumption is 4000 kWh. However, the photovoltaic system with its 20 m^2 photovoltaic cells is connected to the public network and returns 2000 kWh to the public network. This so-called grid connected P.V. system is the first of its kind in Denmark.

The house is not connected to the public sewerage system. All waste water is led through an indoor biological purifying plant. The discharge from the purifying plant is led into a root zone outside the house.

The primary heat supply of the house is solar heating entering through the large glass dome in the middle of the house. In order to prevent the house from becoming as hot as a green house, large sun sails are "set" automatically to protect the windows when the house is getting too hot.

All systems in the house are automatically controlled. The light, for instance, is on only when there is someone in the room.

The low-emission windows have three layers of low-E glass. Passive solar heat is stored in the brick walls and floors which practically suck in the heat.

The six large sun sails are 15 m^2 each. To provide the force needed to control them and counter wind forces the sails are stretched by heavy springs housed in the tubes around which the sails are rolled. All six sails are moved simultaneously by a gear motor at the top of the pyramid. The entire system is governed by advanced automatic controls which regulate step by step opening and closing of the sails.

Pict. 8.3 The palm house with the glass pyramid and heavy brick walls.

Insulation without thermal bridges.

Efficient insulation is vital for the low energy consumption of the building. VillaVISION is insulated with 400 mm mineral wool and there are almost no thermal bridges.

The floating foundation means that the house floats on top of 400 mm hard mineral wool batts. There is no direct connection to the ground and no thermal bridges, not even under load-bearing walls.

The double-shell construction eliminates thermal bridges in walls and ceilings by separating outer and inner structures with insulation material. The inside supporting posts of the outer wall rest on the edge of the floating foundation plate, allowing the insulation to continue into the outer wall insulation. The beams are similarly placed under the insulation, allowing the insulation and moisture-proof membrane on the warm side of the insulation to extend uninterrupted around the supporting structure.

A high standard of sealing is important to avoid draughts and energy waste. VillaVISION has been sealed with a layer of gypsum-board and a layer of reinforced plastic foil. Both layers have been sealed and pointed at all joints to provide the best possible seal.

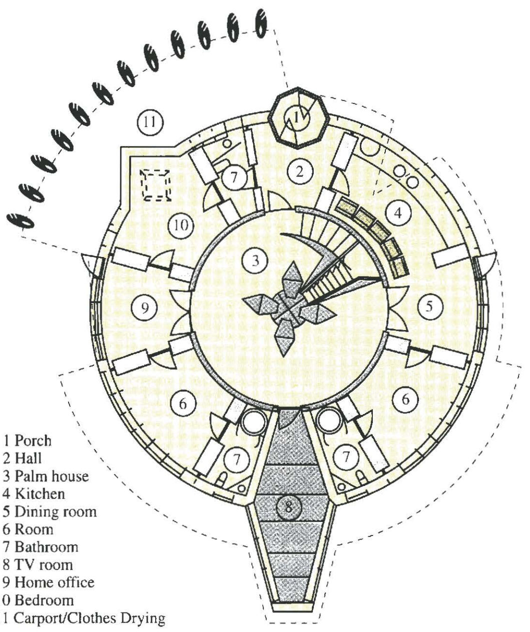


Fig. 8.1 Plan of the house.

Solar and ground heat.

The solar heating system is a new design. The panels are filled with water without antifreeze. The water cannot freeze or boil since either state triggers an automatic emptying process. Heat is stored in a high temperature heat store for domestic hot water and in a low temperature floor heat store for room heating.

Ground heat is solar heat which has been stored in the ground from last summer. It is collected by a new, high efficiency heat pump without CFC gases. The heat is delivered through the concrete foundation plate which also functions as a heat store for solar heat collected through the glass pyramid. The system is self-regulating since the heat discharge from the floor stops when the air temperature in the rooms is equal to the surface temperature of the floor - and that happens quickly on a sunny day in such a well insulated building.

Solar cell power station.

Photovoltaic cells convert light into electricity and Denmark's first grid connected P.V. system is installed in VillaVISION. Grid connection means that the electricity produced by the photovoltaic cells goes to the network like power from any other power station and the house is supplied from the network. This avoids the environmental problems and the expense of storage batteries. The 20 m^2 of photovoltaic cells produce about 2,000 kWh/year.

It is the intention that VillaVISION should be self-sufficient in electricity produced by photovoltaics. It seems possible to attain this goal since the general electricity consumption is held at a minimum, i.a. by light control, use of energy saving bulbs, use of insulated pans with built-in heat, energy saving refrigerator and freezer as well as the use of devices without using the "stand by" electricity consumption.

Fresh air without wasted energy.

In VillaVISION good air quality is assured by keeping polluting materials out of the building.

Fresh air is provided by small, decentralised ventilators combined with heat exchangers to give good, comfortable ventilation precisely where it is needed.

The ventilation system recycles 60 per cent of the heat in exhaust air.

In the palm house the natural ventilation is arranged through the top of the northern part and by sending in extra air through the windows placed along the lower side of the glass roof.

When the residents cook food or take a bath the ventilation speeds up and it slows down again when the air is fresh. If it becomes too hot, the sun sails and the vents automatically open to allow natural ventilation - if it is not raining.

Saving water.

The toilets in VillaVISION are flushed with high pressure and use only one-tenth of the water used by a normal toilet. In the kitchen, water is supplied in electronically measured volumes. In the bathroom, the water runs only when someone puts his hand under the tap. All garden watering and car washing is done with rain water from the big pool in the garden.

Long, hot showers may be important for comfort, but a mini-sauna is more economical in energy, particularly on cold winter days, because almost all the heat loss can be used in the house for room heating.

VillaVISION has its own biological purification system where grey and black waste water is purified and drained into a carp pool in the garden together with rain water. The energy consumption of the pumps in the system corresponds to an ordinary family's share of the energy consumption of a municipal wastewater treatment plant.

Reuse of treated wastewater.

There is not much wastewater in VillaVISION. The building's wastewater is first drained into a septic tank which occasionally has to be emptied of sludge.

The water in the carp pool is constantly circulated through the garden purification system and flows down a stairway to absorb oxygen before it is drained back into the carp pool together with rainwater and the purified waste water. To complete purification, water willows have been planted in the carp pool.

8.2 Case Study 2. **Sabadell, Spain**

Building with transparent insulation

This is a construction of a residential building containing various applications based on the use of transparent insulation materials completed in late-1993, with the objective of studying their energy performance in Mediterranean climatic conditions. Up until now, such experiences had been carried out in countries such as Germany, Great Britain, Holland or Sweden, characterised by Atlantic and Continental climatic conditions.

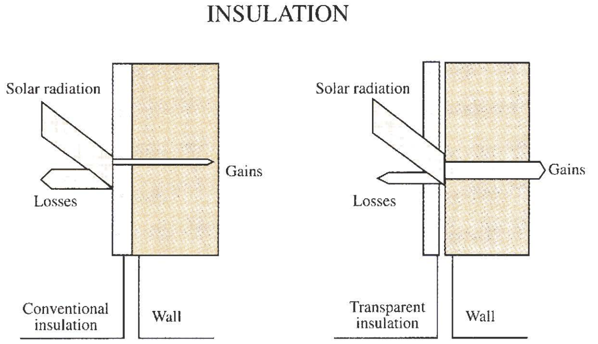


Fig. 8.2 Scheme of heat flow in a conventional insulation and in a transparent insulation.

The first experience in the use of transparent insulation materials in Southern Europe took place in the city of Sabadell in Catalonia.

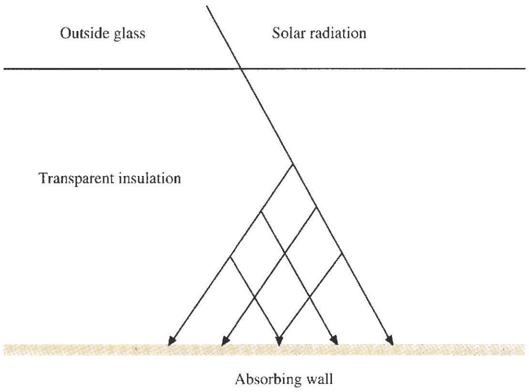
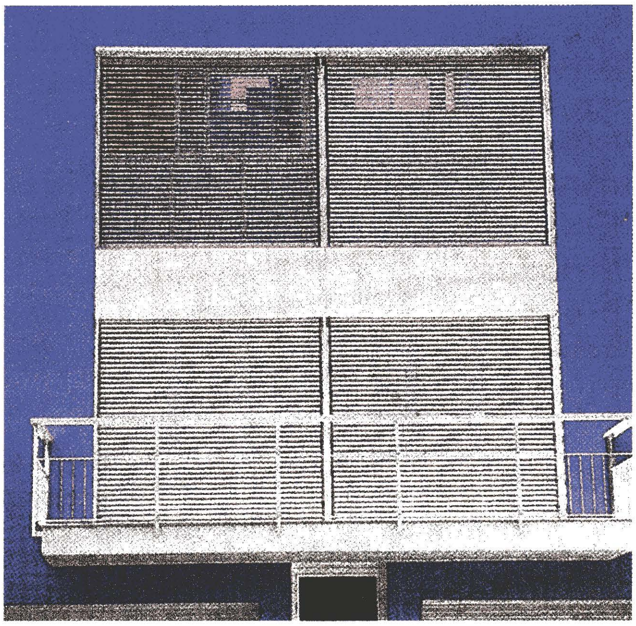


Fig. 8.3 Cross-section of a transparent insulation with capillary structure.

The building in Sabadell, occupying two lots in Carrer Garcilaso, has three 136 m^2 stories, the upper two used for dwellings and occupied by the architects who designed it (Josep Giner, Maria Teresa Mira and Anna Treviño), the ground floor converted into an architect's study. Three basic applications of transparent insulation materials are present in the building: for daylighting, passive solar energy and preheating sanitary hot water.



Pict 8.4 View of the south facade. The transparent insulation is behind the persian blinds.

The functioning principle of transparent insulation is based on the greenhouse effect. The solar radiation, in the form of light, passes through the outer glass layer and the translucent material, heating the wall, which acts as an absorption element. The wall, through the effect of the increase in temperature, emits a high longwave radiant energy, so that most of the calorific energy in the solar radiation penetrates through conduction through the wall and into the interior of the building. Moreover, as the thermal conductivity of the translucent material is very low, heat losses through conduction are minimal.

Transparent insulation can be advantageously applied also to walls facing north, as it will increase the temperature on the outer face of the wall by 3-5°C more than conventional insulation methods, reducing the cold wall effect and decreasing the risk of condensation. It is also advisable to employ shades, such as persian blinds, situated on the exterior of the insulation to avoid overheating inside the building in summer.

Firstly, in order to ensure high levels of natural lighting, 22 m^2 of transparent insulation in the form of cellular polycarbonate was installed between the north front and the air shaft of the building. The material diffuses light throughout the interior of the building without causing the dazzling and heating effects of glass-paned windows.

The second installation of 5 m^2 of transparent insulation was installed on the south face of the second floor as a complement to the direct solar gains surface with double glazing. In order to avoid overheating during the summer, persian blinds were installed on the exterior.

The third application of this material was the installation of a system for preheating sanitary hot water. A 3 m^3 parallelepiped-shaped enclosure was constructed, covered by 7 m^2 of cellular polycarbonate. This preheated the water by around 7-8°C before it entered the 250 litre storage tanks.

The energy saving in heating from the use of these elements is calculated to be 48%, the equivalent of 7,300 kWh per year. To this save must be added the reduced requirements for artificial lighting (4,000 kWh per year) and energy consumption to produce sanitary hot water (500 kWh per year).

The project, which received financial support from the Institut Català d'Energia, had an additional cost of some three million pesetas. Besides the cost of the materials used, this figure includes other costs indirectly related to the demonstration nature of the project. If only the additional cost of the insulating materials - about 700,000 pesetas (4,400 ECU) more than the cost of standard glazing - is considered, the pay-back period on the investment is less than 36 months.

8.3 Case Study 3. **Dublin, Ireland**

The Green Building

The new building is located in Temple Bar, Dublin's cultural quarters, and is being developed by Temple Bar Properties Ltd as part of a major urban renewal programme in the heart of Dublin. Around £500,000 (614,000 ECU) of support has been provided by the EC under the THERMIE Programme.

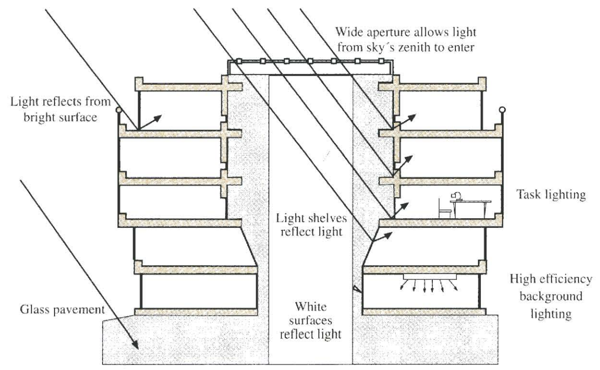


Fig. 8.4 Lighting. Longitudinal schematic.

Homan O'Brien Associates were the building services engineers, who worked closely with the architects, Murray O'Laoire Associates of Dublin and Tim Cooper, THERMIE project manager from Trinity Collge, Dublin.

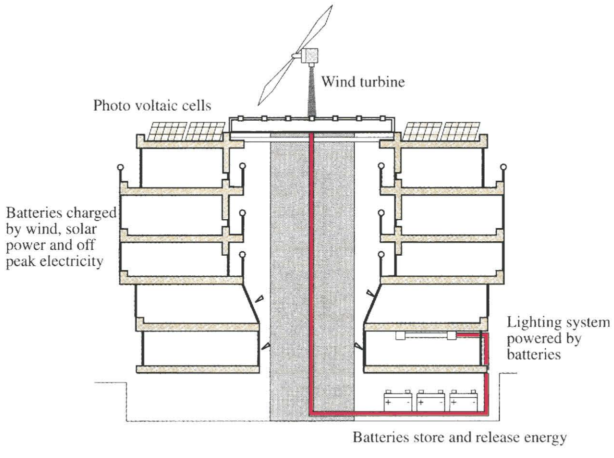


Fig. 8.5 Electrical energy. Longitudinal schematic.

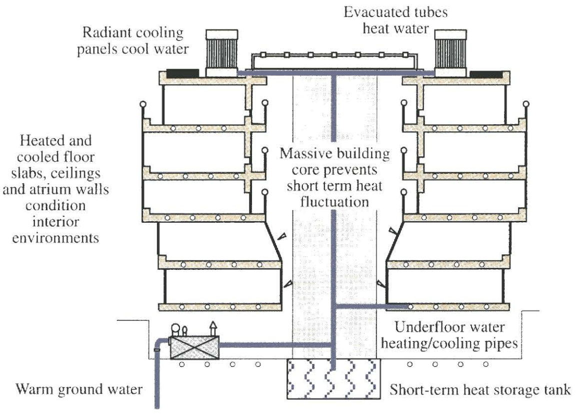


Fig. 8.6 Heating/Cooling. Longitudinal schematic.

The Green Building in Temple Bar, Dublin, has been designed from the outset to achieve high standards of energy efficiency and environmental performance at no extra cost. Cost per m^2 is around £1,075 (1,320 ECU) - about the norm for good offices.

The 1,370 m^2 building is now nearing final completion and is reckoned to be a flagship development to demonstrate what is currently practically achievable on the energy/environment front.

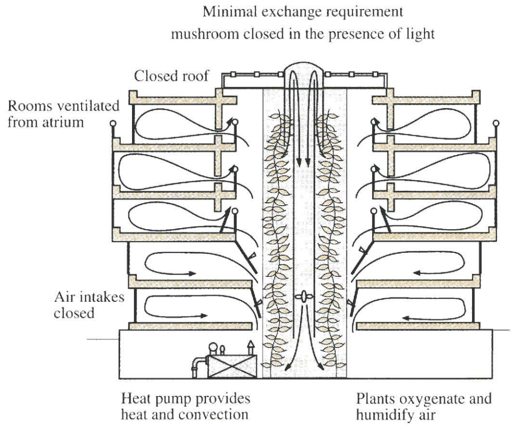


Fig. 8.7 Winter Ventilation-1. Longitudinal schematic.

Computer predictions suggest 81% less energy consumption and 64% less CO_2 emissons.

The total area of modern office buildings in Dublin (just over 1,100,000 m^2) consume around 12£m (15 ECU) per m^2 of energy and generate 100,000 tonnes of CO_2 a year. If savings of this nature could be achieved in Dublin, let alone further afield, the scope for cost savings and reduced CO_2 emissions is colossal.

The developer believes the energy savings of almost £11 (13.5 ECU) per m^2 per year will either result in a premium rent being achieved, or a much quicker letting than might otherwise be achieved.

The building is achieving 81% energy savings:

- By incorporating a high thermal mass; effectively the building can store lots of energy in its heavy fabric. The fabric is encased in an insulated cover that opens up automatically during mild weather conditions.

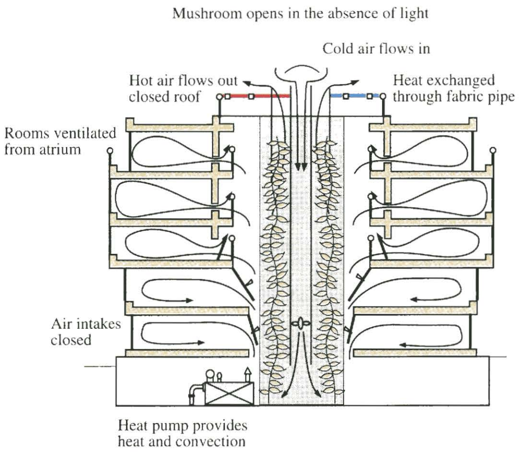


Fig. 8.8 Winter Ventilation-2. Longitudinal schematic.

- It employs natural ventilation that draws air through basement areas planted with carefully selected plants. These help to naturally filter and clean the air and boost the oxygen content.
- A central atrium is incorporated to provide good levels of natural lighting deep inside the office. This also acts as a chimney to draw air up through the building.
- The roof above the atrium opens and closes depending on the weather; when it is dry and hot it opens to transform the atria into an open courtyard; in cold/wet conditions it closes to keep out the rain and retain the heat.
- A heat pump is used to suck heat out of the bedrock below the building. This is then stored in a large hot water tank and used to heat the property via a network of pipes embedded in the floors.
- Roof mounted solar cells and a wind generator are used to power lead-acid batteries that in turn provide electricity for the artificial lighting systems.
- Windows are designed to cover 30% of the wall area; this optimises solar gains and natural daylighting, while minimising heat losses. Double glazed argon filled cavity windows are used.

Other environmental issues of relevance include:

- Extensive use of recycled materials (mainly bricks).

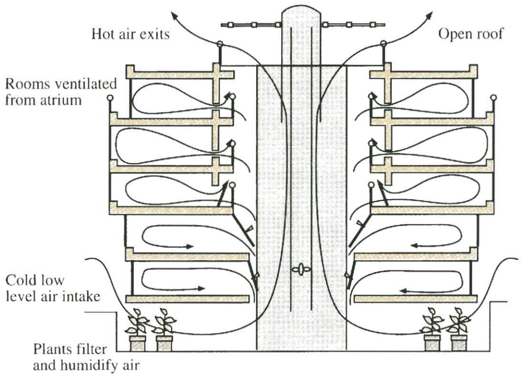


Fig. 8.9 Summer ventilation. Longitudinal schematic.

- Very little steel and aluminium was used, because of the large amount of energy used in its manufacture.
- Rain water is collected and used to supplement the main supplies.
- Recycling of waste: specially designed bins are included.
- Use of environmentally friendly materials, organic paint, etc.

ANNUAL ENERGY CONSUMPTION

	Green Building	Conventional Building
Cooling	4,722	68,611
Heating	15,556	153,333
SHW	35,000	79,167
Motors	6,944	9,722
Lights	0	25,278
Total	62,222 kWh	336,111
	£2,434	£13,477
	2,990 ECU	16,540 ECU
Reduction in energy consumption	81%	
	23 TOE	
Reduction in energy costs	£11,044/year 13,500 ECU	

ANNUAL CO_2 EMISSIONS

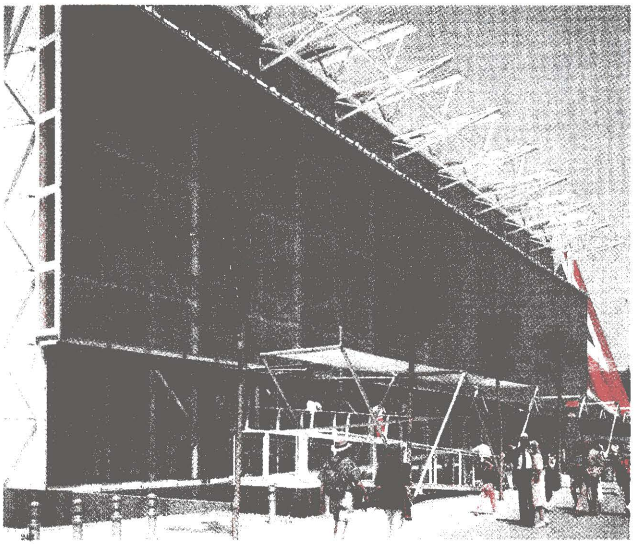
Cooling	3,359	49,262
Heating	11,253	32,110
SHW	25,129	16,578
Motors	4,986	6,980
Lights	0	18,149
Total	44,727 kg	123,079 kg
	33 kg/m²	90 kg/m²
Reduction in CO_2 emissions	64%	

8.4 Case Study 4.

British Pavilion at the Seville Expo'92

The Expo's location, in the hot climate of Seville (southern Spain), suggested an obvious aspect of the theme: how to moderate this uncomfortable climate without resorting to energy-squandering mechanical means.

The British pavilion is a passive climate moderator, and its architecture is a direct and honest expression of this function. In Seville, climate moderation means cooling, so it is the cooling devices that are the most visible parts of the building. The most impressive of these is the cascade of water that flows down the glass curtain wall of the main east facade into a pool, partly inside and partly outside the building. The water has to be pumped, and that means using energy, but the energy, or most of it at least, comes from photovoltaic cells mounted on the roof. Thus the wall is cooled by the heat of the sun.



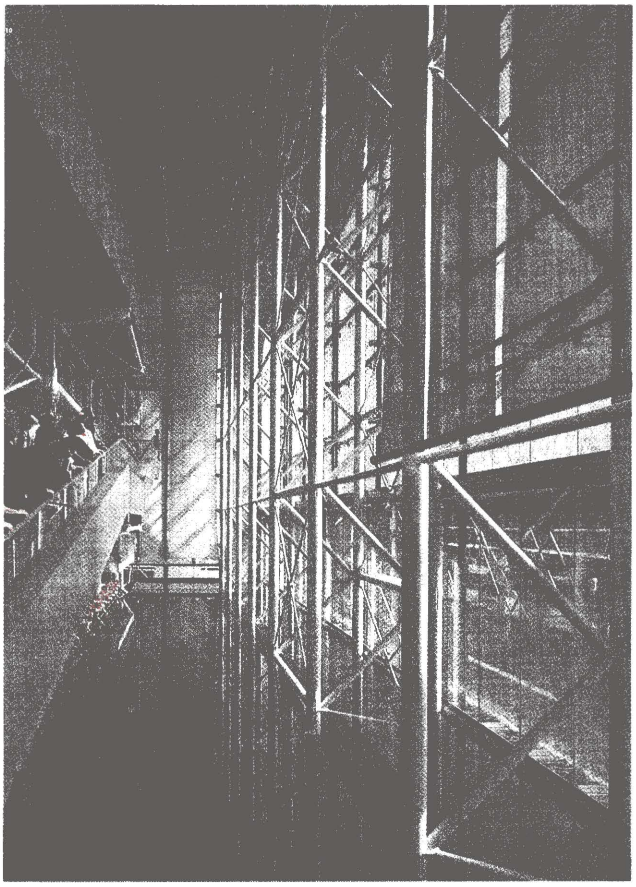
Pict. 8.5 British Pavilion at the Seville Expo'92.

On the roof, it finds the second cooling device, a giant horizontal louvred shutter made from curved fabric blades supported on V-shaped struts. The louvres reduce solar heat gain through the thin insulated roof deck, and they do it in a way which is boldly expressive of their function.

In Seville, the sun is at its hottest in the afternoon, and therefore it is the west facade of the building that is most vulnerable to unwanted heat gain. Here, the cooling device works on a different principle: high thermal capacity. The wall is kept cool by sheer mass. A heavy structure such as a thick stone wall acts like a thermal flywheel, delaying the transmission of heat to the interior until the sun has gone down and then heat is re-radiated to the cool night sky. The wall was built from shipping containers lined with butyl and filled with water - a typical example of technology transfer, using components from outside the normal boundaries of the building industry.

The north and south walls of the building borrow technology from the boat-building industry. Membranes of PVC-coated polyethylene fabric are stretched between bow-shaped circular section steel members and fixed by means of luff grooves in the same way that the sails of yachts are fixed to their masts. On the south facade, the cooling device takes the form of fly sheets attached to the pressed metal struts and tension cables that brace the masts.

These various cooling devices reduce the temperature in the high interior space by about 10 degrees Celsius on the hottest days.



Pict. 8.6 The water pouring down the east wall generates a constantly moving and soothing rippled pattern.

8.5 Case Study 5.

Tchibo Holding AG, Hamburg

The naturally ventilated open-plan office.

In areas with an average wind speed above 2 m/s and relatively short periods with no wind, it is possible to ventilate buildings even with deep plan offices in a natural way by using pressure differences around the building in an intelligent way.

Picture 8.7 shows as a special case the office building of the Tchibo Holding AG in Hamburg where it was requested to ventilate a landscape office with a depth of up to 25 m in order to compensate cooling loads and to evacuate odours etc.

In Figure 8.10 the footprint of the building is shown in which the interior zones that in general cannot be naturally ventilated are marked. In order to achieve the desired ventilation, an interior atrium was created which had to serve as an exhaust duct for the adjacent office areas. In order to make this principle - shown in Figure 8.11 - work, the shape of the glass roof of both atria was formed in

Pict. 8.7 Tchibo Holding AG. Hamburg, Vorwaitungs-gebäude CN 2, (Architects: Bürgin & Nissen, Wentziaff. Basel).

wind tunnel tests. This kind of airflow study cannot be executed by computer programs but makes the use of wind tunnel tests at different scales inevitable.

In a first test series the pressure zones around the building were defined and the shape of the roof was optimized. In further large scale tests the airflow throughout the building was optimized in such a way that no draught at the workplace could occur. In addition, the airflow was directed along the massive ceiling construction so that temperature peaks could be reduced by using the thermal mass of the construction. All these measures led to a ventilation concept which enables the occupants to work under conditions of natural ventilation for 70-80 % of the year. Thus the energy costs compared to a standard air-conditioned open-plan offices could be reduced from 140 to 60 DM/m^2 (75 to 32 ECU/m^2) which was proven during four years of operation. In addition the acceptance of the building by the users - who are in a position to define their working environment themselves - is significantly higher than in any air-conditioned environment.

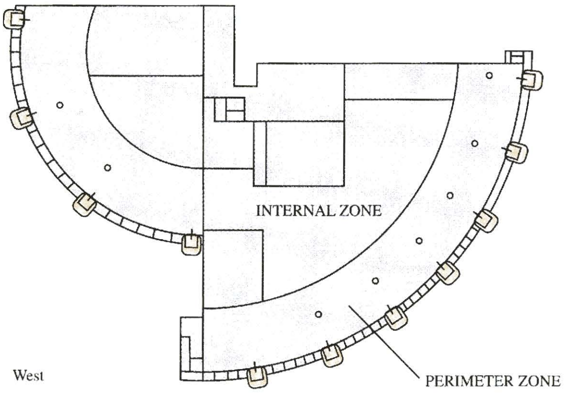


Fig. 8.10 Plant view.

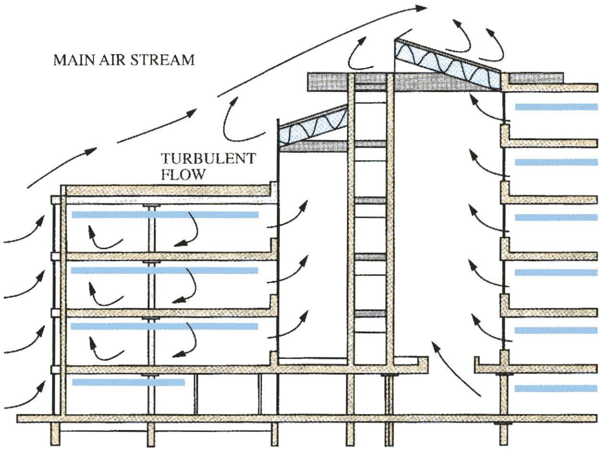


Fig. 8.11 Ventilation Principle scheme.

THE OPET NETWORK

Organisations for the Promotion of Energy Technology

Within each Member State there are a number of organisations recognised by the European Commission as an Organisation for the Promotion of Energy Technology (OPET). It is the role of these organisations to help to co-ordinate specific promotional activities within Member States. These include staging of promotional events such as conferences, seminars, workshops or exhibitions as well as production of publications associated with the THERMIE Programme.

ADEME
27 rue Louis Vicat
F-75015 PARIS
Tel. 33 -1 -47. 65.20.21/56
Fax. 33 -1 -46.45.52.36

ASTER SRL
Via Morgagni 4
I-40122 BOLOGNA
Tel. 39 -51-23.62.42
Fax. 39 -51 -22.78.03

BCEOM
Place des Frères Montgolfier
F - 78286 GUYANCOURT Cedex
Tel.: 33 -1 -30. 12. 49. 90
Fax. 33 -1 -30.12.10.95

BRECSU
Garston, Watford
Hertfordshire
UK - WD2 7JR
Tel.: 44 -923 -66.47.56
Fax. 44 -923 -66.40.97

CCE
Estrada de Alfragide
Praceta 1 - Alfragide
P-2700 AMADORA
Tel.: 351 -1 -471.14.54/81.10/82.10
Fax. 351 -1 -471.13.16

CEEETA-PARTEX cps
Calçada da Estrela, 82 - 1º DTº
P-1200 LISBOA
Silva (PARTEX)
Tel.: 351 -1 -395. 56. 08
Fax. 351 -1 -395. 24. 90

CESEN S.p.A.
Viale Brigata Bisagno, 2
I-16129 GENOVA
Tel.: 39 -10 -550.46.70
Fax. 39 -10 -550.46.18

CORA c/o SEA
Saarländische Energie-Agentur
GmbH
Altenkesselerstrasse, 17
D- 66115 SAARBRÜCKEN
Tel.: 49 -681 -976.21.74
Fax. 49 -681 -976.21.75

COWIconsult
Engineers and Planners AS,
Parallelvej 15
DK-2800 LYNGBY
Tel.: 45 -45 -97. 22.11
Fax. 45 -45 -97.22.12

CRES
19 Km - Marathon Avenue
GR-19009 PIKERMI
Tel.: 30 -1 -603.99.00
Fax. 30 -1 -603.99.04/11

EAB, Flottwellstr 4-5
D-10785 BERLIN
Tel.: 49 -30 -25.49.60
Fax. 49 -30 -25. 49.62.30

Energy Centre Denmark
Suhmsgade 3
DK-1125 KØBENHAVN K
Tel.: 45 -33 -11.83.00
Fax. 45 -33 -11. 83.33

ECOTEC
Research and Consulting Ltd.
Priestley House
28-34, Albert Street
BIRMINGHAM UK - B4 7UD
Tel.: 44 -21- 616.10.10
Fax. 44 -21- 616.10.99

ENEA
Via Anguillarese, 301
S. Maria di Galeria
1 - 00060 ROMA
Tel.: 39 -6 -30.48.18/36.86
Fax. 39 -6 -30.48.64.49

ETM Consortium
51, rue Colonel Picquart
B- 1030 BRUXELLES
Tel.: 32 -2 -646.88.14
Fax. 32 -2 -646.14.40

ETSU
Harwell, Oxfordshire
UK - OX11 ORA
Tel.: 44 -235 -43.33.27
Fax. 44 -235 -43.20.50

EUROPLAN CHORUS
2203 Chemin de St-Claude
Nova Antipolis F - 06600 ANTIBES
Tel.: 33 -93 -74. 31.00
Fax. 33 -93 -74. 31 31

EVE - Cadem
Edificio Albia 1
San Vicente 8 - Planta 14,
E-48001 BILBAO
Tel.: 34 -4 -423.50.50
Fax. 34 -4 -424.97.33

FAST
Piazzale Rodolfo Morandi 2
I-20121 MILANO
Tel.: 39 2 76 01 56 72
Fax. 39 2 78 24 85

FIZ/KFA, FIZ Karlruhe
Postfach 2465 D-76012 KARLSRUHE
Tel.: 49 7247 808 351
Fax. 49-7247-808-134

KFA Jülich
Projektträger BEO
Postfach 1913 D-52425 JÜLICH
Tel.: 49 -2461 -61.37.29/59.28
Fax: 49 -2461 -61.69.99

FORBAIRT
Glasnevin IRL-DUBLIN 9
Tel.: 353 1 837 01 01
Fax. 353 1 837 28 48

Friedemann und Johnson -
Consultants GmbH
Pestalozzistr, 88
D - 10625 BERLIN
Tel.: 49 -30 -312.26.84
Fax. 49 -30 -313.26.71

GEP
45 rue Louis Blanc
La Défense 1 Cédex 72
F - 92038 Paris la Défense
Tel: 33 -1 -47.17.61.39
Fax. 33 -1 -47. 17.67.47

GOPA - Consultants,
Hindenburgring 18
D-61348 Bad HOMBURG
Tel.: 49 -6172 -93.00
Fax. 49 -6172 -3 -50.46

ICAEN
Av. Diagonal, 453 Bis, Atic
E-08036 BARCELONA
Tel.: 34 -3 -439.28.00
Fax. 34 -3 -419.72.53

ICEU
Auenstrasse 25
D-04105 LEIPZIG
Tel.: 49 -341 -980.49.69/49.64
Fax. 49 -341 -980.34.86

ICIE
Via Nomentana 133
I-00161 ROMA
Tel.: 39 -6 -884.58.48/854.91. 41
Fax. 39 -6 -855.02. 50

IDAE
Pº de la Castellana 95 - P 21
E-28046 MADRID
Tel.: 34 -1 -556.84.15
Fax. 34 -1 -555.13.89

IMPIVA
Avellanas, 14 - 3ª F
E-46003 VALENCIA
Tel.: 34 -6 -392.00.05/04/03
Fax. 34 -6 -391.44.60

INET/ITE
Azinhaga dos Lameiros à Estrada
do Paço do Lumiar
P-1699 LISBOA Codex
Tel.: 351 -1 -716.51.41/27.50/27.61
Fax. 351 -1 -716.65.69

INNOTEC - Systemanalyse
GmbH, Kurfürstendamm 199
D-10719 BERLIN
Tel.: 49 -30 -882.32.51/34.32
Fax. 49 -30 -885.44.33

INSTITUT WALLON / ENERGIM 2000
10 rue Baron Huart
B- 5000 NAMUR
Tel.: 32 -81 -23.04.52
Fax. 32 -81 -23.07.42

IRO
P.O. Box 7261
NL-2701 AG ZOETERMEER
Tel.: 31 -79 -41.19.81
Fax: 31 -79 -41.97.64

KEMA Nederland B.V.,
Utrechtseweg, 310
NL-6812 AR ARNHEM
Tel.: 31 -85 -56.24.77
Fax. 31 -85 -51.73.62

LDK Consultants Engineers & Planners
7 Sp. Triantafyllou Str.
GR-113 61 ATHENS
Tel.: 30 -1 -856.31.81/2
Fax. 30 -1 -856.31.80

LUXCONTROL
Avenue des Terres Rouges, 1
L-4004 ESCH-SUR-ALZETTE
Tel.: 352 -54 -77.111
Fax. 352 -54 -79.30

MARCH Consulting Group,
Telegraphic House
Waterfront 2000
MANCHESTER UK M5 2 XW
Tel.: 44 -61 -872.36.76
Fax. 44 -61 -848.01.81

NIFES
8, Woodside Terrace
GLASGOW UK - G3 7UY
Tel.: 44 -41 -332.41 40
Fax. 44 -41- 333.42.55

NOVEM
Swentiboldstraat, 21
NL-6130 AA SITTARD
Tel.: 31 -46 -59.52.39
Fax. 31 -46 -52.82.60

OCICARBON
c/o Agustín de Foxá 29, 4º A
E-28036 MADRID
Tel.: 34 -1 -733.86.62
Fax. 34 -1 -314.06.46

PSTI
Offshore Technology Park
Exploration Drive
ABERDEEN UK AB23 8GX
Tel.: 44 -224 -70.66.00
Fax. 44 -224 -70.66.01

RARE c/o Rhonalpénergie
Rue de la République, 69
F-69002 LYON
Tel.: 33 -78.37.29.14
Fax. 33 -78.37.64.91

SODEAN
Bolivia, 11
E - 41012 SEVILLA
Tel.: 34 -5 -462.60.01/11
Fax. 34 -5- 462.63.01

SOGES S.p.A.
Corso Turati, 49
I-10128 TORINO
Tel.: 39 -11 -319.08.33
Fax. 39 -11- 319.02.92

SYNERGIA
Apollon Tower
64, Louise Riencourt Street
GR - 11 523 ATHENS
Tel.: 30 -1 -64.96.185
Fax. 30 -1 -64.96.186

TÜV RHEINLAND
(Kst 931)
Am Grauen Stein
D- 51105 KÖLN
Tel.: 49 -221 -806.0
Fax. 49 -221 -806.13.50

University College Dublin
Energy Research Group
School of Architecture
Richview, Clonskeagh
IRL-DUBLIN 14
Tel.: 353 -1 -269.27.50
Fax .353 -1 -283.89.08

VLAAMSE THERMIE COORDINATIE
Markiesstraat, 1
8e verdieping, B-1000 BRUSSEL
Tel.: 32 -14 -33.27.16
Fax .32 -14 -32.11.85

Zr-E
Wieshuberstrasse 3
D-93059 REGENSBURG
Tel.: 49 -941 -461.190
Fax. 49 -941 -464.19.10

These addresses are subject to possible change. For further information please contact:

OPET-CS
18, av R. Vandendriessche
B-1150 BRUSSELS
Tel.: 32 -2 -778.28.11
Fax: 32 -2 -771.56.11

Produced by:

Generalitat de Catalunya
Departament d'Indústria i Energia
Institut Català d'Energia

Av. Diagonal, 453 Bis, Àtic
E-08036 Barcelona
Tel.: +34-3-439.28.00
Fax.: +34-3-419.72.53
Catalunya-Spain

By order of:

The European Commission
Directorate-General for Energy (DG XVII)
Strategy-Dissemination-Promotion (D/1)
200, rue de la Loi,
B-1049 Brussels, Belgium

ISBN 84-393-3696-9

9 788439 336969