



European Commission Thermie Project to reduce energy and improve comfort and environment



What is EC2000?

A Thermie Target Demonstration

Project including 7 new non-domestic buildings;

- > with linking activities between sites;
- > demonstrating the latest low energy techniques;
- > covering design, construction and monitoring;
- > promoting the concepts and stimulating replication.

Natural Ventilation and cooling strategies in new office designs

INFORMATION DOSSIER

NUMBER

2

MARCH 1998

The EC2000 principles

- > reducing energy consumption by 50% compared with traditional buildings;
- > reducing CO₂ emissions by up to 70%;
- > avoiding air-conditioning, or minimising its energy use;
- > providing good internal visual and thermal conditions;
- > allowing individual control of lighting, heating and cooling where possible;
- > stimulating environmentally friendly design and construction.

Building uses

Offices; Lecture rooms; Learning Resources Centre; Municipal facilities; Sports arena; Exhibition and conference facilities.



This information bulletin is one of a series reporting on the experience of the design, construction and monitoring of EC 2000 buildings

1
3
4
5
6
7
8

Fire Safety in Atria

Energy efficient buildings – the Client's view

Control strategies for passive buildings

Windows – the Key to Low Energy Design

Design standards for energy efficient buildings

Environmental assessment of seven new buildings

Energy efficient building technologies explained

Energy Comfort 2000 Information Dossier

Natural ventilation and cooling strategies in new offices.

This information dossier is one of a series reporting on the experiences gained during the design, construction and monitoring of EC2000 buildings. The dossiers have also been enhanced by the inclusion of experiences and case studies from other buildings outside the EC2000 project.

**prepared by W/E Consultants
Rik Vollebregt
Chiel Boonstra
Enhanced by University of Athens
Mat Santamouris**

Natural ventilation and cooling strategies in new offices

Natural ventilation systems in new office buildings

Ventilation serves to provide fresh air all year and to remove excess heat in summer. Natural ventilation, as opposed to mechanical ventilation, uses no fans to drive the air. There are several advantages related to natural ventilation. A considerable saving on energy can be achieved as no fans are specified or are used only sporadically. Users have a large and clear influence on the intake of fresh air because ventilation provisions are positioned in the facade and are completely or partly manually controlled. This may also help to relieve symptoms associated with sick building syndrome. In summer natural ventilation at night helps to prevent overheating during the day. Ducts for mechanical ventilation are normally placed in the floors, and their absence releases space that can be used in the architectural concept or may mean that a lower building can be built. The main drawback of natural ventilation is that heat cannot easily be recovered from exhaust air.

Products such as air inlets, specifically designed for natural ventilation have emerged on the market recently. Computer models to are now available for engineers to aid in the design. These developments have made possible the application of natural ventilation systems whilst avoiding traditional risks.

Natural ventilation systems rely on natural driving forces, such as wind and the temperature difference between a building and its environment, to drive the flow of fresh air through a building. If a system is carefully designed, wind may push air in at the facade and draw it out again at the roof. Fresh air from outside is warmed inside. The air rises as it warms, which guides the flow further through the building. This is known as the passive stack effect. More common is the use of cross ventilation, while single sided natural ventilation could be very effective if well designed.

Although cheap and energy efficient, wind and temperature vary greatly and the challenge for natural ventilation designs is to provide sufficient fresh air all through the year. In some cases passive systems have to be supported by mechanical ventilation. It is important to

ensure that during winter enough fresh air enters the building without causing comfort problems.

A natural ventilation system has to satisfy the same requirements a mechanical one does. Fresh air has to be sufficient, depending on floor area, occupants and type of building. Indoor climate has to be comfortable, resulting in criteria for air temperature and speed. Energy conservation needs place a restriction on the maximum admissible amount of fresh air. Summer ventilation demands a minimum amount of fresh air to be effective. Other requirements related to ventilation may be the rejection of sound from outside, prevention of sound transfer between rooms and the corridors and decreasing external pollution.

A natural ventilation system consists of components to guide and control the flow of air through the building. Although most are common, some components are innovative and it is partly because of recent developments that natural ventilation can be applied even more often. Ventilation inlets are components that are normally placed in the facade and vary from openable windows to self adjusting air inlets. Ducts, sometimes covered with a sound attenuating mat, serve to transport air further. Quite often features of the building itself, such as atria or stairways, serve as main air transport routes. Used air may leave the building through constructions, designed to use wind to draw air from the building. The type of offices and rooms in the building are important also. Open plan offices need more air and are occupied by users that change the level of ventilation less frequently. In cellular offices the level of ventilation is changed more often.

In this dossier we present calculation methods that have aided the design of natural ventilation systems. Further, we present the concepts that were applied in four buildings of the EC2000 Thermie Target Demonstration Project and one building outside the EC2000 project. In these project cases, we focus on the ventilation system and it's special features, the design process and the lessons learned.

Natural ventilation and cooling strategies in new offices

Calculation of air flows

Introduction

Natural ventilation design is no routine job. Features of the building, the local climate and novel components form a combination with initially unknown qualities. Therefore special tools are used in their design. The calculation methods described below are very useful in this respect. The continuing improvement of those models has now reached the level where they are used more or less as accepted design tools. Natural ventilation design benefits strongly from those novel tools. Problems related to natural ventilation, such as insufficient ventilation, uncontrolled ventilation and draughts can be assessed and eliminated in the design stage.

Two major types of air flow calculation models are to be distinguished.

Natural Ventilation Tools

Transfer of air between the building and the surrounding environment as well between the various zones of the buildings play a very important role in the overall thermal balance of buildings, while regulating to a certain degree the levels of thermal comfort and of indoor air quality.

Exchange of air can be achieved either by mechanical means (mechanical ventilation), or through the large openings of the building's envelope (natural ventilation). Air is also exchanged through cracks and other small size openings (infiltration).

Knowledge of the exact air supply to a building is necessary to determine its thermal performance and the concentration of the indoor pollutants. Calculation of air flow through large openings, through natural ventilation, is a complicated task. The random nature of the wind makes estimation of air flow characteristics much more complicated than in the case of mechanical ventilation.

Classical fluid dynamics provides a stable scientific background to calculate the air flow of the ventilation systems. This can be achieved either by using computerized fluid dynamic techniques (CFD's) or more simplified network models.

Computational fluid dynamics (CFD)

Computerised fluid dynamics tools are based on the solution of the Navier Stokes equations combined with turbulence models. These tools

determine the field of air velocity in a zone, the flow rate through various components, and the concentration of indoor pollutants in zones. Also, they combine efficient heat transfer models to calculate the thermal balance of various building elements. Although these tools are very powerful, only experts are able to use them while their cost is high. Another problem is related to the knowledge of the climatic boundary conditions that are rarely known. Recent research has shown that CFD solutions are of high variability inside the limits of fuzziness of the input data. Therefore, the use of complicated CFD techniques is not the more suitable solution, especially for small and medium projects. Some very well known CFD tools are PHOENICS, FLOWVENT, etc.

Multizone air flow models

Network calculation models are based just on the equation of mass conservation combined with some empirical knowledge. These tools can efficiently simulate the air flow rate in a building, when mechanical ventilation techniques are used, as well as the concentration of indoor pollutants but do not provide any information on the velocity field in a space. Well known network models for mechanical ventilation systems are AIOLOS, COMIS, AIRNET, and BREEZE. Network models are easy in their use while their cost is minimal. Some of the models like AIOLOS are free to the public. AIOLOS is developed in the framework of the ALTENER program of the European Commission. AIOLOS is based on the algorithms of the PASSPORT-AIR, air flow tool, developed in the framework of the PASCOOL research program and provides the user with specialized powerful algorithms calculating the air flow rate through large openings as well as design assistance. The model is also coupled with a thermal model to quantify the impact of natural ventilation techniques to the thermal balance of the buildings.

Some empirical manual methods have been also proposed to calculate air flow through large openings, through natural ventilation. Some of them are the British Standard Method, and the manual algorithms of NORMA. These tools provide an estimate of the air flow but should be always be used in the limits of their validity.

Natural ventilation and cooling strategies in new offices

Natural Ventilation Potential in Urban Areas

Air flow around isolated buildings is well known. Due to flow down the windward facade, this is characterized by a bolster eddy vortex, while behind the building there is a lee eddy drawn into the cavity of low pressure (due to flow separation from the sharp edges of the building top and sides). Further downstream is the building wake, characterized by increased turbulence but lower horizontal speeds than the undisturbed flow.

With regard to the air flow patterns in urban configurations, canyons between buildings have a very high importance in determining the potential of natural ventilation techniques.

Air can flow along the canyon, perpendicular to the canyon or, more commonly, air flows at a certain angle relative to the long axis of the canyon. Unfortunately the existing research on this latter scenario is considerably smaller compared to the scientific information for perpendicular and along the canyon flows. However, it is known that when the flow above the roof is at some angle of attack to the canyon axis, a spiral vortex is induced along the length of the canyon, similar to a cork-screw type of action. For intermediate angles of incidence to the canyon long axis, the canyon airflow is the product of both the transverse and parallel components of the ambient wind, where the former drives the canyon vortex and the latter determines the along canyon stretching of the vortex.

As a result of the above mechanisms, wind speed inside the canyons in a urban environment is seriously decreased and as a mean value is close to 10-30 % of the undisturbed wind speed over the buildings. Although ambient wind speeds can easily exceed 4 m/sec, the speed inside the canyon increases up to 1 m/sec, and rarely exceeds it.

Decrease of wind speed seriously affects the potential for natural ventilation of buildings in the urban environment. To better design natural ventilation in urban buildings, different methods have been proposed to consider realistic wind speeds. In fact, various methods, both simplified or detailed have been proposed to calculate the effects of the building location on the natural ventilation effectiveness. The methods in general propose techniques to reduce either the wind speed or the air flow rate due to

the relative location of the building and the characteristics of the neighbouring buildings.

A simplified but quite comprehensive method is developed and proposed by the Florida Solar Energy Center. The method proposes a 'Terrain Correction Factor', TCF, to multiply the design air change rate in order to take into account the effects related to the reduction of the wind speed because of the building location. The proposed values are given in Table 1 for 24 hours and night ventilation strategies.

Terrain Type	TCF, 24 hours ventilation	TCF, Night only ventilation
Oceanfront or > 3 miles water in front	1.30	0.98
Airports or flatlands with isolated-wall separated buildings	1.00	0.75
Rural	0.85	0.64
Suburban or Industrial	0.67	0.50
Centre of Large City	0.47	0.35

Table 1 Terrain Correction Factor

The same method proposes a reduction coefficient to take into account the effect of the neighbourhood buildings. The coefficient is based on the wall height of the upwind building, h , as well as on the gap between the building and the adjacent upwind building, g . Values of the Neighbourhood Correction Factor are given in Table 2 as a function of the ratio g/h .

Ratio g/h	Neighbourhood Correction Factor
0	0.00
1	0.41
2	0.63
3	0.77
4	0.85
5	0.93
6	1.00

Table 2 Neighbourhood Correction Factor

The final air flow rate can then be calculated as the product of the design air flow rate multiplied by the Neighbourhood Correction Factor and the Terrain Correction Factor.

Case Studies

Natural ventilation and cooling strategies in new offices

APU Learning Resource Centre, Chelmsford, Essex, UK

Text: Chris Twinn, Ove Arup & Partners

Features

Varying window openings to control ventilation
Trickle ventilation in winter
Atrium air stack as driving force
Pitched roof creates draw

Project description

Anglia Polytechnic University (APU)'s new campus is sited on a redundant industrial area alongside the River Chelmer, in Chelmsford, Essex. The Learning Resource Centre at APU consists of 6000 m² of library, education and associated social facilities, and is designed to cater for heavy use with extended daily operating hours.

Restrictions and requirements by Building Codes or authorities

Along with the requirements by Building Codes, the aim of the design was to be environmentally sensitive. Further, the client required simple systems, robust finishes, minimum maintenance, daylighting and low capital and running costs. Attempt was also made to avoid conventional, all-mechanical solutions to the peak cooling loads of 40 W/m².

There is no UK requirement for naturally ventilated buildings. The APU design is based on a 24-hour averaged fresh air flow rate (see below)

building type	university
minimum required ventilation (l/s per person)	8 l/s

Design problemsolving and communication between architects and engineers

As cross ventilation would be insufficient in this 30 m-deep building, a warm air stack in the central atria provides the means for natural ventilation. Particularly critical are the air flows on the top floors. Here, the stack height and therefore the driving force is at its minimum. As a result, flow reversal could occur with lower floor warm air finding it easier to exit the building via the top floor windows instead of the atrium openings.

Obviously, the stack height driving force is considerably greater on the lower floors. In the APU project the flow via each floor is balanced by throttling to varying degrees on each floor. This meant reducing the openable window area on each floor in proportion to the increased stack height. Security concerns precluded manual control of many low-level windows, so an arrangement of actuator-driven clerestory windows was used. These are arranged in facade orientation groups on each floor, controlled by a local room temperature sensor.

Wind created forces can easily overwhelm the stack driving force. To avoid this potential conflict the natural wind co-efficients occurring on either side of the pitched roof can be used to maintain a negative pressure in the atrium and create a draw, a condition that can be induced by closing windward and opening leeward atrium vents. Wind effects on the windows are dealt with by the local temperature sensors. As wind increases cold air infiltration, the windows will start to close. The amount of open window area in the roof is kept in proportion with the amount of open area in the perimeter to balance incoming and outgoing airflows.

During winter, experience has shown that windows are often kept shut in naturally ventilated buildings. This results in stuffy polluted internal conditions which, ironically, can maintain internal humidity levels. At APU the solution to this problem is an engineered trickle ventilation arrangement. The local buoyancy effect generated by the perimeter finned-tube heaters within their casings is used to draw air through small fresh air vents from outside. The intention is not to achieve anything like the 8 litres/s of fresh air per person at full occupancy, but to provide a continuous background tempered fresh air supply. Atrium air quality sensors initiate window opening should their hydrocarbon calibration indicate excessive pollutant levels - the atrium stack thus provides a back-up purge facility.

Opening and closing of the windows is controlled by the building management system. The trickle vents are controlled manually.

The APU design is based on a 24 hour averaged fresh air rate. This means that overnight the building is flushed and a large reservoir of fresh air available for the morning state of occupancy. This permits a reduced daytime continuous trickle ventilation rate.

Natural ventilation and cooling strategies in new offices

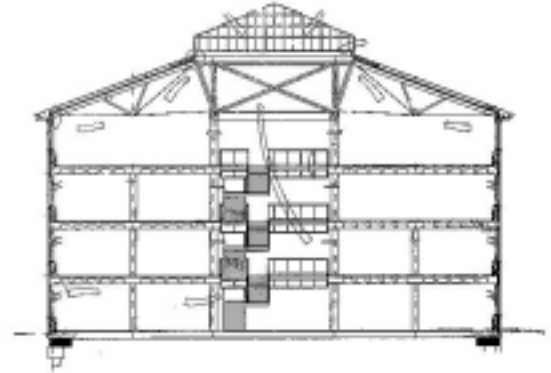
inlet type and size	automatic windows and vents
internal air flow route	open workspace, atrium
exhaust, type and size	windows in pitched roof atrium

Cooling

For more than 90% of the year adequate free cooling is available directly by using outside air from opening windows, assisted by the atrium stack. It is during periods of peak outside air temperatures that night-time air cooling of the structure is needed to provide supplementary cooling. A cool, exposed high thermal capacity building structure provides lower radiant temperatures and, therefore, cooler comfort conditions. Obviously, for that radiant effect the structure must be directly visible to the occupant. To use it to its full potential during peak days in summer, it must also have the means for discharging the absorbed daytime heat so that it is available for the following day. The stack provides an ideal method for driving night-time ventilation to cool the structure.

A key design issue is how long night venting should be permitted before the structure becomes too cool, and so needs heating the following morning. The approach at APU is to use the daytime stored excess heat to decide when it has been discharged at night.

Architect and Energy consultants: ECD Architects and ECD Energy and Environment Engineering and Building Physics: Ove Arup and Partners



A section of the building showing the library floors and the atrium where windows are opened depending on wind direction. *diagram: Chris Twinn, Ove Arup & Partners*

APU	heating season, day ventilation	summer, day ventilation	summer, night ventilation
air supply	small vent	automatic windows	automatic windows
exhaust air	atrium windows	atrium windows	atrium windows
ventilation /person	less than 8l/s		

Lessons learned

The design has found solutions in which users are still free to open their windows while the fresh air remains distributed evenly over all floors.

At APU natural ventilation was achieved, at modest cost, by keeping solutions simple.

Project data

Client: Anglia Polytechnic University

Tax Office Extension, Enschede, NL

Features

- Self adjusting air inlets
- Atrium air stack as driving force
- Chimneys create draw
- Mechanical back up

Project description

Natural ventilation and cooling strategies in new offices

The EC2000 building in Enschede, a city with some 100,000 inhabitants, is located close to the railway station in the centre. The project concerns a new wing with five office floors and a total floor area of 4,300 square metres. The ground floor is a garage for bicycles and cars. The floor plan is wedge-shaped with an atrium located in the center of the wedge. The atrium is surrounded by corridors, connected by bridges. The five meter deep office rooms are located at the edges of the building. The long facades of the new wing are oriented North and South.

Restrictions and requirements by Building Codes or authorities

The natural ventilation design in Enschede faces several difficulties, along with the requirements by Building Codes. A fresh air volume of 6.5 m³ per hour for each square metre of office area or 14 litres/second per person has to be supplied. To avoid mechanical cooling in summer, a double amount of fresh air is necessary during summer nights. The design has to meet a maximum of 150 weighted hours during which room temperature may exceed 25.5°C. In winter, the inlet of fresh air must not lead to draughts. Finally, office workers on the South facade must not be bothered by noise from the nearby railway.

building type	office
minimum required ventilation (l/s per person)	14l/s

Design problemsolving and communication between architects and engineers

The natural ventilation is part of a total energy efficient design that in turn is part of the building design. So from early in the design phase the energy and the building physics consultants were included in the design team. After an initial phase where a preliminary design and directions for solutions were established the consultants worked out some alternative designs. Communication lines were kept short so no energy was spent in perfecting partial designs that would not fit into the total.

inlet type and size	self adjusting vents, 30x10cm per vent
----------------------------	--

internal air flow route	cellular offices, plenum, atrium
exhaust, type and size	6 cowls @71cm on atrium

Ventilation inlets of a self adjusting type were chosen. These minimised the risk of cross ventilation, excessive ventilation and interference. It had to be established however, if it was possible to let in cold air without draughts. After initial tests this proved possible, provided the inlet, being 36 cm wide and 10 cm high, was mounted just below the ceiling. After consultation with the architect, who didn't want the look of the facade to be disturbed, an ideal location for the inlets was found behind the overhangs of the facade cladding where the sun shading device is installed.

Another device, a light shelf to help sunlight entering deep into the room, interfered with the air flowing from the inlets. After consulting the daylight engineer the shelf was moved a few centimeters from the wall. This configuration was tested in the climate chamber of the building physics consultant and proved to function adequately: the shelf even had a strengthening influence on the jet of inlet air which ideally remains just below the ceiling until it has reached room temperature. An opening of 560 cm² to the plenum serves to transport used air from the room to the atrium.

The used air is removed from the building by special chimneys. The ventilation cowls have an inner diameter of 71 cm and a height of 152 cm. The pressure drop in the cowls is below 2 Pa, so that air is removed effectively. An inner cone protects from rain and wind blowing in. The chimneys also are an important characteristic of the building when viewed from outside. The architect and consultant agreed on a design with six cowls, regularly placed on top of the roof.

Calculations showed that natural ventilation is inadequate at wind speeds below 1 m/s and outside temperature 5 and 15 °C. In this case ventilation will be driven mechanically by two exhaust fans in the top of the atrium. The fans have a flow rate of 5700 m³/hour and are controlled dependant on wind speed and internal and outside temperature. Summer nighttime ventilation also needs back up occasionally. Four fans ensure sufficient air when the wind speed falls below 5 m/s and the outside temperature is above 20°C.

Natural ventilation and cooling strategies in new offices

The noise problem at the South facade was easily solved with acoustic dampers at the self adjusting air inlets.

‘breathing’ building, and of avoiding lightweight structures, in Enschede the idea of using thermal mass led to a semi-exposed concrete structure. The step forward consists of new developments

Enschede	heating season, day ventilation	summer, day ventilation	summer, night ventilation
air supply	one vent pp	two vents pp, windows	two vents pp
exhaust air	6 cowls on atrium	6 cowls on atrium	6 cowls on atrium
ventilation/person	14 l/s	28 l/s	
ventilation rate per hour	2	4	4

Lessons learnt

It appears that the project in Enschede will realise the goals set. The use of primary energy will be less than half that of comparable commercial buildings. A substantial part of the savings can be attributed to natural ventilation including the avoidance of mechanical cooling: 40 kWh/m² per year or 65% of the total savings.

The design has been carefully checked using calculation models (that are used for ordinary buildings too) and climate chamber tests. It is believed the design will work properly in the varying weather conditions it will experience.

The ventilation design did contain several novel components that needed extra attention in selecting and testing. It appeared that all required components were on the market. The costs of the natural ventilation, although using state of the art technology, did not rise above the amount estimated. So, in short, it was learnt that natural ventilation works: it saves energy, is on the market today and does not cost too much. One has to keep in mind however that natural ventilation cannot be implemented in any building anywhere; it relies on features of the building and the local climate. The ventilation design has to fit with the total design of the building.

Interview with project representative

The architect, Ruurd Roorda:

“The design phase of the Tax office made clear to me that environmentally friendly building is taking a step forward and a step backwards at the same time. The step backwards consists of the reuse of ancient typologies, for instance the Pantheon in Rome is a striking example of a

in ventilation and lighting techniques, techniques that use hidden power of the wind, the rain and the light of the day. The steps forward and backwards are equally important and give the building both low-tech and high-tech aspects.

The building uses 100% of the available site. Hereby a gap is formed between the north- and the south-orientated offices. This gap ‘breaks’ the double-corridor system, allowing the building to breathe. The gap runs along the length of the building, forming a wedge-shaped, longitudinal atrium. The roof of this atrium is lifted in order to enlarge the chimney-effect. Giant chimneys top this roof, providing for the air exhaust. Air inlets can be found in the facade, just above the daylight window.

Because of the image of the client (the government should never waste money!), it was agreed that the building should not necessarily have an experimental or costly appearance. Therefore many of the innovative elements can be found on the inside, whereas the ventilation equipment and the sunblinds are hidden behind the tiles of the facade.

The early stage and the extensive formation of the design team made it possible to come to an integrated design. The architectural and the Thermie design were done at the same time, with extensive interrelation. It is impossible to think of the design of this building without stressing that it was made by putting together items brought forward by all members of the design team.”

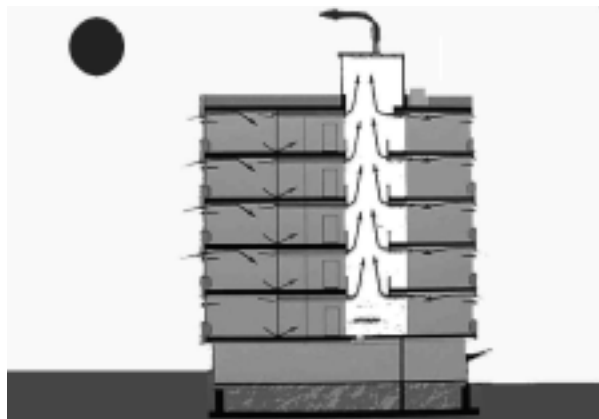
Project data

Client: Rijksgebouwendienst, Directie Oost

Architect: Rijksgebouwendienst, DO&T, job architect: Ruurd Roorda

Natural ventilation and cooling strategies in new offices

Engineering: Rijksgebouwendienst, DO&T
Building physics: Peutz & Associates
Energy concept: W/E Consultants
Daylight concept: Esbensen



A section of the whole building showing the ventilation pattern: air enters the rooms through vents in the facade, flows via the atrium and exits through the facade.



An image of one room showing the self adjusting vents in the facade. Used air exits through acoustic ducts in the lowered ceiling to the atrium.

AVAX Building, Athens, GR

Features

- Single sided or cross-ventilation
- Openable windows
- Mechanical extract back up
- Floor plenum for fresh air inlet

Project description

The AVAX building is located on a confined site in the city of Athens. Only the Eastern facade faces open air, while the rear side only faces a small void. It has three basement levels (due to the ground not being level), a ground floor, three office floors and a penthouse. All offices are located at the East facade while the corridors and staircases are located at the rear (see figure below).

Restrictions and requirements

A lot of care has to be taken to avoid overheating with the climate in Greece. Natural ventilation will often suffice, but sometimes has to be supplemented. As the rear side of the building is wind shielded, only the front may serve to let fresh air in. When outside conditions such as noise, pollution, rain or temperature don't allow opening windows there has to be an alternative available.

Design

In a design study the possibility of using cross ventilation and the effect of user behaviour has been investigated. To this purpose a multizone model, 'passport-air', was used. When agreeable, external windows are used for ventilation. The design study showed that even at adverse conditions (no wind, small temperature difference) sufficient ventilation could be provided with window openings of 1 m² or more. When the internal door is shut, the ventilation is single-sided but still sufficient. When internal doors and the window at the rear of the building are opened a cross-ventilation pattern emerges. The amount of fresh air then depends somewhat on the number of offices with an open door, but is always sufficient.

In the eventual design, the natural ventilation is backed-up by additional measures. When windows have to be closed, fresh air enters the building at the window sills and is distributed via the floor plenum. A central extract fan may drive this air when necessary. A ceiling fan in the offices is expected to extend the comfort zone to 29 °C. Above that fan coil airconditioning units at the facade (with ice storage at the top of building) are used to ensure a comfortable summer indoor climate. Additional passive cooling measures include the use of the thermal mass of the exposed ceiling, automatic night cooling and external automatic shading.

Lessons learnt

Natural ventilation and cooling strategies in new offices

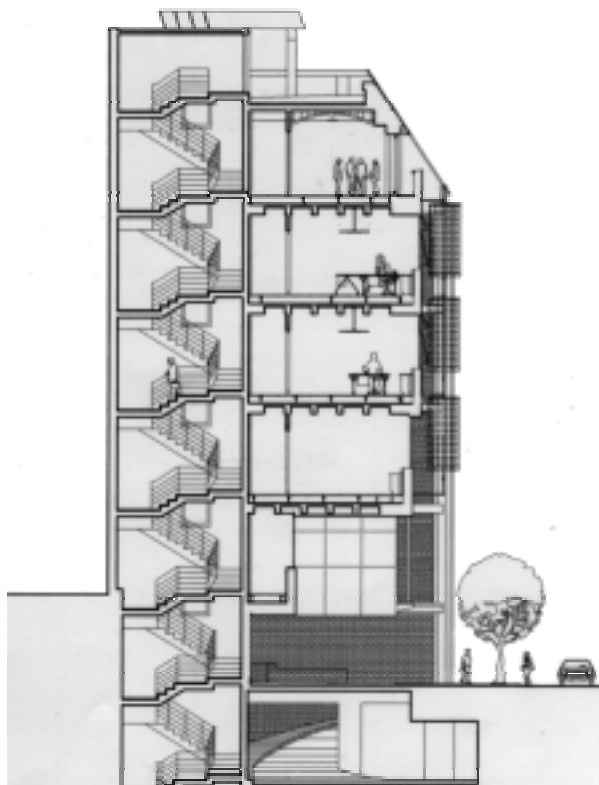
The design shows that even at a difficult confined site, a natural solution can be found that will work most of the time. When the passive options are used to their fullest, relatively simple additional measures suffice to ensure thermal comfort even in the worst conditions.

Project data

Client: AVAX S.A.

Architect: Meletititki, Alexandros Tombazis

Consultant: Protechna Ltd.



A section of the AVAX building. Ventilation provisions are located in the facade, air is removed via the stairwells.

Leeds City Office Park, UK

Features

Atrium stack for exhaust air
Mechanical supply, passive exhaust
Heat recovery in winter
Optimised design using CFD

Project description

The building site lies to the South of the Leeds city centre. The building measures 6500 m² gross floor area, distributed over three floors. The floor plan consists of two symmetrical and rectangular floor plates, separated by a wedge-shaped atrium. The atrium slopes down from the back of the building to the front.

Restrictions and requirements

Because of intensive traffic near the site, pollution and noise don't always allow for opening windows. It is not always possible to supply fresh air directly through the facade.

Design

The ventilation system consists of mechanical supply and natural exhaust. Occupants may also open windows to let in fresh air. Fresh air is taken in at the roof to avoid noise and pollution problems. Then it is transported through an underfloor pressurised plenum. This is separated into ducted voids with balancing dampers to regulate and distribute air flow in each area. Floor air diffusers supply the air into the office. Warm used air rises to the ceiling and leaves the offices through grilles to the atrium. The atrium stack serves to exhaust the used air through automatically operated windows at the top.

In winter, the used air can be mechanically extracted from the atrium and used in a heat recovery unit to preheat fresh supply air. In summer, the ribbed concrete ceiling/floor is used to dampen temperature variations and to store heat during the day. The heat is removed afterwards by night ventilation.

A CFD study was performed to optimise the distribution and number of air diffusers and to establish the effect of opening perimeter windows on ventilation effectiveness. With the perimeter windows closed, it was shown that the amount of air from each floor was 40%, 33% and 27% from the bottom up, and also that twice as much air is taken from internal offices than from those on the perimeter. As a result, the density of floor diffusers was increased in perimeter areas. With the perimeter windows open the outer offices have good single sided flow, whilst inside areas are evenly ventilated. Even when the lower window was shut, the CFD model still predicted good ventilation to the outer offices, supplemented by the underfloor supply.

Lessons learnt

The design has shown that it is possible to use passive (exhaust) ventilation even at a noisy

Natural ventilation and cooling strategies in new offices

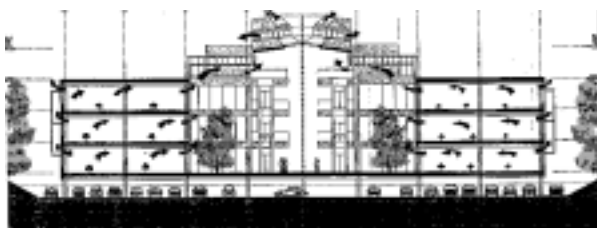
site. In winter, the passive exhaust is combined with heat recovery. CFD proved a useful tool in optimising ventilation effectiveness.

Project data

Client: British Gas Properties

Architect, Engineers and Cost Consultant: Peter Foggo Associates

Consultant: Halcrow Gilbert Associates Ltd.



Ventilation paths in the Leeds City Office Park. The building is mechanically ventilated with exhaust air being extracted through the atrium.

as the floors are connected through stairwells. In the centre of the building the flat roof is elevated to create some facade area to let in daylight.

Restrictions and requirements

The site is near the North Sea coast where wind speeds are high so the ventilation system has to deal with high wind speeds and gusts.

Design

The natural ventilation design focuses on air inlets in the facade, just in front of the convectors (air heaters). Air may leave the building at the leeward side of the building and at the top. The inlets are self adjusting. A sensor in the inlet continually measures air speed. If the air flow rises, a servo motor closes the vent so that the total flow rate remains constant. The wind pressure on the building has been established by testing a macquette in a wind tunnel. Inlets are connected to the building management system in groups, according to the orientation. The flow rate that has to be maintained by the inlets can be changed either manually or by the BMS. A switch allows the user to open or close the inlet or let it run automatically. The building management system controls the inlets to lower the ventilation flow rate at night and during the heating season and to increase it in summer.

Thermal comfort has been established in a climate chamber. Several geometries of inlet, convector and shielding were tested to ensure that incoming air is warmed by the convector. It was also ensured that the convector would not freeze during midwinter nights. The inlets were tested to confirm that they are capable of maintaining a constant flow rate, even when windpressure changes considerable in a short time (gusts).

Public Building, Schiedam, NL

Features

Self adjusting air inlets

Inlets controlled by BMS

Inlets behind convector heater

Project description

The project concerned is a public building in the city centre of Schiedam. The building contains a library with some offices that is ventilated naturally. The library is located on three floors and it's facade is oriented to the North and South. The library is essentially one air volume

Lessons learnt

High wind speeds and gusts are successfully dealt with using self adjusting air inlets. The inlets react fast to changing wind pressure and it is possible to maintain a constant air flow rate. A geometry of inlet, convector and shields has been devised so that fresh air enters the room without causing discomfort.

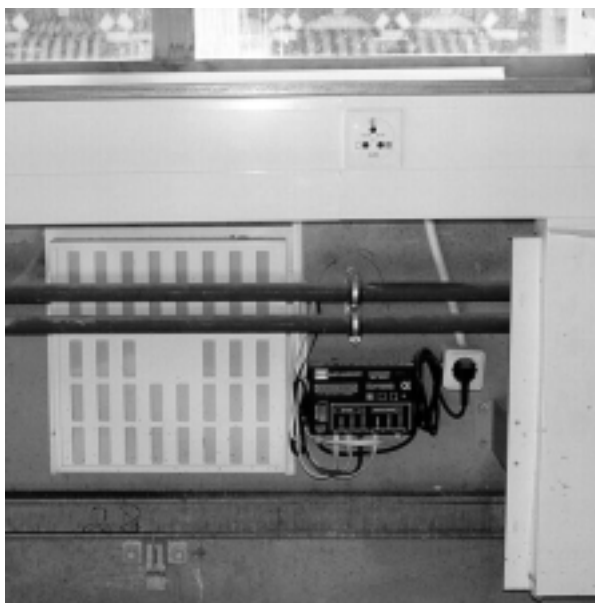
Project data

Client: Municipality of Schiedam

Architect: Architectengroep b.v.

Consultant: Peutz and Associates

Natural ventilation and cooling strategies in new offices



Air inlets situated behind convector heaters.

Office Building Meletitiki Ltd, Athens, GR

Features

Cross ventilation
Openable windows
Ceiling fans
Fan assisted night ventilation

Project description

The project is the architectural office of Meletitiki Ltd., A.N. Tombazis and Associates. It was constructed in 1995 and is privately owned. The office occupies the space of the right hand wing. The other spaces are used by a construction company.

The long axis of the building runs north to south. The main entrance is on the eastern facade. The west and south facades of the building overlook an open space. A rectangular section of the East facade is adjacent to another building, which is part of the complex. The remaining part of the facade (20 m long) overlooks a paved semi-urban space. Opposite to the East facade of the office there is a second building.

The envelope structure of the building is heavy, consisting of thick, well insulated exterior walls. Double glazed window openings are mainly

located on the east and west facades, providing adequate daylight conditions in the working spaces. Movable exterior roller shades above all windows are used in order to improve both visual and thermal comfort in the hot periods of the year.

The windows are positioned on the same central axis on the east and west facades. This produces high illuminance on the working plane of the drawing boards, which are placed in front of the openings. All window sills are 0.65 m above floor level. There are also four monitor windows on the third floor. All the windows are shaded by exterior blinds and the monitor windows by interior blinds.

These blinds are made of a special white plastic cloth with small holes on its surface. The shading devices are adjusted by a mechanically controlled rotation mechanism in order to provide effective shading. Panels of cloth hanging from the roof are used to shade the monitor windows on the upper level.

Ventilation of the space can be controlled by the occupants by opening various windows to enhance the natural flow of the air. Ceiling fans are distributed in all levels to improve the circulation of indoor air in the cases when indoor temperature conditions exceed the acceptable levels for thermal comfort. Additionally, a system of two exhaust fans supplying $2 \times 25000 \text{ m}^3/\text{hour}$, is located at the roof of the building. The ceiling as well as the exhaust fans are automatically turned on/off according to set-point temperature values imposed to a computer control program.

The building is located in Polydrosso, a residential area in the northern suburbs of Athens. The local climate is mild; the heating period lasts from November to March while the cooling period lasts from June to September. During the summer period, the prevailing wind direction in the morning is north with a wind speed often exceeding 6 m/s. In the afternoon the wind blows mainly from the south or the south-west directions with lower speeds.

Natural ventilation techniques are used in order to avoid overheating in the summer, as well as to improve thermal comfort conditions. Manual control of ceiling fans as well as opening different windows to maintain an efficient cross ventilation of the interior spaces help towards maintaining a thermally comfortable indoor

Natural ventilation and cooling strategies in new offices

environment. Ventilative cooling is achieved using night ventilation techniques.

Mechanically assisted night ventilation.

The indoor air temperature of the building was monitored during two weeks in summer 1995. The measurements were taken during the vacation period (26 July to 11 August of 1995). During those 16 days, the building was empty of occupants (there were no internal gains) and the air conditioning system was off. While in this free floating situation, the building underwent night ventilation during eight nights, from 10pm to 6am of the next day. During the night ventilation period, a system of two exhaust fans was used in order to supply the building with outdoor air at a rate of $2 \times 25000 \text{ m}^3/\text{hour}$. Additionally, four windows (three on the east and one on the south facade) were kept open during the same period of the day. During the rest of the day, all windows and doors of the building were kept closed. Indoor air temperature was monitored at several levels in the building.

The thermal performance of the building is very good. When outdoor air temperature reaches 36°C , the mean indoor air temperature is 29°C , while night ventilation techniques lower the peak indoor air temperature by at least 2°C .

Lessons learned

The architectural characteristics of this building (tall building with an open plan structure of the interior space) permit a vertical circulation of the air due to the stack effect. The most efficient opening configuration to allow for a wide air circulation in the building is cross ventilation, with openings on both the upper and the lower floors. In this case, an upward movement of the air is enhanced by the presence of a vertical temperature stratification. Single sided ventilation with openings at different levels on the same facade is not as efficient. Cross ventilation with openings on the same floor causes high local air change rates and restricted airflow in the rest of the building.

The high inertia of the building makes it a good example of the possibilities of application of night ventilation to office buildings. The climate in the area where this office is located is characterized by large temperature swings, with night temperatures low enough for night ventilation to be applied. This technique was found to reduce the maximum indoor air

temperature by $1\text{--}2^\circ\text{C}$. Taking advantage of the heavy mass of the building, this strategy contributes towards delaying the peak load hour by 4-5 hours.

Project data

Client: Meletititki,
Architect: Meletititki, Alexandros Tombazis
Monitoring ventilation: University of Athens,
within the framework of the AIOLOS project.

Natural ventilation and cooling strategies in new offices

Overview of case study natural ventilation solutions

	Anglia	Enschede	Schiedam	Leeds	Athens (AVAX)	Athens (Tombazis)
building type	university	office	library	office	office	office
minimum required ventilation (l/s per person)	8 l/s	14 l/s	14 l/s	14 l/s	14 l/s	14 l/s
driving force	stack, wind	stack, wind (mechanical backup)	stack, wind, mechanical exhaust	mechanical supply, stack, wind	wind, stack, mechanical back up	wind, stack, mechanical back up
inlet type and size	automatic windows and vents	self adjusting vents, 30x10 cm per vent	self adjusting vent	supply air distributed underneath floor	window sills, floor plenum, windows	windows
internal air flow route	open workspace, atrium	cellular offices, plenum, atrium	open workspace, atrium	office ceiling, atrium	offices, corridor	cross ventilation, ceiling fans
exhaust, type and size	windows in pitched roof atrium	6 cowls @71 cm on atrium	atrium windows	atrium, facade windows	back face windows, mechanical	windows, mechanical exhaust
heating season, day ventilation	trickle vent, atrium, windows	one vent pp, 6 cowls on atrium	vent behind radiator convector	balanced ventilation and heat recovery	cross ventilation when agreeable	cross ventilation
ventilation/person	8 l/s 24 hour average	14 l/s	not applicable	25 l/s	35 l/s	35 l/s
ventilation rate per hour	0.55 - 2	2	0.7 - 2	2.5	5 - 6	5 - 6
summer, day ventilation	automatic windows, atrium windows	two vents pp, windows, 6 cowls on atrium	vents, exhaust fan	openable windows, mechanical supply	windows, ceiling fans	windows, ceiling fans
ventilation/person	depends on room temp.	28 l/s	not applicable	25 l/s	35 l/s	35 l/s
ventilation rate per hour	2 (measured)	4	1.8	2.5	5 - 6	5 - 6
summer, night ventilation	automatic windows, atrium windows	two vents pp, 6 cowls on atrium	vents, exhaust fan	mechanical supply	mechanical exhaust, automatic	mechanical exhaust, automatic
ventilation rate per hour	11 (measured)	4	2	5	30 - 35	30 - 35
control inlet	trickle/manual	manual	automatic	automatic	automatic	manual
windows	manual/automatic	manual	manual	manual	manual	manual
exhaust	automatic	automatic	automatic	automatic	automatic	automatic

Natural ventilation and cooling strategies in new offices

Conclusions

It has been learned that natural ventilation permits different solutions. For example in Chelmsford the even distribution of air was ensured by varying the opening of windows with floor height, while in Enschede self adjusting air inlets were used. Wind forces create a draw in Chelmsford by adequate opening of windows in the pitched roof whereas in Enschede special ventilation cowls are used. It has been demonstrated that natural ventilation designs can be made to overcome specific problems such as noise and security or overheating.

Natural ventilation solutions can be used even at difficult, confined or noisy sites and in climates ranging from Mediterranean to sea climates.

New design tools, such as CFD and multizone models, are suitable in the early design phases to evaluate different ventilation concepts and in the following phases to optimise natural ventilation solutions.

Natural ventilation can be designed to fit a specific building if architect and ventilation consultant cooperate closely

All EC2000 buildings will be monitored and actual performance data of the systems will be available in the future.

Further reading

Strangely enough, no textbooks are available, entirely devoted to the treatment of natural ventilation. Natural ventilation is treated as a side step in textbooks on Heating, Ventilation and Air Conditioning. Some descriptions of it can also be found in texts on passive cooling and passive building design. The Pascool project of the European Commission produced important material on passive cooling. Other sources of information can be user manuals for multizone air flow models.

Literature:

- Natural Ventilation Handbook; 1998; Santamouris M. et al.; James & James; London; UK
- Lüftungs- und klimatechnische gebäudeausrüstung (in German); 1996; Nowotny, S. and Feustel, H.E.; Bauverlag; Wiesbaden; Germany. A thorough and modern treatment of conventional Heating, Ventilation and Air Conditioning, but also chapters on natural ventilation basics and multizone models.
- Passive cooling of Buildings; 1995; Santamouris M. and Asimakopoulos, D.; James & James; London; UK. Describes the fundamentals of passive cooling together with the principles and formulae; includes a chapter on natural ventilation.
- Passive Building design - A handbook of natural climatic control; 1994; N.K. Bansal et al.; Elsevier; Amsterdam; The Netherlands. Aspects of passive cooling and ventilation are treated, project descriptions from Europe and India.
- Passive and low energy cooling of buildings; 1994; Givoni, Baruch; Van Nostrand Reinhold; New York; USA. Contains basic principles, empirical formulae and descriptions of projects in Israel and the southern USA.

Products originating from the Pascool project (general brochure available at M. Santamouris, University of Athens; dept. of applied physics):

- Final report of the ventilation and thermal mass task; 1995; available at M. Santamouris, University of Athens; dept. of applied physics. Presents experimental and theoretical studies in the field of natural ventilation.
- PASSPORT-Air, user manual and program; 1995; available at M. Santamouris, University of Athens; dept. of applied physics. Description of multizone air flow model.
- CPCALC+ Fundamentals, user manual and program; 1995; available at Mario Grosso; Politecnico Torino; dipartimento di Scienze e Technice. Description of a method to calculate wind pressure around buildings.

Multizone air flow models are described in:

- BREEZE 6.0, User Manual; 1993; Building Research Establishment; Garston, United Kingdom

Natural ventilation and cooling strategies in new offices

- COMIS, Fundamentals of the multizone air flow model Comis Technical note 29; 1990; F.V. Allard, V.B. Dorer, H.E. Feustel et al., AIVC, Coventry, Great Britain
- CONTAM93 - User Manual (NISTIR 5385); 1994; G.N. Walton; National Institute of Standards and Technology; United States
- MVRM 5.0 - Analysis of the ventilation control after house improvement (in Dutch); 1989; H. Hoiting; FAGO - Eindhoven University of Technology; The Netherlands

The principles of Computational Fluid Dynamics are described in:

- Numerical heat transfer and fluid flow, 1980, S.V. Patankar, Mc Graw-Hill, New York

Acknowledgements

The authors would like to acknowledge the contribution of all those involved in the projects mentioned as case studies in this dossier.

Legal Notice

Neither the Commission of the European Communities nor any person acting on behalf of the Commission is responsible for the use which might be made of the information contained within.

Project information will include

- > Individual project profiles;
- > Information Bulletins on a range of technical and operational subjects;
- > Newsletters;
- > Displays and models;
- > Slide sets.

Cross project activities include

- > design workshops and information exchange;
- > environmental assessment;
- > cross climate thermal modelling;
- > design and performance comparisons and reporting.

CONTACTS

Project Coordinators

Simon Burton
ECD Energy and
Environment Ltd
Brussels Office
Rue Abbe Cuypers 3
1040 Bruxelles
Belgium



Tel: 322 741 2442
Fax: 322 734 7910
Email: ecdebru@ibm.net

Technical Coordinator

Henrik Sorensen
Esbensen Consulting
Engineers
Teknikerbyen 38
DK 2830 Virum
Denmark



Tel: 45 45 834224
Fax: 45 45 836834

Experts

Chiel Boonstra
W/E Consultants
Crabethstraat 38j
Postbus 733
NL-2800 AS Gouda
The Netherlands



Tel: 31 182 683434
Fax: 31 182 511296

Emilio Miguel Mitre
EMMA
Paseo Zorrilla 98, 7
E 47006
Valladolid
Spain



Tel: 34 83 221330
Fax: 34 83 220898

INDIVIDUAL SITE AND COUNTRY CONTACTS

Site Number 1

Lisbon Expo 98, Atlantico, Portugal

Promoter

Atlantico
Marechal Gomez da Costa 37
1800 Lisboa
Portugal

Tel: 3511 831 9717
Fax: 3511 837 3952

Architect

Skidmore Owings & Merrill
46 Berkeley Street
London W1X 6NT
U.K.

Tel: 44 171 930 9711
Fax: 44 171 930 9108

Regino Cruz
Arquitectos e Consultores, LDA
Rua Prof. Ricardo Jorge, 3A
Miraflores 1495
Lisboa
Portugal

Tel: 3511 410 3996
Fax: 3511 410 7140

Services Engineers

Louis Malheiro da Silva
Estrada da Torre 79-85
1700 Lisboa
Portugal

Tel: 3511 757 7822
Fax: 3511 759 9564

Site Number 2

The Queen's Building
Anglia Polytechnic University,
Chelmsford, UK

Promoter

Mel Barlex
Anglia Polytechnic University
Victoria Road South
Chelmsford
Essex CM1 1LL
U.K.

Tel: 44 1245 493131
Fax: 44 1245 495943

Architect and Energy Consultants

ECD Architects Ltd
ECD Energy and Environment Ltd
11-15 Emerald Street
London WC1N 3QL
U.K.

Tel: 44 171 405 3121
Fax: 44 171 405 1670

Services Engineers

Ove Arup and Partners
13 Fitzroy Street
London W1P 6BQ
U.K.

Tel: 44 171 636 1531
Fax: 44 171 465 3669

Site Number 3

Schiedam Public Building, The
Netherlands

Jan Deenik

Municipality of Schiedam
Postbus 61
NL 3100 AB Schiedam
The Netherlands

Tel: 3110 246 5555
Fax: 3110 473 7504

Architect

Hans Ruijsenaars
Architectengroep b.v.
Prinsengracht 483
1016 HP, Amsterdam
The Netherlands

Tel: 3120 6221965

Consultants

Peutz and Associates
6585 ZH Mook
Postbus 66
Lindenlaan 41
Molenhoek
The Netherlands

Tel: 3180 58 5017
Fax: 3180 58 5150

Site Number 4

Universite d'Aix en Provence, France

Owner

Rectorat Aix en Provence

Agent

Serge Jaure
GEST
120 Avenue des 2 Ponts
Cazilhac 34190
GANGES
France

Tel: 33 4 67 73 8907
Fax: 33 4 67 73 8549

Architects

G. Daher, F. Guy, R. Inglesakis
ATELIER 9
Architectes Urbanistes Associes
54 Rue Sainte Victoire
13006 Marseille
France

Tel: 33 91 37 9900

Bioclimatic Consultants

ArchIMEDES
120 Avenue des 2 Ponts
Cazilhac 34190
GANGES
France

Tel: 33 4 67 73 8907
Fax: 33 4 67 73 8549

Site Number 5

Tax Office, Enschede, The Netherlands

Promoter

Etienne Schoenmaeckers
Rijksgebouwendienst
Directie Oost
Postbus 9202
6800 HC Arnhem
The Netherlands

Tel: 31 26 3713800
Fax: 31 26 4458204

Architect

Ruurd Roorda
Rijksgebouwendienst
Directie Ontwerp & Techniek
Postbus 20952
2500 EZ The Hague
The Netherlands

Tel: 31 70 339 1882
Fax: 31 70 339 5030

Energy Consultants

W/E Consultants
Crabethstraat 38j
Postbus 733
NL-2800 AS Gouda
The Netherlands

Tel: 31 182 683434
Fax: 31 182 511296

Site Number 6

Leeds City Office Park, UK

Phil Kirby

British Gas Properties
Aviary Court
Wade Road
Basingstoke, Hants
RG24 8GZ
U.K.

Tel: 44 1256 308803
Fax: 44 1256 308799

Architect, Engineers and Cost Consultants

Mike Jeffery
Foggo Associates
55 Charterhouse Street
London EC1M 6HA
U.K.

Tel: 44 171 490 4040
Fax: 44 171 490 2889

Consultant

Halcrow Gilbert Associates Ltd
Burdorop Park
Swindon SN4 0QD
U.K.

Tel: 44 1793 814756
Fax: 44 1793 815020

Site Number 7

Avax Office, Athens, Greece

Promoter

Mr. Constantine Kouvaras
AVAX S.A.
Skoufa 64
10680 Athens
Greece

Tel: 301 364 4561
Fax: 301 364 7265

Architect

Alexandros Tombazis
Meletitiki - Alexandros Tombazis
and Assoc
27 Monemvasias
GR-15125 Polydrosos Str
Amarousiou
Greece

Tel: 301 6800 690
Fax: 301 6801 005

Consultant

Protechna Ltd
Tositsa 17
106 83 Athens
Greece

Tel: 30 94 33 0069
and: 30 18 83 9174
Fax: 30 18 83 9653

Engineers

Team M-E Consulting Engineers
15-17 Sarantapihou St.
GR-114 71 Athens
Greece

Tel: 301 361 3641
Fax: 301 364 3253

Design Project

Inteco Building, Valladolid, Spain

Promoter

Gerardo Hernandez Garcia
Edificios Inteco s.l.
Arco Ladrillo s/n
Edif. Centro Madrid - 3 - 1º
47008 Valladolid
Spain

Tel: 34 83 47 5612
Fax: 34 83 23 8008

Architect and Energy Consultants

Emilio Miguel Mitre
EMMA
Paseo Zorrilla 98, 7
E 47006
Valladolid
Spain

Tel: 34 83 221330
Fax: 34 83 220898



For information about Thermie Targeted
Projects, you can contact Mr A Landabaso,
Directorate-General for Energy (DGXVII),
European Commission, 200 rue de la Loi,
B-1049 Brussels, Fax: 32 2 2950577

EC 2000 STARTS JULY	>	>	>	>	>	EC 2000 FINISHES DECEMBER 1998
BUILDINGS COMPLETED	• ANGLIA POLYTECHNIC UNIVERSITY LRC	• LEEDS OFFICE	• RGD ENSCHEDE	• SCHIEDAM PUBLIC BUILDING • MMSH AIX-EN PROVENCE	• LISBON EXPO 98 • AVAX SA OFFICE	
1993	1994	1995	1996	1997	1998	