Building Advanced Ventilation Technological examples to demonstrate materialised energy savings for acceptable indoor air quality and thermal comfort in different European climatic regions.

Advanced Ventilation Technologies

Case Study No 5
EDIFÍCIO DAS PÓS-GRADUAÇÕES
PORTO, PORTUGAL

Supported by

Intelligent Energy Europe

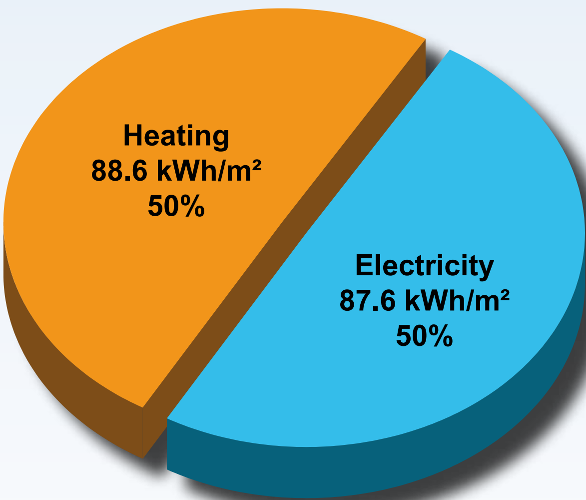
INTRODUCTION

The EPG building is located on a university campus in a suburban area of Porto. Its immediate surroundings are open spaces with the nearest building being 25 m away. Nearby buildings are generally of a similar or lower height.

Summary Table of key design parameters.

Building data	
Building type	Office and educational facilities
Total floor area	2 900 m²
Mean occupant density	9 m²/person
Occupied hours	3 800 hrs/year
HVAC data	
Ventilation system type	Mechanical ventilation with natural ventilation for night cooling.
Heating system	
Cooling system	Chilled water, via AHUs.
Ventilation rate	Not available
Heat recovery efficiency	Not applicable
Cooling load (typical)	120 kW
Heating load (typical)	240 kW
Building fabric data	
Window U-value	2.77 W/(m² K)
Window g-value	0.75 (winter); 0.37 (summer)
Exterior wall U-value	0.48 W/(m² K)
Base floor U-value	2.04 W/(m² K)
Roof U-value	0.71 W/(m² K)
Climate data	
Design outdoor temperature for heating	2.3°C
Design outdoor temperature for cooling	27.5°C
Heating degree days (include base temperature)	1 979 days (base 20°C)
Cooling degree days (include base temperature)	43 days (base 25°C)

The building is situated in a climate zone with a high cooling load.



Annual energy use.

BUILDING DESCRIPTION

Originally intended to provide facilities for technological companies developing new products, the purpose of the building was changed at the construction stage to house post-graduate facilities for the Economics Faculty of the University of Porto. The building offers 2 900 m² of useful floor area containing a mixture of offices, teaching spaces and computer rooms. This is arranged in the form of three separate blocks linked by a central corridor (figures 1 and 2). The south block has three floors and the central and north blocks two floors. Buildings may be occupied between 08:00 and 22:00 according to the range of activities.

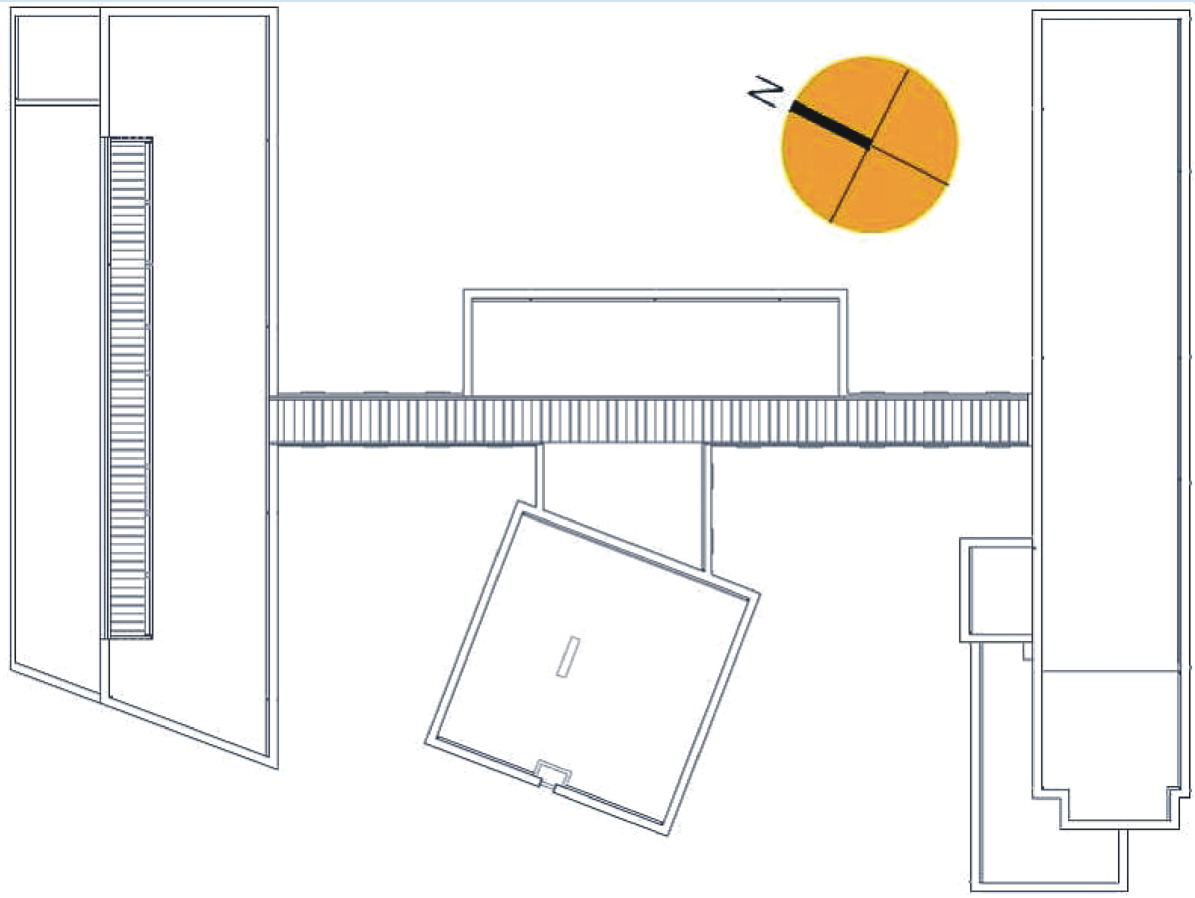


Figure 1. Plan view showing the three main blocks and linking corridor.

Figure 2. Sectional view of the building.

DESIGN SOLUTIONS

The building was designed to make the best use of the moderate climate in order to provide a comfortable indoor environment together with low energy consumption. The H-shape of the building plan optimises the use of solar radiation to provide free space heating and natural day-lighting. In the south and north blocks, corridors and circulation spaces are placed on the north side, with offices and other spaces are on the south side. The south-facing room depth was kept below 8 metres in the north and south blocks and below 4 metres in the central block, to enhance natural light distribution and to reduce dependency on artificial lighting. To reduce solar gain in summer, south-facing windows were provided with overhangs and shading. The majority of the glazing was located on south façades and the glazing facing east and west was kept to a minimum. Where possible, clerestory glazing was introduced to provide direct gain and day-lighting to those parts of the building without a southern exposure. All windows are wood-framed with double-glazing.

The envelope consists of a high inertia “double brick wall” (Figure 3). Between the outer brick and inner concrete components of the wall, there is a layer of 50 mm of polystyrene and a 40 mm air gap, giving the walls an excellent thermal insulation. Potential thermal bridges across windows, corners, etc were also insulated.

The building is mechanically ventilated throughout. In order to limit costs and energy consumption, the use of full air-conditioning was restricted at the design stage to the central block, containing the spaces with the highest internal heat gains. The remaining spaces were supplied only with tempered outside air, with no recirculation. Subsequently, the use of some rooms in the north block was changed to contain IT equipment, resulting in the need for additional cooling of these rooms. Heating is supplied by a 300 kW central boiler and distributed (i) to radiators in circulation spaces, offices and some classrooms in the north and south block; (ii) to the fan-coil units supplying the central block and (iii) to induction units to

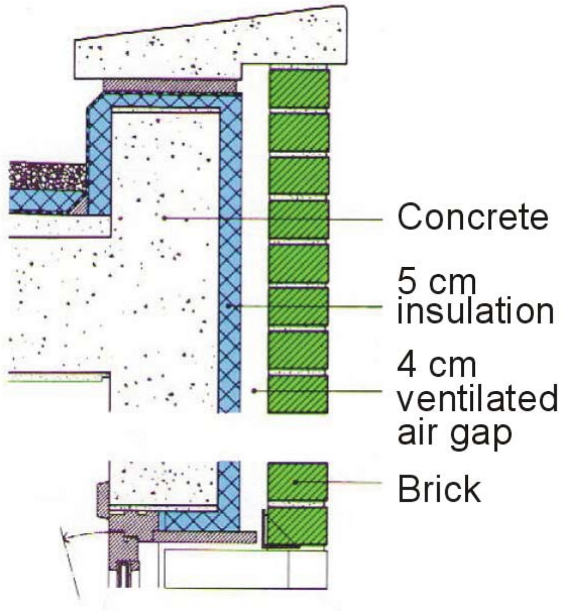


Figure 3. Section through external wall.

the IT rooms in the north block. Cooling is provided by a central 200 kW chiller. Cooled water is supplied to the make-up air supply for the offices and classrooms in the north and south blocks and to the air handling and induction units of the spaces requiring additional cooling. In addition there is provision for natural ventilation through openable windows to supply night-time free cooling.

VENTILATION STRATEGY

As noted earlier, the building is mechanically ventilated. In small rooms incoming air enters close to the radiators and leaves via door to adjacent corridors. To provide good distribution, in larger spaces air incoming air enters at floor level and leaves via openings at ceiling level. Induction units are used to introduce the air to the IT rooms in the north block. The building also uses cross-ventilation, in conjunction with a thermally heavyweight concrete inner surfaces to provide free cooling during the night in the summer and in other suitable weather conditions. This is achieved using windows that were designed to open without compromising building security (Figure 4).

PERFORMANCE

(i) Energy performance

Collected data on the performance of the building gives an annual consumption of gas for heating of 88.6 kWh/m² and electricity consumption by the chillers for cooling of 4.7 kWh/m²; by fans is 19.3 kWh/m² and by lighting and office equipment is 63.6 kWh/m² giving a total electricity consumption of 87.6 kWh/m². The Portuguese EPDB regulations assess performance in terms of primary energy consumption which for this building is 26.6 kgep/m². This is substantially less than the current regulatory requirement of 35 kgep/m², and results in an A classification.

Figure 4. Openable window and operating mechanism.

(ii) Indoor environment performance

(a) Thermal

Figures 5 and 6 show the average values of air temperature and relative humidity measured during working hours in a room subject to a high thermal load on 13 working days in January 2009. Indoor temperature remains close to 20ºC and humidity within the range 30% to 60% which should assure comfortable conditions.

(b) Ventilation

Figure 7 shows average CO_2 concentration measured over the same period as the temperature and humidity. The average concentrations ranged from 470 ppm to 620 ppm. In all cases these were below the Portuguese regulatory requirement of 1000 ppm, indicating good air quality.

(iii) Occupant assessment of performance

A summary of the results of a sample survey of 49 occupants, carried out in 2008, is given in Table 1. In general, occupants expressed a good degree of satisfaction with conditions in the winter but much less so in summer, particularly in relation to the thermal environment. There was a high degree of satisfaction with both the artificial and natural lighting.

DESIGN LESSONS

This building provides an example of using innovative design approaches to achieve a building with low energy consumption by providing ventilation and air-conditioning matched to the particular use of spaces within the building. In designing the building advantage was taken of available simulation methods such as Radiance software which was used to examine solar gain and light distribution in order to determine features such as window size, overhang dimensions and room depth. Possible improvements which might now be considered include the use of heat recovery where full air-

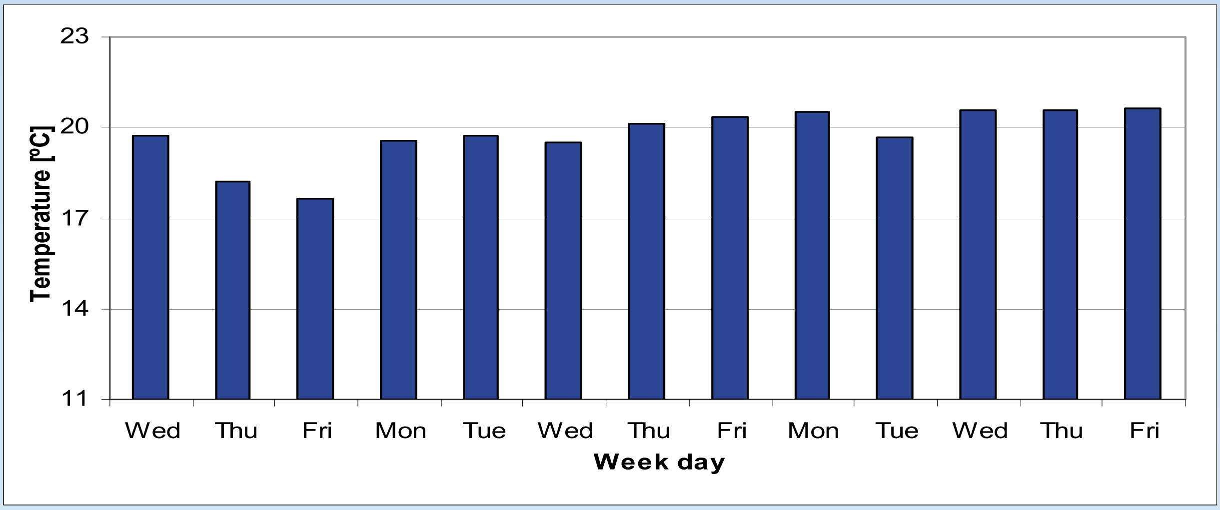


Figure 5. Average air temperatures measured during occupied hours during a winter period.

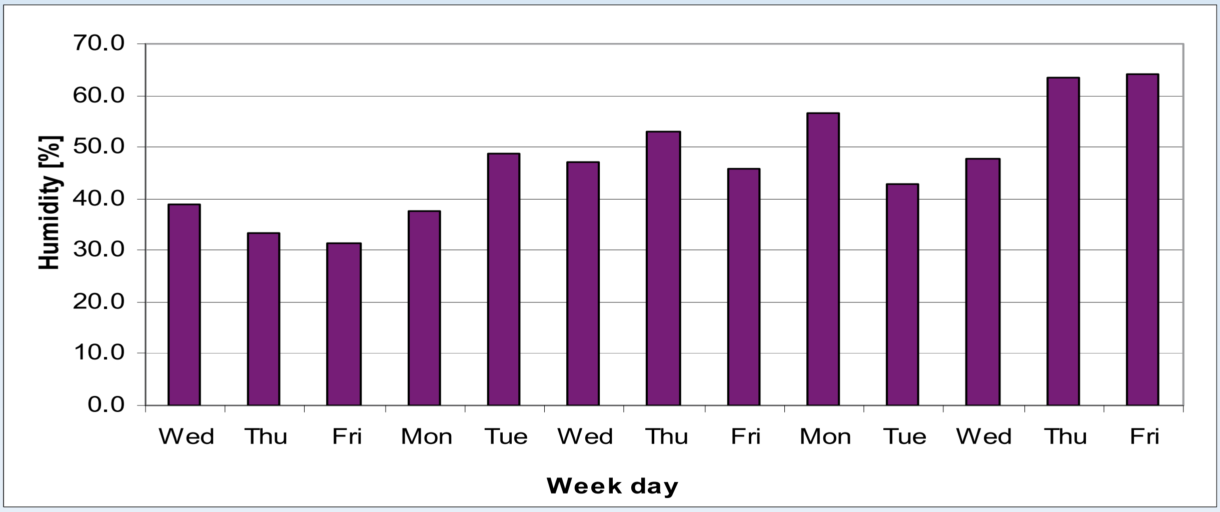


Figure 6. Average relative humidity measured during occupied hours during a winter period.

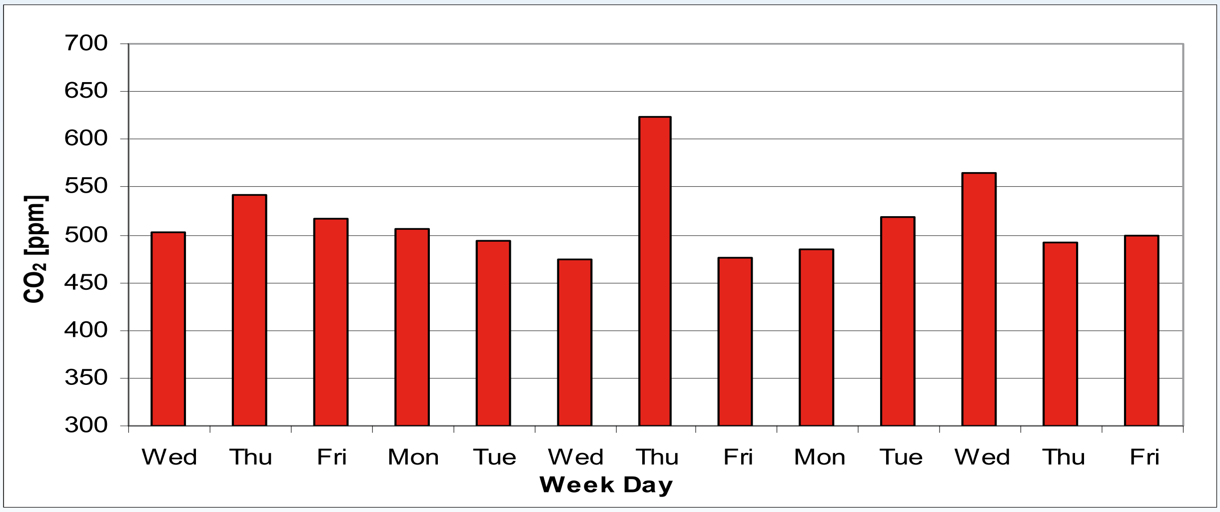
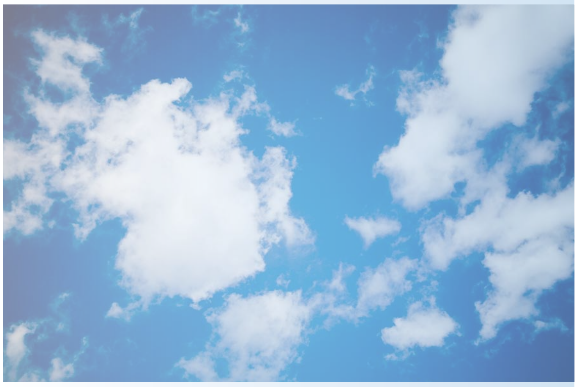


Figure 7. Average CO_2 concentration measured during occupied hours during a winter period.

Table 1.
Summary of occupant assessment of the indoor environment.

	Summer %	Winter %
People finding the **overall indoor environment** acceptable	47	62
People finding the **thermal environment** acceptable	30	70
People finding the **indoor air quality** acceptable	58	82
People finding the **acoustic environment** acceptable	67	70
	Artificial %	**Natural %**
People finding the **lighting** acceptable	88	97



EPG Building – South Block.

Design team information
Designers and contractors

Client	University of Porto
Tenant	FEP
Architect	Camilo Cortesão
Engineering coordination	Eng. Pedro Quinta Fernandes
HVAC	INEGI
Electrical Engineering	FASE
Day-lighting	Dr Marc Fontoynont

conditioning systems are installed and the use of roof-mounted photovoltaic collectors to reduce electricity consumption from the national grid.

GENERAL

Key points concerning the design

- **Careful design and orientation of building to take advantage of solar gain in winter and to reduce gains in summer.**
- **Use of make-up air only units where possible in order to reduce both cost and energy consumption of mechanical ventilation installation.**
- **Use of night-time natural ventilation together with internal thermal mass to provide free cooling.**

REFERENCES

BUSINESS INNOVATION CENTRE; Porto/Portugal, Building 2000, Commission of the European Communities, 2001.

Brochure authors: J L Alexandre and M Silva, Faculdade de Engenharia da Universidade do Porto (FEUP).

Building Advanced Ventilation Technological examples to demonstrate materialised energy savings for acceptable indoor air quality and thermal comfort in different European climatic regions.

BUILDING ADVENT

Full title of the project: Building Advanced Ventilation Technological examples to demonstrate materialised energy savings for acceptable indoor air quality and thermal comfort in different European climatic regions. Building AdVent is funded by the European Commission, Directorate-General for Energy and Transport as part of the Intelligent Energy - Europe Programme.

It is estimated that energy consumption due to ventilation losses and the operation of fans and conditioning equipment is almost 10% of total energy use in the European Union and that about one third of this could be saved by implementing improved ventilation methods. A number of projects have been undertaken under the auspices of the European Union (under the SAVE and ALTENER programmes) and the International Energy Agency (Energy Conservation in Buildings and Community Systems Annexes 26 and 35) to identify and develop improvements in ventilation technology.
The AdVent programme is intended to build on these and has three principal objectives:

- Classification of existing building ventilation technologies as applied in built examples and collection of information on building performance.
- Identification of barriers for future application.
- Preparation of case-studies in a common format, together with training material

BUILDING ADVENT PARTICIPANTS

Coordinator

Buro Happold Consulting Engineers .... UK

Participating Organisations

Brunel University .... UK
National and Kapodistrian University of Athens .... Greece
Helsinki University of Technology .... Finland
Aalborg University .... Denmark
Faculdade de Engenharia da Universidade do Porto .... Portugal
International Network for Information on Ventilation and Energy Performance (INIVE) .... Belgium

Major Sub-Contractors

Federation of European Heating and Air-Conditioning Associations (REHVA) .... The Netherlands
International Union of Architects .... France/Greece
—Architectural and Renewable Energy Sources Work Programme (UIA - ARESWP)

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