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 13

CITY ACADEMY
BRISTOL, UNITED KINGDOM

Supported by

Intelligent Energy Europe

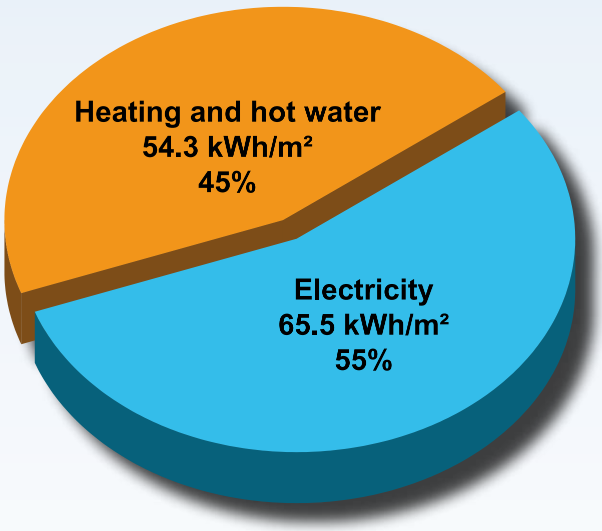
INTRODUCTION

The City Academy is located in a suburban area of Bristol. Its immediate surroundings are playing fields. Other buildings in the locality are of similar or lower height.

Summary Table of key design parameters.

Building data	
Building type	Secondary school
Total floor area	12 000 m²
Mean occupant density	1 250 students
Occupied hours	3 000 hrs/year
HVAC data	
Ventilation system type	Mixed natural and mechanical ventilation
Heating system	Distributed boilers with mainly underfloor heating
Cooling system	Split system for computer rooms
Total ventilation rate	Not applicable
Heat recovery efficiency	Not applicable
Design cooling load	36.8 kW installed capacity
Design heating load	480 kW installed capacity
Building fabric data	
Window U-value	1.9 W/(m² K)
Window g-value	Not available
Exterior wall U-value	0.35 W/(m² K)
Base floor U-value	0.25 W/(m² K)
Roof U-value	0.25 W/(m² K)
Climate data	
Design outdoor temperature for heating	-4°C
Design outdoor temperature and RH for cooling	Not applicable
Heating degree days (include base temperature)	1 787 (base 15.5°C)
Cooling degree days (include base temperature)	Not applicable

The building is situated in a climate zone with moderate heating and cooling loads.



Annual energy use.

BUILDING DESCRIPTION

The school has two floors and, for administrative purposes, is arranged in five areas, or 'villages', A to E, linked by a central spinal corridor at each floor level. The corridor is orientated approximately north east/south west. Each village includes a full height atrium containing computers and IT equipment. Villages A to D consist principally of classrooms while village E contains general facilities, including reception, kitchen, library, offices and a meeting hall.

Core hours within the school are between 8:30 am and 15:30 pm. The kitchen supplies breakfast and lunch during break times. After school clubs and detention continue until 18:00, after which the school empties. The facilities are used extensively out of core hours by the wider community. Figure 2 shows hours of use in more detail.

DESIGN SOLUTIONS

The school has a high facade/floor area ratio, which can increase heat-loss, but usually facilitates passive design and natural cross-ventilation. All spaces within the building are heated by an underfloor system supplied by distributed plant with three 60 kW condensing boilers in villages A-D, and five 60 kW condensing boilers in village E. Each manifold is linked to a temperature sensor, which controls a bypass valve as room temperature increases. The heating circuits are compensated, supplying lower temperature hot water as external temperatures increase. The BMS system also has optimum start/stop controls, avoiding unnecessary heating when the building is unoccupied. In the zones exposed to external noise, incoming air is tempered by a low-pressure hot water heater battery whilst, for other zones, supply fans include an electrically heated element.

Figure 1. Plan view of the main school buildings.

Where possible, rooms are naturally ventilated but the exposure of some facades to external noise has required that a significant proportion are mechanically ventilated. Thermal mass is incorporated in the ground floor classroom ceilings. High ceilings with clerestory windows in first floor classrooms (Figure 3) allow natural cross ventilation and natural lighting from two directions. The building uses lighting controls throughout the space, with PIR and photocell controls in classrooms and PIR only in circulation spaces. Control of lighting in common spaces, such as the library, is by timer which can be manually over-ridden by occupants. Classroom lights are suspended up/down lighting luminaires with two 54 W T5 lamps. The installed lighting load in classrooms is 11.4 W/m² and is 14.8 W/m² in circulation spaces. All lighting is dimmable and therefore actual running loads are greatly reduced.

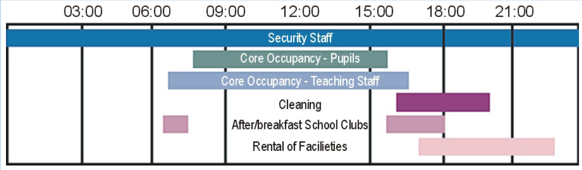


Figure 2. Typical daily occupancy pattern.

Figure 3. First floor roof showing clerestory opening lights.

VENTILATION

The approach to ventilation is partly determined by acoustic constraints. 18 classrooms are exposed to external noise and are required to have a sealed façade. Incoming air is drawn by a 4 kW variable speed fan through buried concrete ductwork and distributed to individual classrooms. Supply to each classroom is controlled by a damper which closes if a classroom is not scheduled for occupancy. Fan speed is controlled according to the number of rooms occupied at any time. The underground supply ducts pre-heat air in winter and pre-cool in summer. Air extract is by PIR-controlled individual room extract fans for ground-floor classrooms and naturally in first-floor classrooms via motorised high-level glazed openings (Figure 4). Those classrooms that are not exposed to noise are supplied by natural ventilation via openable windows and have similar extract arrangements as the noise-protected rooms (Figure 5). Other spaces have a mix of natural ventilation and mechanical ventilation (usually extract-only ventilation). The sports hall incorporates a mixed mode system, in which extract fans are enabled when the internal temperature rises above 24ºC. Cooling is provided by split systems for 4 computer rooms and 2 music rooms, with a total cooling capacity of 36.8 kW.

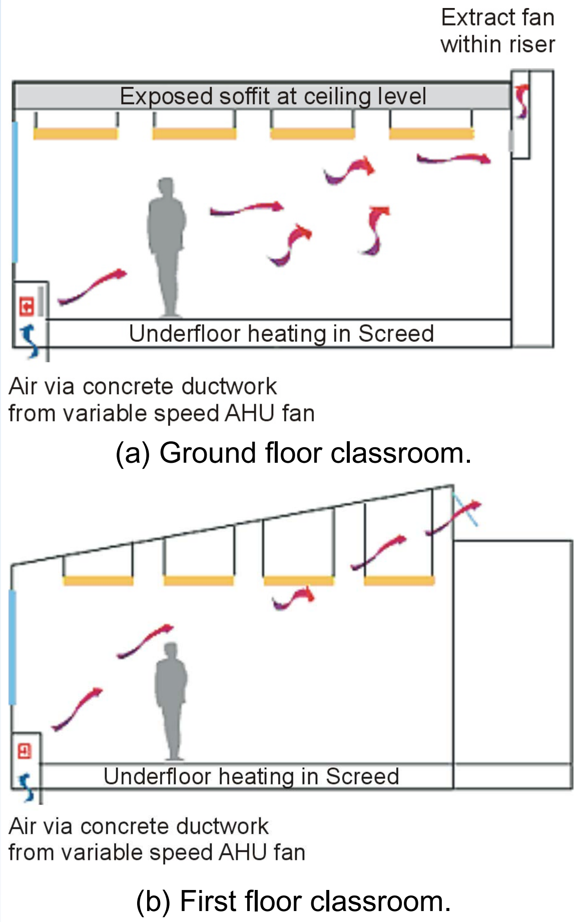


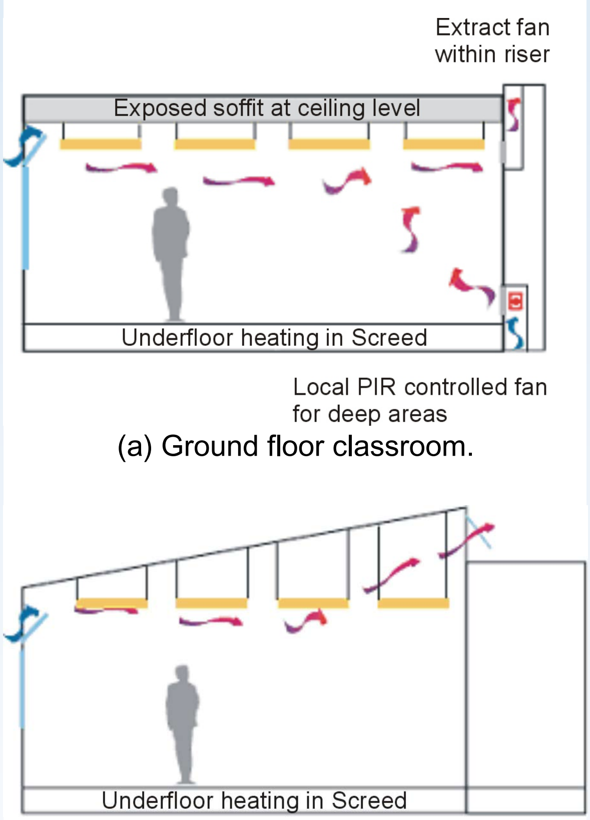
Figure 4. Ventilation of noise-protected classrooms.

PERFORMANCE

(i) Energy performance

Information on energy use was obtained from energy records and data provided by the utility supplier. Adjusting for weather, energy consumed for heating was, in total, 54.3 kWh/m²; of which 44.7 kWh/m² was for space heating and 9.6 kWh/m² was for water heating and kitchen use. Total delivered electrical energy was 65.5 kWh/m² of which 18.1 kWh/m² was for lighting; 12.9 kWh/m² was for pumps, fans and controls; 3.5 kWh/m² for cooling and 31.0 kWh/m² for other purposes including catering, computers and other equipment. Total energy consumption amounted to 119.8 kWh/m².

Figures 6(a) and 6(b) compare the annual heating and electrical energy consumption by the building with the benchmarks currently used for school



(b) First floor classroom.

Figure 5. Ventilation of classrooms without noise protection.

buildings in the UK and show that fossil fuel consumption is substantially better than the UK good practice benchmark. Electricity consumption is, however, considerably higher. One reason for this is the rapid increase in the installed load of ICT equipment within schools in the since the benchmarks were formulated.

(ii) Indoor environment performance

(a) Thermal

Temperatures were measured in two first floor classrooms during summer: CR1 is naturally ventilated (Figure 5b); CR2 is protected against noise and ventilation is provided mechanically via the buried concrete ductwork (Figure 4b). Figure 7 shows the variation in temperature in each classroom compared with ambient air temperature over a 30-day period from 22/06/06 to 22/07/06. The performance of CR1 and CR2 are similar, with a small reduction in occurrences of overheating for the mechanical ventilation strategy. When ambient peak temperatures exceed 25°C internal peak temperatures are of a similar magnitude.

The number of occupied hours for which air temperature exceeded 28°C during the summer period was 116 for the naturally ventilated classroom, CR1, and 66 for the mechanically-ventilated classroom, CR2 in comparison with 80 hours set out in the national guidelines for school buildings.

(b) Ventilation

Carbon dioxide concentrations were measured during the heating period in two classrooms: CR1 is naturally-ventilated on the first floor (Figure 5b) and CR3, is mechanically-ventilated on the ground floor (Figure 4a). The results are summarised in Figure 8. The mechanically ventilated classroom has lower carbon dioxide concentrations, exceeding 1000 ppm on 10% of occasions whereas concentrations exceeded 1000 ppm on 35% of occasions in the naturally ventilated classroom.

Background ventilation in a mechanically ventilated classroom, with the mechanical system switched off was found to be quite high, at 1.65 ach.

(iii) Occupant assessment of performance

A questionnaire survey of 38 adult occupants to assess their impression of the indoor environment. The results are summarised briefly in Table 1. While occupants were very satisfied with the lighting and acoustic environment, a lower proportion expressed satisfaction with the overall environment. A likely contributory factor is the low proportion satisfied with the thermal environment, principally being too cold in the heating season. The surveys were conducted during the first year of occupation and since this time thermal comfort of occupants is likely to have improved in line with the general trend observed in newly occupied buildings.

DESIGN LESSONS

The under-floor heating used throughout the building meant that a lower return temperature was achieved when operating the boilers in condensing mode throughout the year. The use of zone controllers, instead of TRVs meant that a higher degree of control could be achieved in avoiding overheating spaces. The ventilation air volumes in the building are linked to both occupancy and outside temperature, applying

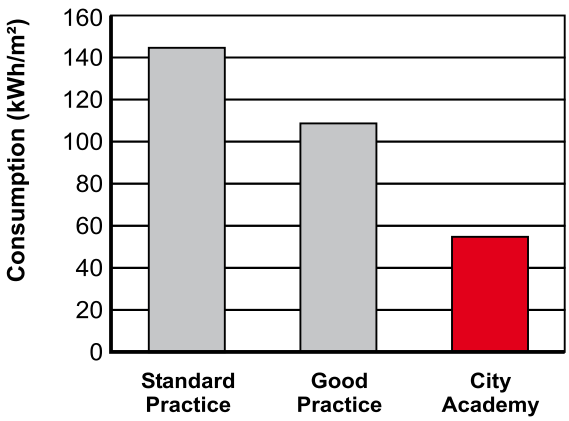


Figure 6(a). Gas consumption for space and water heating.

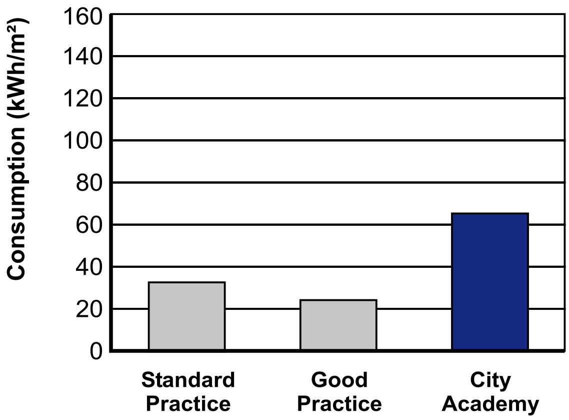


Figure 6(b). Electricity consumption

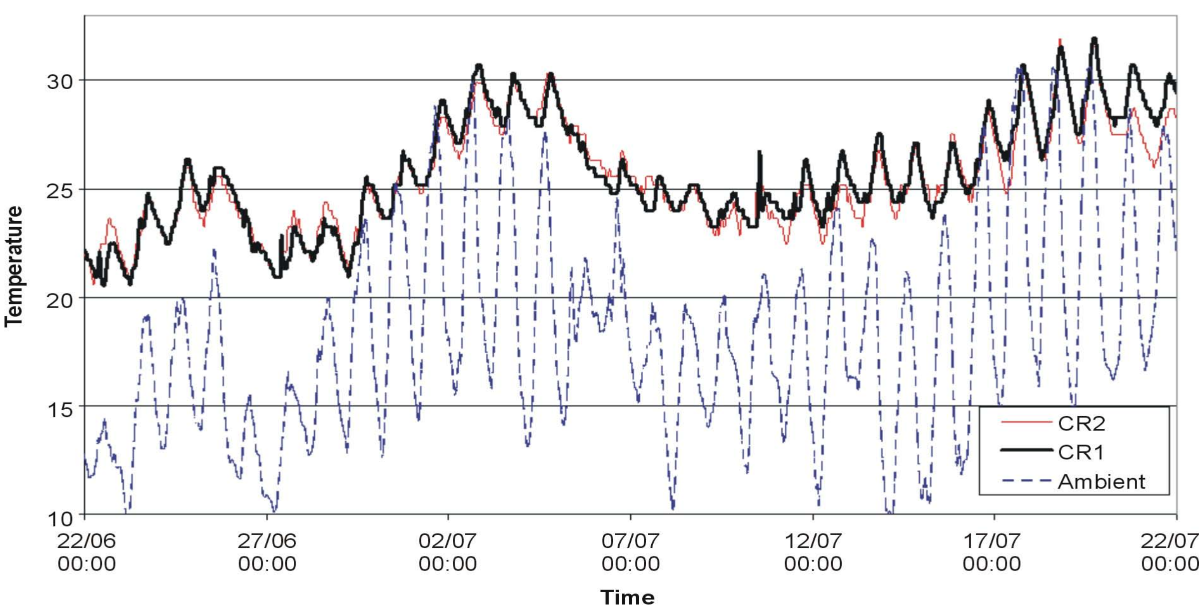


Figure 7. Summer (2006) air temperature measured in naturally (CR1) and mechanically (CR2) ventilated classrooms.

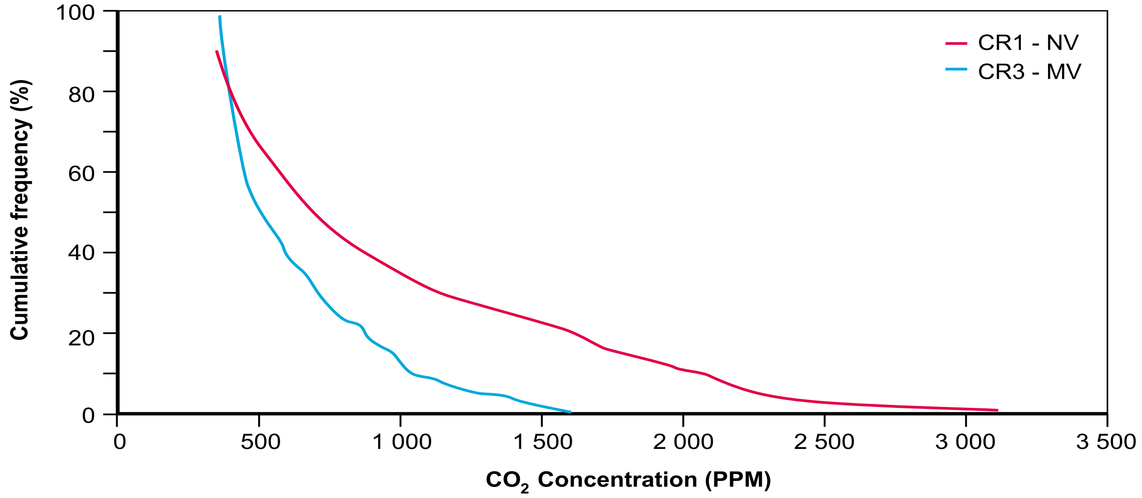


Figure 8. Comparison of CO_2 levels in the heating period in naturally (CR1) and mechanically (CR3) ventilated classrooms.

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

	Percentage satisfied %
People finding the **overall indoor environment** acceptable	62
People finding the **thermal environment** acceptable	22
People finding the **indoor air quality** acceptable	50
People finding the **acoustic environment** acceptable	92
People finding the **lighting** acceptable	78

Design team information
Designers and contractors

Architect	Feilden Clegg Bradley Studios
Engineering Consultant	Buro Happold
Mechanical & Electrical Contractor	Lorne Stewart
Project Management	University of the West of England

more control that can be achieved using natural ventilation, and defaults to of in a more effective manner than central AHUs. The zoning allowed the reduction of circulation lengths and enabled specific demands to be matched. The decentralized strategy also utilized much smaller individual boiler capacities, thus reducing the duration that boilers operate at part load.

GENERAL

Key points concerning the design

- **Good fuel economy as a result of distributed heating plant.**
- **Underfloor heating provided for low return temperatures, allowing optimum operation of condensing boilers.**
- **Ventilation control in classrooms based upon occupancy schedule and PIR detectors.**

REFERENCES

Pegg I M, Cripps A and Kolokotroni M. Post-occupancy performance of five low-energy schools in the UK. ASHRAE Transactions, Vol. 113, Part 2, pp3-13, 2007.

Brochure authors: A Cripps, Z Gill, I Pegg and G Susman, Buro Happold.

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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