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 14

THE ACADEMY OF ST. FRANCIS OF ASSISI
LIVERPOOL, UNITED KINGDOM

Supported by

Intelligent Energy Europe

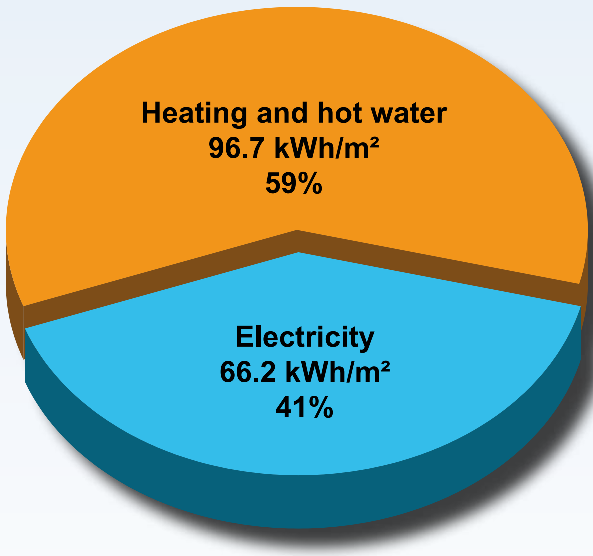
INTRODUCTION

The St Francis of Assisi Academy is a secondary school located in a suburban area of Liverpool and is closely surrounded by mainly two-storey housing.

Summary Table of key design parameters.

Building data	
Building type	Secondary school
Total floor area	7 900 m²
Mean occupant density	10 m²/person
Occupied hours	2 500 hrs/year
HVAC data	
Ventilation system type	Mixed natural and mechanical ventilation.
Heating system	Condensing gas boiler supplying radiators, AHU heating coils and under-floor heating.
Cooling system	VRV system with air-source heat pump.
Ventilation rate	8 l/s per person (mechanical ventilation)
Heat recovery efficiency	Not applicable
Design cooling load	85 kW
Design heating load	988 kW
Building fabric data	
Window U-value	1.5 W/(m² K)
Window g-value	Not available
Exterior wall U-value	0.33 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)	2 284 days (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 building is arranged on five levels, with a 10 m high main assembly hall housed in a basement and extending into the ground floor (Figure 1). To the west of the building are single level classrooms. The main entrance is located on the north side of the building and at the front of the school there is a cyber cafe and an ICT teaching room. At the north side of the building are the technology rooms, whilst in the south are the music rooms. Above the technology rooms on the north side of the building are science classrooms on the first floor and general teaching rooms on the second floor. The only other rooms are on the first floor and comprise learning resource rooms and the art rooms.

The building has 24-hour security, with core teaching hours between 8:00 am and 16:30 pm. Teaching staff are present in the building from between 7:30 am and 17:00 pm. Cleaning takes place between 17:00 pm and 19:00 pm, with after school clubs until 18:00 pm. There is limited use of the facilities out of core hours. The facilities are used out of core hours by the wider community. Figure 2 shows hours of use in more detail.

DESIGN SOLUTIONS

The designers considered aspects of sustainable design throughout the project. In terms of energy efficiency the school utilises natural ventilation and introduces north light and skylight into the space where possible. Where mechanical ventilation is required, most systems incorporate heat recovery; large spaces (dining room, main hall and drama) utilise variable fan speed control based on room carbon dioxide levels.

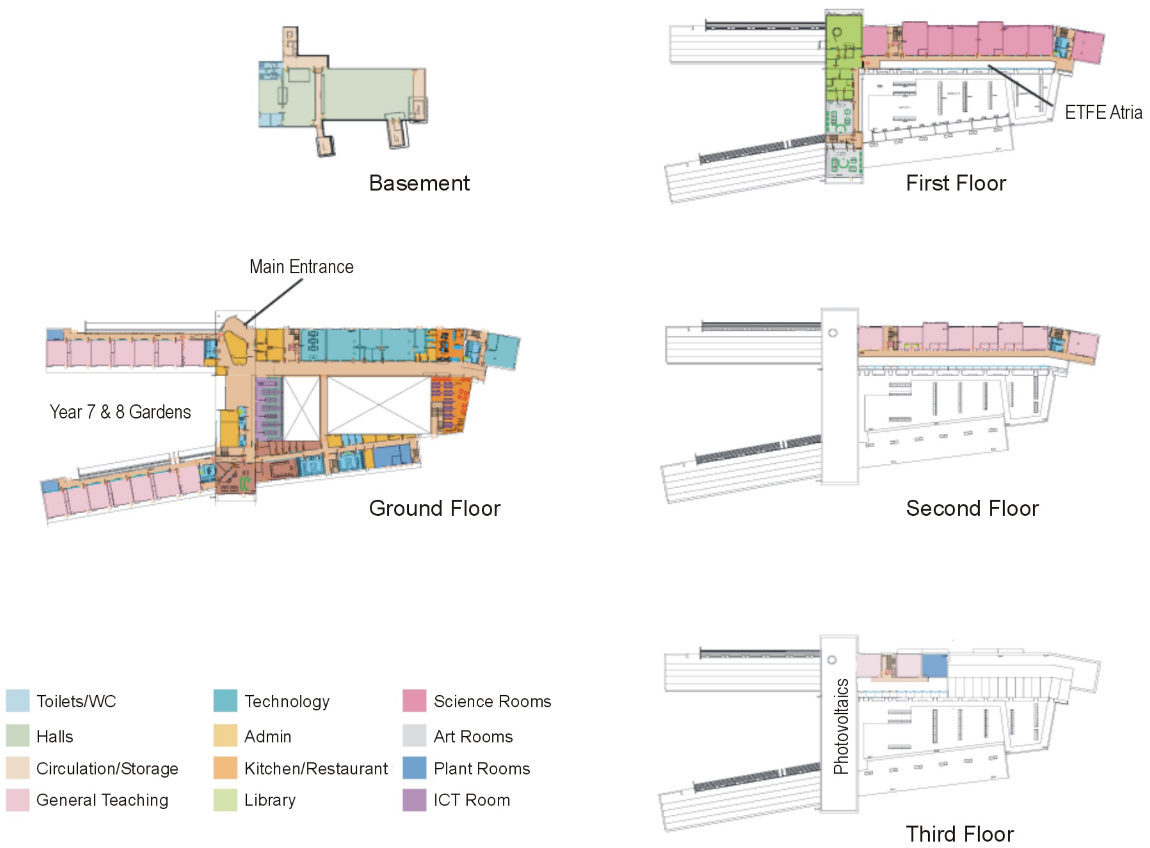


Figure 1. Plan view showing room arrangements.

Heating is supplied by condensing boilers and distributed by low-level radiators and heater batteries in air handling units. The basement is heated by under-floor circuits. All circuits are compensated for external conditions, to reduce supply temperatures and to enable boilers to operate in condensing mode. Hot water is supplied to the basement zones and changing rooms from the ground floor plant room. The kitchen, toilets and main teaching classrooms are supplied from the third floor plant room. This is supplemented from a 3 kWth solar thermal collector.

Cooling is provided using a variable refrigerant flow heat recovery air-source heat-pump. The rationale was to use the system to balance heating and cooling where possible, with the server room providing an ideal heat source in the winter and mid-season.

All classroom zones are lit to 350 lux with T5 up/down lighter luminaires. Corridors use compact fluorescent lighting. There are simple PIR switches in all classrooms in the north teaching block, the art rooms and in all toilet areas. Electricity supply is supplemented by photovoltaic panels located above the library/art rooms. These are designed in conjunction with glazing to introduce north light to these rooms. The space between the four-storey north teaching block and the main hall forms a naturally-lit atrium with a translucent roof made from ethylene tetrafluoroethylene (ETFE) (figures 3 and 4). The internal construction is principally concrete to provide thermal mass to absorb solar gains.

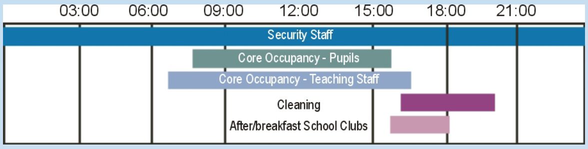


Figure 2. Typical daily occupancy pattern.

Figure 3. The atrium showing the ETFE translucent roof.

Figure 4. ETFE atrium and main hall roof.

VENTILATION

Figure 5 shows the method of ventilation of various zones within the school. The single-storey, ground floor classrooms to the west of the building are naturally ventilated because they are sheltered from road noise. The halls in the basement of the school are mechanically ventilated, incorporating heat recovery and demand controlled ventilation based on carbon dioxide levels in the space. The ICT space, music practice rooms and server rooms have mechanical supply and extract with room fan coil units. Cooling is supplied via a variable refrigerant flow, heat-recovery air-source heat-pump. This allows heat to be effectively moved between zones and suits a simultaneous heating and cooling demand. Science and technology rooms on the ground and first floor teaching blocks are mechanically ventilated to reduce noise ingress; however the second and third floor classes are naturally ventilated. The ETFE atrium is naturally ventilated by manually-operated vents on the south side and extracts at high-level on the North facade, through an external plant room (Figure 6).

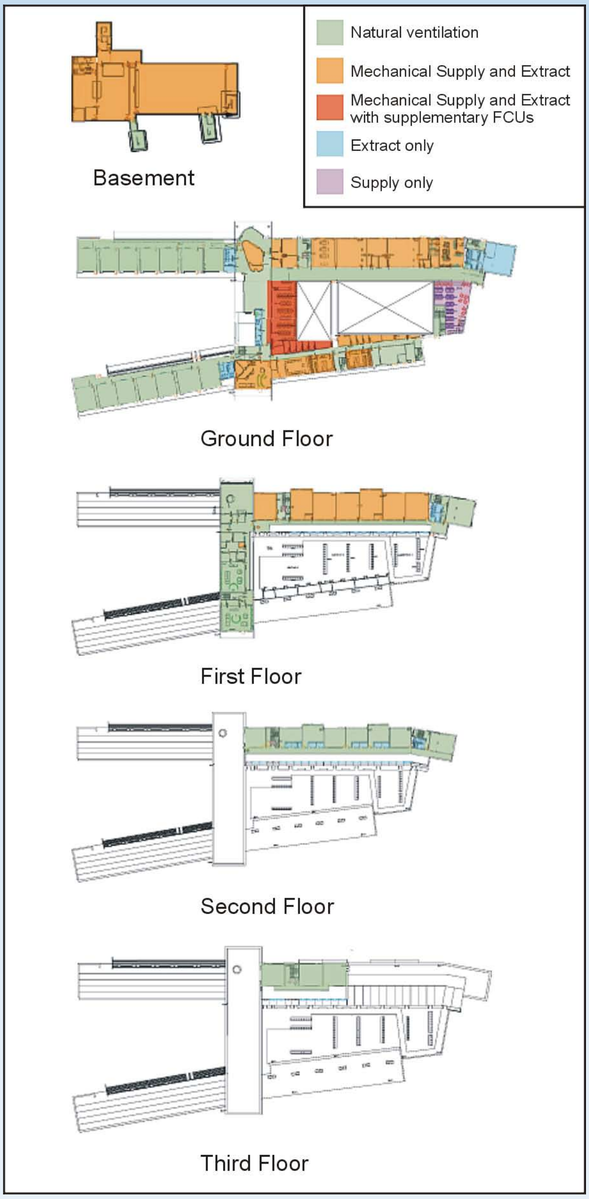


Figure 5. Zonal arrangement of methods of ventilation.

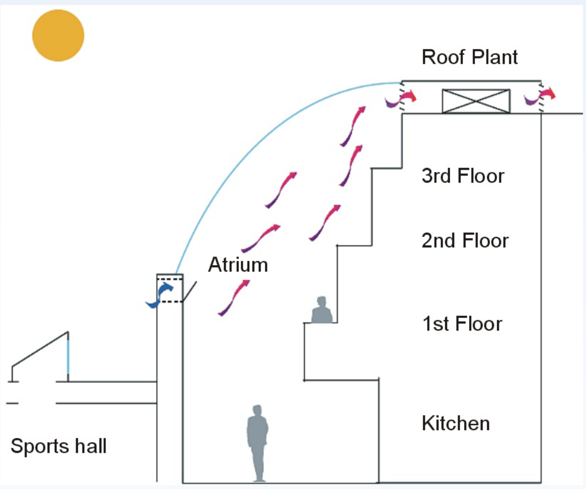


Figure 6. Natural ventilation of the atrium.

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, 96.7 kWh/m²; of which 84.0 kWh/m² was for space heating and 12.7 kWh/m² was for water heating and kitchen use. Total delivered electrical energy was 66.2 kWh/m² of which 16.2 kWh/m² was for lighting; 24.4 kWh/m² was for pumps, fans and controls; 5.0 kWh/m² for cooling and 22.9 kWh/m² for other purposes including catering, computers and other equipment. A further 2.5 kWh/m² was supplied by the roof-mounted PV collectors. Total delivered energy consumption amounted to 162.9 kWh/m².

Figures 7(a) and 7(b) compare the annual heating and electrical energy consumption by the building with the benchmarks currently used for school buildings in the UK and show that fossil fuel consumption is 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 period since the benchmarks were formulated.

(ii) Indoor environment performance

(a) Thermal

Figure 8 shows the relationship between the ambient air temperature and the resultant temperature for two classrooms, CR1 and CR 2, between late-May and mid-July. CR1 is in the single storey ground floor block to the west of the building and is naturally ventilated; CR2 is on the first floor of the three storey block on the north side of the building and is mechanically ventilated. During hot spells, peak temperatures in both classrooms remained several degrees below ambient peak temperatures. Over the measuring period classroom temperatures never exceeded 26ºC with the naturally ventilated classroom, CR1, generally being approximately 2°C cooler than the mechanically ventilated classroom CR2. Over the whole summer period the temperature in CR2 exceeded 28°C for only 2 hours and 25°C for 349 hours. This is well within the national guideline for school buildings.

(b) Ventilation

Typical ventilation rates were measured using carbon dioxide as a tracer gas in a second floor naturally ventilated classroom. With windows closed, the infiltration rate was found to be 0.21 ach. With windows open, the ventilation rate was 3.61 ach.

(iii) Occupant assessment of performance

A questionnaire survey of 39 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 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.

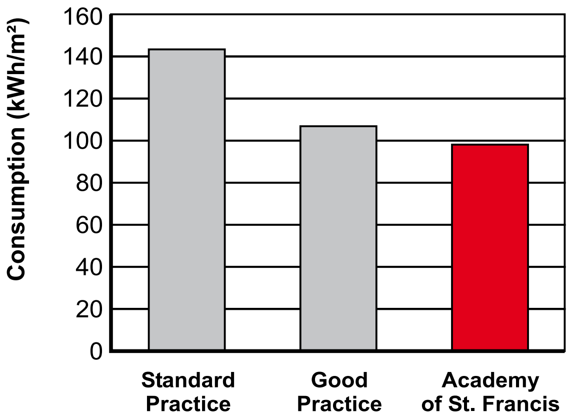


Figure 7(a). Gas consumption for space and water heating.

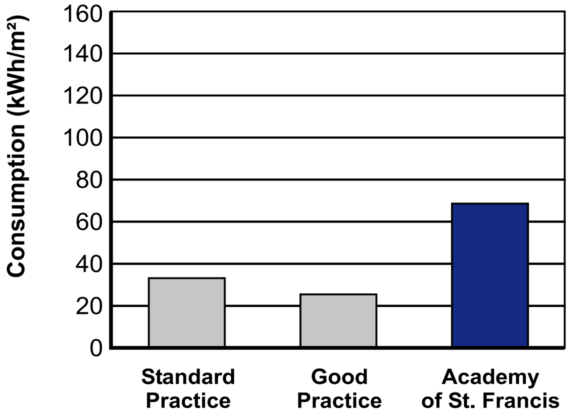


Figure 7(b). Electricity consumption.

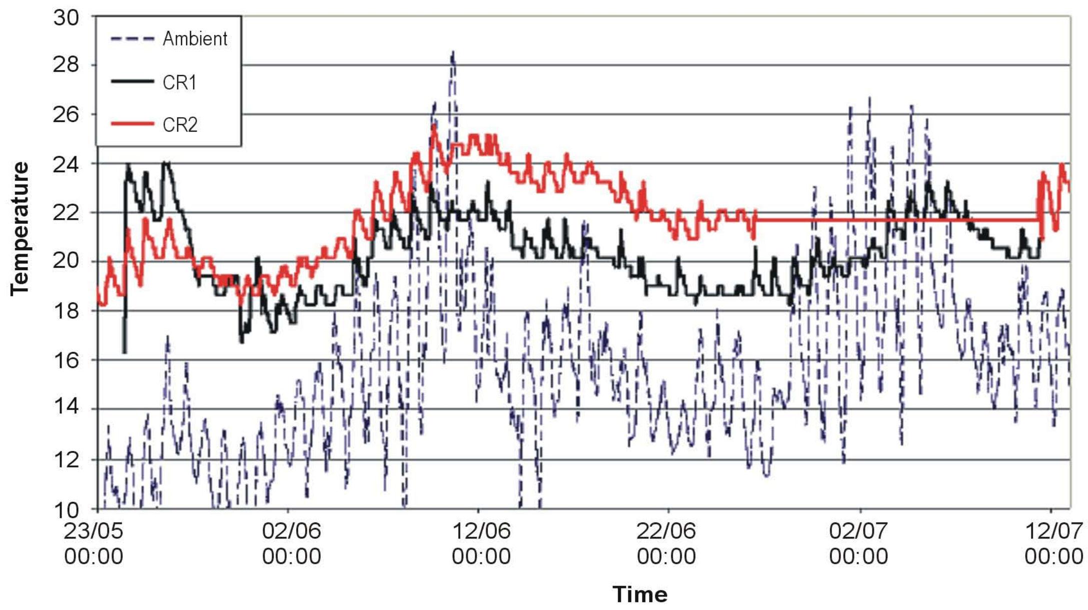


Figure 8. Summer (2006) temperatures measured in two classrooms.

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

	Percentage satisfied %
People finding the **overall indoor environment** acceptable	72
People finding the **thermal environment** acceptable	44
People finding the **indoor air quality** acceptable	56
People finding the **acoustic environment** acceptable	87
People finding the **lighting** acceptable	59

Roof-mounted photovoltaic panels.

Design team information *Designers and contractors*	
Tenant	Anglican Diocese of Liverpool and RC Archdiocese of Liverpool
Architect	Capita Percy Thomas
Building Services Engineering	Buro Happold
Structural Engineering	Buro Happold
Quantity Surveyors	Gardiner Theobold
Construction management	Mott MacDonald

Naturally ventilated ground floor classroom

DESIGN LESSONS

Teachers were initially unaware of the concept behind night-cooling and required training from the design team to provide guidelines when the night cooling should be used.

GENERAL

Key points concerning the design

- **East – west alignment allowed substantial area of south-facing façade to encourage passive solar gain in winter.**
- **Use of internal exposed concrete to provide thermal mass in conjunction with night-cooling to reduce day-time peak temperatures.**
- **Extensive use of natural lighting, including atrium.**

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 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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