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 17

FREDERICK LANCHESTER LIBRARY
COVENTRY, UNITED KINGDOM

Supported by

Intelligent Energy Europe

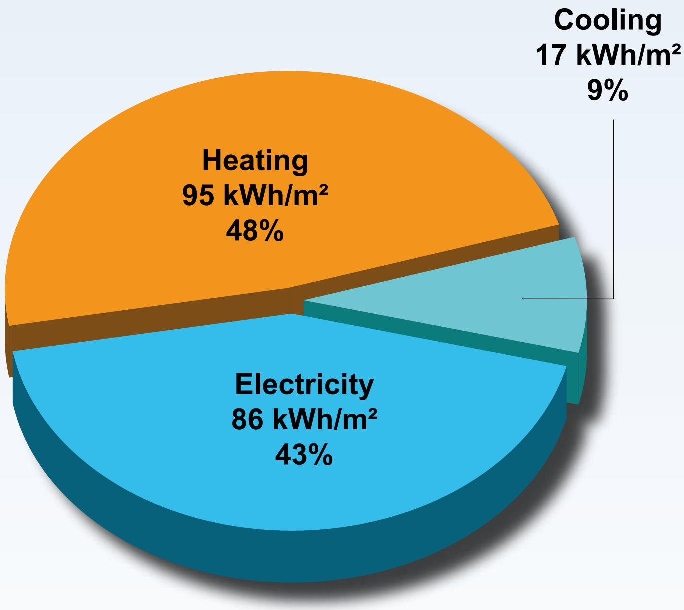
INTRODUCTION

The building is in an urban location, close to the centre of the city of Coventry. It is on a compact site, with adjacent buildings of a similar height. It is exposed to traffic noise from a nearby inner ring road.

Summary Table of key design parameters.

Building data	
Building type	Library
Total floor area	9 100 m²
Mean occupant density	Not applicable
Occupied hours	4000 hrs/year
HVAC data	
Ventilation system type	Primarily natural ventilation, with air conditioning for separate basement.
Heating system	Condensing gas boiler
Cooling system	Night-time free cooling
Total ventilation rate	Not applicable
Heat recovery efficiency	Not applicable
Cooling load	Not applicable
Design heating load	
Building fabric data	
Window U-value	2.0 W/(m² K)
Window g-value	
Exterior wall U-value	0.25 W/(m² K)
Base floor U-value	0.27 W/(m² K)
Roof U-value	0.18 W/(m² K)
Climate data	
Design outdoor temperature for heating	-3°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)	18 days (base 18.3°C)

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



Annual energy use.

BUILDING DESCRIPTION

The Frederick Lanchester Library forms part of Coventry University. It has a gross floor area of 9 100 m² and is unusual in that, although it is a deep-plan building occupying a 50 m by 50 m footprint, it is ventilated naturally with no artificial cooling, except for a separate basement area which is air-conditioned. Figures 1 and 2 show the general layout of the building.

By its nature the building has a large number of transient occupants. At the design stage 2 500 entries per day were anticipated. In practice, this has increased to 5 000. In addition a number of staff work permanently in the building. The building is open for use for approximately 4 000 hours per year.

DESIGN SOLUTIONS

Apart from a basement, comprising about 12% of total gross floor area and containing central computer equipment, the building is naturally ventilated. The deep plan of the building is broken up by multiple light-wells to provide both daylight and air flow paths. Heavyweight construction is used with exposed concrete ceilings. Apart from air-conditioning for the basement, summer temperatures are controlled by a combination of internal blinds, deep window reveals, fixed screens and night cooling by ventilation. High-frequency lighting is provided with daylight-linked dimming. The T5 luminaires have a 60%/40% split down/up distribution. Medium temperature hot water provided by high efficiency,

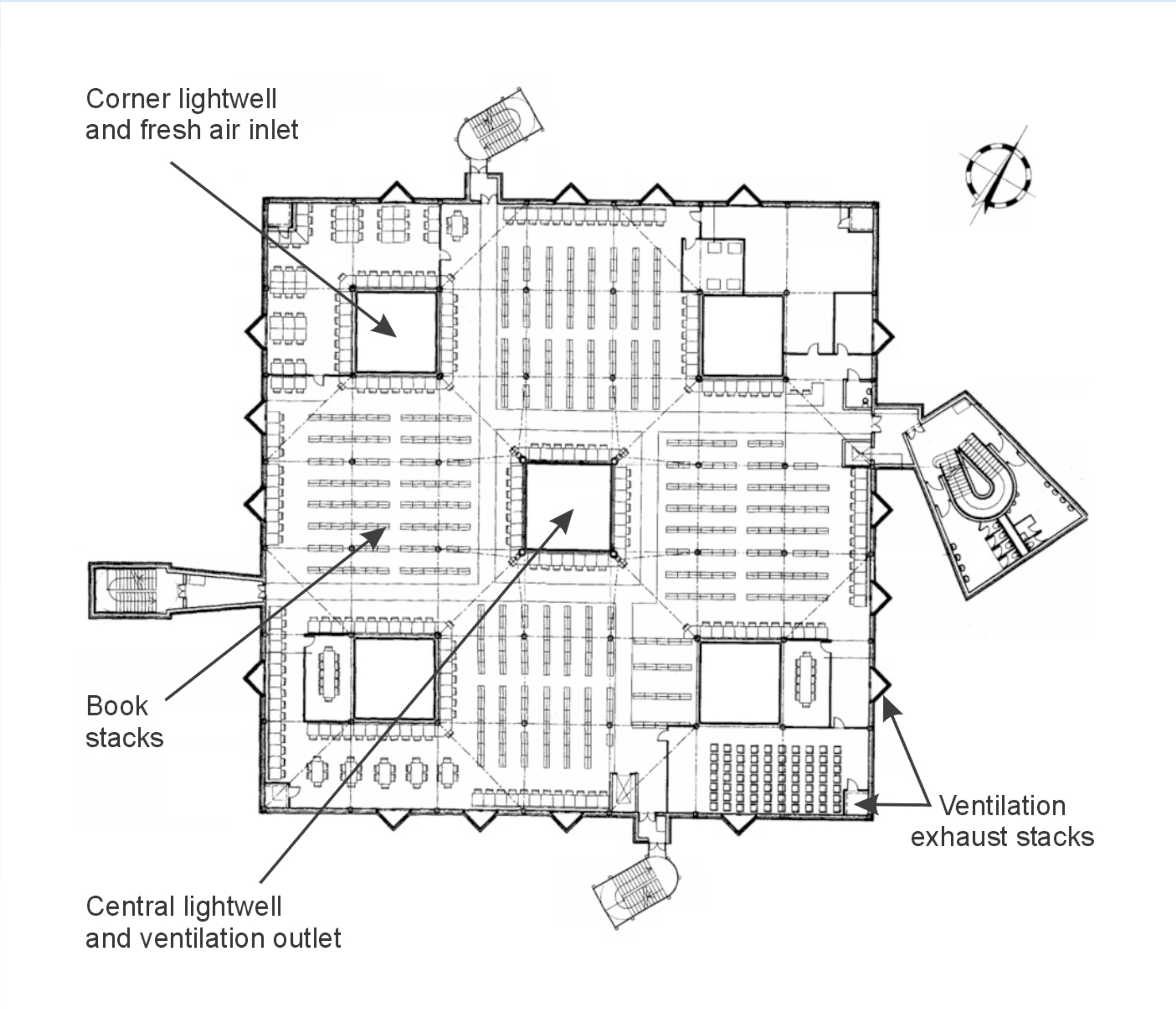


Figure 1. Plan view of building.

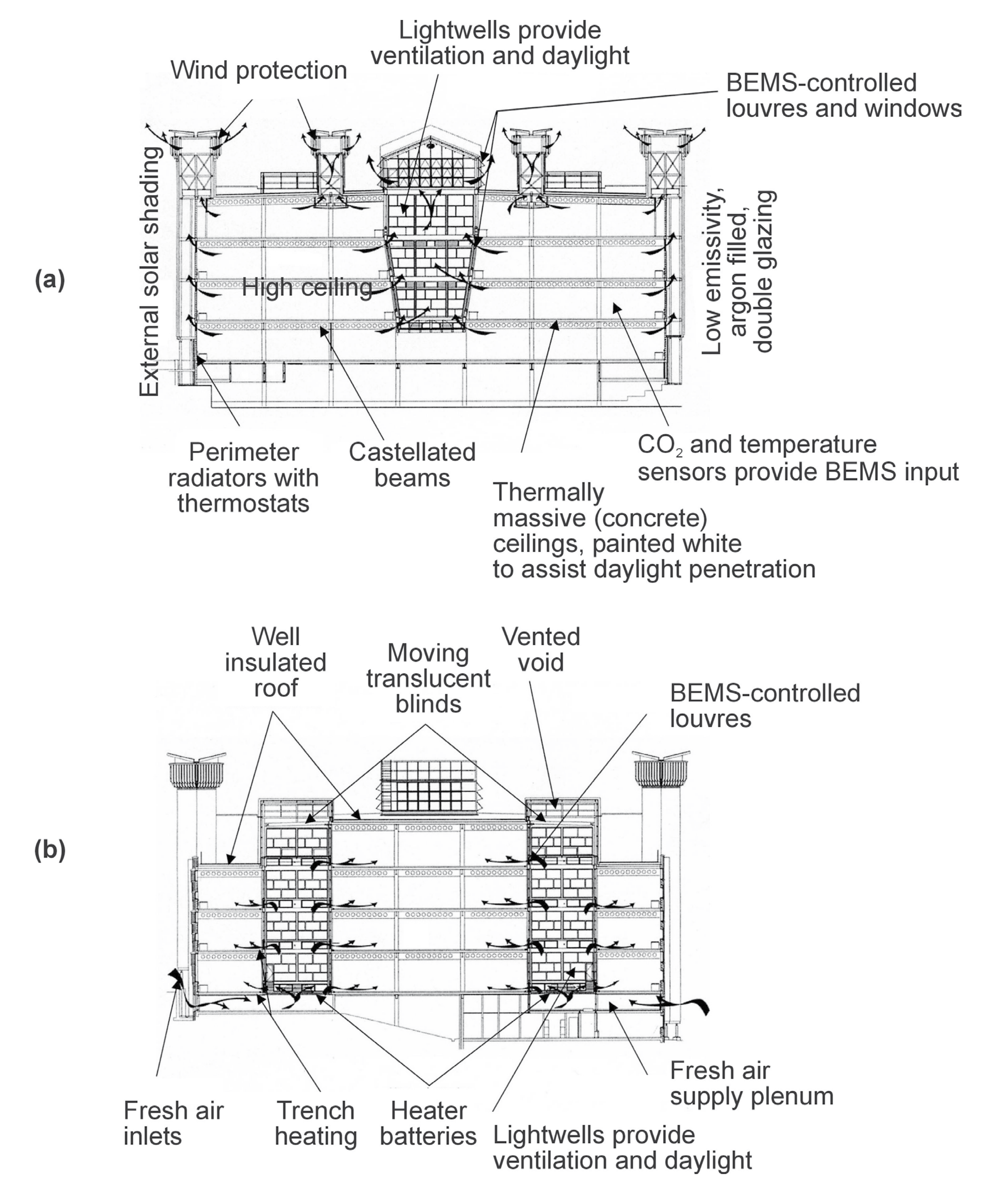


Figure 2. Sections through the building, showing natural ventilation flows.

non-condensing boilers, supplies perimeter heating (principally radiators) and pre-heats incoming air through the natural ventilation system, using trench heaters. The heating, lighting and ventilation installations are controlled by a BEM system using temperature and carbon dioxide sensors for each 6 m by 6 m zone throughout the building.

VENTILATION

In order to provide natural ventilation a tapering central lightwell provides extract ventilation, supplemented by 20 perimeter stacks with a 1.8 m by 1.8 m cross section. The stacks terminate 6 m above roof levels with fittings to prevent reverse flow due to wind pressure. Air entry is via a plenum under the ground floor to the base of four 6 m by 6 m square corner lightwells. Under the influence of stack effect air is drawn via the four corner lightwells (Figure 3(a)) into each floor and extracted via the central lightwell (Figure 3(b)) and the smaller perimeter stacks. In winter the incoming air is warmed by pre-heating coils at the base of the supply lightwells and by trench heating at the point that the air from the lightwells enters each floor. Cooling is provided passively by thermally heavy-weight exposed concrete ceilings. The BEM system controls dampers and openable windows depending upon indoor and outdoor temperatures, wind speed and direction and internal carbon dioxide concentrations. The system incorporates a self-learning algorithm to estimate the need for overnight cooling. Over-cooling is prevented by monitoring slab temperature.

PERFORMANCE

(i) Energy performance

The energy used for heating, cooling and electricity was obtained from meter readings. The total annual delivered energy consumption for 2004 was 198 kWh/m² with a breakdown as follows: (i) gas for space heating and DHW – 95 kWh/m², (ii) electricity – 86 kWh/m² and (iii) cooling (basement HVAC only) – 17 kWh/m². Figures 4(a) and 4(b) compare the annual heating and electrical energy consumption by the building (corrected for the extended hours of use of the Library) with benchmarks current at the time of construction given in the UK Energy Consumption Guide 19: Energy Use in Offices (ECG19). These show that consumption is considerably better than for air-conditioned buildings and comparable with good practice naturally-ventilated open-plan buildings.

(ii) Indoor environment performance

(a) Thermal

Indoor air temperatures measured over a full year from June 2004 to June 2005. The data were taken from 8 BEMS sensors situated at two positions on each floor, located on different walls at a height of 1.5 m. Temperatures were measured at hourly intervals and averaged over all eight measuring locations.

Table 1 shows the number of hours and percentage of occupied hours that the air temperature exceeded the following values: 25°C, 27°C and 28°C.

Current national benchmark figures (CIBSE 2006) for a naturally ventilated building require that an operative temperature 28°C should be exceeded for less than 1% of occupied hours. Even allowing for the fact that there will be small differences between air and operative temperature, the building clearly meets this criterion.

Figure 3(a). Bottom of a light-well: air rises vertically past heating fins and then through BMS-controlled louvres into library.

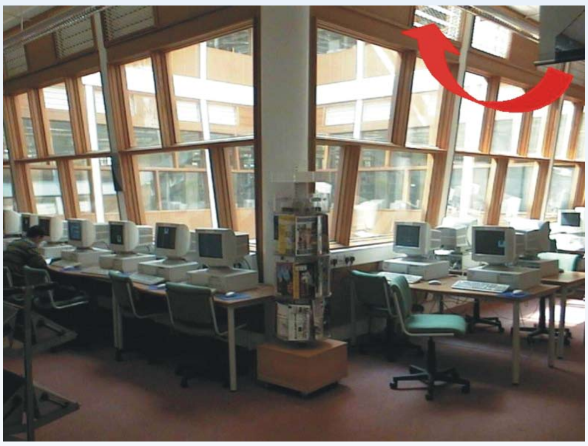


Figure 3(b). Mid-height of central light-well: air at ceiling level passes out through control louvres into the central well.

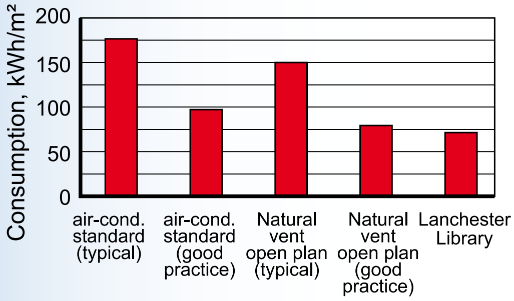


Figure 4(a). Comparison of space heating consumption with UK benchmark values for office buildings.

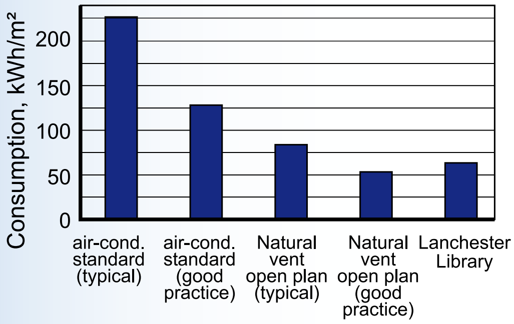


Figure 4(b). Comparison of electricity consumption with UK benchmark values for office buildings..

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(b) Ventilation

Carbon dioxide concentrations were measured over a representative six week period at four locations on one floor. There are no specific UK standards for carbon dioxide concentration in library or office buildings, although a maximum of 1000 ppm is used for schools. In the Coventry Library carbon dioxide did not exceed 350 ppm above ambient during the measurement period, indicating that it would be fall within Category I according to EN 15251 (Table B4).

(iii) Occupant assessment of indoor environment

A summary of the results of a sample survey of building users and full-time occupants, carried out in 2008, is given in Table 2.

In general, occupants are satisfied with conditions in the summer but are less so in the winter. Dissatisfaction is primarily with thermal comfort in the winter with complaints of cold and draught, particularly by occupants located on the north-east and north-west sides of the building.

DESIGN LESSONS

- **The building has generally performed well. There are a number of recommendations which might benefit the design of future buildings using the same principles.**

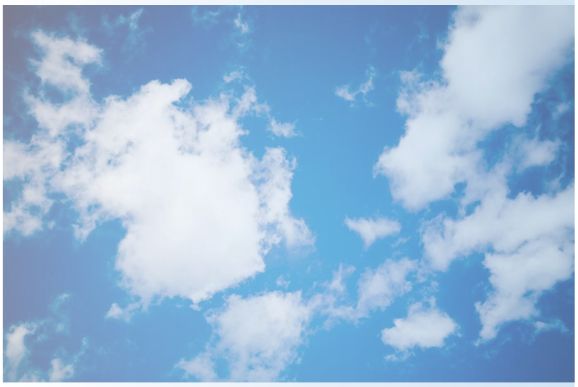
- **Areas which are occupied for longer periods of time could be co-located and access to other areas limited. This would enable night-time**

Table 1.
Percentage of occupied hours for which selected air temperatures are exceeded.

Reference temperature	Number of hours over stated temperature (h) / Percentage of occupied hours over stated temperature (%)				
	Ambient	Ground floor	1st floor	2nd floor	3rd floor
25°C	149 h / 4.1%	78 h / 2.0%	0 h / 0%	32 h / 0.8%	152 h / 3.8%
27°C	73 h / 2.0%	0 / 0	0 / 0	0 / 0	0 / 0
28°C	48 h / 1.3%	0 / 0	0 / 0	0 / 0	0 / 0

Table 2. Summary of occupant assessment of the indoor environment.

	Summer %	Winter %
People finding the **overall indoor environment** acceptable	83	62
People finding the **thermal environment** acceptable	79	58
People finding the **indoor air quality** acceptable	70	77
People finding the **acoustic environment** acceptable	66	60
	Natural %	**Artificial %**
People finding the **lighting** acceptable	90	90



Design team information
Designers and contractors

Client	Coventry University
Architect	Short and Associates
M & E Engineering Consultants	Environmental Design Partnership
Energy Consultants	IESD, De Montfort University and University of Wales, School of Architecture
Structural Engineering Consultants	Taylor Boyd and Hancock
Main Contractor	ISG Totty

ventilation to be operated without affecting the comfort of night-time occupants.

- **The performance in summer can be improved if air inlet dampers are closed down when the indoor dry-resultant temperature is below outdoor temperature. Carbon dioxide control can be used to override such closure if required.**
- **Consideration could be given to controlling the extent of opening of automatic vents on a seasonal basis. This would reduce the risk of over-ventilation in the winter, thereby reducing both energy consumption and the possibility of draughts.**
- **Experience has also shown that is important that facilities management staff are fully aware of the principles of the natural ventilation system and its controls.**

GENERAL

Key points concerning the design

A deep-plan, multi-storey building can be adequately ventilated naturally, using appropriately placed light-wells and stacks. This means the architectural design has to be integrated with the ventilation design from the very beginning of the design process.

REFERENCES

Krausse B, Cook M J and Lomas K J. Environmental performance of a naturally ventilated city centre library. Energy and Buildings, 39, 2007, pp791-801.

Lomas, K J. Architectural Design of an Advanced Naturally Ventilated Building Form, Energy and Buildings, 39 (2007) pp166-181.

Cook, M J and Short C A. Natural ventilation and low energy cooling of large, non-domestic buildings - Four case studies, International Journal of Ventilation, 3 (4) (2005), pp283-294.

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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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