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 10
VEJLANDSHUSET
COPENHAGEN, DENMARK

Supported by

Intelligent Energy Europe

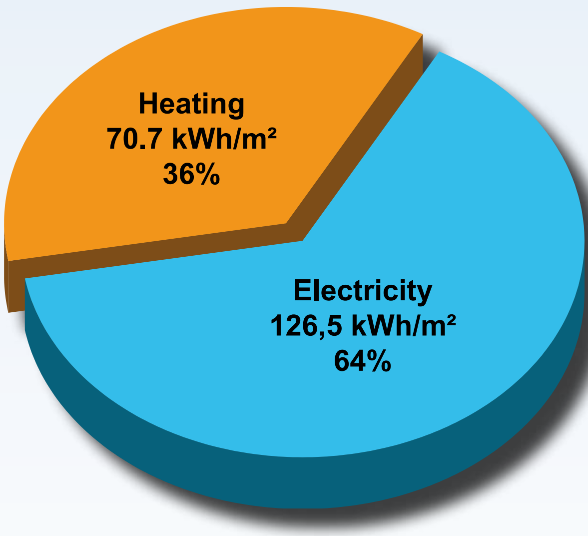
INTRODUCTION

The Vejlandshuset is located in a suburban area of south Copenhagen. Although there are buildings of a similar height in the locality there is sufficient distance between them to avoid any wind shelter or shading of the building. Running parallel to the west façade is a raised railway line above a road but these give rise to only a low level of external noise.

Summary Table of key design parameters.

Building data	
Building type	Office building
Total floor area	13 500 m²
Mean occupant density	22.5 m²/person
Occupied hours	2 000 hrs/year
HVAC data	
Ventilation system type	Mainly natural ventilation, controlled by indoor temperature and CO_2 concentration; mechanical ventilation of meeting rooms and facilities
Heating system	District heating supplying radiators
Cooling system	Night cooling
Total ventilation rate	Not applicable
Heat recovery efficiency	Not applicable
Design cooling load	Not available
Design heating load	Not available
Building fabric data	
Glazing U-value	1.1 W/(m² K)
Window g-value	Not available
Exterior wall U-value	0.19 W/(m² K)
Base floor U-value	Not available
Roof U-value	Not available
Climate data	
Design outdoor temperature for heating	-12°C
Design outdoor temperature and RH for cooling	Not applicable
Heating degree days (include base temperature)	2 909 days (base 17°C)
Cooling degree days (include base temperature)	Not applicable

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



Annual energy use.

BUILDING DESCRIPTION

Vejlandshuset was completed in 2005. It is five-storey office building with a central atrium and total floor area of 13 500 m². On the ground floor there are shared facilities including reception, cafeteria, and an open area for visitors. The four upper floors contain office space. The top floor also includes a plant room and an open terrace. Design occupancy is 600 and operating hours are between 07.00 and 18.00. Figure 1 shows a plan view of the first floor.

DESIGN SOLUTIONS

Heating is supplied from the district heating system. Both mechanical and natural ventilation are used in the building. Mechanical ventilation is used in the most densely occupied areas, while automatically controlled intermittent, or pulse, natural ventilation is used in the open plan office areas. A building energy management system controls both the heating and ventilation systems in each of the zones shown in Figure 1. On each floor, temperature is monitored in all 14 zones

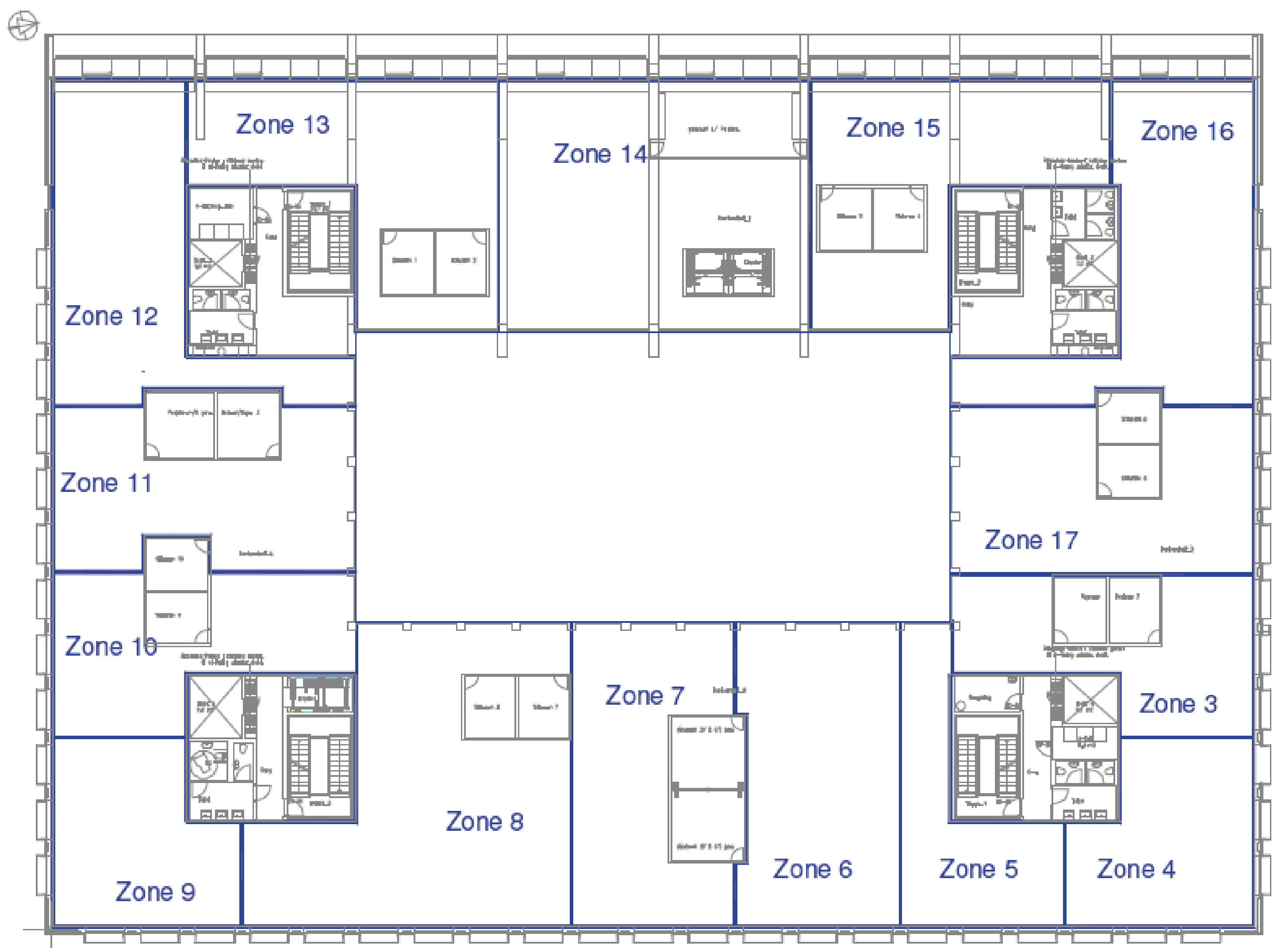


Figure 1. Plan view of first floor showing layout of office space.

on each floor and carbon dioxide concentration in four zones. The building is well insulated and air tight.

On the western façade of the building the windows are protected from afternoon solar gain by the use of brise-soleils supporting solar PV cells. The windows and atrium roof provide a high degree of day lighting which, together with smooth automatic light control, ensures minimal use of energy for lighting.

VENTILATION STRATEGY

The ground floor is mechanically ventilated. The second to fifth floors are naturally ventilated, except for the meeting rooms. The office space is positioned around a central atrium (see Figure 2) with a glassed roof with openable windows and automatic solar shading. All façades have the same window distribution and all windows have openable components, one automatically controlled and the other available for manual operation. Ventilation openings open automatically for some time when CO_2 or temperature level exceeds the set-point. The openings open only in the zone where the set-points were exceeded. Duration of opening depends upon the season and outdoor conditions. Meeting rooms on each floor are mechanically ventilated with balanced mechanical ventilation.

Figure 2. The atrium, showing the glazed roof and open connections to each floor.

Night-time ventilation is used, in conjunction with the heavy construction of the building to provide cooling and reduce daytime peak temperatures during summer.

PERFORMANCE

(i) Energy performance

Based on measurements for 2007, the building draws 70.7 kWh/m² from the district heating system. Electricity for lighting, office equipment and the operation of mechanical ventilation fans and other building services over the same period was 126.5 kWh/m². In addition a small amount of natural gas, 0.9 kWh/m² was also used.

(ii) Indoor environment performance

(a) Thermal

Measurements of temperature in 18 zones, obtained from the BEM system, were analysed. These showed a satisfactory level of air temperature. Taken across all zones, the average time for which the temperature was 26°C was 52 hours. This compares well with the Danish regulations (DS474:1993) which require that 26°C should not be exceeded for more than 100 hours in any one year and that 27°C should not be exceed for more than 25 hours. The first criterion was only exceeded in two zones, for 120 hours; these zones were found to have a high occupant density. No zones failed the second criterion.

In addition, detailed measurements, including air velocity, were made in two selected zones, A and B, over three short, week-long periods representative of summer, winter and spring/autumn conditions. The highest local air velocities in the zone were measured during the winter period to be 20 cm/s. In zone A, the comfort temperatures were achieved during all seasons. This corresponds to 20% dissatisfied. In zone B, the temperatures in the occupied zone were also acceptable but close to the upper limit defined for comfort temperatures during summer and winter, respectively.

(b) Ventilation

In addition to temperature, measurements of CO_2 were also obtained from the BEM system. Over the whole measurement period, the level of CO_2 concentration only exceeded the level of 1000 ppm set by the Danish Working Environment Authority for a few hours during winter when the air change rate was minimised to maintain the temperature in the offices. These results wee confirmed by the short period measurements short period measurements in which CO_2 concentrations were found to be in the range 500 to 800 ppm, with the highest levels in the winter.

(iii) Occupant assessment of performance

A questionnaire survey was carried out in August/September 2006 to assess occupant satisfaction with the indoor climate. The results of the analysis of the responses from 366 occupants are summarised in Figure 3 and Table 1. Occupants were asked to assess various aspects of the indoor environment using a scale from 0 to 10 (0 – very satisfactory: 5 – neutral; 10 – absolutely unsatisfactory).

In general, the results show that occupants are satisfied with overall indoor environment and comfort in Vejlandshuset. However, 40% of

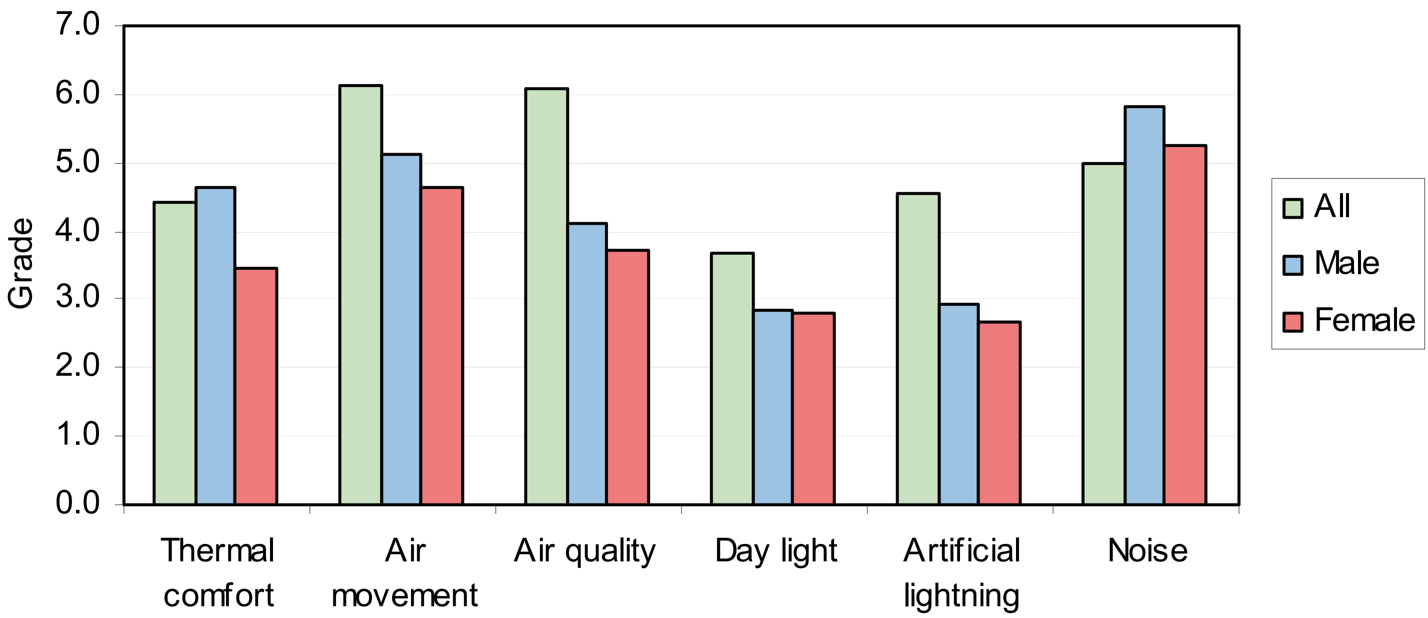
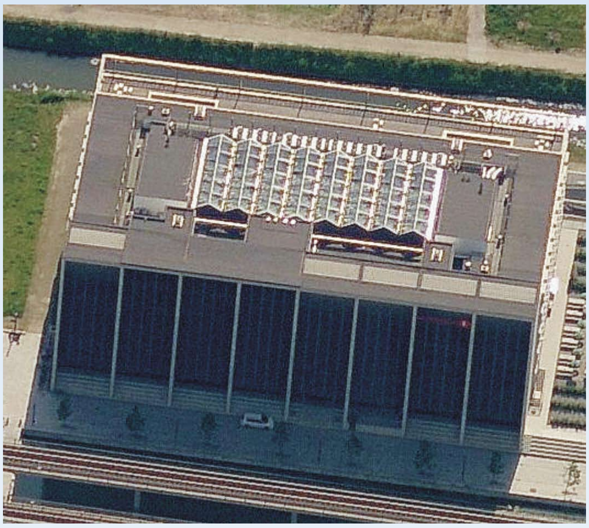


Figure 3. Perception of thermal comfort, air movement, air quality, lightning and noise (0: very satisfactory, 10: absolutely unsatisfactory).

Northern façade.



Western façade.

Southern façade.

occupants dissatisfied with thermal comfort. The reasons for their dissatisfaction varied from too warm, too cold or too variable air temperature. More detailed analysis found that most of the dissatisfied occupants have their worked desk near to the south or south-west façade of the building. This is the area with a high solar gain and one suggested cause for the problem was insufficient use of the manually operated solar shading, which tended to be operated only when an occupant was exposed to direct solar radiation. On the question regarding air quality in the offices, 69% of the respondents were satisfied. This corresponds very well to the general conception of natural ventilation as a provider of clean air.

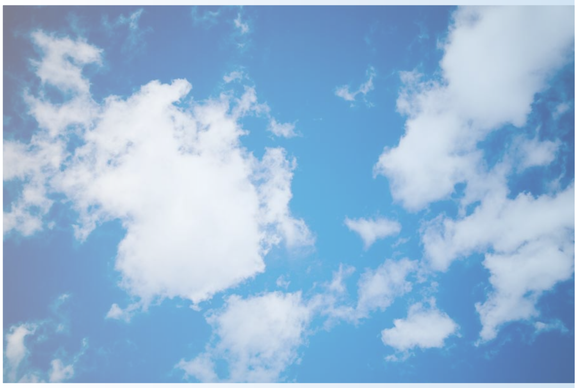
Natural daylight in the offices was positively also evaluated with most occupants being satisfied with the conditions. Some complaints were received with regard to noise level as a result of the open plan arrangement of the offices.

DESIGN LESSONS

The incidence of thermal discomfort in some zones was identified to be a result of local high internal heat gains resulting from a high occupant density. This should be avoided by giving due consideration to the arrangement of work stations.

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

	Percentage satisfied %
People finding the **overall indoor environment** acceptable	73
People finding the **thermal environment** acceptable	70
People finding the **indoor air quality** acceptable	66
People finding the **acoustic environment** acceptable	–
People finding the **lighting** acceptable	84



Design team information
Designers and contractors

Developer	The Sjælsø Group
Tenant	Københavns Energi A/S, NIRAS A/S, Carlson Wagonlit Travel
Architect	Schmidt Hammer Lassen architects (SHL)
Engineering Consultants	NIRAS A/S, Windowmaster A/S

As a result of the short period, detailed measurement periods and the analysis of the questionnaire responses, it was concluded that it is important to provide simple guidance to occupants on the best use of manually operated windows and controllable solar shading.

GENERAL

Key points concerning the design

- **Time, CO_2 and temperature-controlled natural pulse ventilation, with the advanced control strategy that changes depending on outdoor air temperature.**
- **Option for occupants to control ventilation openings.**
- **Use of mechanical ventilation in areas of high intermittent occupant density, such as meeting rooms, and common areas such as Control of temperature increase in the atrium and mechanical ventilation in zones with the high loads. Solar cells, well, superior tightness, automatic light control and good day lighting.**

REFERENCES

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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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