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 8

POIKKILAAKSO SCHOOL
HELSINKI, FINLAND

Supported by

Intelligent Energy Europe

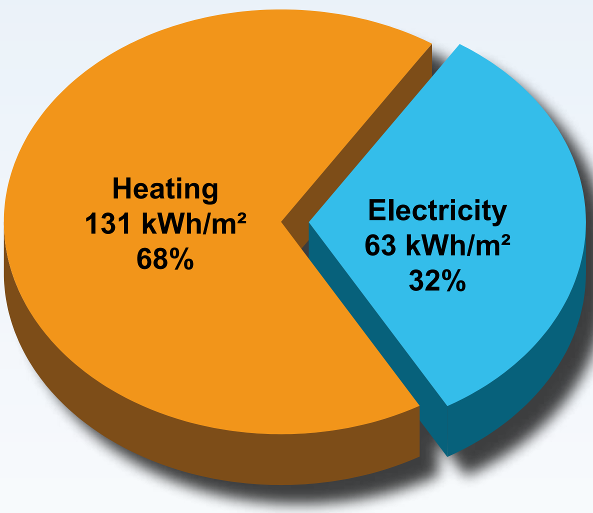
INTRODUCTION

Poikkilaakso School is located about 200 m from the coastline on a small relatively flat forested cape in the eastern part of Helsinki. All the surrounding buildings are low rise.

Summary Table of key design parameters.

Building data	
Building type	Primary school
Total floor area	3 132 m²
Mean occupant density	9 m²/person (overall average)
Occupied hours	2 000 hrs/year
HVAC data	
Ventilation system type	Mechanical ventilation
Heating system	District heating
Cooling system	Small A/C system for computer room only
Total ventilation rate	34 000 m³/h
Heat recovery efficiency	80%
Cooling load (typical)	Not applicable
Specific heating load	60 W/m²
Building fabric data	
Window U-value	1.7 W/(m² K)
Window g-value	0.55
Exterior wall U-value	0.25 W/(m² K)
Base floor U-value	0.30 W/(m² K)
Roof U-value	0.22 W/(m² K)
Climate data	
Design outdoor temperature for heating	-26°C
Design outdoor temperature and RH for cooling	Not applicable
Heating degree days (include base temperature)	3 989 days (base 17°C)
Cooling degree days (include base temperature)	194 (base 15°C)

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



Annual energy use.

BUILDING DESCRIPTION

Poikkilaakso School is a small primary school and day nursery completed in 2001. The school is designed for 270 children (aged 7 to 13) and the day nursery for 42 children (aged under 5). The building is owned by the city of Helsinki. The net heated floor area of the building is 3 132 m^2 and volume 17 580 m^2. The building is usually fully occupied from Monday to Friday between 08.00 to 14.00 and partly occupied (the day nursery and some of the teachers) between 14.00 to 17.00. The school is closed in the summer from June to August. Figure 1 shows a plan view.

DESIGN SOLUTIONS

The building is connected to the Helsinki area district heating distribution system. Customers receive heat from the hot water circulating in the heating distribution network. The temperature of the district heating water varies usually between 65°C and 115°C for the supply and between 40°C and 60°C for the returning water, depending on the outdoor air temperature. In the summer the heat is needed only for the domestic hot water production. Heat extracted from the district heating network is used in the building for domestic hot water and space heating through the hot water radiators and central air handling unit.

The Poikkilaakso School was a pilot project in which some elements typical for hybrid systems were combined with mechanical ventilation. The ventilation system is a fully mechanical low pressure system, having central air-handling unit including filtering, heat recovery, fans, heating coil and silencers. The aim was to achieve low heating and electricity consumption by using demand controlled supply ventilation to individual rooms, with air transferred via internal rooms to a single central exhaust and heat recovery between main exhaust and supply ducts.

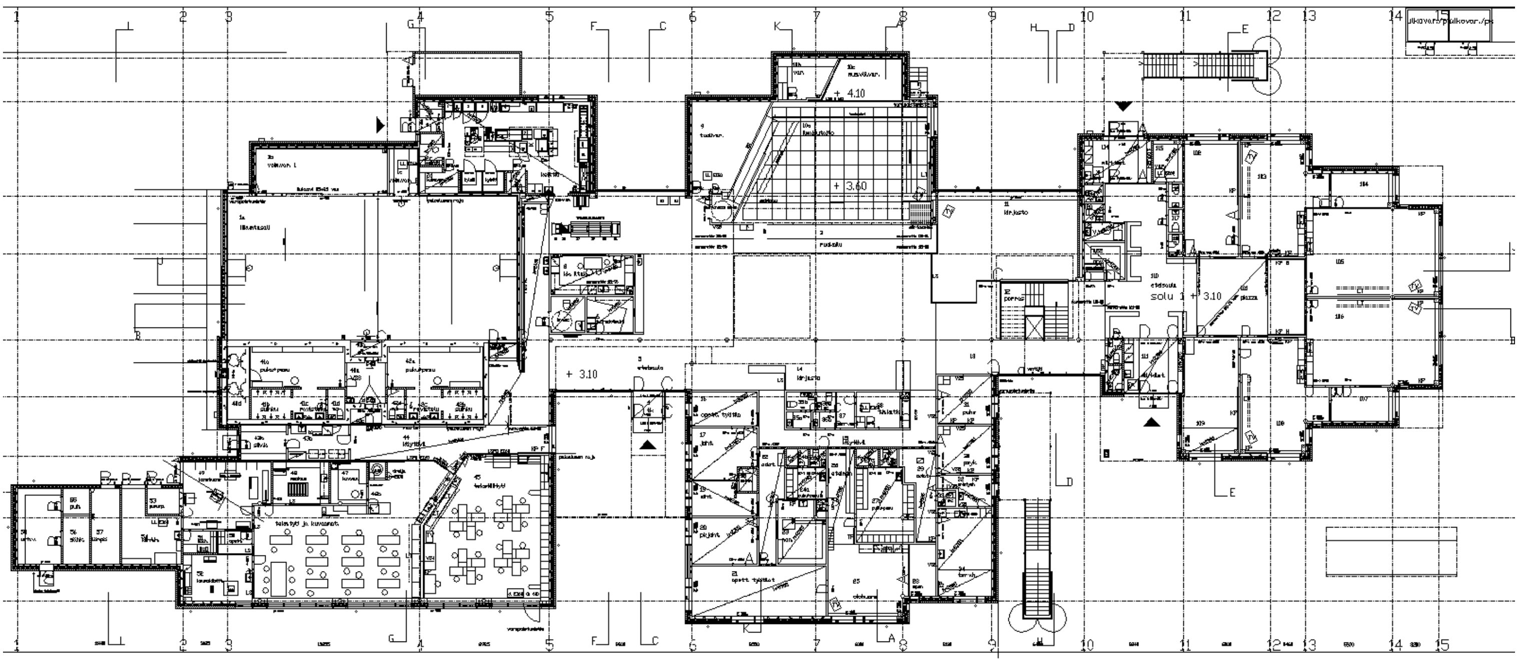


Figure 1. Ground floor of Poikkilaakso School.

VENTILATION STRATEGY

The building has mechanical supply and exhaust ventilation system with heat recovery. Only the computer classrooms are air-conditioned. An air handling unit mounted at roof level serves a large supply air duct on the roof (Figure 2), from which two vertical ducts lead to each classroom and terminate in displacement diffusers (Figure 3). There is a central extract duct from the main hall (Figure 4). The building serves as the return airflow route avoiding the need for suspended ceilings or visible ducts (Figure 5). The supply air is tempered and the principal source of heating of the rooms is by low temperature hot water radiators.

Figure 6(a) shows the schematic layout of the heating and ventilation system. Air is heated and filtered in an air handling unit before it is supplied to the rooms. t 6(b) shows the method of controlling the air supply. Control of the ventilation is based on temperature, CO_2 and occupancy sensors in the classrooms. There are supply airflow dampers for each classroom and a speed-controlled fan keeps constant 50 Pa pressure in the main supply duct on the roof. Design ventilation flow rates were 3 l/s per m² in classrooms, 5 l/s per m² in the dining room and 2 l/s per m² in offices.

Figure 2. Main air supply duct at roof level.

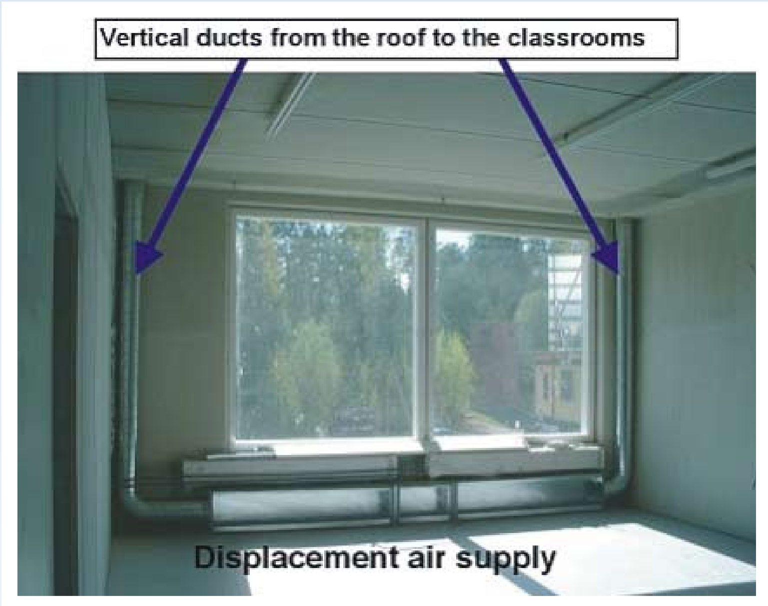


Figure 3. Air supply ducts to classroom diffuser (during construction).

PERFORMANCE

(i) Energy performance

Energy consumption was monitored during 2007. District heating energy use for space heating and domestic hot water was 131 kWh/m² (adjusted for long period degree days). This is more than expected for such a modern building with a demand-controlled ventilation system. An average degree-day-adjusted district heating energy use in Helsinki schools is 165 kWh/m². Major reasons for the relatively high heating energy use are the non-compact building shape and problems in the operation of demand controlled ventilation system, which has mostly been operated in manual, constant air volume mode.

Total electrical energy use for lighting, HVAC and equipment was 63 kWh/m² which is slightly more than average electricity use in Helsinki schools of 52 kWh/m². HVAC electricity use cannot be separated from these total figures.

Figure 4. Central extract in main hall.

Figure 5. Transfer air ducts from classrooms.

(ii) Indoor climate

Short term measurements of temperature and air speed at a range of heights in selected classroom locations in March and June 2008 showed relatively low air speeds and a low predicted percentage dissatisfied (PPD) index. The exception was at low level (0.1 m), close to the diffusers, where speeds of up to 0.25 m/s were measured indicating the possibility of discomfort due to draught. This demonstrates the limitations of displacement ventilation air distribution in crowded classrooms.

Air temperatures were measured over a four week period in May (mixed season) and in November (heating season). Temperature-based thermal comfort foot-print (Figure 7), according to EN25251:2007, shows that temperature remained between 21°C and 23°C (category I) for 55% and between 20°C and 24°C (category II) for 87% of occupied hours in heating season. In the cooling season temperature was below 25°C (category I) in occupied hours for the full measurement period. Limited measurement data exist for the cooling season since Finnish schools are closed in the summer from June to August and measurements were not continued in August.

In the heating season there was a tendency that temperature was quite low in three classrooms out of twelve. The excess hours out of category I and II are mostly caused due to these low temperatures (below 23°C and below 20°C respectively).

Indoor air quality was assessed as category II based upon the design ventilation rate of 3 l/s per m² together with the use of very low polluting materials for up to an occupancy of 23 persons per classroom. In practice, typical occupancy is about 20 persons per classroom.

(iii) Occupant Assessment of Performance

A questionnaire survey of 16 adult full-time occupants (80% response rate) was undertaken in 2008. A very high proportion was satisfied with the internal environment, although a smaller number were satisfied with the specific aspects of indoor air quality and thermal comfort. There was no clear cause for dissatisfaction with thermal comfort but concerns with indoor climate were draught in winter and a lack of air movement in summer. Some complaints of draught

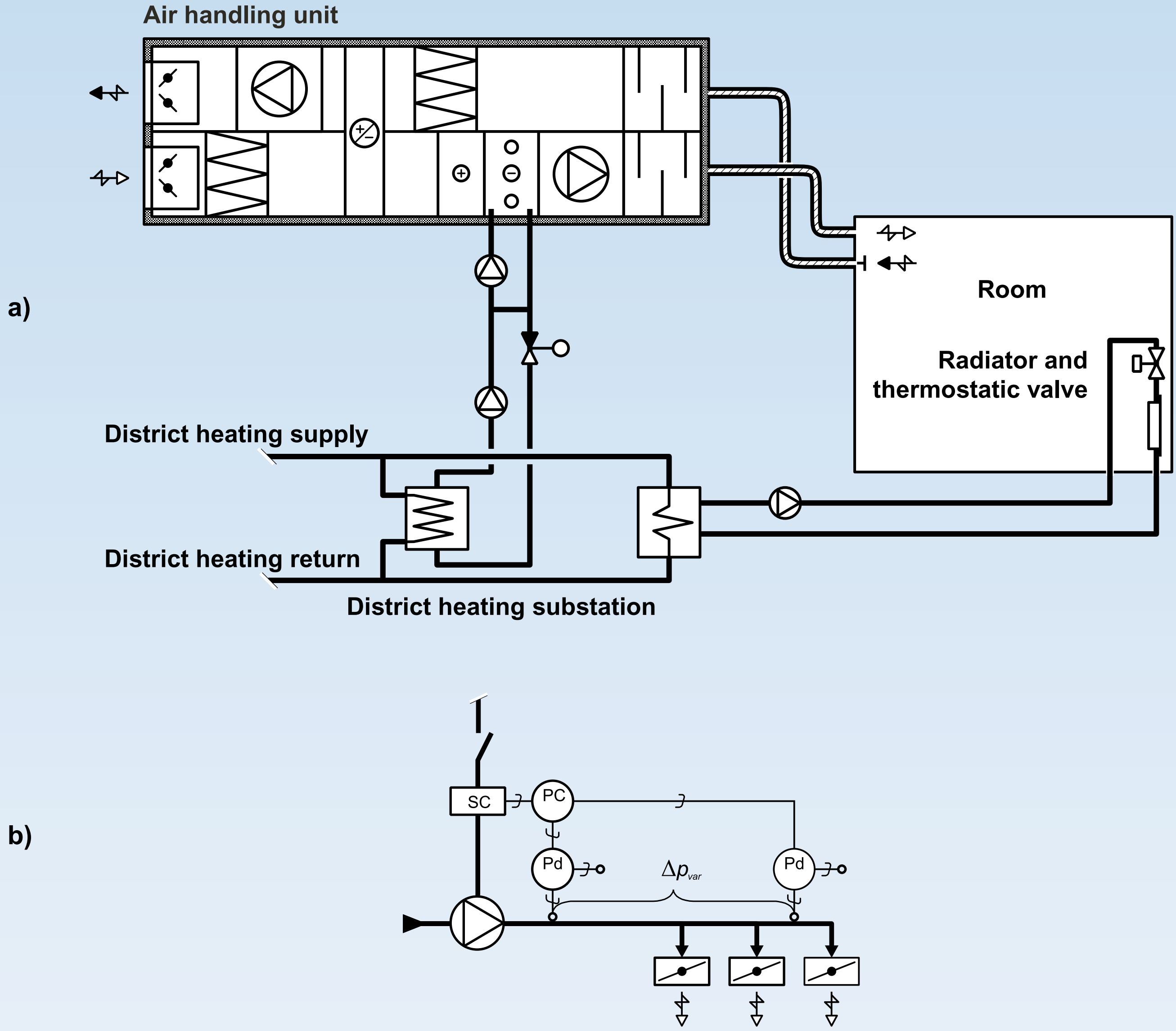


Figure 6. General arrangement of the heating and ventilation system.
(a) Schematic of heating and ventilation system, (b) Schematic of control system.

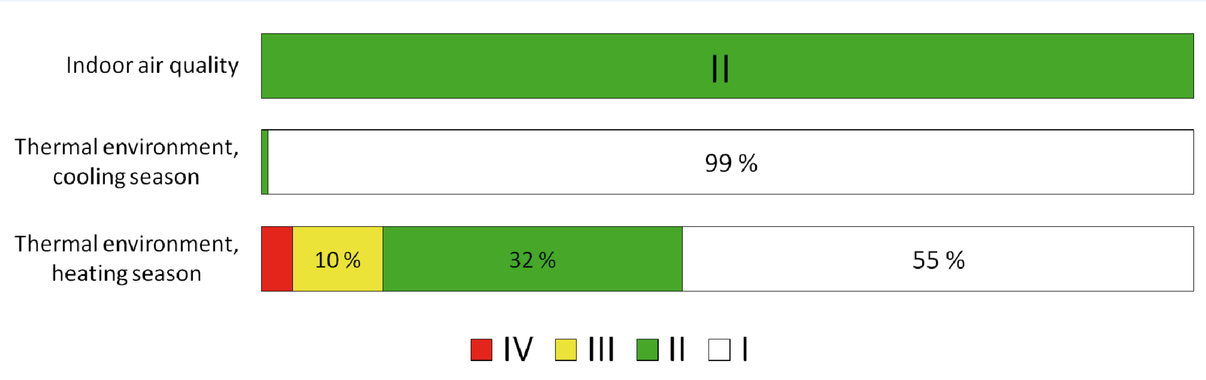
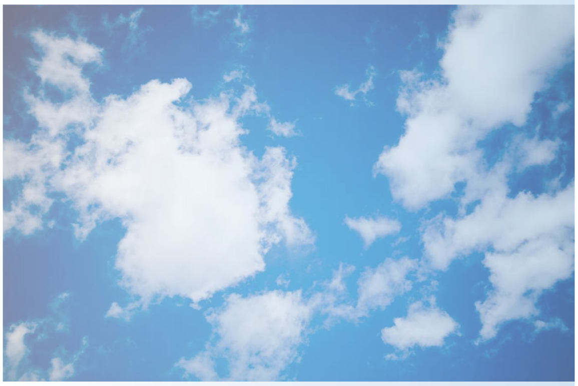


Figure 7. Foot-print of thermal comfort based on measured temperatures and foot-print of IAQ based on ventilation rate.

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

	Summer %	Winter %
People finding the **overall indoor environment** acceptable	93	87
People finding the **thermal environment** acceptable	71	62
People finding the **indoor air quality** acceptable	64	60



Design team information
Designers and contractors

Developer	Helsingin kaupunki (City of Helsinki)
Tenant	Helsingin kaupunki
Architect	Arkkitehtitoimisto Markus Lindroos ky
HVAC Planning	Climaconsult Finland Oy

may be explained by occasional low temperatures measured in the heating season in some of the classrooms (category III and IV in Figure 7).

DESIGN LESSONS

High user satisfaction has been reported in previous studies. School staff has many times pointed it out that there is a "feeling of natural ventilation" in the building with no suspended ceilings and no visible ducts, but the use of displacement ventilation air distribution was found to pose problems, because in the classrooms desks and small cupboards were placed directly near the diffusers, in some cases blocking 20 to 50% of the diffuser area.

Previous measurements show that south façade classrooms overheated during hot periods in the summer. This is a result of poor solar protection and the lack of other relevant measures such as night ventilation cooling or air conditioning.

This school was one of the first designed with a demand-controlled ventilation system and experienced a number of operating problems. These have been solved in similar schools designed subsequently.

GENERAL

Key points concerning the design

Silent and invisible mechanical ventilation system – many users have pointed out that the building has a feeling of natural ventilation but also a superior air quality.

- **Construction integrated supply air ducts and displacement diffusers.**
- **Ductless extract air system based on transferred air and central extract.**
- **Demand controlled ventilation system.**

Brochure authors: J Kurnitski and J Palonen, Helsinki University of Technology.

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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