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 9
YIT OFFICE BUILDING
TURKU, FINLAND

Supported by

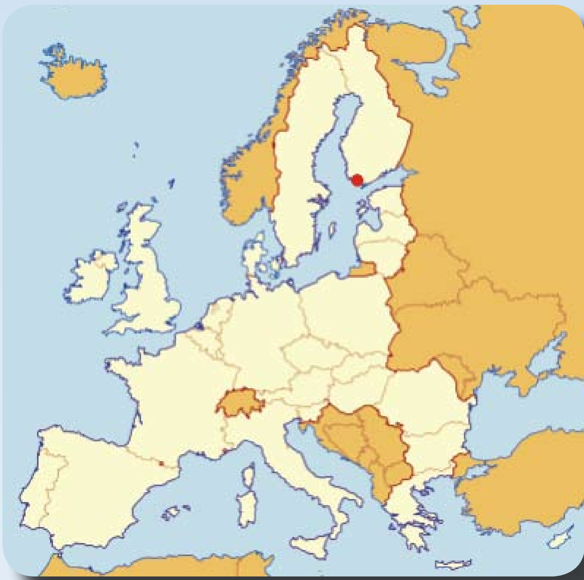
Intelligent Energy Europe

INTRODUCTION

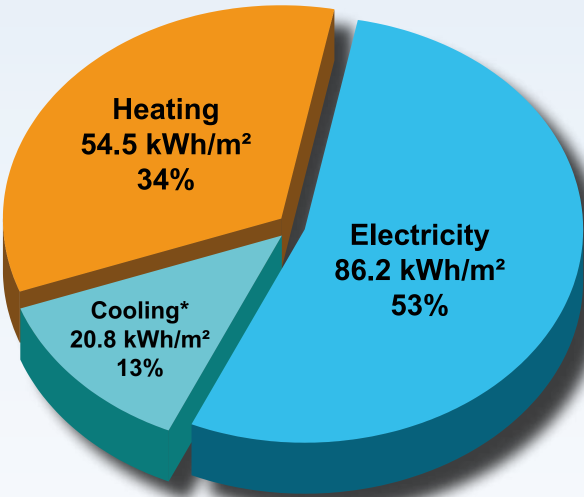
YIT Office Building is located in the city of Turku on the south-west coast of Finland. It is situated in a relatively open, slightly forested, suburban area by a motorway about two kilometres from the Turku city centre. All buildings in the immediate vicinity are low-rise.

Summary Table of key design parameters.

Building data	
Building type	Office
Total floor area	6 900 m²
Mean occupant density	25 m²/person
Occupied hours	2 600 hrs/year
HVAC data	
Ventilation system type	Mechanical ventilation
Cooling system	Central cooling / chilled beams
Ventilation rate (or CO_2 concentration)	3 l/s per m² floor area
Heat recovery efficiency	80%
Cooling load (typical)	50 W/m²
Specific heating load	60 W/m²
Building fabric data	
Window U-value	1.1 W/(m² K)
Window g-value	0.38
Exterior wall U-value	0.22 W/(m² K)
Base floor U-value	0.22 W/(m² K)
Roof U-value	0.14 W/(m² K)
Climate data	
Design outdoor temperature for heating	-26°C
Design outdoor temperature and RH for cooling	27°C; 50% RH
Heating degree days (include base temperature)	4 115 (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.



*delivered district cooling energy

Annual energy use.

BUILDING DESCRIPTION

YIT Office Building is a typical modern five-storey office building and was completed in October 2005. The ground floor (900 m²) serves as a workshop and storage facility and the remaining four floors (6 000 m²) have both open-plan and cellular office spaces. There is a large glass roofed atrium in the centre of the building extending from the first floor to the roof. In the lower part of the atrium (at the second floor) there is a cafeteria and a small kitchen (the second floor partly covers the atrium). A total net floor area of the building is 6 906 m² with a total volume of 34 000 m³. Figure 1 shows a section through the building and Figure 2, a plan view of the second floor.

Figure 1. Cross section of the building.

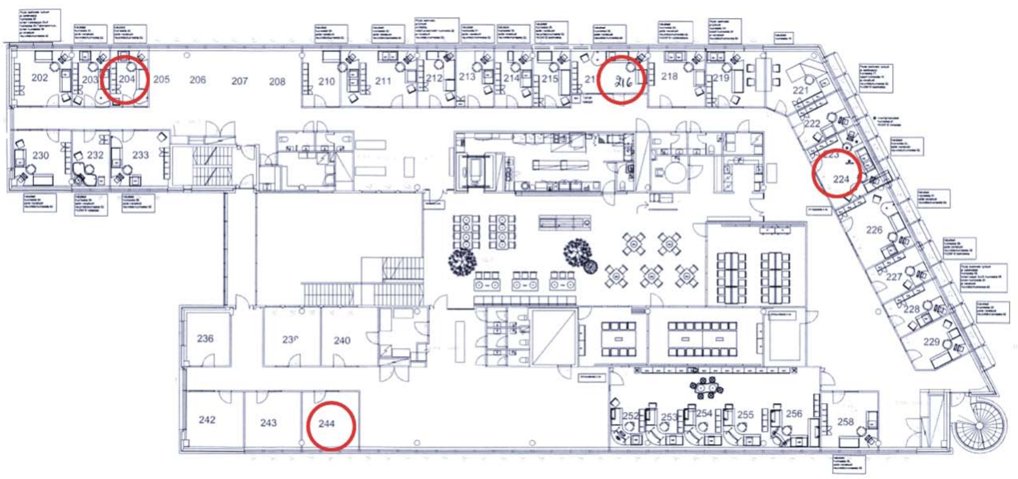


Figure 2. Plan view of the second floor (indoor climate measurement points are marked with red circles).

The building is designed for 270 persons, but in 2008 there were about 180 regular office workers and one large open-plan office space in the first floor was vacant. The office spaces are usually occupied between 08.00 and 17.00 except for weekends, national holidays and the summer holiday period. In addition to office workers there are regular maintenance personnel working in the ground floor on a daily but more irregular basis.

DESIGN SOLUTIONS

The building has an air-conditioning system with mechanical supply and exhaust ventilation and chilled beams. The building is connected to Turku area district heating and district cooling distribution systems. The temperature of water in the district heating main varies between 65°C and 115°C for the supply and between 40°C and 60°C for the return water, depending on the heat demand. In the district cooling network the delivery temperature is +7°C and the return temperature +17°C. District cooling water is produced with free cooling (outdoor air) and compressor technology. All the heating and cooling systems in the building are connected indirectly to the district networks through heat exchangers.

Heat extracted from the district heating network is used in the building for domestic hot water and space heating through central air handling units and hot water radiators. The district cooling water system serves both the central air handling units and chilled beam units installed in the open-plan and cellular office spaces (Figure 3). The chilled beam units have integrated, control equipment, supply air cooling heat exchangers, fluorescent lighting and a communication link to building management system (BMS). Outside normal office hours, the BMS sets lights in the units by default to ¼ power and lighting demand is controlled by IR motion-sensors.

VENTILATION AND AIR CONDITIONING STRATEGY

The building is divided into five ventilation zones: ground floor (heating and cooling), floors 1 to 4 at the western part of the building (heating and cooling), floors 1 to 4 at the eastern part of the building (heating and cooling), dining room and kitchen at the second floor (heating and cooling), top part of the atrium space (heating only). Each zone has its own central air handling unit.

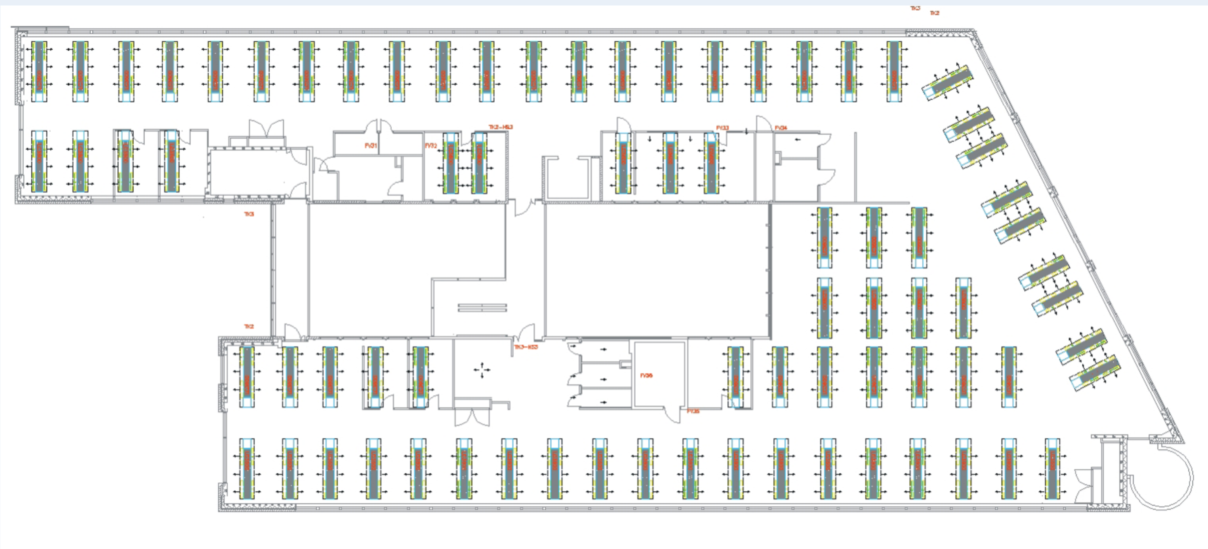


Figure 3. Chilled beam units on the third floor (floors 1 to 4 have a similar arrangement).

Outdoor air is filtered and heated or cooled in central air handling units and supplied to rooms. Supply air is heated in the central air handling units partly with heat recovered from extract air and partly with heating coils. When cooling is needed, supply air is first cooled in the central air handling units and then cooled further in the chilled beam units (figures 4 and 5). The district cooling system serves both the central air handling units and the chilled beam units. Rooms are heated with hot water radiators controlled by thermostatic radiator valves.

All open-plan and cellular office spaces have room conditioning with active chilled beam units installed in the ceiling, and controlled by room temperature controllers. Air volume flow rate is kept constant (constant pressure CAV). Ventilation in the meeting rooms is controlled by occupant and temperature sensors. When a meeting room is occupied the air flow is controlled by the temperature sensor and, when empty, ventilation is reduced to a small fraction (10%) of the normal level. Supply air flow rate is based on ventilation requirements (3 l/s per m² floor area) but is heated or cooled depending on the requirements of the room. The major part of cooling and heating is supplied by the water systems (beams and radiators respectively).

Figure 5. Typical open-plan office space showing location of radiators and chilled beam units.

Supply air temperature is extract air temperature compensated and is set between 17 to 22°C. The supply air temperature is controlled by adjusting the rotation speed of the regenerative exchanger and the water flow control valves of the heating and cooling coils.

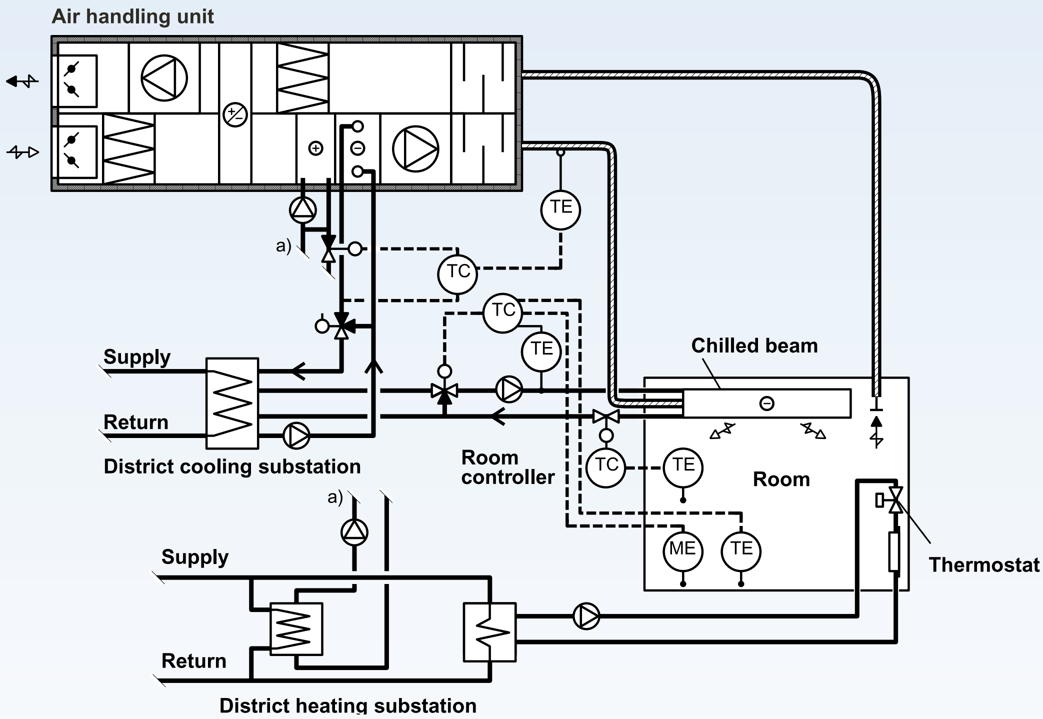


Figure 4. Air conditioning system with mechanical supply and exhaust ventilation and chilled beams.

PERFORMANCE

(a) Energy performance

Based on the data from the BMS for 2008, corrected for standard long period degree days of 4 115 Kd, energy delivered by the district heating system for space heating and domestic hot water was 54.5 kWh/m² floor area. Energy delivered by the district cooling system over the same period was 20.8 kWh/m² floor area. (This value corresponds to 7 kWh/m² floor area electrical energy use for the typical chiller with COP of 3.) Total electrical energy use for lighting, HVAC and equipment was 86.2 kWh/m² in 2008.

The energy use corresponds to typical good energy performance of modern office buildings, expect for the electrical energy use which is somewhat higher than average, probably due to kitchen appliances. Energy performance is better than in the existing office buildings stock in Helsinki, which typically use 138 kWh/m² district heating energy and 85 kWh/m² electricity.

(b) Indoor climate

Indoor climate measurements included both air temperature and air velocity measurements. Ventilation air flow rates were assessed from commissioning measurement protocols, as the building had constant air volume system with ventilation rate of 3 l/s per m². Indoor air quality and thermal environment footprints according to EN 15251:2007 (Figure 6) show an excellent measured performance of the building, as indoor climate belongs mostly to the highest indoor climate category I.

Air temperatures were measured over a four week period in May (heating season) and in July–August (cooling season) 2008. Temperature based thermal comfort foot-print shows that temperature remained between 23.5°C and 25.5°C (category I) for 97% of occupied hours for cooling season. In heating season temperature was between 21.0°C and 23.5°C (category I) in occupied hours for the full measurement period. Daily temperature fluctuations were typically around 1.0°C to 1.5°C in the occupied hours during heating season.

(c) Occupant assessment of performance

Most of office workstations were in landscaped offices without personal workstation temperature control and modest sound insulation typical to landscape offices. This has resulted in low satisfaction with the acoustical environment. Satisfaction with room temperature was nearly as good as can be expected for this type of landscaped office without personal control. Satisfaction with overall indoor environment, indoor air quality and lightning was excellent.

DESIGN LESSONS

In a cold climate heating of the ventilation air is the most significant heat loss especially in the non-residential buildings. To achieve adequate energy performance of the building, the use of controlled ventilation rates and heat recovery is essential in a cold climate. For that reason natural ventilation systems with high ventilation rates and no heat recovery cannot be used in a cold climate.

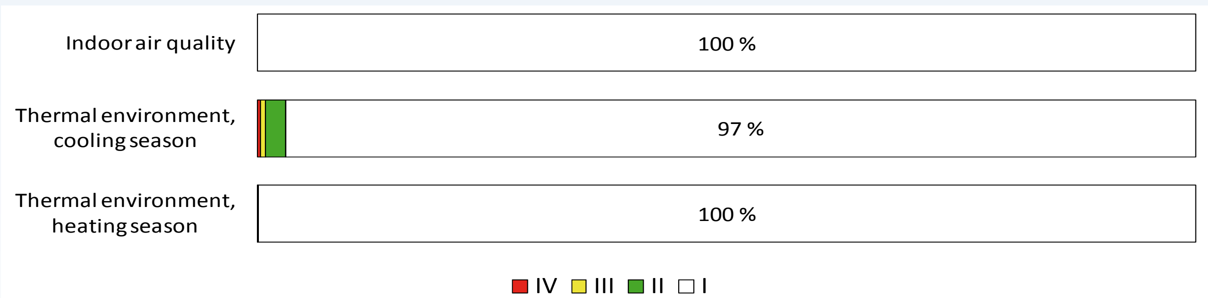


Figure 6. Indoor air quality and thermal comfort footprint according to EN 15251:2007.

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

	Summer %	Winter %
People finding the **overall indoor environment** acceptable	86	91
People finding the **thermal environment** acceptable	73	76
People finding the **indoor air quality** acceptable	82	90
People finding the **acoustic environment** acceptable	59	57
People finding the **lighting** acceptable	95	95

Typical cellular office with a chilled beam.

Design team information
Designers and contractors

Developer	YIT
Tenant	YIT
Architect	Arkkitehtitoimisto Erkki Salmi Oy
HVAC Planning	Insinööritoimisto Juhani Lehtonen Oy

Energy performance of described ventilation system is achieved through effective heat recovery in the air handling unit. Another benefit is low specific fan power (electricity use of the ventilation system) due to relatively low ventilation rates. As ventilation rates are based only on the ventilation need caused by human occupancy, they are significantly lower compared to all-air systems where ventilation rates are based on cooling or heating need. To achieve low specific fan power, low pressure design of ductwork and demand controlled ventilation control in meeting rooms are used.

GENERAL

Key points concerning the design

- **Each room has room controller which enables the highest thermal comfort standard.**
- **Chilled beams, low velocity induction devices, provide silent air distribution with low air velocities.**
- **The ventilation system is easy to control as it is basically CAV system where cooling and heating is separated from ventilation.**
- **Compared to VAV systems, low air velocities and silent operation are major advantages.**
- **An effective heat recovery and low specific fan power ensure an excellent energy performance.**

REFERENCES

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Kurnitski J, Kolokotroni M, Farrou I, Warren P. Building AdVent project demonstrates advanced ventilation technologies for good indoor climate and energy performance, *REHVA journal, December 2008, 48–53.*

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

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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