SF1

Elementary school of Oulujoki, Finland

1 Photo

Figure 1: View of Oulujoki school

2 Project summary

The purpose of the project was to investigate how renovation of ventilation improves the quality of indoor air and it's effects on energy consumption in fifteen school buildings. The IEA Annex 36 case study school built in the 1940s, represents the typical school building built in post-war conditions. In the renovation process the old natural ventilation system was replaced with a mechanical supply and exhaust ventilation system. The most important aim of the renovation work was to improve the quality of the indoor air.

The first stage of renovation (1997) only included the classrooms, corridors and gym. Both measurements of indoor air quality and questionnaires to teachers were made before and after the first stage of the renovation work.

3 Site

Finland, Oulu; *latitude:* 65,0°N, *longitude:* 25,5°E, *altitude:* 10 m. *Mean annual temperature:* +1°C, *mean winter temperature:* (December – February): –10 °C.

4 Building description /typology

4.1 Typology / Age

Typology/Age	Pre 1910	1910–30	1930–50	1950–70	1970–
The multi-storey school			●		
The central corridor school			●		
The side corridor school					

School grades: Elementary School (7-13 year old)

4.2 General information

Year of construction: 1947
Year of renovation (as described here): 1997
Total floor area: 2,522 m^2, *total floor area for school:* 1,365 m^2
Total volume: 9,340 m^3
Number of pupils: approximately 220 pupils

Typical class room
size: 60 m^2
number of pupils: 20–33 pupils

The school is a typical 3 storey central-corridor school, built in the 1940s. The school consists of two buildings. One building was formerly a hostel for the students but is now converted into classrooms and teachers´ rooms. The school is a brick construction with insulation in the cavity between the brick layers. The windows are mainly triple glazed with wooden frames. The earlier school building was connected to the hostel facility with a gateway in 1990.
The ventilation system was changed from a natural ventilation system to a mechanical ventilation system with heat recovery. No other renovation measures have been carried out at this stage.

4.3 Architectural drawings

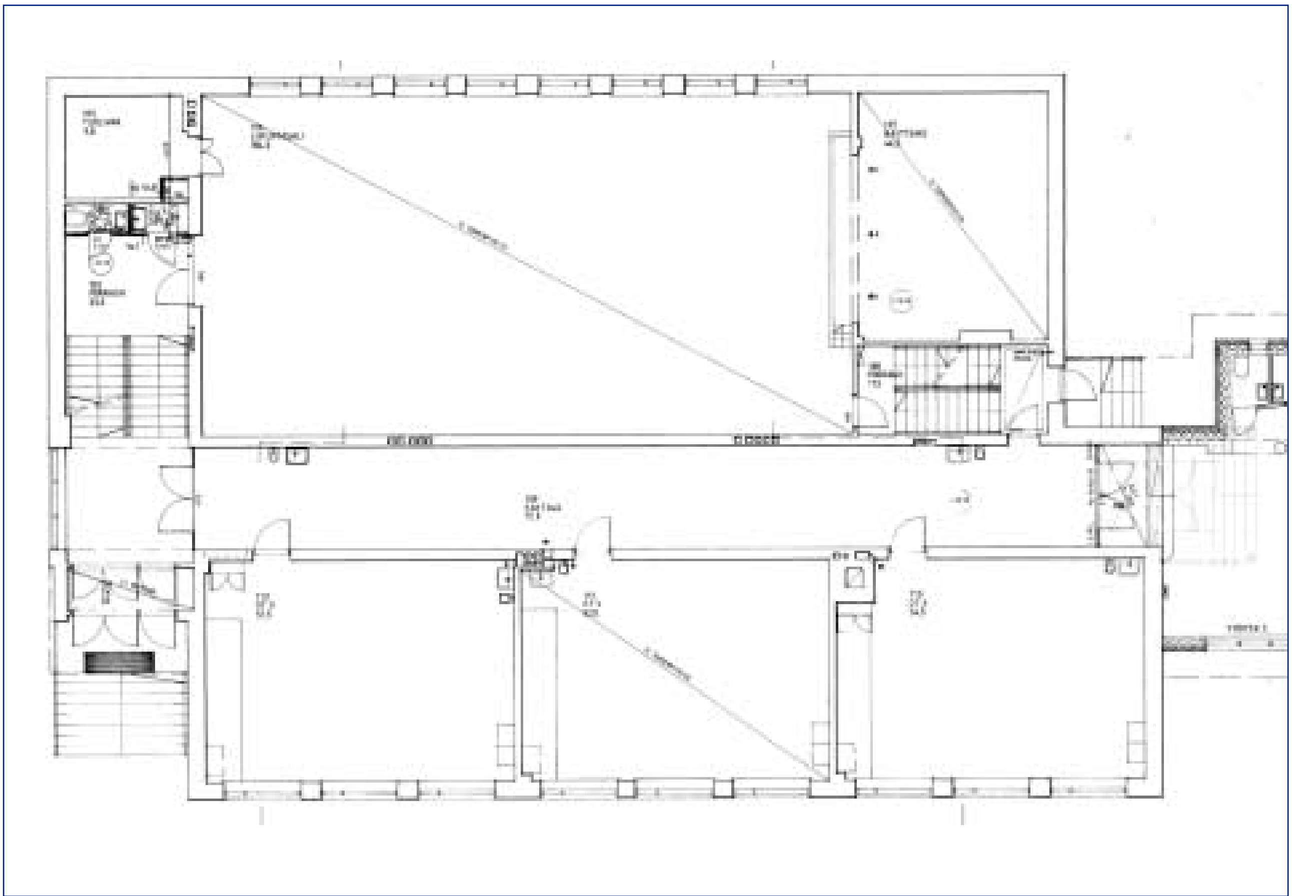

Figure 2: Floor plan: general layout of the 1st floor main building - gym and classrooms

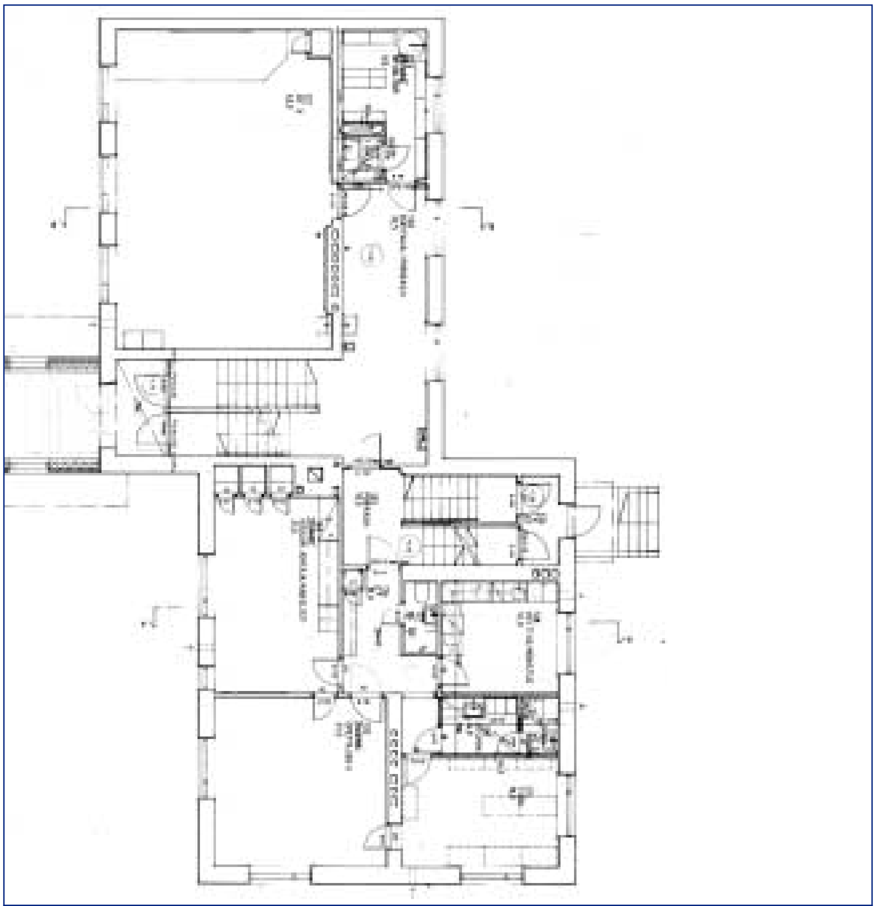

Figure 3: Floor plan: general layout of the 1st floor side building

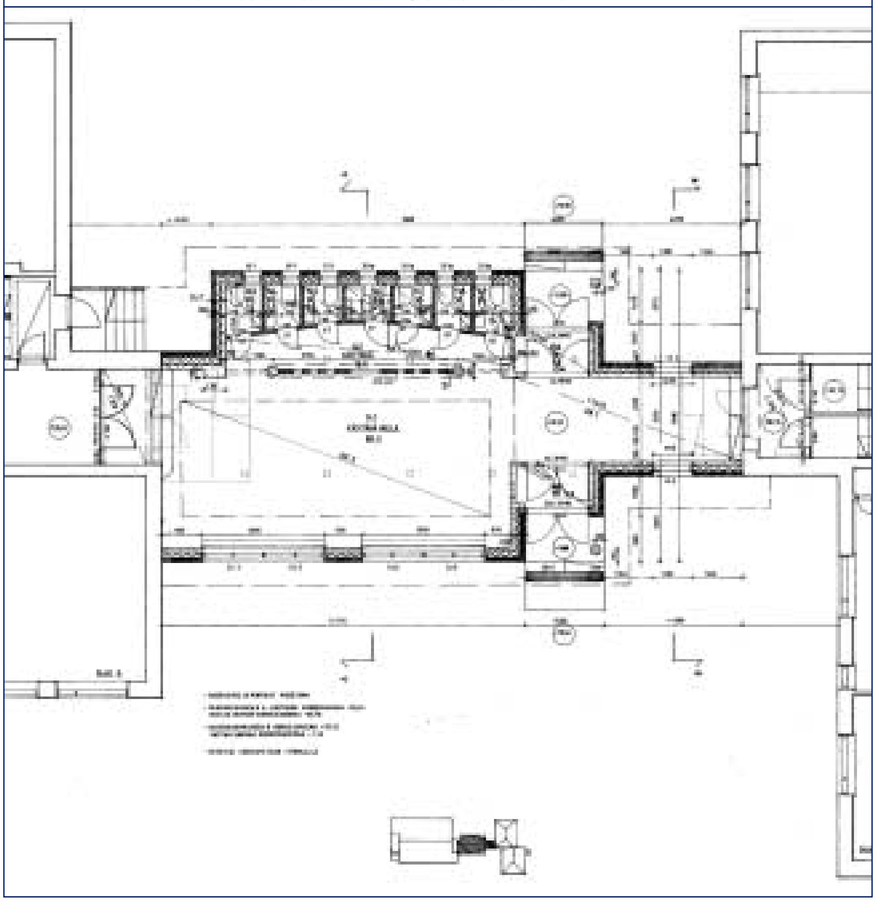

Figure 4: Floor plan: general layout of the gateway between main building and side building

5 Previous heating, ventilation, cooling and lighting systems

- central heating, radiators
- natural ventilation system in classrooms
- mechanical supply and exhaust ventilation in kitchen (since 1978)

The heating system was originally based on its own wood burning boiler, but the facility has been connected to a district heating network, and the boiler was removed. The existing ventilation system was a natural ventilation system in the classrooms, there were adjustable air supply units in the window frames but the CO_2 concentration at the end of the lessons could increase > 1500 ppm, this was apparent, especially during afternoon lessons, when the CO_2 concentration was already high at the beginning of the lesson. There were also dust problems and too high indoor temperatures in some areas.
In 1978 the kitchen and dining area was equipped with a mechanical supply and exhaust ventilation system. There were 7 exhaust fans, serving kitchen, dining room, cellar, operating rooms and rest rooms. The lighting system is based on fluorescent tubes, which are going to be changed for low-energy ones.

6 Retrofit energy saving features

6.1 Ventilation

Mechanical supply and exhaust ventilation with heat recovery
Pre-heating of ventilation air: yes
Heat recovery: yes (rotating heat exchangers)
No cooling, no humidifiers.
Gym: power boost controlled by timer or sensors of indoor air temperature
Air flows of rooms were calculated from guide values of National Building Code of Finland:

Classrooms: 3 l/s, m^2
Corridors: 1 l/s, m^2
Gym: 2 l/s, m^2 and extra boost 6 l/s, m^2

No changes for heating or lighting systems. The ventilation system was changed, based on new systems with heat recovery and pre-heated fresh air. Heat recovery units are rotating heat exchangers, no cooling, no humidifiers (not generally used in Finland).

7 Resulting Energy Savings

Energy consumption, measured:

	Heating	Electricity *
Before the renovation 1 September 1996 to 28 February 1997, 26 weeks	350 MWh	39 992 kWh
After the renovation 1 September 1997 to 28 February 1998, 26 weeks	328 MWh	47 849 kWh
Change	–22 MWh	+7 857 kWh

**whole school building*

Estimated energy consumption (electricity) of new ventilation system
The use of the system: 10 hours a day, 5 days a week, period studied 26 weeks

E_{fans} =	7 800 kWh
$E_{heat\ recovery}$ =	234 kWh
$E_{waterpump}$ =	349 kWh
Σ =	8 383 kWh

The heat consumption before ventilation renovation was 50 - 64 kWh/m^3/a. The electricity consumption was 5.9 - 8 kWh/m^3,a and water consumption was 0.07 - 0.085 m^3/m^3/a. The average values for typical school buildings built at this time were 52 kWh/m^3/a for heating energy, 8.8 kWh/m^3/a for electricity and 0.18 m3/m3/a for water consumption. The energy consumption figures were equavalent to average schools while water consumption was lower. The problem was poor IAQ, and according to the questionnaire, both teachers, students and employees complained about the indoor air quality, which was confirmed by measurements.

8 User evaluation

Questionnaires to teachers before and after the renovation

Percentages of teachers who suffer indoor air problems:

Symptoms	Before	After
Inadequate ventilation in winter, weekly	67 %	22 %
Stuffy air in winter, weekly	44 %	13 %

Before retrofitting the CO_2 concentration at the end of the lessons could increase > 1500 ppm. This was especially apparent during afternoon lessons, when the CO_2 concentration was already high at the beginning of the lesson. There were also dust problems and too high indoor temperatures in some areas. These results show that the main problem has been solved by ventilation renovation. The indoor air quality has improved. The total energy consumption has reduced because of the heat recovery of ventilation, but the changes of the system increased the consumption of electricity.

9 Renovation costs

Ventilation work: 240 FIM/m^2 = 40 €/m^2

10 Experiences/Lessons learned

10.1 Impact on indoor climate

The quality of the indoor air measured in the school buildings of the project was significantly improved after renovation. The CO_2 concentrations varied between 1200 ppm and 2400 ppm before the renovation.
After the renovation process the CO_2 concentration in these schools (originally equipped with natural ventilation) was below 1250 ppm and the maximum values decreased on average by 850 ppm.
The maximum values of CO_2 during one lesson (45 min) in this case study school varied 1500 - 1700 ppm before renovation, and after the renovation the values were 650 - 750 ppm. The temperature increase during the lesson was 1.5 - 2.5°C before the renovation and after the renovation only 1°C. The relative humidity maxima before the renovation was 34 - 39% and after the renovation 32 - 35%.

Because of weather conditions in Finland, in order to guarantee proper indoor air quality in schools and to gain high energy economy, school buildings mainly have to be equipped with mechanical ventilation and heat recovery in the renovation. This does not exclude the use of hybrid ventilation systems or boosted natural ventilation systems, if these systems are installed and implemented in a proper way.
In order to achieve good ventilation performance and good indoor air quality, school building owners (and authorities) should demand more detailed plans and calculations from designers and pay also more attention to a good learning and teaching environment. In life cycle cost calculations, the costs of better indoor air quality/student/year are not significantly higher compared with the lower indoor air quality level.

Measurements	Before	After
Maximum of CO_2 during one lesson (45 min)	1500–1700 ppm	650–750 ppm
Maximum temperature of indoor air	+24 °C	+24 °C
Increase of temperature during one lesson	1.5–2.5 °C	1 °C
Maximum of relative humidity of indoor air	34–39 %	32–35 %

Quality of indoor air in classrooms before and after the renovation:

10.2 Practical experiences of interest for a broader audience
Considering the Finnish outdoor climate, it has been proven by measurements and questionnaires that in order to guarantee good indoor air quality and to reach high energy economy, school buildings in Finland have to be equipped with mechanical supply and exhaust ventilation which also includes heat recovery from the exhaust air.

In order to achieve successful ventilation and good quality of indoor air, school building owners have to demand more detailed plans and calculations from designers and give them enough time to finish them properly.

Commitment of the various parties involved in a construction project to an indoor climate goal is still a new concept in current construction and confirmation of the goal in the sites under study was incomplete in both the planning and contracting phases. Nevertheless, the developers of the sites studied thought that the goal was achieved quite well, or at least satisfactorily. These evaluations were supported by the results of indoor climate measurements.

Planning applications facilitate the calculations needed to achieve a good indoor climate. In order to be able to evaluate the adequacy and accuracy of the calculations, the client should require them to be presented and documented as planning documents. This would improve the quality of the plans and the compatibility of the final results with the design aims.

In current construction practice, a goal-oriented implementation process is hindered by the dividing up of responsibility for implementation of the indoor climate among too many parties. Each party should commit themselves to indicating the implementation of their share by means of either calculations or measurements. Furthermore, control of this type of system requires a development organization with sufficient professional supervisory resources.

Measurements in all cases verified an improvement in IAQ. However, the analysis of the renovation process revealed that improvements could have been higher if regulations and good practice had been followed carefully at all stages.

10.3 Resulting design guidance

The reports of the research projects and the guidance books have been sent to all cities in Finland.

11 General data

11.1 Address of project

Oulujoen ala-aste, Sangintie 129, FIN-90650 OULU

11.2 Project dates

Research projects:
Indoor Air and Energy Economics in School Buildings 1996–1999
Implementation of Ventilation in Educational Buildings 1999–2000

11.3 Date of report / revision no.

22nd January 2003

12 Acknowledgements

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