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Retrofitting halves school's heating bill

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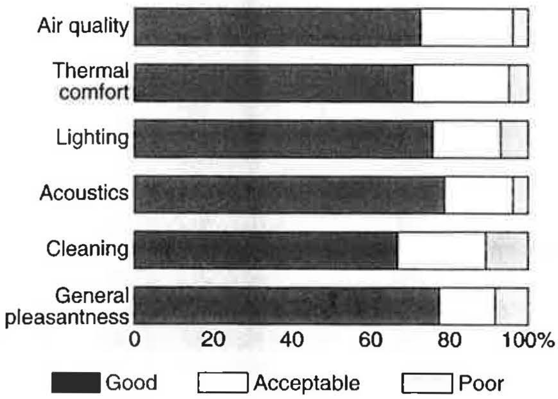
The Jändel school in southern Sweden was thoroughly retrofitted in 1994-95. Both lighting and ventilation systems have been designed for high energy efficiency. New windows with excellent insulating performance have been installed. A before and after comparison shows that the energy required for heating has been reduced from about 210 kWh/m² to about 94 kWh/m² a year, i.e. a reduction of about 55%. Electricity for building services systems has decreased by about 20%, despite the fact that considerably more computers are used in the school today than prior to rebuilding.

The Jändel school, Sweden.

Figure 1: The results of the questionnaire at the Jändel School.



The Jändel School outside Karlskrona in southern Sweden was built in the 1960s in the form of single-storey buildings with flat roofs. During 1994-95, it underwent major retrofitting. The school now has a pitched roof, reducing the risk of moisture damage and providing space for fan rooms and ventilation ducts.

Both lighting and ventilation systems have been designed for high energy efficiency. New windows, with very low U-values have been installed. This has eliminated cold downdraughts from the windows, so that radiators are no longer needed below them. Instead, any extra heat that is needed is supplied via the ventilation air. In order to prevent excessive temperatures in classrooms, the windows have a protective solar layer.

Measurements of both the indoor climate and energy use were made during January 1995. The results, complemented by a questionnaire that was carried out at the same time, show that the indoor climate is very good and that the overall energy efficiency is good (see **Figure 1**).

A comparison before and after retrofitting shows that the energy required for heating has been reduced from about 210 kWh/m² a year to about 94 kWh/m² a year, i.e. a reduction of about 55%. Electricity for building services systems has also fallen significantly, by about 20%, despite the fact that considerably more computers are used in the school today than prior to the rebuilding.

Questionnaire

The overall result from the questionnaire was excellent. About 90% of those questioned (both pupils and teachers) felt that air quality, thermal comfort, lighting, acoustics, and the general standard of the environment were good or acceptable.

Ventilation and heating

After the retrofitting, the heating system was integrated into the ventilation system. Any additional heat needed is supplied to the air in the building by the ventilation air.

The ventilation system consists of four air treatment units, installed in the roof space. The main distribution ducts are large enough to allow entry for maintenance and cleaning. Heating coils are placed in the main distribution duct.

The fans are of an axial type, with variable frequency speed control. The heat exchanger is a double flat-plate heat exchanger with bypass dampers for capacity control.

There are no air filters in the system: instead, insect netting is fitted over the supply air intakes. The school is in a rural area, with little air pollution. Some of the larger dust particles settle out in the distribution ducts, so vacuum cleaners allow cleaning at each air-handling unit and in the supply air duct.

The air-flow rate to each classroom is about 200 l/s, i.e. almost 7 l/s per person in a full classroom. Air is supplied through two supply air fittings mounted in the wall, blowing the air downwards at high speed, as shown in **Figure 2.**

Although the air velocities at the supply fittings are high, integral ejectors for the room air, together with the fact that the high air velocities are limited to a space of only a few centimetres above the floor, mean that no draught problems are experienced. This was confirmed by the results of the questionnaire and by interviews with personnel.

Air velocities 85 cm from the air supply fittings:

Height above the floor (cm)	Air velocity (m/s)
2	1.25
10	0.40
30	0.12
60	0.10

The air is distributed across the floor, and then rises to be removed through exhaust air fittings in the ceiling.

During the summer, the air-flow rate can be increased to about 300 l/s per classroom. The night air-flow rate is about 120 l/s per classroom, i.e. about 60% of the day rate.

Electrical efficiency

Measurements show that the specific fan power (SFP) is about 1.5 kW (m³/s) at the nominal flow rate of about 200 l/s per classroom. The annual average value of SFP is even lower, at about 1.2 kW (m³/s).

Specific fan power is a key quantifier in describing the electrical efficiency of a ventilation system. The lower the value, the better the performance. For new buildings, NUTEK recommends an SFP target of 1.5 kW (m³/s).

Air quality

Measurements of carbon dioxide concentration and smoke in a classroom show that the air change performance is good, as illustrated in **Figure 3.**

Noise

No complaints about noise were received during the questionnaire. Measured noise level in a classroom, without activities, is about 27 dBa, which is a low value.

Room temperatures

Both equivalent temperature and room temperature were measured in a classroom. The equivalent temperature allows for the effects of draughts and radiation. Draughts and cold surrounding surfaces have the effect of making the equivalent temperature lower than the air temperature. The measurements showed that the equivalent temperature was about 1°C lower than the air temperature (see **Table 1**).

Figure 2: Each classroom contains two supply air fittings in the corridor wall.

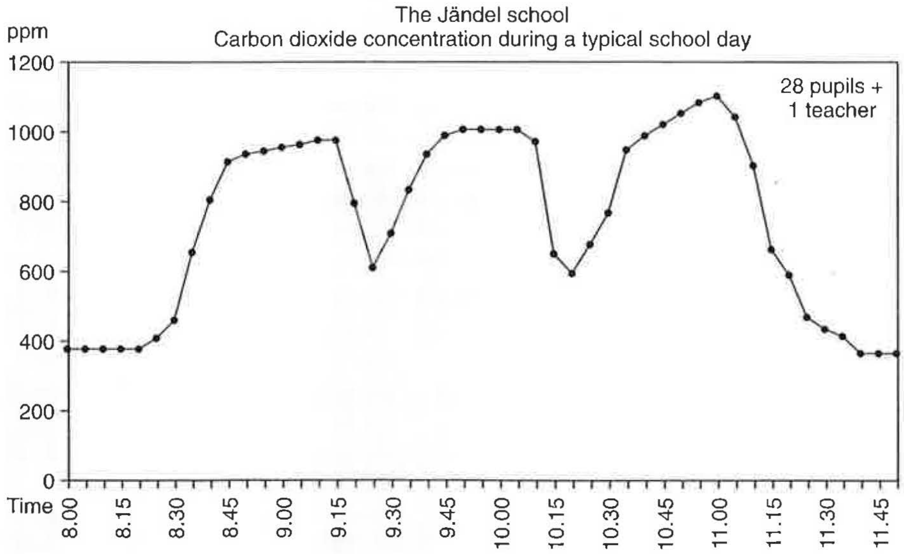


Figure 3: Variations in carbon dioxide concentration during a morning in January. The measurements were made at a height of 170 cm above floor level. At the breathing zone level (h = 110 cm), the carbon dioxide concentration is about 100 ppm lower.

Measurements in a classroom	
Measured equivalent temperature	Max. 21.5°C (in a full classroom) Min. 17°C (at the start of a lesson)
Outdoor temperature	+3°C

Table 1: Equivalent temperatures measured in a classroom.

At the time of making the measurements, the supply air temperature was about 19°C.

Windows
Extremely high-performance windows were installed in the Jändel School, having a U-value of 1.0 W/m²K, which is low. A standard triple-glazed window has a U-value of about 1.8 W/m²K.

The surface temperature of the inside of the glass was measured at six points. The room temperature was 20°C and the outdoor temperature 3°C. The lowest temperature on the inside of the window was about 19°C, which was also the lowest temperature on the casement. This means there is no risk of cold downdraughts or radiation draughts. This was also confirmed during the smoke tests that were performed: there were no downward air currents by the windows.

Heat recovery
A double flat-plate heat exchanger was installed for heat recovery. Made of polypropylene, it has a high temperature efficiency of almost 90%. However, this high temperature efficiency is at a price, in the form of pressure drop. The pressure drop across the heat exchanger is about 350 Pa, which means that a fan power of almost 1.5 kW per fan is required to drive the air through the heat exchanger at the air-flow rates used.

Lighting
Luminaires in the classrooms and group rooms etc. incorporate high-frequency lamps. This has the effect of reducing the required installed power by about 25% relative to conventional lamps, as well as eliminating flicker.

Lighting in corridors and classrooms is turned off by occupancy sensors.

NUTEK's recommendations for lighting in schools are largely complied with (see **Table 2**).

Luminances are high, which means there is a risk of dazzle.

The luminaires produce both up-light and down-light. The ceiling height is 2.5 m, and the luminaires are fitted at a height of 2.3 m. Installed lighting capacity in classrooms is about 9 W/m².

Cost of investments

The total cost of retrofitting the school was about SEK 15.3 million (USD 2.2 million) in 1995. The total retrofit area is 3,560 m². The cost of a conventional retrofit would have been a little higher, about SEK 16.7 million (USD 2.4 million). If we compare the cost of the new ventilation system with a conventional retrofit the cost is about SEK 400,000 (USD 57,000) lower: SEK 2.4 million compared to SEK 2.8 million. This is mainly because the ventilation system is "simpler" than a conventional system, without a lot of advanced technology.

The electrical installations (which include lighting) were more expensive than a conventional retrofit: SEK 850,000 (USD 122,300) compared to SEK 620,000 (USD 89,200). This is due to more advanced control equipment for the lighting. The system has both occupancy sensors and daylight sensors.

The total cost was lower because no new radiators were installed. With the new superinsulating windows not much heat is needed. When the school requires extra warmth, the heat is distributed with the ventilation air.

Conclusion

The energy use for heating in the school was reduced from about 210 kWh/m² a year to about 94 kWh/m² (about 55%). Electricity is reduced by about 20%. The cost of the investment is lower than a conventional retrofit which tells us that energy efficient retrofits do not have to cost more. Goals need to be set up for energy efficiency that are then followed throughout the entire building process. It is also very important that everyone involved in the project is informed about the goals that have been set, and their role to help achieve them.

As an extra bonus the students and teachers working in the Jändel school now have a much better indoor climate.

Table 2: Lighting measurements.

Lighting in classrooms	Measured value	NUTEK's recommendations
Illuminance, reading zone	600 lux	> 500 lux
Illuminance, general	> 300 lux	> 300 lux
Illuminance, blackboard	about 300 lux	> 500 lux
Luminance, normal field of view	Max. 6000 cd/m²	< 3500 cd/m²
Flicker	HF operation	HF operation
Installed power	9 W/m²	13 W/m²

For further details, please contact Michael Kronström, Karlskrona Local Authority, Properties Section, tel.: +46-455 83 117, or the Swedish National Team (address on back cover).