1. Energy-Efficient Retrofit of the Käthe-Kollwitz-School in Aachen, Germany

1.1 Photo

Figure 1: Entrance area of the school before the retrofit

1.2 Project Summary

The Käthe-Kollwitz-School showed very high heating energy consumptions before the retrofit. Together with poorly insulated exterior surfaces, which resulted in non-optimal teaching and learning conditions, and damaged building parts, this lead to the idea of taking part in the German retrofit programme "EnSan" of the Ministry of Economy. All demonstration buildings in the programme have the aim to reduce the primary energy of heating and electricity by 50 % by the retrofit. For Käthe-Kollwitz-School this meant to improve the energy efficiency of the external envelope and of the heating, ventilation and lighting systems. The school was going to be retrofitted in three parts, using the experiences gained from the first part for the subsequent parts.

1.3 Site

Aachen is located in the Western part of Germany close to the Belgian border at an elevation of about 100 m. It's climatic conditions are best described by the Essen Test Reference Year (TRY). The coldest month is January with a mean of 1,9 °C, the warmest July with 17,4 °C. The mean annual temperature is 9,6 °C and the mean winter temperature 7,1 °C.

1.4 Building description /typology

1.4.1 Typology / Age

The school was erected in the years 1951 and 1955 in Aachen-Burtscheid. In the year 1978 the school was enlarged by a sports hall and in 1990 by an extension. The building harbours at 9600 m² gross floor area about 2200 pupils and 85 teachers. It consists of three parts with different ages and a sports hall and is used nowadays as a vocational school. The different building sections were erected mainly as a side-corridor school, but are linked in a way that can be described as the comb-shaped school type.

Typology/Age	Pre 1910	1910-1930	1930-1950	1950-1970	1970-
The comb-shaped school				x	x

1.4.2 General information

The block of buildings to be renovated was built in several sections during the fifties, the seventies and the nineties (1951, 1955, 1978,1990). The total floor area amounts to 9600 m². A typical classroom is about 55 m² and meant for about 20 pupils. The work in the school building started in 2000 and was finished in the 2003.

1.4.3 Architectural drawings

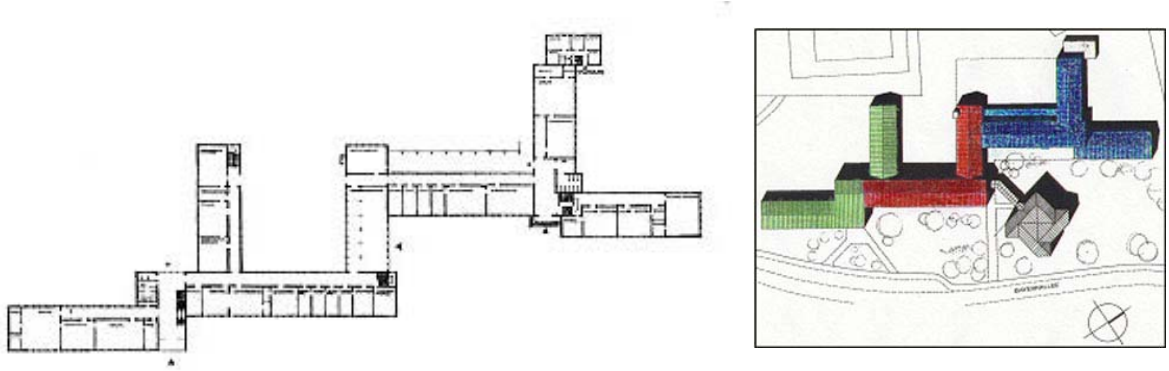

Figure 2: Left: Floor plan of the Käthe-Kollwitz school building.
Right: Aerial view of the different retrofit sections.

1.5 Existing heating, ventilation, cooling and lighting systems

Heating:
The existing central heating system was supplied by two gas burners with each 500 kW load. The heat delivery was managed by fluted radiators made of steel or cast iron. Not all rooms had thermostats.

Figure 3: Photo of the gas burners before the retrofit

Ventilation:
The classrooms and the rooms for teachers were naturally ventilated by the windows. The kitchen and the practical room for chemistry were mechanically ventilated. Air-conditioning is not necessary.

Lighting:
The actual lighting system was outdated in most parts. In some areas the lighting system had been replaced in recent years without exploiting the possibilities to save energy. Non-cut-off flourescent tubes are partly still installed in the classrooms. Additionally opal bowl luminaires are used.

1.6 Retrofitting energy saving features

1.6.1 Energy saving concept

As the school must remain in use, the retrofit will be realised in three parts, each one during the long summer holidays. The main aims of the project are to reduce the primary energy consumption by 50 %, to present a model-like integrated planning process and to control the calculated demands by monitoring and documentation. Additional aims are to include the users like teachers, pupils and the caretaker, to include measures like the design of the surroundings, use of solar thermal energy and rainwater use and to pay attention to a preferably short payback time.

1.6.2 Building

Status quo of the building fabric before the retrofit:
The external walls consist of 36,5 cm of brickwork, visible from the outer side and covered with plaster on the inner side. At the radiator niches, the wall thickness was only 14 cm. The windows dated from 1951 and were therefore single glazed. The frames were partly rotten and untight. The attic floor is not used and neither the ceiling to it nor the roof was insulated. There is a cellar below most parts of the building. The cellar ceiling and the base slab of the other areas were not insulated.

Retrofit Concept:
The external walls will be insulated with a composite thermal insulation system using polystyrene foam. In some parts a high-quality elemented facade insulated with mineral wool will be applied. The insulation thickness in both facades will be 12 cm. With the exception of the newest building segment all windows will be replaced by wooden/aluminium framed windows with low-e-coatings and a U-value of 1,3 W/m²K. The top ceiling will be insulated with a 20 cm thick cellulose fill. The walls of the heated parts of the cellar and the cellar ceiling to the unheated parts will be insulated, too. Table 2 presents the U-values before and after the retrofit.

Surface	Area [m²]	U-Value [W/m²K]	
		Before retrofitting	After retrofitting
External wall	1400	1,4/2,6	0,27/0,30
Windows	3100	5,2	1,3
Base floor/cellar ceiling	3150	1,7	0,30/1,7
Ceiling to the attic floor	3150	1,7	0,17

Table 2: U-values of the building envelope before and after retrofit.

1.6.3 Heating
During the retrofit the existing two gas burners with a load of 500 kW each will be removed and the supply will be transfered to the district heating system. The single pipe systems will be replaced by a double pipe system and parts of the existing heating elements will be removed since the heat load will be much smaller. The domestic hot water will get a smaller water storage with a volume of 300 l. Formerly the school had two storage vessels of 1000 litres each. The reduction was proved to be optimal by measurements.

1.6.4 Ventilation
It was decided to install a decentralised mechanical ventilation system with controlled exhaust air fans. A central building control system including a single room control for the heating of the classrooms, the lighting of the rooms and the user-dependent ventilation will help to decrease the energy demand of the building.

1.6.5 Lighting
The existing electrical lighting will be replaced by dimmable energy efficient light tubes in reflecting housings with electronic ballasts.

1.7 Resulting energy savings
As the retrofit is still under construction only calculated data for the time after the retrofit can be given. The current primary energy consumption of the building amounts to 299 kWh/m²a. From that 252 kWh/m²a are needed for the heating and 17 kWh/m²a are needed for the electrical energy (multiplied by the factor 2,8). The aim is to reduce the primary energy consumption to 140 kWh/m²a.

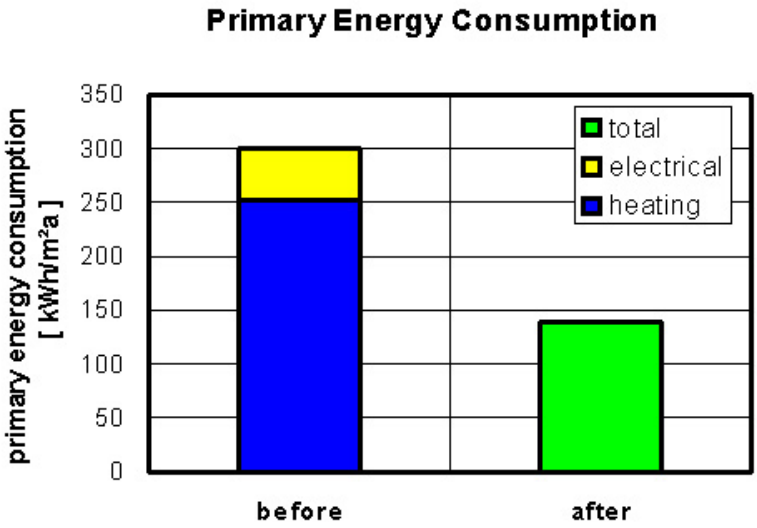

Figure 4: Energy consumption before and calculated demand after the retrofit.

1.8 User evaluation

The retrofit is still ongoing in some parts. Therefore the users were not yet asked to evaluate the changes. However, some photos of the retrofitted building parts are available.

Figure 5: Photos of the auditorium (left) and the administration block (right) after the retrofit.

1.9 Renovation costs

The costs of the retrofit of the Käthe-Kollwitz-School were estimated to be about 2,8 Million Euros. In table 3 the expected costs are divided into the different construction elements.

Position	Cost estimation [Euro]			
	Section 1	Section 2	Section 3	Total
External wall	119.315	127.928	137.348	384.591
Windows/doors	335.372	267.840	161.364	764.576
Roof/top ceiling	35.059	82.325	54.002	171.386
Cellar ceiling/cellar walls	7.133	26.587	-	33.720
Additional building costs	20.196	54.197	66.724	141.117
Heating/ventilation/lighting systems	368.920	140.057	219.286	728.263
Design	259.315	141.598	141.769	542.682
Total	1.145.310	840.532	780.493	2.766.335

Table 3: Cost-estimation of the retrofit.

Currently the construction of section 1 is finished. The costs increased by 5 % compared to the estimations, which was mainly caused by higher costs for the heating and ventilation system (+20 %). Table 4 shows the final costs of the separate elements. The costs for the external wall represent both the composite insulation system (103 Euro/m²) and the high-quality elemented facade (200 Euro/m²).

Position	Estimated	Realised	Building element related
	Euro	Euro	Euro/m²
External wall	119.315	156.707	175
Windows/doors	335.372	236.144	310
Roof/top ceiling	35.059	40.743	53
Cellar ceiling/cellar walls	7.133	7.132	46
Additional building costs	20.196	62.303	-
Heating/ventilation/lighting system	368.920	442.831	-
Design	259.315	259.315	-
Total	1.145.310	1.205.175	-

Table 4: Comparison between cost-estimation and realised costs for section 1.

1.10 Experiences/lessons learned

not yet available.

1.10 General data

1.10.1 Address of project

Käthe-Kollwitz-Schule, Bayernallee 6, 52066 Aachen, Germany

1.10.2 Project dates
Project initiation: 1999
Design completed: 2000
Renovation construction completed: 2003
Monitoring and evaluation completed: 2005

1.10.3 Date of report / revision no.
January 2004, no. 1

1.11 Acknowledgements

Project Coordination	City of Aachen, Department Building Management
Research Team	contor für architektur und stadtplanung aachen (casa) VIKA-Ingenieur GmbH, Aachen
National Support program	German Ministry of Economy and Technology Projektträger Jülich (PTJ)

Author: Heike Kluttig, Fraunhofer Institute of Building Physics

1.13 References
[1] project homepage: www.ensan.de