

Exemplary Retrofitting of an Old School in Stuttgart - EROS -

City of Stuttgart, Germany

Summary

The objective of the project was to demonstrate the potentials of a retrofitting process for a typical school in West-Germany from an energy point of view. The block of buildings that was renovated was a primary school in the city of Stuttgart, built in several segments during the thirties, the fifties and the seventies. Supervised by Stuttgart's municipal office of environmental protection, the Fraunhofer-Institut für Bauphysik (IBP) and the Institut für Kernenergie und Energiesysteme (IKE) worked out an action plan from an energy point of view. In this process the municipal office for construction, the architect, engineers and our project partners from industry were involved. The design phase was completed during spring 1996. An architect together with an HVAC-engineer planned and realised the retrofitting, supervised by the municipal office for construction. The work in the school buildings started in the summer break 1996 and finished summer break 1997. After the realization phase a two-year period of measuring the actual energy consumption gave proof of the concept.

End-user area	Target Audience	Technical
<input type="checkbox"/> New buildings	<input type="checkbox"/> Citizens	<input checked="" type="checkbox"/> Energy efficiency
<input checked="" type="checkbox"/> Refurbishment of buildings	<input type="checkbox"/> Households	<input checked="" type="checkbox"/> Heating
<input type="checkbox"/> Transport and mobility	<input checked="" type="checkbox"/> Property owners	<input type="checkbox"/> Cooling
<input type="checkbox"/> Financial instruments	<input type="checkbox"/> Schools and universities	<input type="checkbox"/> Appliances
<input type="checkbox"/> Industry	<input type="checkbox"/> Decision makers	<input type="checkbox"/> Lighting
<input type="checkbox"/> Legal initiatives (municipal regulations, directives, etc)	<input checked="" type="checkbox"/> Local and regional authorities	<input type="checkbox"/> CHP
<input type="checkbox"/> Planning issues	<input type="checkbox"/> Transport companies	<input type="checkbox"/> District Heating
<input type="checkbox"/> Sustainable communities	<input type="checkbox"/> Utilities	<input type="checkbox"/> Solar energy
<input type="checkbox"/> User behaviour	<input type="checkbox"/> ESCOs	<input type="checkbox"/> Biomass
<input type="checkbox"/> Education	<input type="checkbox"/> Architects and engineers	<input type="checkbox"/> Wind
<input type="checkbox"/> Other	<input type="checkbox"/> Financial institutions	<input type="checkbox"/> Geothermal
	<input type="checkbox"/> Other	<input type="checkbox"/> Hydro power
		<input type="checkbox"/> Other

Context

The block of buildings that was renovated is a primary school in the city of Stuttgart, built in several segments during the thirties, the fifties and the seventies. The floor area of 5420 m² includes the classrooms, halls, lobbies and staircases and a gymnasium. Each part of the construction is typical for its period. Thus the building represents the average school building in the western part of Germany.

The energy consumption in the early nineties averaged at about 210 kWh/m²a, the original value of 1977 being 382 kWh/m²a. This was mainly the result of „good housekeeping“, that is ‘no-cost measures’. The Normalized Performance Index (NPI) for electricity was 11 - 12 kWh/m²a.

Objectives

The objective was to demonstrate the potentials of a retrofitting process for a typical school in West-Germany from an energetic point of view. Combining the renewal of the space heating system with the reconstruction of the building envelope yields synergetic effects. The project aimed at minimizing the future energy consumption and optimizing the economy of the retrofitting at the same time. Thus, both operating costs and emissions are reduced. The goal was also to improve the thermal insulation at least according to the standard of the German regulations on thermal insulation (1995) for new buildings.

Process

Supervised by Stuttgart’s municipal office of environmental protection, the Fraunhofer-Institut für Bauphysik (IBP) and the Institut für Kernenergie und Energiesysteme (IKE) worked out an action plan from an energetic point of view. In this process the municipal office for construction, the architect, engineers and our project partners from industry were involved. The design phase was completed during spring 1996. An architect together with an HVAC-engineer planned and realised the retrofitting, supervised by the municipal office for construction. The work in the school buildings started in the summer break 1996 and finished summer break 1997. After the realization phase a two-year period of measuring the actual energy consumption gave proof of the concept.

The first step was to get a detailed picture of the status quo. Both the building envelope and the heating system had to be analyzed. Based on surface area, heat transmission coefficients and the occupation of the building, the theoretical heat demand was calculated. The IKE did the analysis of the heating system including boilers, piping, control and radiators.

Status quo of the building fabric (IBP)

From an energetic point of view the building fabric met the requirements during the time of construction: The first segment, building 1, is a solid brick building. In the 1950’s a reinforced concrete building with solid brick clothing was added (building 2). Building 3, added 20 years later, is a reinforced concrete framework with three-ply- boards as internal and external thermal insulation.

All buildings suffered from severe heat losses through heat bridges, especially at the building component connections. The windows were mostly composite windows with wooden frames (double glazing) without sealing. They showed severe deficiencies.

The lighting had to be considered as poor due to strong dazzlement - effects. Thus the artificial lighting was switched on during daylight hours despite sufficient daylight supply while the blindings were closed at the same time.

Concept of the building

Due to the very heterogeneous wall types different thermal insulation systems were used. A list of possible insulation systems was developed (i.e. heat insulation plaster, composite thermal insulation, internal insulation). For all buildings, the greatest possible savings could be achieved by insulating the outside walls. Styrofoam as internal insulation was to be applied where the original facades were kept untouched. On most of the other facades an external insulation was applied. Different systems were

compared regarding energy efficiency and costs to gain experience for future planning. Insulating the roof of the gymnasium was to yield great savings too.

Much smaller is the influence of improved windows. For the windows the potential of the passive use of solar energy and aspects of lighting had to be considered. A low-E coated glazing with a lower thermal transmission coefficient (U - value) would reduce the heat loss of the building but at the same time suffer from a lower g - value and a lower light transmission due to the infrared reflecting layer on the glass. Thus north facing windows would intentionally have different properties compared to south facing windows. The glazing had to be optimized with respect to the total energy consumption including heat and lighting. Different types of frames (aluminum, wood-aluminum and PVC) combined with various glazings ($k_v = 1,8; 1,3; 1,0$ and $0,8 \text{ W/m}^2\text{K}$) are compared.

The roof of building 2 could easily be insulated by teachers and students themselves using Styrofoam which would reduce the costs significantly and the school community usually has a much closer relation to energy issues when own activities of the school community are involved.

In other projects, was observed that insulating roofs of school buildings (total area 13.000 m^2) originated a reduction of energy consumption exceeding the calculated amount by a factor of up to 2.

The combination of measures with the optimum cost effectiveness was evaluated, at first for all building components separately. The next step was to compare the best solution for each component for the whole building. The annual heat savings were plotted versus the cost of the measure. In this evaluation it was considered that additional insulation reduces the heat load and thus leads to a smaller heating system. ($0,54 \text{ DM/W}$ for the radiator and $0,18 \text{ DM/W}$ for the boiler)

The replacement of the lighting system was not cost effective. Only if the painting of the room (higher reflection) and the new lamps are considered no cost measures, the additional control system is cost effective. In a segment of building 2 two different control strategies are implemented, both with the EIB system.

Status quo of the heating system

For the HVAC-system, too, the technical standard is typical for the time of construction. No major retrofitting has been done so far. All three buildings of the school got their heat from a boiler house in the oldest building. The low-pressure steam boilers (1969) with 800 kW where originally fired with coal and later converted with an oil/gas burner. The boilers were switched on and off by the caretaker. Building 1 was still heated with steam, building 2 and 3 had a hot water system fed by a heat exchanger. Piping and radiators stem from the time of construction. The circuits had a weather compensating control with fixed time settings. In the classrooms no further control devices are installed.

Concept for the heating system

The heating system of the school was completely renovated. The boiler house with boilers and piping was completely replaced. The low pressure steam system in building 1 was replaced as well. The new radiators were sized by the rule of Bach: The width of the radiator equals the width of the window above. Additionally, the product of radiator area times temperature difference between mean radiator temperature and room temperature has to be equal to the product of window area times the temperature difference between surface temperature of the window and room. Thus in the biggest possible area of the room comfortable conditions can be obtained.

In building 2 the existing radiators remained. Zone controls were installed there to adjust the room temperature to the actual requirement. To only heat the classrooms during class hours, the teacher

has to press a button close to the door to continue heating the room for the following hour. Otherwise the temperature drops to a base temperature.

In building 3 the radiator valves were replaced by tamper-proof thermostats.

For the office of the headmaster a separate control circuit was installed to allow off hour heating.

For the apartment of the caretaker a completely separate heating system with a small gas boiler was installed.

Two boilers delivers heat for space heating: A condensing boiler for base load, and a low temperature boiler for peak load, both with low NO_x - gas burners.

The peak load of the boilers can be reduced by 60 %. The system temperature is 60°C/40°C at -12°C ambient temperature. The radiators were oversized to allow a quick heat up in the intermitting operation of a school.

The simulation showed that the low temperature level allows an optimal use of the condensing boilers during the heating period.

Measurements

For two years, the energy consumption of the building was monitored by the IKE.

The goal was to obtain the actual energy balance of the building complex, to verify the simulation models and to optimize the operation of the building (heating, illumination and shading). Therefore a number of sensors were installed in the building: Temperature-probes, heat meters for the circuits and some classrooms, gas meters, illumination meters, pressure difference probes for the heating circuits and sensors for the operating status (window, blindings, lighting etc.) lead to a precise understanding of the actual conditions in the school.

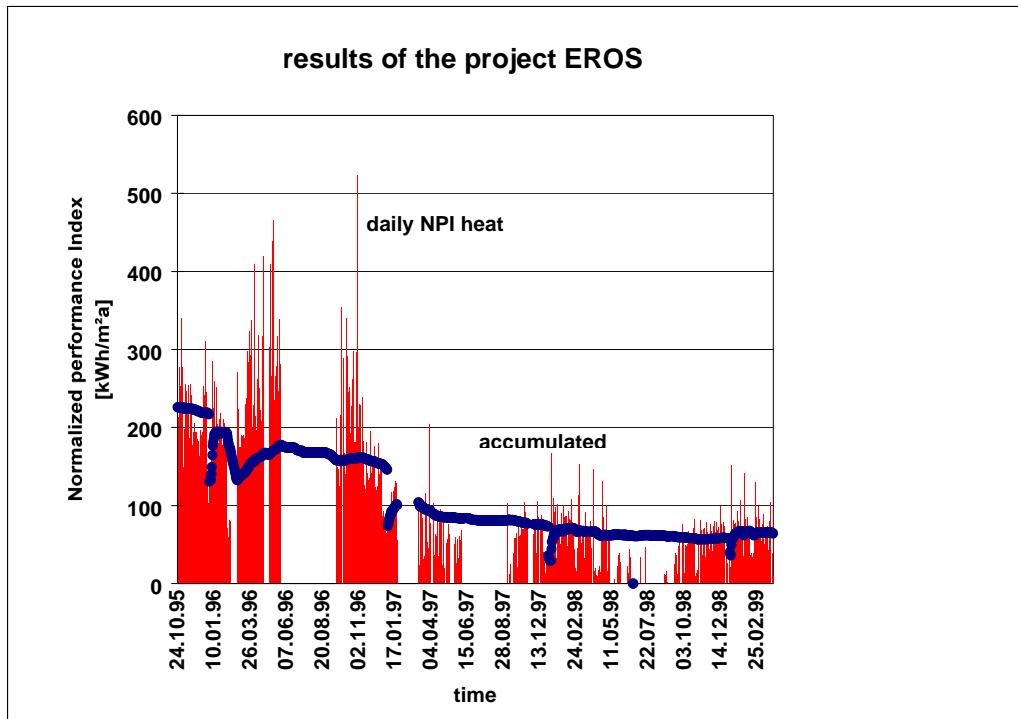
Financial resources and partners

The financing of the project relied on three partners:

The city of Stuttgart took care of the basic renovation. 11 partners from industry sponsored the project with a total amount of DM 700,000.

The federal secretary of state for research gave an additional funding of DM 1,900,000 for the research part of the retrofitting. The project was calculated with total costs of DM 4,200,000.

Results



Lessons learned and repeatability

When retrofitting old buildings, not only the building deficiencies must be repaired. The complete building with both the building shell and the HVAC - system has to be analysed to find the concept with the best-cost efficiency. With the low budget of the municipalities this approach is a novel one and will be hard to establish.

Contact for more information:

Organisation / Agency: Landeshauptstadt Stuttgart Amt für Umweltschutz
 Main contact: Dr. Ing. V. Kienzlen
 Address: Gaisburgstraße 4, 70182 Stuttgart
 Tel: 0711/216-2241
 Fax: 0711/216-2413
 E-mail: u360500@stuttgart.de