A Retrofitting for Energy Conservation including Atria: The Bertolt-Brecht-School in Dresden, Germany

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1 Photos

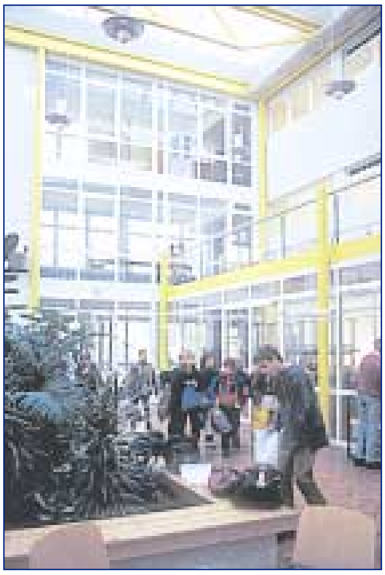


Figure 1: *Left:* North-west view of the school after retrofitting.
Right: The eastern courtyard, now transformed into an atrium.

2 Project summary

The Bertolt-Brecht-School represents one of the so-called "typical schools" built with a prefabricated modular concept (Plattenbauweise) in the former German Democratic Republic in the 60's and 70's. About 180 schools of this type exist in the Dresden area alone. The heating energy consumption of the school was very high before the retrofit because of no insulation, bad window qualities and poor airtightness. The energy-efficient retrofit concept included the reduction of the thermal transmittance of the building envelope and the transformation of the courtyards into two atria. Thus they can be used as common rooms such as canteen and auditorium. The aim was to show the energy saving potentials and the possible improvements of the school's social facilities.

3 Site

The Bertolt-Brecht-School is located in the urban environment of the city of Dresden, the capital of the state of Saxony, in the Eastern part of Germany at Lat. 51° north, Long. 13.9° east at an altitude of 106 m. The monthly average outdoor temperatures are close to 0°C (D:0.4°, J:–112°, F:–0.7°,M:3.2°) in winter and near 17°C (J:16.5, J:18.1, A:17.8, S:14.4) in summer. The building is almost unobstructed.

4 Building description /typology

4.1 Typology / Age

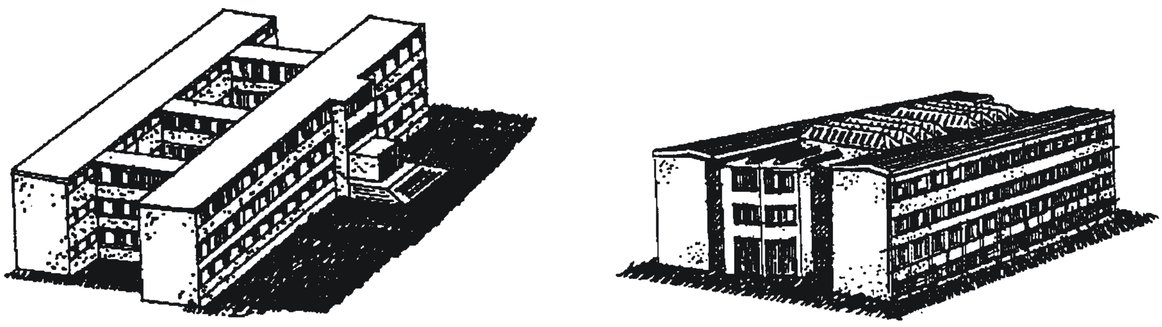
Typology/Age	Pre 1910	1910–30	1930–50	1950–70	1970–
The multi-storey school The side corridor school				● ●	
The main hall school					after retrofit

The building was built in the seventies in the Schuster style. It consisted of two blocks of which each could be put in the category of a side-corridor school, connected by the 3 staircase wells. After retrofitting, as a result of transforming the courtyards into two atria, the building can be described as a main hall school.
The building is now used as a secondary school.

4.2 General information

The Bertolt-Brecht School is one of the so-called "typical schools" built with a prefabricated modular concept (Plattenbauweise) in the former German Democratic Republic in the 60's and 70's. It was originally used as a polytechnical school. The building consisted of two rectangular east-west aligned three-storey blocks connected by three staircases.
The total floor area of 2407 m^2 includes the classrooms, atria and staircases. There are 20 classrooms with an area of 50 m^2 and 6 practical rooms. The retrofit work of the school building started in 1993 and was finished in 1995.

4.3 Architectural drawings



before retrofitting

after retrofitting

Figure 2: Isometric drawings of the Bertolt-Brecht School in Dresden before and after the retrofit showing the addition of the two atria and a new part at the western side of the school.

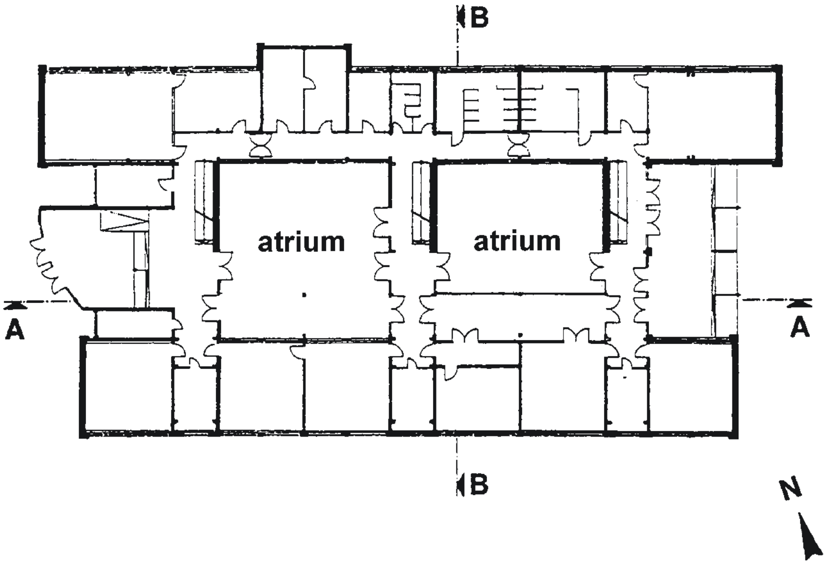


Figure 3: Ground floor plan of the Bertolt-Brecht-School in Dresden after the retrofit.

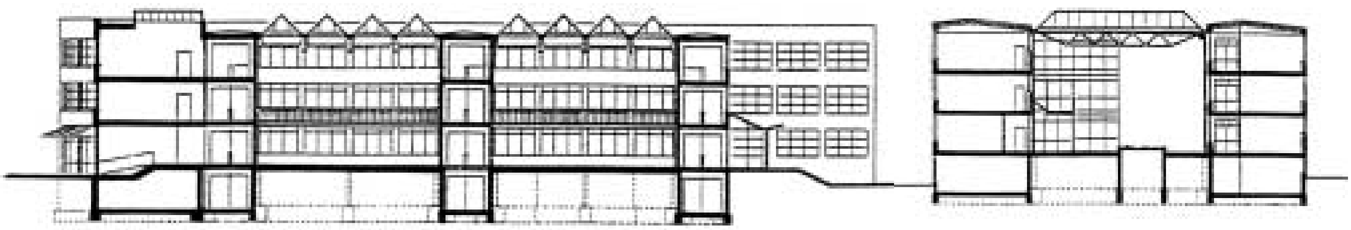


Figure 4: Two sections of the Bertolt-Brecht-School in Dresden after the retrofit.

5 Previous heating, ventilation, cooling and lighting systems

Heating:
The building is connected to the municipal heat distribution. The rooms were and still are heated by radiators with thermostats.

Ventilation:
Ventilation was provided by windows and air leakage.

Lighting:
The lighting was mainly by daylight. Because of the windows on two sides and the large window area, the daylighting conditions were good.

6 Retrofit energy saving features

6.1 Energy saving concept

Besides standard measures like improving the thermal insulation of the facades, the retrofitting process strongly concentrated on transforming the courtyards into atria, thus including these spaces into the thermal as well as social-cultural concept. The atria are the heart of the ventilation concept, allowing for night ventilation during summertime, drawing the colder air from the outside classroom facades through the classrooms into the atrium and in winter time using the opposite direction by ventilating preconditioned air of the atria into the classrooms assisted by fans. Also, transmission losses towards the former courtyards are reduced nowadays by the higher temperature levels within the atria. Additional usable floor areas of about 400 m^2 have been gained which are now used as schoolyard, auditorium and reading spaces. To gain more classroom spaces a western three storey block has been added.
The transformation of the open courtyards into atria reduced the daylight supply to the classrooms due to structural elements and the additional glazing

layer. To keep the reduction as small as possible extensive daylighting studies were performed. Due to bilateral daylight supply of most of the classrooms and the careful atrium design the daylighting condition still has to be considered very satisfactory. The demand of electrical energy for artificial lighting was significantly reduced in some classrooms by a daylight dependent artificial lighting control system.

6.2 Building

Table 1: U–Values of the building envelope before and after retrofitting.

Building part	U-Values [W/m^{2}K] Before Retrofit	After Retrofit
Exterior Wall	1.82	0.28
Cellar Wall	3.03	0.43
Ground Floor	3.50	0.44
Roof	0.95	0.25
Windows (Rooms)	2.6	1.5
Glazed Roof of Atria	–	1.6

The existing exterior walls have been insulated with 12 cm composite thermal insulation system using styrofoam. The roofs have an additional 15 cm of insulation, the ground floor and cellar walls were improved by installing 8 cm insulation. The existing windows were replaced by low-E coated glazing in wooden frames.
The main modification besides improving the insulation was the transformation from courtyards into atria. Because of this, the relationship between the building envelope and the heated volume of the building was improved. The atria are part of the ventilation concept. The floor area of the two atria is about 400 m^2. The glazed area of the atria roofs is about 300 m^2. The rest of the area of the hip roofs consists of frames and static elements. The atria were not meant for permanent use but only on special occasions.

6.3 Heating

The existing heating system of the school remained. Only malfunctioning pieces have been replaced and a new control system was installed. Due to that, a night set-back and a weekend set-back is possible. In the atria three local hot air convectors per atrium were installed at a height of 3.5 m.

6.4 Ventilation

The ventilation concept is based on the new atria. It is shown in figure 5. Night ventilation during summertime (on the right of the diagram) draws cold air from the outside classroom facades through the classrooms into the atrium. This process is supported by fans which are automatically linked to windows at the atria roofs and in the classrooms in order to prevent over-pressure. In wintertime (on the left of the diagram) the opposite direction is used by ventilating preconditioned air out of the atria into the classrooms.

6.5 Lighting

A manually managed canvas shading system below the atria roof was installed to reduce overheating. There were only few days in summer during student holidays when the room temperatures were not acceptable. The daylighting situation of the classrooms may be disturbed by the roof, especially if the shading is closed. Despite this reduction, the daylight supply to the classrooms has to be considered satisfactory. In selected rooms daylight dependent artificial lighting control systems were installed.

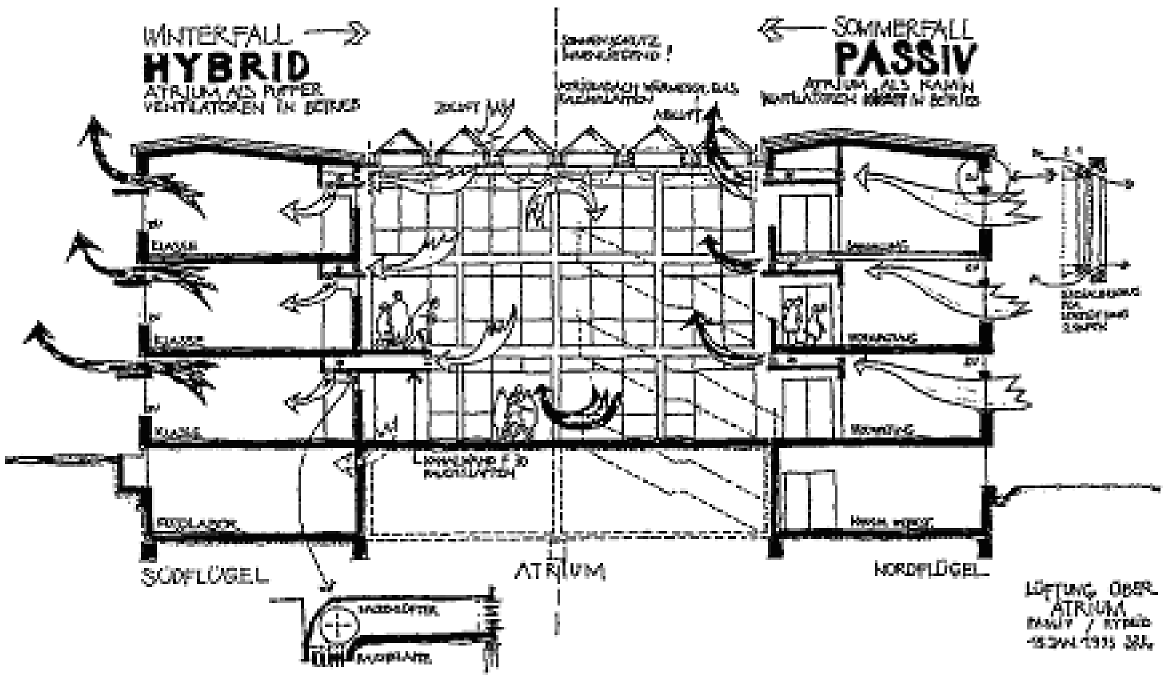


Figure 5: Ventilation concept in winter (on the left side of the diagram) and summer (on the right side of the diagram).

6.6 Other environmental design elements

The simultaneous use of the atria and the classrooms led to acoustical problems. To reduce the noise, the ventilation through the atria was reduced.

7 Resulting Energy Savings

During the concept phase several simulations were done. The daylighting investigations were performed in an artificial sky. The energy concept was validated in an extensive monitoring period over two years from 1996–1998. More than 200 sensors were installed. Amongst others things, special attention was paid to air flow dynamics between the atria and the classrooms.

Heating:

The heating energy consumption could be reduced by the retrofit by over 75%. The expected heating energy consumption of 55 kWh/m^{2}a was exceeded in both periods because of the change of usage of the atria. The difference from the energy concept is that the atria were heated during the whole heating period because the users decided after the retrofit measure to use the atria also in wintertimes.

Before Retrofitting	**After retrofitting**		
	According to Energy Concept	Monitored '96 / '97	'97 / '98
283 kWh/m^{2}a	55 kWh/m^{2}a	69 kWh/m^{2}a	69 kWh/m^{2}a

Table 2: Heating energy consumption before retrofitting and the values monitored in the two heating periods after retrofitting, compared to the heating energy demand according to the energy concept
(simulation with SUNCODE PC).

Lighting:

The quality of the daylighting situation remained good with little deficits for the classrooms at the ground floor because of the new atria roof. The comparison between rooms with and without a daylight dependent artificial lighting control system showed, that the saving of energy was about 77%, but on the other hand the system used was expensive.

Ventilation:
Because of the change of use of the atria there are also problems with the ventilation concept. The planned ventilation for the wintertime in which the fan should bring preheated air from the atria into the classrooms did not work, because the users closed the openings of the atria because of comfort problems (cold air streams). As said above the atria was not planned for consistent use in the winter. The fans nevertheless worked and they drove the air from the corridors to the atria and from there to the classrooms. By that only pre-used air could be gained and electrical energy for the fans was used. The users have to open the windows as before to get fresh air. Thus the ventilation strategy for the winter could not be realized. The automatic night ventilation during the summer time worked very well.

8 User evaluation

The acceptance of the atria as a meeting point and location for social activities was very high, so they were also used during lessons as classrooms. Because of the ventilation through the atria, there are sound paths which caused some acoustical nuisance.
The daylighting of the classrooms was sufficient, the handling of the control system was acceptable to the users. The manually managed shading system of the roof of the atria was unsatisfactory because of sporadic use. Initially it was planned to have an automatic control, but manual controls were installed to reduce costs.
The ventilation was not as efficient as expected because of the change of use in contrast to the energy concept. The consequence was that ventilation through the windows had to be used more often.

9 Renovation costs

No detailed cost information is available.

10 Experiences/Lessons learned

10.1 Energy use

The heating energy demand was decreased by 75%, the artificial lighting energy in certain classrooms up to 77%. Despite the change of usage of the atria the expected energy savings could be mostly realized.

10.2 Impact on indoor climate

The atria were designed to serve mostly as a non-heated thermal buffer zone. Nevertheless the acceptance as a meeting point and location for social activities was very high, such that during wintertime the atria were, in contrast to the concept, heated very often. Therefore the atrium could not play the intended role in the hybrid ventilation concept for the classrooms.

10.3 Economics

No detailed information is available.

10.4 Practical experiences of interest for a broader audience

By creating atria the usable floor area of a school can be increased. Yet in schools with no auditorium (such as this so-called Schuster type school) it seems to be inevitable that the teachers and pupils use the atria as a bright and nice surrounding for different purposes all year round. Therefore atria should not be used as preheating zones in the ventilation concept because they will need to be heated in the winter.

10.5 Resulting design guidance

- Using the courtyards as atria is the most energy efficient way to extend the school area.
- Due to the high acceptance of the atria they should not be intended to be preheating zones.
- Daylight dependent artificial lighting controls have a high energy reduction potential but are expensive measures.
- A night-ventilation strategy combined with an efficient shading strategy leads to comfortable summer conditions.

11 General data

11.1 Address of project

Bertolt-Brecht-Gymnasium, Lortzingstr. 1, 01307 Dresden

11.2 Existing or new case study

Project initiation: 1992
Design completed: 1993
Renovation construction completed: 1995
Monitoring and evaluation completed: 1998

11.3 Date of report / revision no.

June 2002, no. 6

12 Acknowledgements

Authors: Heike Kluttig, IBP
Retrofitting of the school was a joint venture of 4 institutes, funded by the German Ministry of Research:
Architect: IBUS, Institut für Bau-, Umwelt- und Solarforschung, Berlin
Building Physics: TUD, Technical University of Dresden, Institut für Bauklimatik (project lead), Dresden
Atria Design: IBP, Fraunhofer Institute of Building Physics, Stuttgart
Daylighting: Technical University of Berlin, Fachgebiet klimagerechtes und energiesparendes Bauen, Berlin

Monitoring organisation

Long-term monitoring: Technical University of Dresden supported by IBP, Fraunhofer Institute of Building Physics, Stuttgart
Short-term monitoring: IBP, Fraunhofer Institute of Building Physics, Stuttgart

13 References

[1] Petzold, K. et ali: Energetische Sanierung und energieökonomische Erweiterung unter Verbesserung des sozial-kulturellen und des pädagogisch-funktionellen Niveaus von Typenschulbauten, Bericht zur Phase 1. Berlin, Dresden, Stuttgart, April 1994.

[2] Petzold, K., Meinhold, U.: Energetische Untersuchungen an einem Schulgebäude. KI – Luft- und Kältetechnik 11/1999.

[3] Petzold, K. et ali: Energetische Sanierung und energieökonomische Erweiterung unter Verbesserung des sozial-kulturellen und des pädagogisch-funktionellen Niveaus von Typenschulbauten, Phase II, Schlußbericht. Berlin, Dresden, Stuttgart, November 1998.