projekt*info* 12/06

BINE Informationsdienst

Studying and working in comfort

- **Innovative energy concept has passed its first test in practice**
- **2005 heating consumption: approx. 37 kWh/m^2 p.a.**
- **2005 primary energy characteristic value: 116 kWh/m^2 p.a.**
- **Students and teachers commend very good interior climate**

Fig. 1

New building at the Gebhard Müller School in Biberach an der Riss, Germany. Exterior blinds protect against unwanted heat influx.

In Germany, approximately 12.3 million students attend general and vocational schools. Today, in light of pedagogical issues such as the PISA study, or all-day school concepts, the public is again paying more attention to the topic of schools than was the case a few years ago. A whole array of complex demands are made of a school's architecture and building services equipment, due to the special type of usage. School buildings comprise very different areas (classrooms, corridors, atria, sport halls) with different usage periods. High occupancy densities in the classrooms, which entail high internal thermal loads and strict air hygiene requirements, must be taken into account. Adequate lighting conditions, glare protection, sun protection, and indoor acoustics are also important for studying and working in comfort. Because the school building should aid study, not hinder it, and should also enable energy-efficient operation.

The Gebhard Müller School is a business school in the Kreis-Berufsschulzentrum Biberach (Biberach District Vocational School Centre). This new building meant that the school was to have its own building, oriented towards the contractor's very ambitious requirements with regard to comfort, flexibility of the indoor areas, and energy consumption. The construction project includes an innovative energy concept, with a heating requirement of approximately 30 kW/m^2 p.a. ("3-litre house"). The room concept should allow considerable flexibility, and alongside closed classrooms, should also provide open study zones. Room temperature control occurs by means of thermal activation of the reinforced concrete slabs. Ground water serves as the main heat source and the only cold source, via a heat pump system when heating, and directly through a heat exchanger when cooling. The entire building is ventilated mechanically. The design also incorporates optimal utilisation of daylight, as well as effective sun protection and glare protection.

Due to the innovative concept, the school's new building is facilitated and evaluated as part of the support initiative "Energy-Optimised Construction (EnOB)", which is sponsored by the German Federal Ministry of Economics and Technology (BMWi). One area on which the Biberach project is focussed, is on optimising the operation of system technology. The building was handed over in September 2004, and at the beginning of 2005, it was possible to start the two-and-a-half-year phase of optimisation of operations and measurement.

▶ Building concept

Fig. 3: Floor plan of the school building and interior view of the large atrium

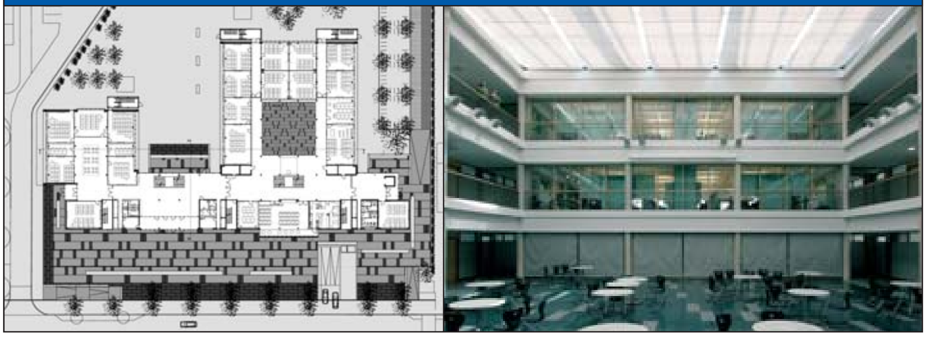


Fig. 2: Building summary

Contractor / Investor	District of Biberach, Germany
Architecture	Elwert-Stottele-Rädle Project Group – Ravensburg, Germany
Location	Kreisberufsschulzentrum Biberach an der Riss, Baden-Württemberg, Germany
Planning and construction timeframe	2001 to 2004, completion in September 2004
Structural design	Solid reinforced concrete structure with mullion-and-transom curtain wall facade
Net floor area (NFA) without underground car park, heated (area with energy requirement)	10,650 m²
Net floor area (NFA) with underground car park	15,383 m²
Main usable area	5,542 m²
Gross volume without underground car park, per DIN 277	43,639 m³
A/V ratio	0.31 m⁻¹

The three-storey school building comprises one wing along the access road. Two cubic building structures, in which the classrooms are situated, join onto this wing. All building structures are interconnected by a central hall in the main wing (fig. 3). Running along the hall in the suspended ceiling, is the equipment channel, from which the supply channels branch off into the corridors and rooms. The building has two atria. The large atrium is suitable for school events (approximately 500 seats) and for concerts, as it has very good acoustics. An underground car park is situated beneath the building, with a ceiling which has 18 cm of rockwool insulation on the underside.
The decisive requirement of the concept was to enable flexible room sizes, and to create open study zones as well as closed classrooms. The central hall, which the whole building opens onto, is suitable for this purpose. Flexible room sizes can be realised by means of a newly developed module concept. Every module has identical technical equipment (air conditioning system, IT). Thus, rooms can be made larger or smaller by repositioning the dividing walls along the facade. The building is a reinforced concrete structure, the main wing is designed as a solid construction with a perforated facade, and the cubic classroom buildings are constructed as skeleton structures with a mullion-and-transom curtain wall facade. The slabs are largely uncladded, and have an average thickness of 35 cm, so additional impact sound insulation and flooring is unnecessary. Despite spaciously laid-out traffic areas, a compact building with an average U-value of 0.43 W/m²K was the result.

Lighting

Exterior blinds with a light-diverting function protect the classrooms and administration rooms from unwanted heat influx, and ensure a glare-free working environment. The atria have interior sun protection made of coated fabric. Solar protection glass (g-value 0.21) was installed to reduce heat influx in staircases, the cafeteria, and conference areas.
The level of daylight in the building was optimised with the aid of simulation calculations. The exterior blinds are controlled automatically, according to the position of the sun, and also partly according to room temperature, but can also be operated manually. The corridor areas are supplied with daylight via the atria, and supplement the natural lighting of the classrooms by means of skylights. The artificial lights are switched on by the user, and are switched off either completely, or row by row, depending on the available daylight.

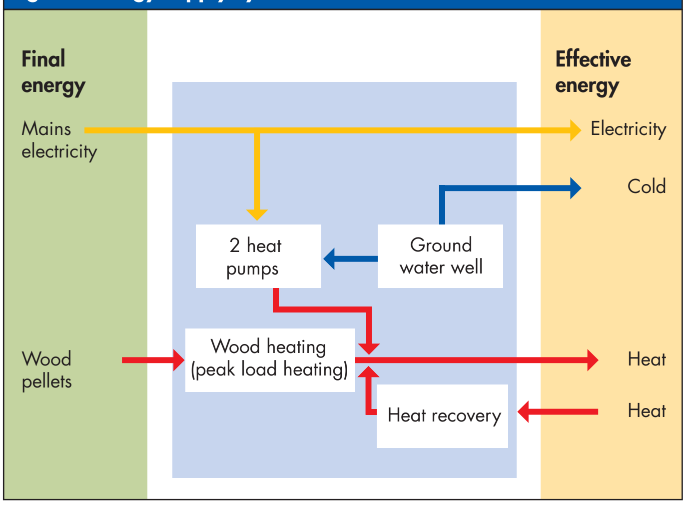
▶ Energy supply components

System	Komponenten	Details
Heating/Cooling	Building element activation (TABS)	Tubes lie in the centre of approx. 35 cm-thick concrete slabs
	Source of heat or cold	Ground water, 300 kW ground water cooling
	2 heat pumps	2 x 37 kW electricity and approx. 150 kW heat, to cover base load
	Backup heating	Wood pellet boiler to cover peak load (nominal capacity 120 kW)
	Underfloor heating	In large atrium and lavatory areas
Ventilation	3 central ventilation systems for air intake and extraction	Supply air is heated via heat pumps in winter, and cooled directly by ground water in summer, 19-23 °C
	Control	Room-specific, according to air quality (mixed gas sensors), max. air renewal factor: 4.5
	Heat recovery	Rotary heat exchangers, heat recovery level approx. 70%
Lighting	Natural lighting	Windows, atria, skylights
	Artificial lighting	Suspended lamps with 50% indirect light, downlights, control in traffic areas via combination of motion detectors and light sensors
	Sun protection	Exterior blinds with light-diverting function, controlled automatically
Control	Coordination of all functions via technical centre	Centralised monitoring, building allows user intervention: window opening and sun protection

Planning

Before the construction work, the contractor (the District of Biberach) debated at length in district council meetings, and set itself the objective of realising an exemplary, innovative building concept. A Europe-wide invitation to tender attracted applications from numerous planning offices. According to a list of criteria, five offices were selected, and were asked to submit a plan. In conferences, a commission of architects and school staff facilitated the development of these plans. Thus, it was already possible to have a guiding influence during the planning process.

Fig. 4: Energy supply system



Heating, cooling and ventilation

At approximately 30 kWh/m² p.a., the calculated annual heating requirement of this compact and well-insulated building is very low. For heating and cooling, the building primarily uses thermo-active building systems (TABS). In winter, the temperature level of the TABS heating water is increased to temperatures of up to 28 °C overnight. The supply temperature is controlled centrally in four separate zones, but cannot be altered for individual rooms. Two heat pumps cover the base heating load. Ground water serves as a heat source for the heat pumps, as the ground water streams which are present at the site meet the prerequisites very well. The ground water is made accessible by means of a 16 m-deep supply well and two injection wells. In summer, the ground water serves as the sole cold source for direct cooling by means of a heat exchanger.

The occupancy density of classrooms requires high air renewal rates in order to ensure the desired air quality. Thus, the entire school building is mechanically ventilated all year round by means of three centralised ventilation systems with heat recovery. Air is heated solely via the heat pumps when outdoor temperatures are approximately -5°C or above. Only when outdoor temperatures drop lower, are backup heat exchangers activated, provided with higher supply temperatures by means of a wood pellet boiler. In summer, temperature control of the supply air occurs via the ground water heat exchanger and cold exchanger. Mixed gas sensors control the supply air volume according to whether or not a classroom is occupied. One window can be opened per room module. Window contacts cause the ventilation system to be deactivated in the respective room, as soon as the window is opened.

Fig. 5: Electricity consumption / primary energy (measured) based on the heated NFA for the year 2005

		(kWh/m²p.a.)
Heating/Ventilation	Ventilation	11.2
	Heat pumps	10.6
	Auxiliary energy e.g. pumps	10.0
	Primary energy	95.7
Light	Lighting	6.7
	Primary energy	20.2
Primary energy balance	Building services equipment	116
Biomass	Primary energy, estimated	0.1
	Primary energy for building services equipment, without other consumption	116.1

Operating experience and optimisation measures

Fig. 6: Reduction of heat pumps' supply temperature as a result of monitoring and optimisation of operations; comparison between 2005 and 2006

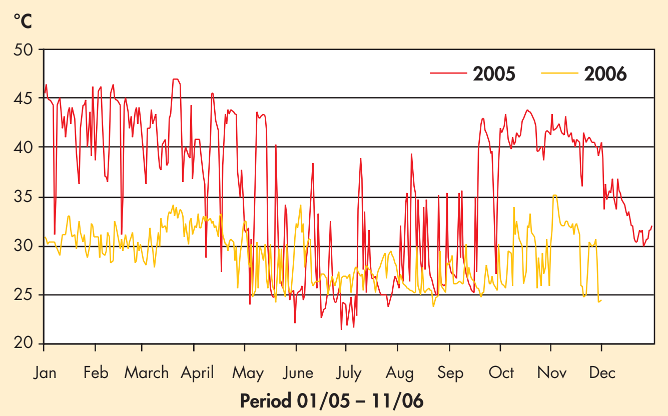
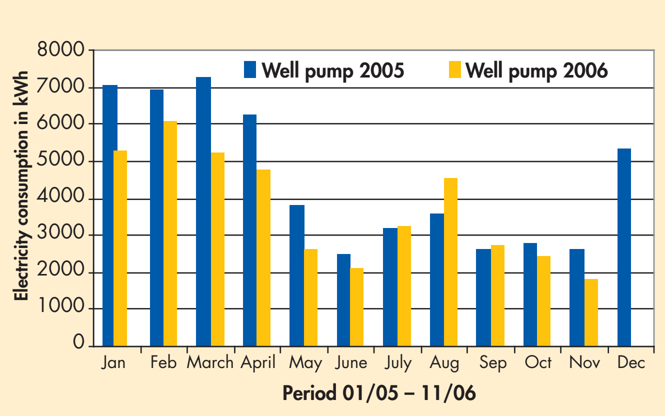


Fig. 7: Comparison of the well pump's monthly electricity consumption in 2005 and 2006. Data from ongoing monitoring.



The school was planned with a very sophisticated energy concept. Now, the questions are: how well does the concept stand up in practice, and how can operation of the technical systems be optimised? In order to answer these questions, a large volume of data, e.g. electricity consumption of individual components (heat pumps, ventilation systems, auxiliary electricity for pumps, controllers, lighting), room temperatures, and consumption of heating and cooling energy, was measured for the entire building, recorded in the technical centre, and reported.

The results from 2005 confirm the predicted high thermal comfort with good air quality, both in winter and in summer. The air-tightness measurement (n_{50} = 0.34^{-1}) showed that while the entire building met the requirements, the technical centre indicated significant leaks. Here, subsequent improvements were necessary, most of which are now complete.

The wood pellet boiler was practically unnecessary in 2005, as the output of the heat pumps was sufficient. To date, the energy consumption values still show deviations from the planned values. For instance, the heating consumption of 37 kWh/m² p.a. in 2005 is somewhat higher than the calculated value of 30 kWh/m² p.a. The low maximum heat pump supply temperature of 28°C which was planned, was greatly exceeded in 2005 (up to 48 °C) for control-related reasons. This deviation and a number of other problems (e.g. pumps' running times and cycle times) were successfully corrected by optimisation of operations (fig. 6).

The electricity consumption of individual components shows that the optimisation of systems operation had a measurably positive effect. In the summers of 2005 and 2006, due to the high performance of TABS, the building was cooled more than was required. Thus, optimisation measures are being implemented now, and in the future, for adjustment purposes, i.e. for reduction of cooling, in order to lower the pumps' energy consumption in summer (fig. 7).

Overall, the support initiative's energy objective, a primary energy characteristic value for heating, ventilation, cooling and lighting of 100 kWh/m² p.a., was not yet fully achieved in 2005, with 116 kWh/m² p.a. (fig. 5). However, it can be expected that this target will be reached in the future, due to the measures which have already been taken, especially regarding the control technology.

Fig. 8: Gross construction costs without underground car park*

Building construction (cost group 300)	€ 850.--/m²
Technical systems (cost group 400)	€ 415.--/m²

**Based on net floor area, in accordance with DIN 276*
Basis: cost quotations

▶ Conclusion

Since September 2004, the school building has been used full-time by approximately 1,700 students and around 91 teachers , who are very satisfied with "their" school. As well as the building concept, the interior climate in particular is praised. A survey indicated that the air quality and the temperature in the classrooms are considered to be very good to excellent. The readiness to identify oneself with the school has improved significantly due to the new school building. This is also evident in the way the furnishings are handled.

In 2005, the annual primary energy requirement for heating, cooling, ventilation and auxiliary energy was already approximately 70% below that of a conventional school building with uncontrolled window ventilation, static heating surfaces, and conventional heat generation with a gas boiler. As the building's heating energy consumption, at approximately 37 kWh/m² p.a., turned out to be somewhat higher than calculated, there are currently efforts being made to achieve the ambitious planned value of 30 kWh/m² p.a. by means of optimising operations. The same applies to the heat pumps, for which the supply temperature is to be reduced further. The optimisation of overall systems operation during the first phase of occupancy was successful in lowering the 2006 electricity consumption for distribution of air and water. Further savings are by all means still possible, and are currently being investigated. A final analysis of the measurement phase will occur in 2007.

The building's high energy requirements and the system technology make it necessary above all to facilitate and optimise the dynamic operation of the entire system. This is also confirmed by the monitoring results. Despite comprehensive communication and documentation, it was initially necessary to adapt numerous operational processes to suit the requirements. Also of significance, is that a building with good thermal insulation can exhibit very high tolerances regarding deviations in systems operation, without comfort being reduced. The result is higher energy consumption which is not initially noticeable.

The school has very good technical equipment, and in conjunction with the sophisticated system technology, which makes correspondingly complex measurement and optimisation measures necessary, the concept cannot easily be transferred to other school buildings.

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Cross-project documentation
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▶ ADDITIONAL INFORMATION

Links
- www.fh-biberach.de
- www.enbau.de
- www.enob.info
- www.elwert-stottele.de
- www.gms-bc.de/gms/

Service
- Additional information is available online from BINE at www.bine.info (Service/InfoPlus) in German.

Literature

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Images
- Figs.1 and 3, pp 1+4 background image: Lichtbildner Albrecht Immanuel Schnabel Götzis – Voralberg
- Fig. 3 floor plan: Projektgemeinschaft Elwert-Stottele-Rädle

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