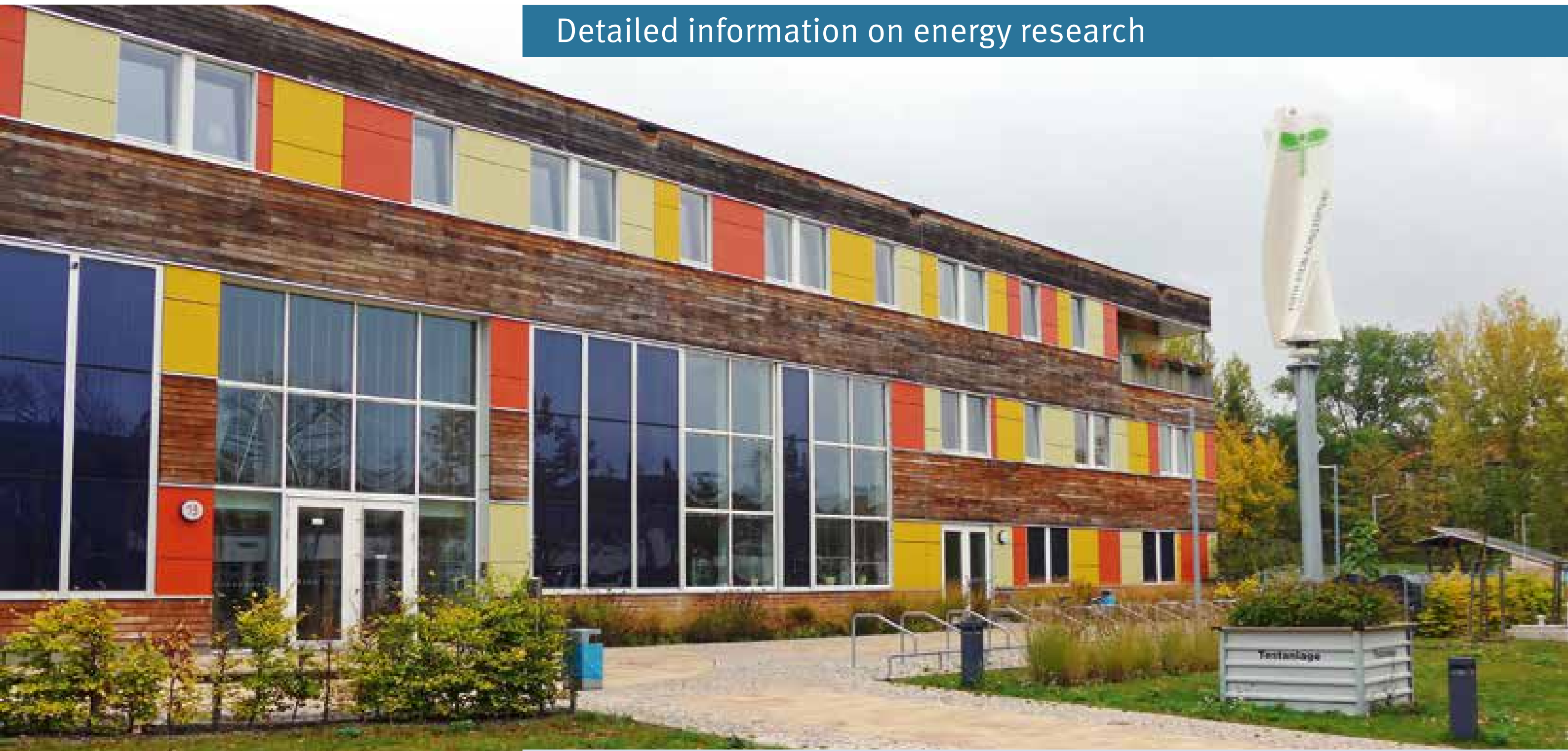
Projektinfo **11**/2018

Detailed information on energy research



Passive House primary school in Halle undergoes monitoring

Acceptance study shows considerable satisfaction among the pupils and teachers, but also a need to improve the technical concept

BINE
Information Service

The ecclesiastical funding body wanted to use ecological building materials for the construction of a new primary school and, with the energy-optimised building, ensure a high degree of learning comfort with manageable operating costs. This resulted in the first Passive House school building to be constructed using a timber frame structure in Saxony-Anhalt. Multi-year monitoring and accompanying sociological research have verified both its energy efficiency and acceptance. The new building consumes 90 per cent less heating energy than comparable primary schools in Germany, but still has reserves in terms of the electricity consumption. The school forms part of the nationwide EnEff:Schule research initiative implemented by the German Federal Ministry of Economic Affairs and Energy.

St. Francis Primary School in Halle, which opened in February 2014, provides two parallel classes in each year. It offers 200 pupils in the classrooms, after-school care centre and assembly hall a pleasant indoor climate and an attractive setting for motivated learning and teaching.
The funding body, the Edith Stein School Foundation from the Diocese of Magdeburg, had requested a sustainable and ecological structure built to the Passive House standard. “Responsibility to ourselves and our children requires a clear shift toward energy conservation and the efficient use of the resources entrusted to us. Our commitment to the integrity of creation should be clearly reflected in the new building for St. Francis Primary School and thus become a model for other construction projects, including in our diocese,” says Foundation Director

This research project is funded by the

Federal Ministry for Economic Affairs and Energy (BMWi)

Steffen Lipowski. The building is almost completely constructed as a timber frame structure, largely from renewable raw materials and recycled building materials. The three-storey school building, which does not have a basement, consists of two staggered, almost equally sized rectangular blocks. The building includes classrooms, an after-school care centre, administration area, caretaker‘s flat, school kitchen and assembly hall (Fig. 1). The building is built to the Passive House standard, but is not certified by the Passive House Institute in Darmstadt.

Building in detail

In order to achieve the required Passive House standard, the building envelope was constructed with high thermal insulation and, as far as possible, without thermal bridges. The designers opted for a timber frame structure, of which 80 % consists of renewable resources. This also took into account the desire for a sustainable and ecological construction method. The structure of the outer wall is constructed using double-T timber beams, with the voids completely filled with cellulose. The U-value of the external components ranges between 0.10 and 0.16 W/m²K. The construction method with large amounts of renewable (timber, cellulose) or recycled building materials (concrete and foam glass ballast) is very compact. Even three years after going into operation, the air tightness still attains a very good value of $n_{50} = 0.26^{h-1}$.

Six ventilation systems with heat recovery ensure sufficient fresh air. Presence detectors in each classroom and carbon dioxide sensors in the assembly hall control the airflow rate.

The building is heated by the ventilation systems; just four offices with low external heat are equipped with electric radiators. This air heating, which uses the district heating return line from a neighbouring secondary school, provides the school with the required space heating.

To warm the domestic hot water for the school kitchen and the caretaker‘s flat, the south-facing facade is equipped with solar thermal systems with a 36 m² collector surface which feed the solar heat into a 2 m³ stratified storage tank. Peak load coverage is provided by an integrated 9 kW electric heating element. There is no auxiliary heating using a district heating heat exchanger, as originally planned, because the supply temperature of the district heating is too low at 45 °C. It was also initially planned to supply surplus heat from the solar thermal system to a latent heat storage system. However, the salt hydrate storage tank is practically never used, as there is hardly any surplus heat once the two other storage tanks have been charged.

The water heating for the remaining school operation (sanitary facilities) is provided by local water heaters.

Two grid-connected photovoltaic systems with a total output of 78 kW_p mainly supply the ventilation systems as well as the energy-intensive operation of the school kitchen. This provides up to 300 meals on normal school days for pupils from both the primary school and the neighbouring secondary school. A micro-wind turbine with a 1 kW capacity was installed, but this has failed to prove itself in practice as a result of huge downtime losses. The likewise envisaged battery storage system with a 25.6 kWh storage capacity was used for just a few weeks before completely failing due to a technical issue. The school is not planning to replace it at the moment.

Fig. 1 *Ground floor plan of St. Francis Primary School (plant rooms, sanitary spaces, school kitchen with assembly hall and after-school care centre)*

Building data/Measures/Components	***Details***
Gross floor area	*3,764 m²*
Net heated floor area	*2,963 m²*
Shell surface/volume ratio A/V	*0.345 m^{-1}*
Specific transmission heat loss H'_T	*0.33 W/m²K*
U value [W/m²K]	
• Exterior wall	*0.12*
• Solar wall	*0.16*
• Window	*0.60*
• Mullion and transom facade	*0.60*
• Flat roof	*0.10*
• Floor slab	*0.09*
Roof-integrated photovoltaic modules	*Total peak power 78 kw_p*
Facade-integrated solar collectors	*36 m², 214 kWh/m²p.a. (aperture area)*
Heat supply	*Ventilation system with heat recovery, preheating via geothermal heat exchanger, auxiliary heating via district heating*
Lighting	*Mainly presence-controlled, partly with daylight sensors, rod-shaped fluorescent lamps with electronic ballast devices*
Ventilation	*Six ventilation systems, natural ventilation is possible*
Anti-glare/solar shading	*Solar shading louvres in box windows (in intermediate cavity)*

Fig. 2 *Measures and components in the building*

Results of the monitoring

The monitoring aimed to provide, on the one hand, specific recommendations for the client and operator in order to improve the operation and, on the other hand, general knowledge for future school buildings.

Owing to delays in the construction and the insolvency of the main design team, the regular data collection for monitoring did not begin until the end of 2015. Results are now available up to March 2018.

The research team from Magdeburg-Stendal University of Applied Sciences compiled the data from five sources:

The central monitoring server with the measurement stations for the intensive monitoring, the existing storage units for the two central ventilation systems as well as the solar thermal and photovoltaic systems, and the electricity meter data from the Stadtwerke Halle municipal utility company. The following detailed evaluations are thus possible: annual overviews of the energy and media flow, evaluation of the indoor climate parameters with in-depth analysis of two classrooms and the assembly hall, measurements of the renewable energy and ventilation technology efficiency, and measurements of the building envelope.

Energy flow maps for the district heating, electricity and water/rainwater were created. The following results are becoming evident:

- With the heating deployment, 75 % is useful heat with 25 % network losses. The high network losses are due to the fact that the main district

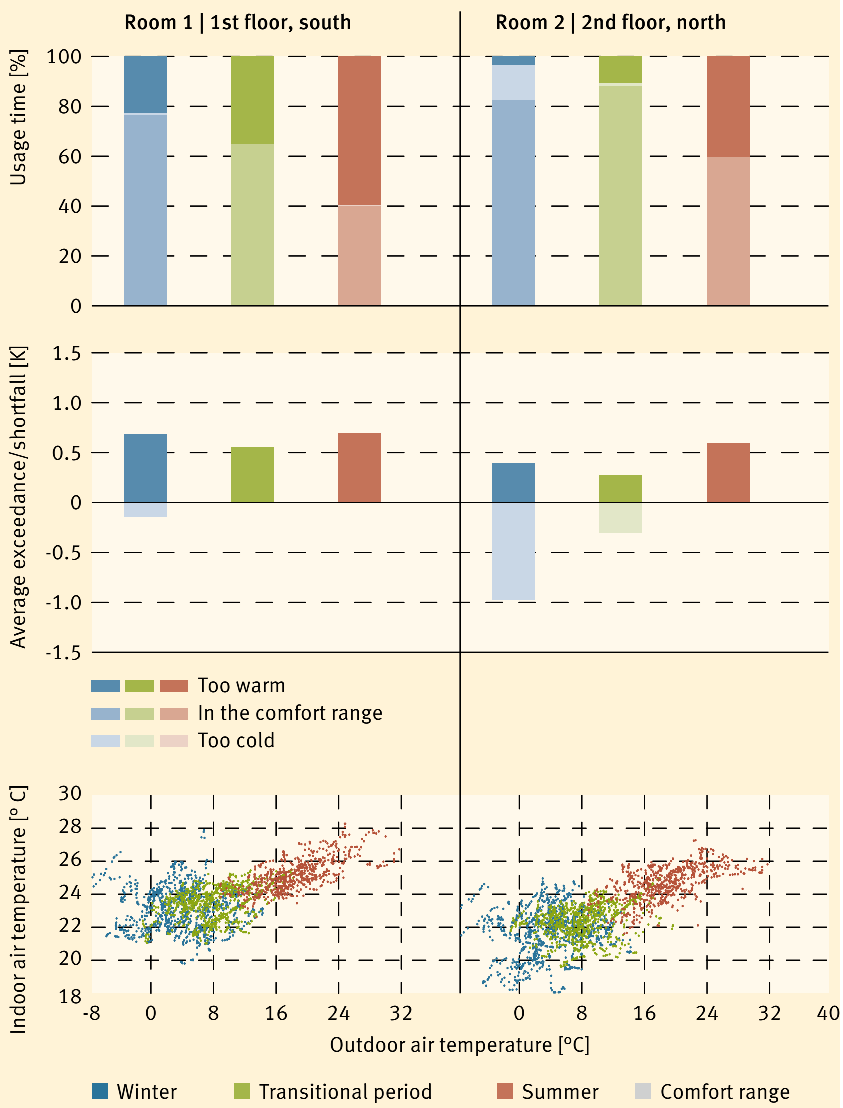


Fig. 3 *Evaluation of the comfort air temperature during the usage period in accordance with DIN EN 15251*

heat supply is located 70 metres away and the underground heat pipes are therefore correspondingly long. • The largest heat loads are the two central heating auxiliary heat exchangers for the assembly hall, administration and corridors with a total of 56 % of the useful heat consumption for approximately 41 % of the total area. These are closely followed by the central air heating system for the classroom area. • The measured heat consumption amounts to approximately 14 kWh/m²p.a., including network losses. The primary school therefore consumes only about 10 % of the national average for primary schools in Germany and achieves the Passive House level. • The photovoltaic plants achieve an average annual electricity yield of 81 MWh/p.a. The self-utilisation rate for the generated electricity is about 52 %. • The electricity consumption amounts to an average of 110 MWh/p.a., of which approximately 60 % is drawn from the electricity grid and the remainder is produced via the PV systems on site. • The largest electricity loads, which account for almost 50 % of the total electricity consumed by the school building (without kitchen), are the two central ventilation systems. The chosen concept leaves, however, little scope for optimisation; it is recommended that the heating and ventilation functions should be separated in future projects. • The solar thermal energy delivers up to 214 kWh/m²p.a. relative to the aperture area, which corresponds to expectations. • The water consumption for the entire building in 2017 amounted to 776 m³/p.a., 70 % of which was purchased as drinking water while the rest was collected as rainwater and used as process water for the toilet facilities. During the course of the monitoring it was revealed, however, that the costs for operating the pumps for the rainwater harvesting system are very high, so that it is still unclear whether this concept will continue to be operated.

Results of the accompanying sociological research

The evaluation compared the surveys of the school pupils and teachers as well as the group discussions. The results show that both the students and the teachers are positive about the new school building and feel comfortable in the building. One criticism is that it often gets too warm in the classrooms in summer. Students and teachers then feel that the air is too stuffy. Conversely, it was revealed during the group discussions that the north-facing rooms for the after-school care centre were perceived as too cold during the winter holidays. The problems were partly due to faulty ventilation regulation. This was identified and remedied as part of the ventilation optimisation. It turned out that the regulation had mixed up the northern and southern rooms in the after-school care centre. At times the night-time ventilation during the summer was also inadvertently deactivated. Despite ventilation optimisation, the locally chosen concept – with a uniform supply air temperature for all rooms – means that unequal heating of the northern and southern rooms cannot be avoided. Some teachers complain that particularly the interaction between the blinds, windows and lighting control is not self-explanatory. Simple operating instructions were therefore created as part of the monitoring.

Good air in classrooms

Many different studies show that there is a link between the classroom air quality and students' performance and concentration. The ventilation system with heat recovery ensures sufficient fresh air in the classrooms. This ensures a hygienic indoor air quality and also allows the temperature in the rooms to be controlled. In St. Francis Primary School it is also possible to supply fresh air via the box windows. To prevent the classrooms from overheating in summer, the excess heat in the window cavity can be released by tilting the outside windows. In winter, the solar gains can be fed into the room by opening the inner windows.

In winter, the geothermal heat exchangers pre-heat the outside air, which means that less energy is required for auxiliary heating. In summer, the outside air is pre-cooled by the geothermal heat exchanger. The passive cooling of the building using night-time ventilation in summer is showing some very good results.

The air quality of the classrooms is rated as very good with hourly average CO_2 values during the usage time of ‹1,000 ppm. Although the Pettenkofer limit was exceeded in up to 41 % of the usage time, the values usually remained below 1,500 ppm, which – especially when compared with manually ventilated schools – corresponds to a good air quality (Fig. 3).

Good air for good learning

Schools should serve as role models, as they are used spatially not only for learning but also as a place of experience that can shape the behaviour and attitudes of the school students.
As part of the Energy-Efficient Schools (EnEff:Schule) research initiative implemented by the German Federal Ministry for Economic Affairs and Energy, twelve projects (7 refurbishments, 5 new-build schemes) are showing which measures are technically feasible as well as how much energy can be saved and at what cost.
Accompanying sociological research is evaluating the influences on user behaviour and acceptance as well as the effects on learning comfort and everyday school life.
In addition to many other criteria, a very important comfort factor in classrooms is the air quality. The results of the monitoring show, however, that this often does not meet expectations. Mechanical or hybrid ventilation is therefore recommended for both new-build schemes and refurbishments. The desired indoor air quality must be known when designing the systems, from which the air exchange rate can then be derived.
The CO_2 content has proved itself in practice for classifying the indoor air quality.
The evaluations verify that central or hybrid ventilation concepts are more suitable for new school buildings but that decentralised systems are more suitable for school refurbishments. The ventilation systems used in the EnEff:Schule project are regulated differently. Two strategies are recommended: CO_2-led and schedule-led regulation.
Ventilation signals are suitable for supporting the window ventilation, which, depending on the CO_2 concentration, are illuminated red, yellow or green.
The air quality was rated as being mostly poor in the sociological surveys. It is therefore recommended that sufficient ventilation should be provided so that 1,200 ppm CO_2 is not exceeded.
The ventilation systems require continuous monitoring during operation, including maintenance and repair work. Not only should the system parameters be checked and optimised during the commissioning, but the users should also be briefed in detail on how to operate them. They need to know how to use the ventilation systems to achieve a good indoor climate.

Project participants

- **Project management:** Edith Stein School Foundation from the Diocese of Magdeburg, Steffen Lipowski, steffen.lipowski@bistum-magdeburg.de, www.bistum-magdeburg.de/kultur-bildung/schulstiftung/grundschulen/index.html
- **Monitoring:** Magdeburg-Stendal University of Applied Sciences / Department of Water, Environment, Construction and Safety, Prof. Dr.-Ing. Kati Jagnow, kati.jagnow@hs-magdeburg.de | www.hs-magdeburg.de
- **Architect:** Steinblock Architekten GmbH, Magdeburg

Links and literature (in German)

- projektinfos.energiewendebauen.de – Forschung des BMWi zu energieoptimierten Gebäuden und Quartieren
- www.franziskusschule-halle.de
- Reiß, J.; Illner, M.; Erhorn, H. u. a.: EnEff:Schule. Wissenschaftliche Begleitforschung zum Forschungsvorhaben „Energieeffiziente Schulen". Abschlussbericht Phase 2. FKZ 03ET1075C; 03ET1075A. Dez. 2017. 757 S. Fraunhofer IBP Bericht. WB 201/2017. https://doi.org/10.2314/GBV:1010951262

More from BINE Information Service

- Refurbished vocational college achieves energy-plus level. BINE-Projektinfo brochure 09/2018
- School: Refurbished from Plattenbau to Passive House. BINE-Projektinfo brochure 08/2017
- Breath of fresh air for new school buildings. BINE-Projektinfo brochure 16/2014
- Ventilation in schools. BINE-Themeninfo brochure I/2015
- This Projektinfo brochure is available online at www.bine.info under Publications/Projektinfos.

BINE Information Service reports on energy research projects in its brochure series and newsletter. You can subscribe to these free of charge at www.bine.info/abo

Imprint

Project organisation
Federal Ministry for Economic Affairs and Energy (BMWi)
11019 Berlin
Germany

Project Management Jülich
Forschungszentrum Jülich GmbH
Doris Laase
52425 Jülich
Germany

Project number
0327430 O

ISSN
0937-8367

Publisher
FIZ Karlsruhe · Leibniz Institute for Information Infrastructure GmbH
Hermann-von-Helmholtz-Platz 1
76344 Eggenstein-Leopoldshafen
Germany

Author
Jutta Perl-Mai

Contact · Info

Questions regarding this Projektinfo brochure? We will be pleased to help you:

+49 228 92379-44
kontakt@bine.info

BINE Information Service
Energy research for application
A service from FIZ Karlsruhe

Kaiserstraße 185–197
53113 Bonn, Germany
www.bine.info

Supported by:
Federal Ministry for Economic Affairs and Energy
on the basis of a decision by the German Bundestag

Concept and design: iserundschmidt GmbH, Bonn – Berlin, Germany · Layout: KERSTIN CONRADI · Mediengestaltung, Berlin, Germany