Energy-Plus Primary School, Hohen Neuendorf, Germany

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Summary

Germanys first new build energy-plus school building is based on an integrated design approach that provides excellent learning conditions regarding spatial quality, air quality, thermal and visual comfort. The main technical features are the highly insulated passive house standard, a newly developed hybrid ventilation concept, the use of renewable energy sources and the integration of innovative building components.

Keywords:

Plus-Energy-Building, Passive House, Hybrid Ventilation, Integrated Design, School Building

1.0 Introduction

The primary school in Hohen Neuendorf, north of Berlin, is the first new-build plus-energy school building in Germany. The building provides a gross floor area of 7.414 m² and is designed to enable primary school teaching in accordance with contemporary needs. The project comprises of the construction of a primary school with an integrated triple-field sports hall. The integrated design approach conceives all technical, energy-based and functional requirements as an integral part of the architecture and permits a lean technical concept with a simple, easily controllable and low maintenance engineering system for reaching a high comfort indoor climate. The goal of the project is to show, that it is possible to realise a Plus Energy School building without increased costs in comparison to a new “standard” building.

Fig. 1 Primary School Building, view from West

2.0 Integrated Architectural and Technical Concept

2.1. Objectives

Based on the ambition of the City of Hohen Neuendorf to become a Green City and the need to minimise the long term running costs, the main objective for the design of the primary school was to develop a sustainable concept that provides good learning and teaching conditions with low operational costs for the commune.

The task was to develop an integrated architectural design that integrates the technical needs, the conditions of use, users behaviour and the economical and ecological requirements.

2.2 Building Concept

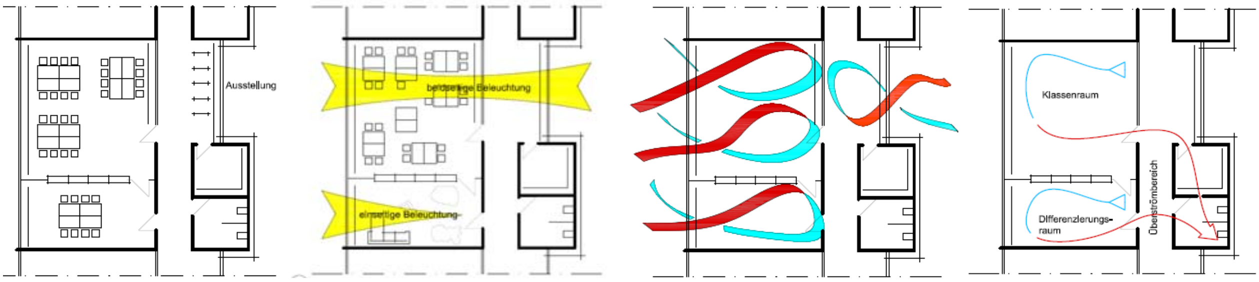
The building complex comprises a primary school and a sports hall. The primary school is designed for 540 pupils and 18 classrooms, specialist rooms for arts, music, computing, nature sciences, a small library and a cafeteria. A central "school avenue" connects all functions of the building. The classrooms are oriented to the south. The sports hall offers a floor area of 1,215 m² and is divisible into three parts. The total floor area of the two storey building is 7.400 m².

Fig. 2 Ground floor and first floor

Fig. 3 Elevations of the East and west facade

2.3. Integrated Spatial and Technical Strategy

In cooperation with the teaching team a room concept has been developed that enables different kinds of teaching situations. The so called “home area” consists of a multifunctional room in combination with a smaller teaching room, an extended circulation space, a wardrobe and a sanitary unit for each class. The technical concept for ventilation and lighting is based on this room concept.



Home area for one class   daylighting   natural ventilation   mechanical ventilation

Fig. 4 Utilization and technical concept for a “home area”

2.3.1. Hybrid Ventilation Concept

By grouping the class room and sanitary unit to a “home area” a combination of natural and controlled ventilation can be realized. The advantages of both ventilation types are combined to create a good balance of thermal comfort, air quality, user acceptance and energy efficiency. The ventilation of the classrooms is primarily achieved by a rapid natural ventilation during the breaks using motor controlled full-height vent windows. With only this type of ventilation CO_2 levels will increase quickly during the lessons. Thus it is combined with a small mechanical ventilation for dampening these magnitudes. The supply air flow for the classrooms correlates to the amount of the exhaust airflow needed for the sanitary units. A good thermal comfort in summer is achieved by means of passive night cooling using the motor controlled vent windows cooling down the large areas of thermal storage mass.

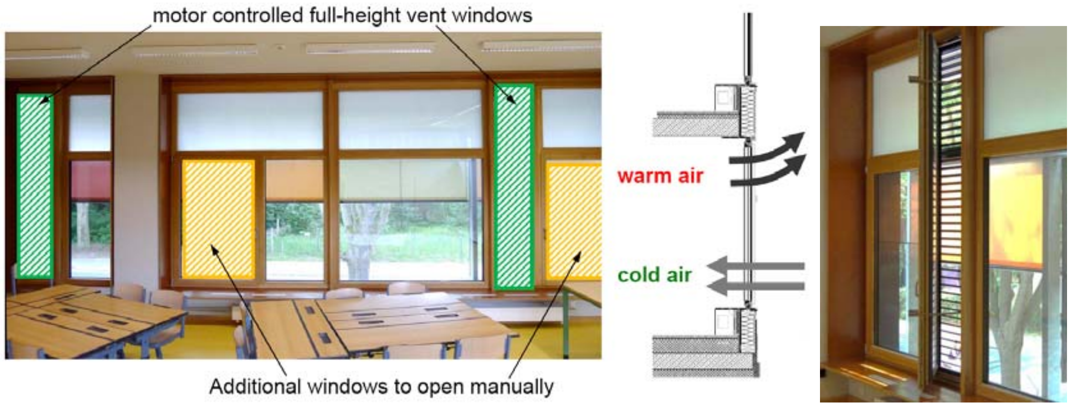


Fig. 5 Windows for natural ventilation

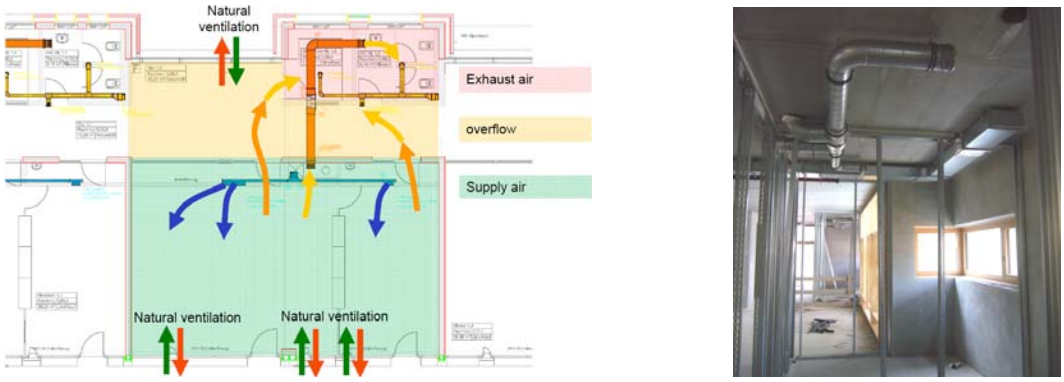


Fig. 5 Hybride ventilation scheme, simple and cheap installations

2.3.2. Daylighting and Solar Control

The south oriented facades of the classrooms have been developed in detail to provide efficient solar shading, natural lighting und passive solar energy gains. Fixed exterior blinds protect the windows against incident solar radiation in summer, vertical fabric blinds enable efficient solar control due to user requirements.

Fig. 6 South facade of the classrooms in detail, view from outside, calculated daylight factors (home area)

The windows above the fixed blinds have a nanogel-glazing to diffuse daylight. The windows that are not equipped by external shading devices have integrated fixed solar shading and daylight guiding louvers available. Almost every space is designed to have a very high daylight autonomy. The deep spaces of the classrooms receive natural light from two opposite sides, the small rooms get natural light from one side only. Also the circulation spaces are well oriented to the daylight to provide attractive room quality.

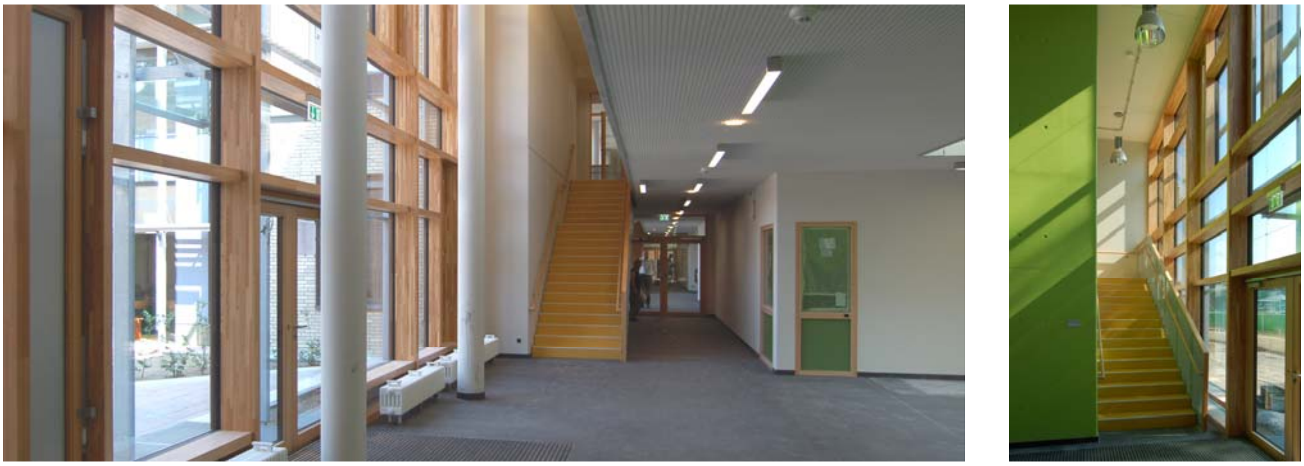


Fig. 7 Circulation spaces

Fig. 8 Interior view of the sports hall

2.3.3. Acoustics and Thermal Storage Mass

One research objective in the project is the trade-off between thermal storage in the concrete ceilings on one side and a good room acoustic quality on the other side. To achieve best possible results for both requirements the concrete ceilings are left uncovered for good thermal contact and the biggest part of all available wall surfaces is covered by highly efficient broadband acoustic absorbers (Fig. 9). Thus a high room acoustic quality (according to the ambitious DIN 'education' standard) can be achieved without affecting the passive cooling function of the ceilings. In the sports hall the reverberation is considerably less than recommended by DIN 'sports' standard in order to improve speech transmission quality.

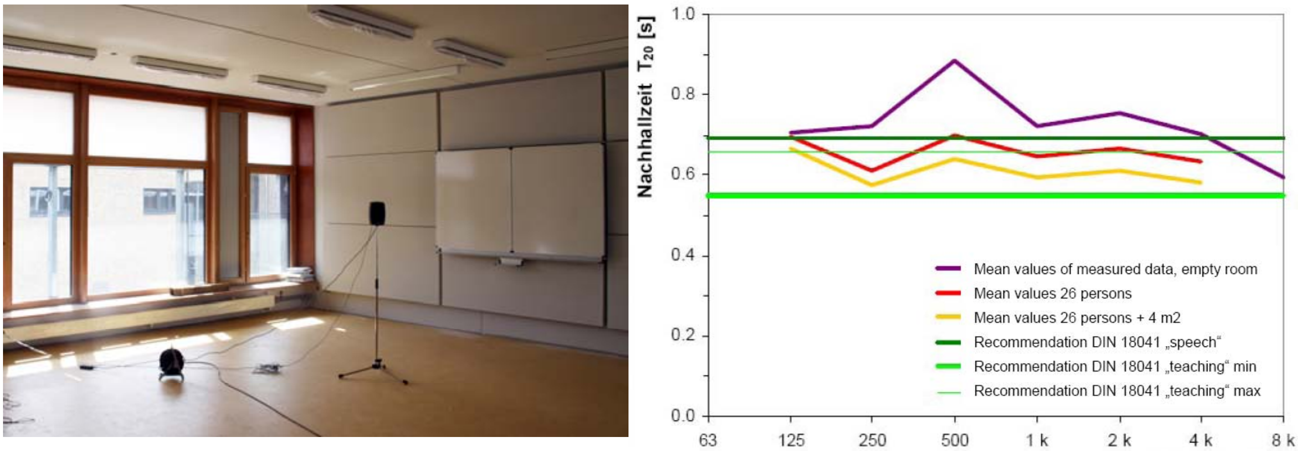


Fig.9 Interior view of a classroom, measurements of reverberation

2.4. Building Construction

The main structure of the building comprises of concrete walls, concrete ceilings and a concrete roof for the school building, and a timber roof construction for the sports hall. The building has a very good thermal insulation level that achieves the passive house standard.

Table 1 U- values of the building envelope

	U- value	
Exterior wall 1	0,15	W/m^{2}K
Exterior wall 2	0,13	W/m^{2}K
Windows	0,80	W/m^{2}K
Roof	0,11	W/m^{2}K
Slab	0,10	W/m^{2}K

Fig. 10 The school building seen from SE, W and SW

2.5. Energy Concept

Using natural processes and passive technologies was a main objective and precondition to minimize active technical components for a Lean-Building-Concept. Because the technical components have a considerably shorter lifecycle compared to the building envelope, the careful use of active technical systems will significantly reduce the lifecycle costs of the school without compromising a high level of comfort and energy efficiency.

The main features of the energy concept are:

- Passive house standard of the building envelope
- Optimised daylight strategy to achieve high daylight autonomy
- Daylight dependent automatic lighting control
- Detailed facade concept to provide efficient solar control, natural lighting und passive solar energy gain
- Improved thermal comfort in summer using nocturnal ventilation, thermal mass for heat storage and free cooling
- A hybrid ventilation strategy using mechanically opened windows for natural ventilation during the teaching breaks supported by a mechanical ventilation system
- Use of renewable energy resources such as wood pellets for heating, an integrated photovoltaic plant for solar power generation and wood pellet driven combined heat and power generation
- Integration of new and innovative building components. This includes different types of innovative glazing, electrochromic glazing, LED lights, filters and control for the ventilation system.

Fig. 11 View from east – facade of the specialist rooms, cafeteria and sports hall

The combination of the above listed measures lead to a very low primary energy demand for the building. The calculated annual primary energy demand for heating, cooling, lighting and appliances is 23 kwh_{pe}/m^2. A partial compensation of this need is realized by a micro CHP, which is used throughout the year to cover basic loads. For the compensation of the remaining primary energy demand, a building integrated photovoltaic solar power plant of 55 kW_p is used. The annual primary energy production by the CHP and the integrated PV-power plant is 24 kWh_{pe}/m^2a.

2.6. Life-Cycle Analysis

The design phase of the project was accompanied by a life-cycle analysis. The planning team was supported in design, construction, quantity surveying and evaluation by a tool for integrated life-cycle analysis called LEGEP.). All information is structured along life cycle phases (construction, maintenance, operation, cleaning, refurbishment and demolition). LEGEP establishes the following issues simultaneously and for the whole life cycle

- the energy demands for heating, hot domestic water, electricity (according to the German standard EnEV 2009, DIN 18599 and EN 832)
- the building construction, operation (energy-demand, cleaning etc.), maintenance, refurbishment and demolition costs
- the environmental impact (effect oriented evaluation based on ISO 14040 – 43) and resource consumption (detailed material input and waste)

The results cover all aspects like life-cycle costs (LCC) and life cycle assessment (LCA). The number of indicators, which are displayed for the LCA, can be chosen from the CML indicators (Green house potential 100 years, Acidification potential, Photochemical Ozone creation potential, Ozone depletion potential, Eutrophication potential, primary energy consumption renewable and non-renewable, Ecoindicator etc.). The calculated operation costs for the school building are 70 % less than the operation costs of a building of the same size and shape that refers to the german standards (EnEV 2009). The calculated Life Cycle Cost are 25% less.

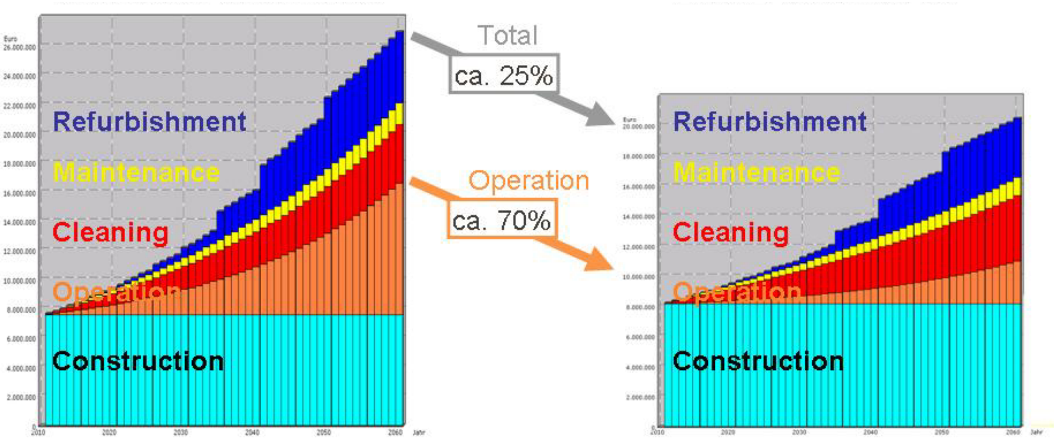


Fig. 12 Life Cycle Cost comparison of german standard new building EnEV 2009 and the new school cumulative 50 years period, mounting rate energy cots 4% per year

2.7. Monitoring

As part of the support programme "energy optimised building", EnOB, of the German Federal Ministry of Economics and Technology, a two-years intensive and a five-years long time monitoring is going to be carried out. The monitoring is aimed at:

- verify the “plus-energy-balance” (balance period is one year of school usage)
- demonstrate and analyse the functionality of the energy concept components
- quantify energies, temperatures, thermal and visual comfort parameters and dynamic effects
- process a fault detection and diagnosis
- optimise the building services system at an early state of operation time
- document the results for the public and in an appropriate way for teaching purposes

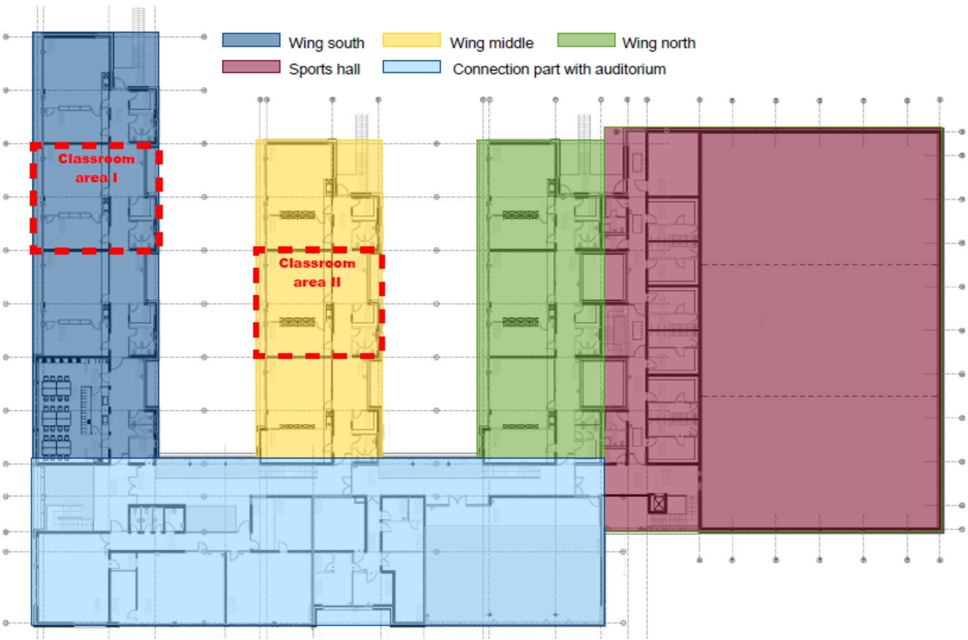


Figure 13: Balance zones of the building

To achieve these goals, data points of the building services system are used and - where necessary - sensors and energy meters were added on. All measured data are collected, stored and delivered via internet server for further analysis automatically. Thus, it is possible to calculate the efficiencies for all

heating, cooling and electricity generators and to establish the energy balance for selected zones, of which two classroom areas are observed in significant detail (see Figure). In these zones, extensive research on thermal comfort, visual comfort and ventilation strategies is going to be carried out. Besides common thermal comfort parameters, the research focuses on daylight, glare, and room air quality, by measuring CO_2 concentration, visualization of airflows and determining the air change rates caused by ventilation.

In addition, temperatures and humidity in different depths of the wall construction as well as surface heat flows for two selected components (outside wall and ceiling) are being measured. This allows the analysis of dynamic temperature and humidity profiles and their impact on room air conditions and building physics.

Figure 14: View from west

References

Client	Stadt Hohen Neuendorf
Project Management Architecture, Construction Supervision Daylighting, Building Physics	IBUS Architekten und Ingenieure, Berlin, Bremen Prof. Ingo Lütkemeyer, Dr. Gustav Hillmann, Hans-Martin Schmid www.ibus-architekten.de
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