INTEGRAL BUILDING AND ENERGY DESIGN OF AN OFFICE BUILDING – COMPARISON OF INITIAL DESIGN IDEAS WITH MONITORED RESULTS

Andreas Wagner, Mathias Wambsganß, Thomas Gropp, Harry Schindler

University of Karlsruhe (TH), Department of Architecture, Building Physics and Technical Building Services
Englerstr. 7, D-76131 Karlsruhe, Germany. E-mail: fbta@fbta.uni-karlsruhe.de

ABSTRACT

Within the program "Solar Optimized Buildings" which is funded by the German Ministry of Economy (BMWi), a building for the DB Netz AG has been realized and monitored. The design concept of the building is dominated by architectural solutions for ventilation, cooling and lighting of the office rooms. Due to the change of responsibilities during the design and building process, the targeted primary energy consumption of 100 kWh/m²y has been exceeded so far. The reasons lie primarily in the inadequate operation of the technical systems for heating, ventilation and artificial lighting.

OBJECTIVES AND BUILDING CONCEPT

Invited to an architectural competition by the DB Immobilien AG, Architrav Architects (Karlsruhe) and the Building Physics and Technical Building Services Group of the University of Karlsruhe developed an energy-efficient building concept for an office building of the DB Netz AG in Hamm, Germany (figure 1). The building which was finished in 1999, has a net floor area of 5974 m² and gives room for approximately 190 work places. The costs of the building had been estimated with 1130 €/m² (according to DIN 276).

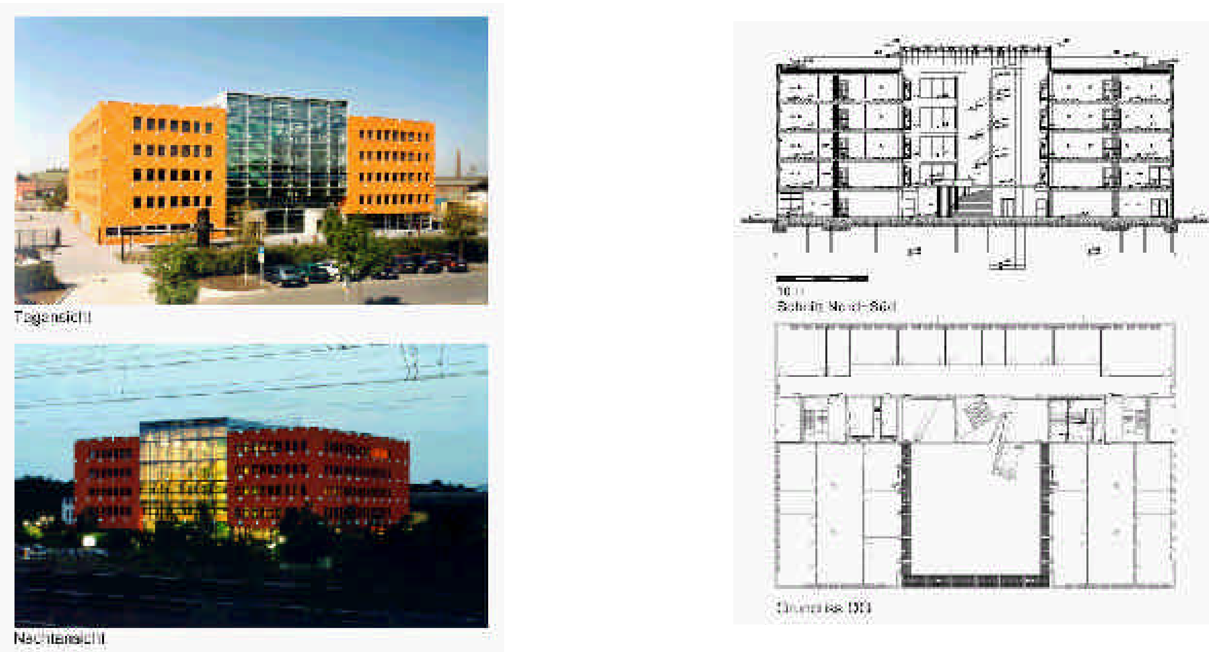

Figure 1: Left: view of the building at day- and nighttime; right: section (North-South) and floor plan

The main objective of the design concept was to primarily use architectural solutions for ventilation, cooling and lighting of the office rooms and to minimize HVAC systems and artificial lighting. This reduces investment and operation costs and involves the users directly into operating the building. A high insulation standard and moderate window sizing guarantee a low heating and cooling energy demand. A central atrium serves as a buffer and gains solar energy during the winter. In summer, solar loads are minimized by efficient shading systems and cross ventilation in the atrium roof. Special shading systems in the exterior office rooms with separately adjustable blinds in the upper part still enable the use of daylight through the windows. Uncovered concrete ceilings serving as mass storage, and night time ventilation are further components to support a passive cooling strategy of the building [Herkel et al].

A ventilation system which is needed for internal zones of the building, offers the possibility to support the night time ventilation whenever required (see figure 2, right scheme). An earth-to-air heat exchanger is integrated into the ventilation system for preheating / precooling the incoming air due to ambient conditions (figure 2). The atrium is conditioned by the earth-to-air heat exchanger as well and serves as a source of fresh air for the adjacent offices.

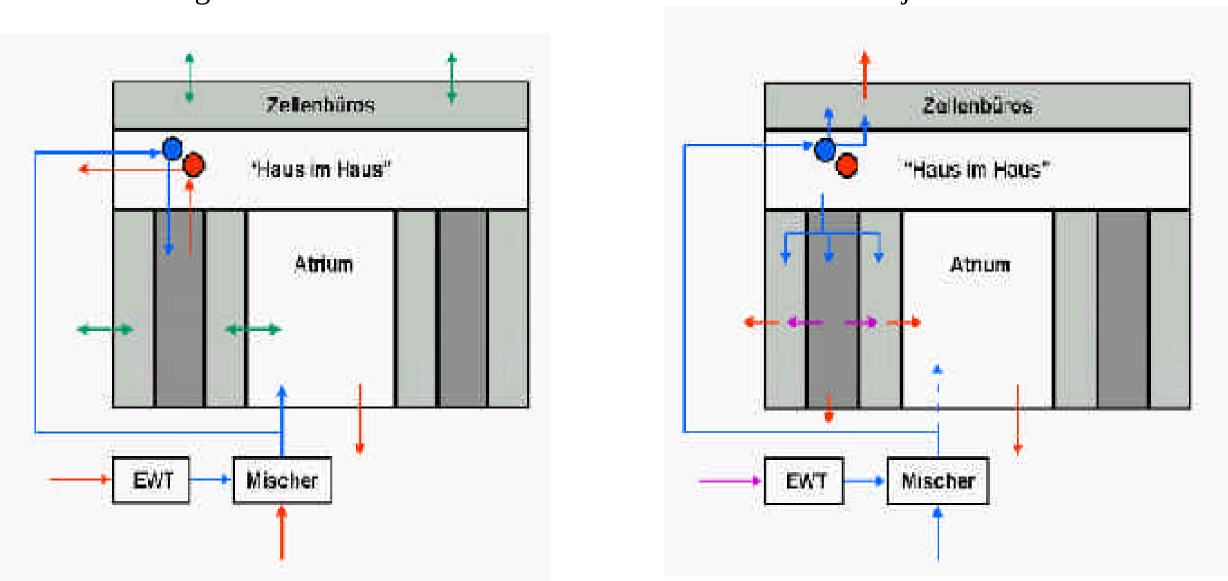

Figure 2: Scheme of the ventilation system of the building (EWT = earth-to-air heat exchanger, MISCHER = mixer). Left side: summer day - offices are naturally ventilated (green arrows), internal zones and atrium are mechanically ventilated (precooling by EWT). Right side: summer night - forced night ventilation for all parts of the building (only in very hot periods, otherwise cross ventilation through the offices and the open atrium roof).

The use of daylight had a high priority in developing the construction of the atrium roof and the structure of the interior facades. Further information about the building and more pictures can be found under www.fbta.uni-karlsruhe.de/dbhamm.

MONITORING RESULTS

The project has been funded by the German Ministry of Economy (BMWi) within the program "Solar Optimized Buildings" [www.solarbau.de]. The general benchmark of this program for funding is an overall primary energy consumption of less than 100 kWh/m²y for heating, ventilation, cooling and lighting. The funding included subsidies for energy-related optimization during the design phase (thermal and daylighting simulations) and a detailed monitoring of the building in operation for almost two and a half years. For the monitoring a data logging with self-controlled data transfer from Hamm to Karlsruhe and self-controlled data check has been developed. A web portal allows direct public access to the data for illustration and data analysis (figure 3).

http://129.13.189.67/hamm_daten/

Figure 3: Web-based data analysis and illustration

Figure 4 shows the total specific energy consumption (electricity and thermal energy) of the building for the period between April 2001 and March 2002. The heating energy demand is dominated by the radiators of the heating system (46% of the total thermal energy). 22% of the thermal energy are needed for the floor heating system in the basement which only heats up 12% of the total heated area. A reason for this high amount are heat losses through the elevator shaft which contribute to the moderate temperatures in the atrium. In addition, 23% of the thermal energy are used for preheating of the incoming air and 9% for hot water consumption (showers, kitchen). The atrium is not heated directly at all. Due to solar gains during the winter, heat gains from the adjacent office zones and the gains from the basement, the mean temperature during winter never fell below 15°C with minimum night time temperatures around 5°C.

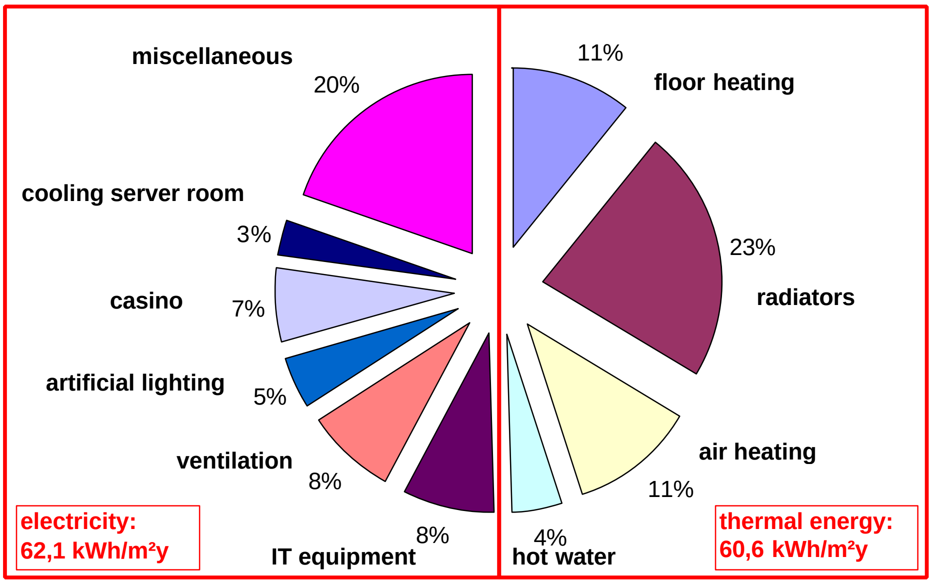

Figure 4: Total energy consumption of the building between April 2001 and March 2002

Regarding the electricity consumption, the main consumers are the IT equipment (16,7% of the total electric energy), the ventilation system (16%), the building's casino (13%), artificial lighting (9,3%) and the cooling of the server room (6%). About 39% of the total electric energy were used by miscellaneous consumers with small single contributions, belonging partly to the technical building services (pumps, elevator, alarm system etc.) and partly to the user equipment (copy machines, coffee machines etc.). 31,5% cannot be identified directly by the monitoring system. The electricity consumption for heating, ventilation, cooling and lighting amounts to approximately 33% of the total electricity consumption of the building.

In figure 5 the comparison of the monitored results and the benchmarks of the funding program is shown. The total end energy consumption for heating, hot water supply and electricity is 37 kWh/m²y above the value which had to be proven during the design phase. The value for electricity here represents the total consumption by the technical building services without any user-related equipment. Due to the conversion factor of 2,8 for electricity, the primary energy consumption of the building exceeds the limit of the funding program by more than 60 kWh/m²y.

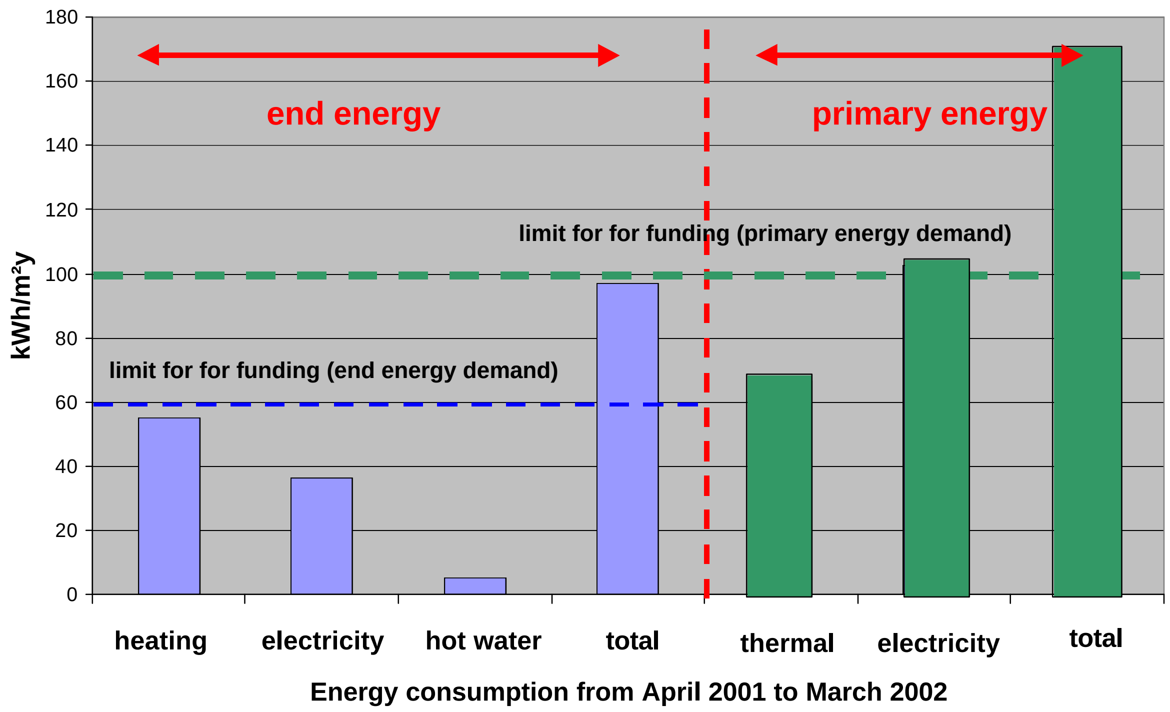

Figure 5: End energy and primary energy consumption of the building between April 2001 and March 2002

DISCUSSION

The reasons for the difference between the targeted values and the real consumption lie primarily in the inadequate operation of the technical systems for heating, ventilation and daylight dependent artificial lighting. This is mostly due to the change of responsibilities during the design and building process. The University of Karlsruhe which was responsible for all energy-related questions during the concept and the design of the building, was not involved in the building process. Therefore many important aspects of the energy concept were not realized consequently. Mainly, the control strategies for the HVAC systems and artificial lighting have not been adapted to the building concept because of missing information transfer to the companies on site.

A thorough analysis of the monitored data allowed to detect the main reasons for the higher energy consumption. Regarding the heating energy consumption, the difference between the targeted and the measured value is mostly due to the operation of the heating and ventilation system. A malfunctioning temperature sensor prevented the heating system from using condensation heat out of the exhaust gas. The heat recovery in the ventilation system did not work properly because of wrongly installed valve. Further, the operation of the earth-to-air heat exchanger caused an extra heating energy demand at times, when the ambient air should be used directly (via a bypass) instead of being precooled in the earth-to-air heat exchanger and being heated up again afterwards. Some heat bridges have been discovered in the building envelope as well which, however, do not contribute significantly to the energy balance. Summing up, the heating energy consumption could be reduced by approx. 10 kWh/m^2y.

In terms of lighting, the daylight autonomy of the working spaces in the exterior office rooms is reduced by the facade construction which shows some relevant differences to the preliminary design plans. The visual comfort in these rooms is lowered by thick and dark window frames. Although the beams and other construction details in the atrium roof reduce the incoming daylight, the electricity consumption for artificial lighting in the offices adjacent to the atrium is not higher than in the exterior offices. Again, the control of the artificial lighting (depending on daylight and presence of the users) is another reason for the higher energy consumption. This is mainly the case in the internal zones and the adjacent zones to the atrium.

Finally, a significantly higher electricity consumption of the ventilator for exhaust air compared to the one for the incoming air (approx. 2,5 times higher) has been monitored and cannot be explained yet. During summer, the cooling of the incoming ambient air by the earth-to-air heat exchanger is not activated by the control unit so far. Taking into account all possible improvements related to the technical systems, a total primary energy demand between 110 and 115 kWh/m^2y could be reached in the future.

Although the targets for the energy consumption could not be reached yet, the building's performance is still far above average compared to standard office buildings in Germany. A comparison with buildings of the DB Netz AG [Froehlich et al] which are very similar in use and age, shows a difference in the total primary energy consumption between 129 and 228 kWh/m^2y. This also indicates the high energy saving potential in existing buildings. The user acceptance in Hamm is high and it is obvious that the concept is robust against system failures and inadequate control strategies.

REFERENCES

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