Museum of Bavarian History
Regensburg, Germany
Dipl.-Ing. Raphaël Vibert, Herz & Lang GmbH

Key Facts
Client: Public building authorities of Regensburg
Architect: Wörner Traxler Richter Planungsgesellschaft mbH
Passive House consulting and dynamic simulation: Herz & Lang GmbH
Use: Public museum with permanent and special exhibitions, conferences, events, opening 2018
Occupancy: max. 1620 people (worse case over all zones) and about 300 000 visitors per year.
Total floor area: 9950 m²
Treated floor area for PHPP-calculation (TFA): 7760 m²
Building standard: certified Passive House according to the criteria of the Passive House Institute of Darmstadt (Germany)
Heating demand: 5 kWh/(m²a) (based on TFA) (Passivhaus criterion: ≤ 15 kWh/(m²a))
Cooling demand: 14 kWh/(m²a) (based on TFA) (Passivhaus criterion: ≤ 15 kWh/(m²a))
Indoor climate requirements: extremely high requirements have been specified by the client in order to ensure optimal conservation conditions for exhibits and best comfort for visitors.

Figure 1 and 2: Rendering east view (on the left) - Rendering west view (on the right)
Source: Wörner Traxler Richter Planungsgesellschaft mbH

Concept – Envelope
Floor slabs: 20 cm XPS-insulation under the concrete slab + 3 cm EPS-insulation under the screed
External walls with ground contact: reinforced concrete with 20 cm exterior XPS-insulation
External walls above ground: reinforced concrete with 26 cm exterior mineral insulation with thermally optimised dowels and thermally optimised bearing construction for the rear ventilated facade.
External overhang: reinforced concrete ceiling with 26 cm exterior mineral insulation and thermally optimised dowels + 3 cm EPS-insulation under the screed
Roof: metallic bearing structure with 36 cm mineral insulation and thermally optimised fixation of the metallic roof covering
Windows: insulated frame with triple glazing and sun protective coating depending on the orientation
Glazed roof: thermally separated metallic frame with sun protective triple glazing

Concept – HVAC

The implementation of the passive house standard is particularly convenient and relevant for buildings with special indoor climate requirements, such as swimming pools or buildings with high occupancy. In addition to the improvement of the comfort and reduction of moisture issues, the passive house concept makes the building as independent as possible from outdoor weather conditions. This means that the HVAC-system and its regulation will mostly have to deal with occupancy parameters without having to cope with additional loads from outside.

The heat and cold generation is based on a concept with several heat pumps connected to the main waste water collector drain of the city of Regensburg, which delivers very favourable and constant temperatures throughout the year (even better than the Danube, flowing close to the building).

The mechanical ventilation of the building is carried out by 8 ventilation units connected to a centralised heat recovery unit with an effective sensible heat recovery efficiency ≥ 75%. The heat exchanger has been combined with an enthalpy controlled bypass in order to deliver air with the most energy efficient energetic and hygrometric properties to the different ventilation units depending on their current needs (heating, cooling, dehumidification, humidification).

The underfloor heating and cooling system covers the base loads of the building and the centralised ventilation system covers the pick loads for heating and cooling as well as the needs of dehumidification and humidification. The quick reaction of ventilation systems combined with several room sensors controlled and weighted by a centralised bus system allows a quick adaptation to changing conditions (peaks of use, weather, etc.). A very narrow corridor for the indoor climate (air temperature of 19 °C +/- 1 K in winter and of 24°C +/- 1K in summer with a relative humidity over the whole year of 50% +/- 5% between 0 m and 3 m height) and extremely smooth variations (maximum variation speed: 1 K/h) have been stipulated by the client.

The energy efficient compliance with the high air quality requirements (CO_2-concentration ≤ 1000 ppm) results from the CO_2 based regulation with room sensors and the adaptable ratio of fresh air (the ventilation system allows an air recirculation ratio from 0% to 100%).

Additional fan coil units are also installed for the air-conditioning of EDP rooms.

Dynamic Simulation - Goals

The achievement of the Passivhaus standard has been investigated and optimised with a multizone PHPP-calculation (Passive House planning package).

For more accurate modelling of the building in the PHPP, the solar gains and shading situations of all glazed areas have been determined with a shading analysis in IESVE, but the main reason for carrying out a dynamic simulation of the whole building with IESVE was the challenge of ensuring the ambitious required indoor climate (see above) without having to oversize the HVAC system (cost effectiveness and space requirement limits). With 300 000 visitors per year, the unavoidable solar gains and the high waste heat of electrical devices and lighting (despite energy efficient products), this is indeed a task that requires a very careful investigation, which nothing but an accurate dynamic simulation can provide. A rougher analysis, such as the ones proposed by cheap software solutions on the market, isn't suitable for this application.

Dynamic Simulation - Model

The whole building envelope has been modelled (figures 3 and 4) and an additional horizontal and vertical division has been defined in the main zones (figures 6 and 7). Neighbouring buildings have of course also been taken into account (figure 3).

But beyond the detailed modelling of the envelope, the particularity of this model is the very accurate modelling of the HVAC system (figure 5). The following parameters have been taken into account in the model:

- Operation parameters of the heat and cold generation system
- Exact construction and operation parameters of the different ventilation units
- Ventilation duct work and related heat exchanges with the adjacent rooms
- Exact position of supply air inlet and outlet points
- Exact position of room sensors
- Weightage of the parameters measured by room sensors in the average value delivered by the bus system that controls the input of the ventilation system
- Operation and regulation parameters of additional heating and cooling systems (underfloor pipes, fan coils, etc.)
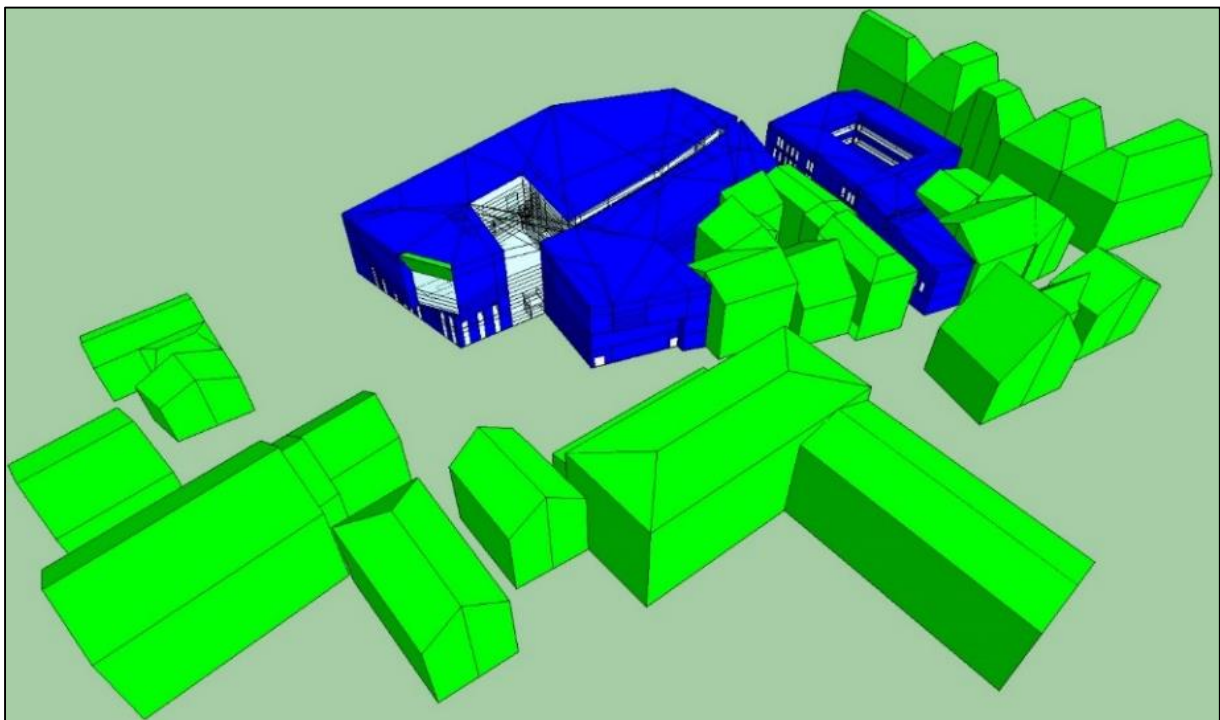
Figure 3: 3D Modell_Museum of the Bavarian history and neighbouring buildings_Southwest
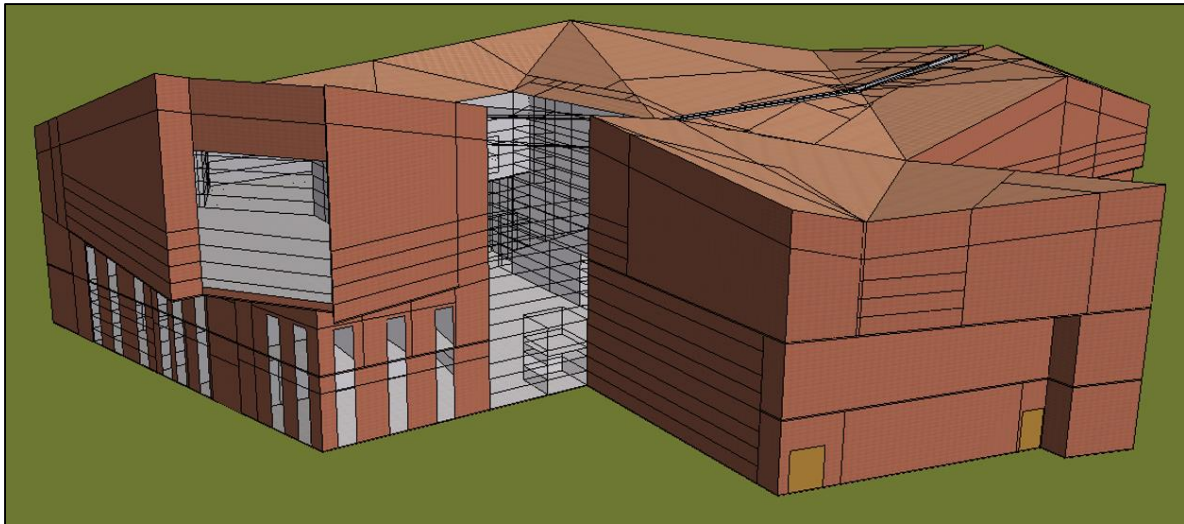Source: Herz & Lang GmbH

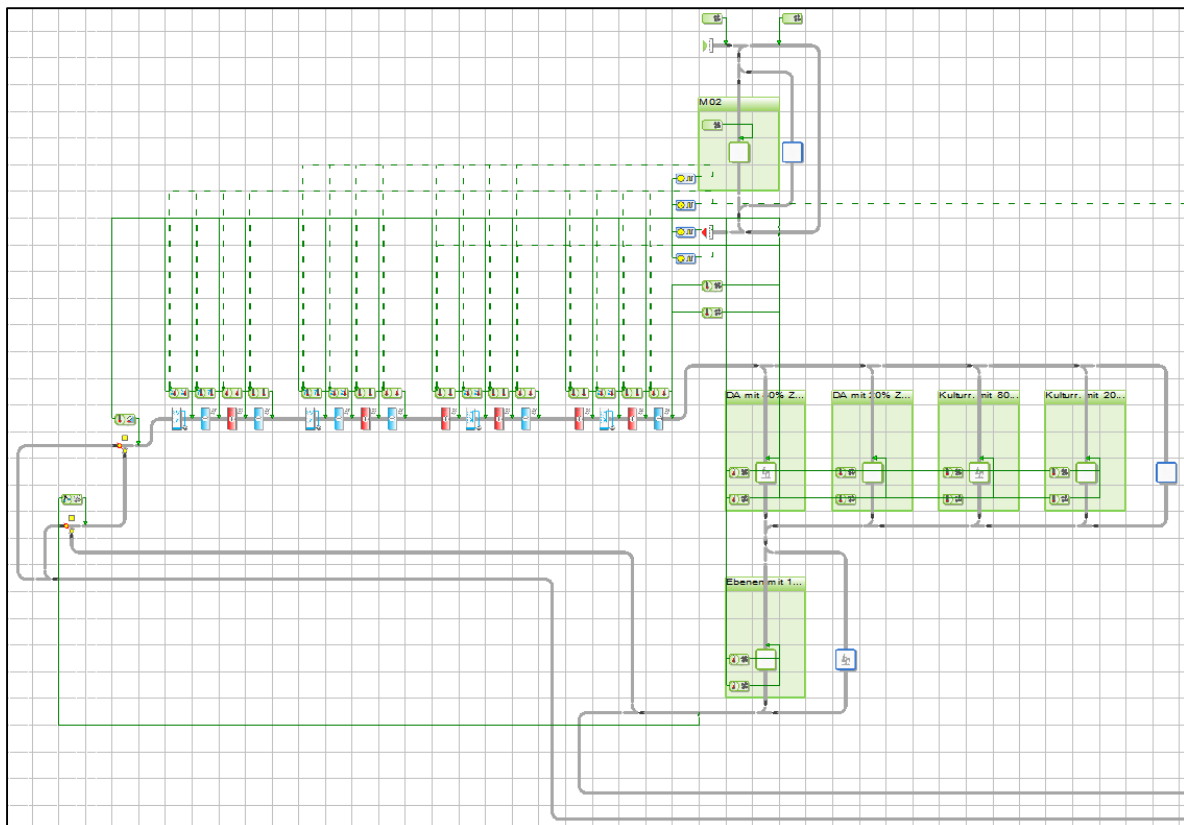Figure 4: 3D Modell_Museum of the Bavarian history_Southwest
Source: Herz & Lang GmbH

Figure 5: Modelling of the ventilation unit of the permanent exhibition with CO_2 regulation, heating and cooling coils for heating, cooling and dehumidification and spray chamber for humidification
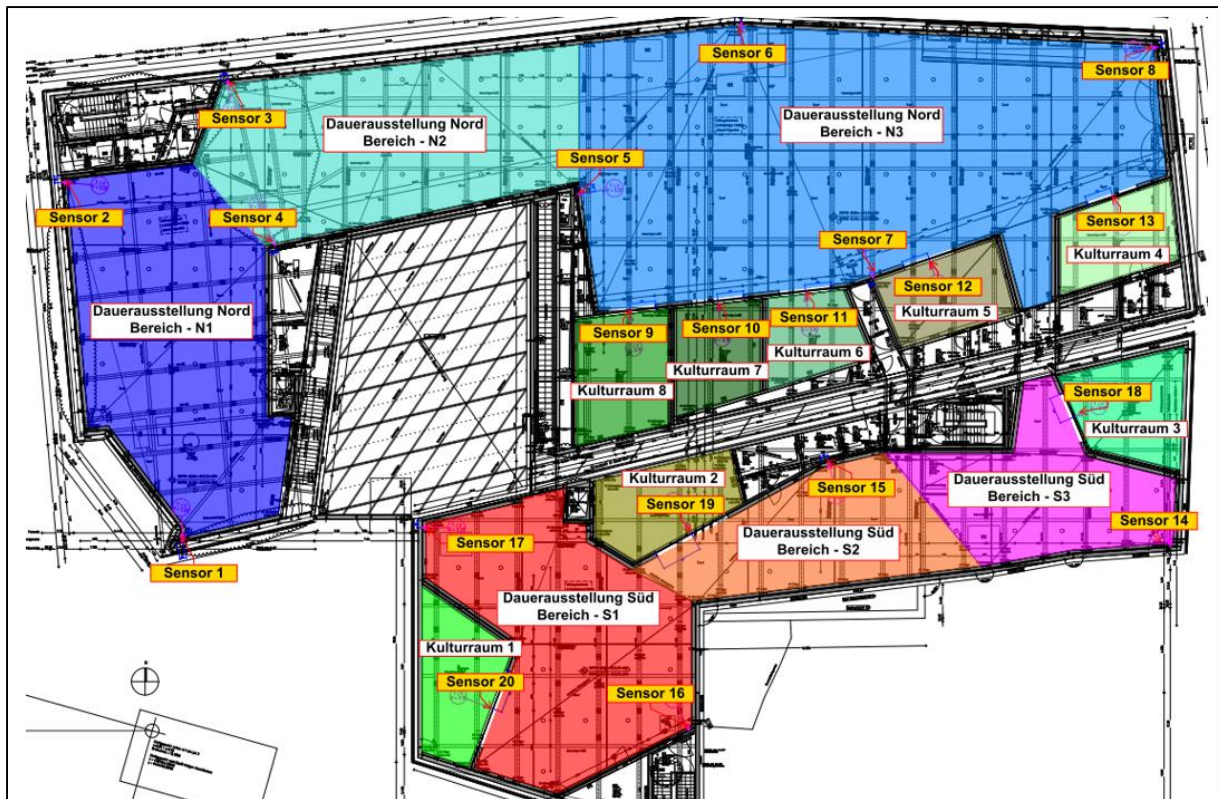Source: Herz & Lang GmbH

Figure 6: Horizontal division of the permanent exhibition and position of room sensors
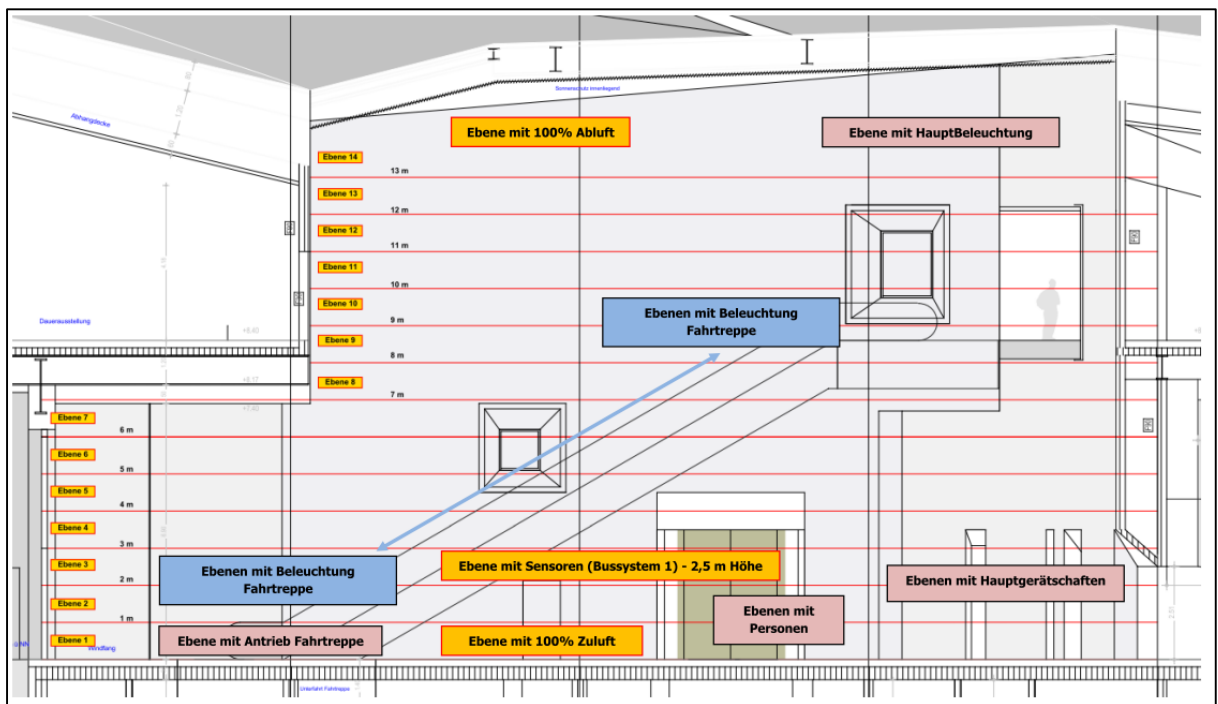Source: Herz & Lang GmbH

Figure 7: Vertical division of the entrance hall
Source: Herz & Lang GmbH
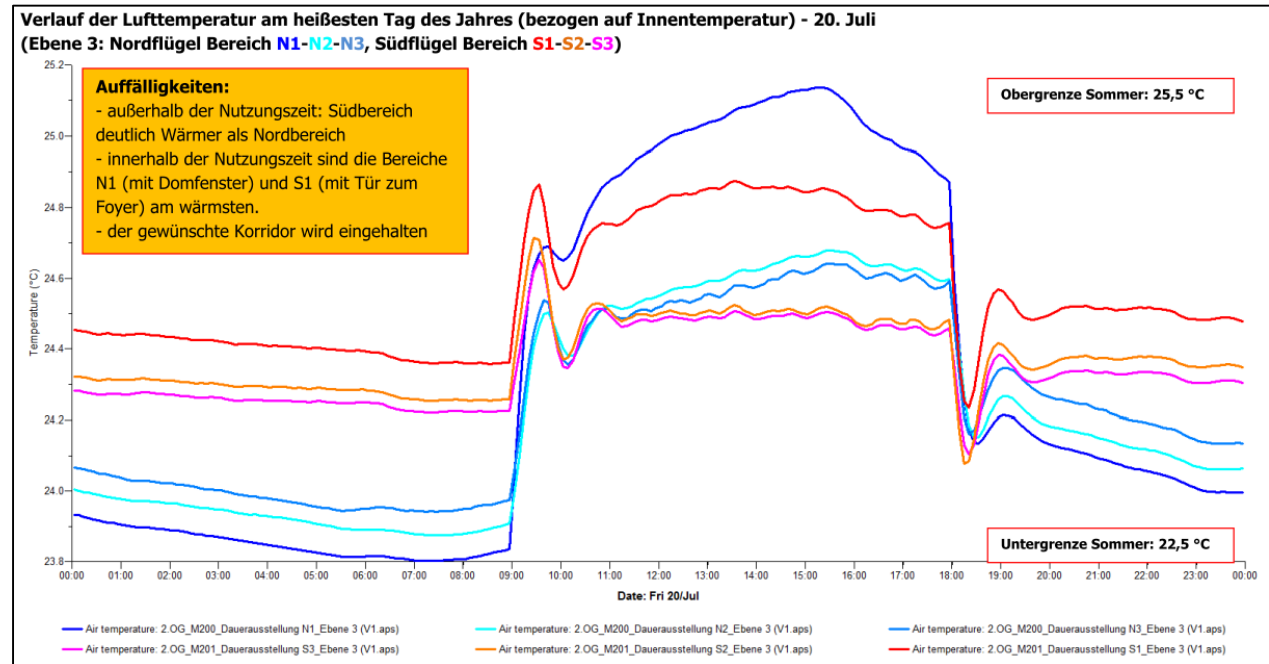
Dynamic Simulation – Results

Figure 8: Air temperature in the permanent exhibition on the hottest day of the year
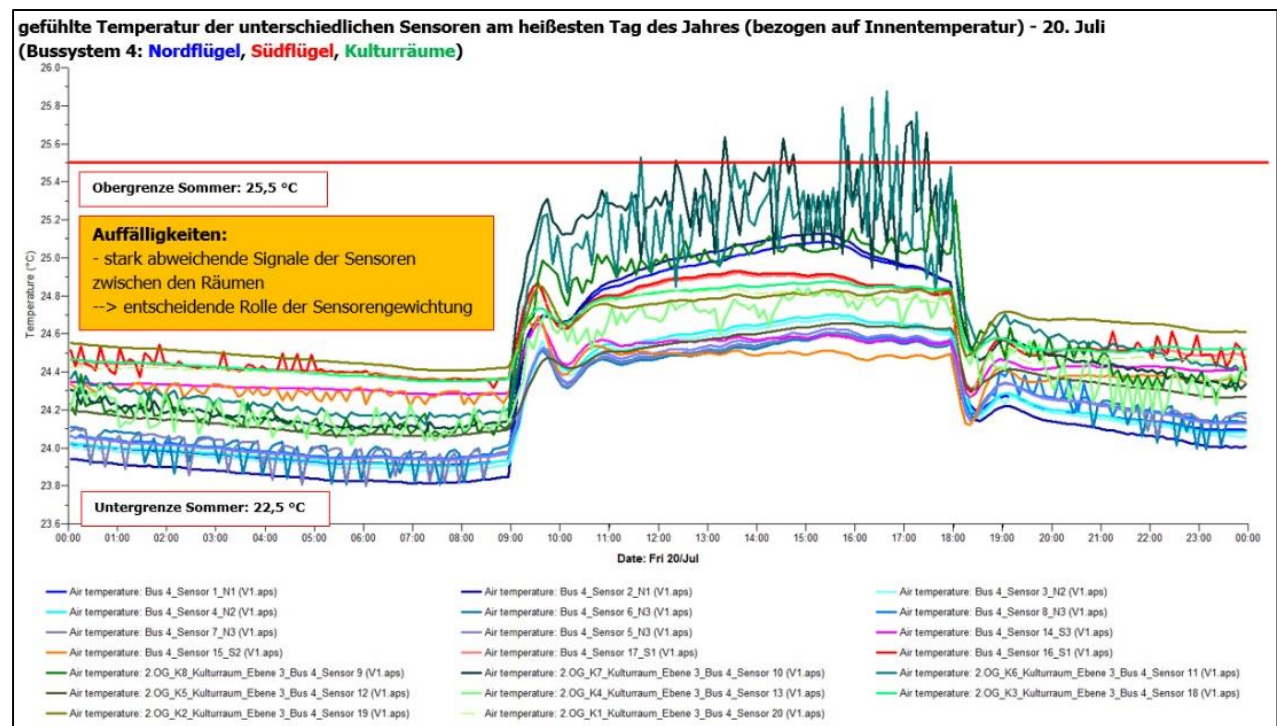Source: Herz & Lang GmbH

Figure 9: Air temperatures measured by the room sensors in the permanent exhibition
Source: Herz & Lang GmbH

The accurate horizontal and vertical division of the permanent exhibition allows a dynamic identification of temperature disparities within the room (figure 8). The air conditioning through the ventilation system is controlled by the average parameters measured by the room sensors (figure 9). Several variations of the sensors weightage for the determination of the average values have been investigated, in order to get the optimal response of the building in every situation. Thanks to this, time will be saved during the building adjustment and commissioning period, which has to be kept as short as possible.
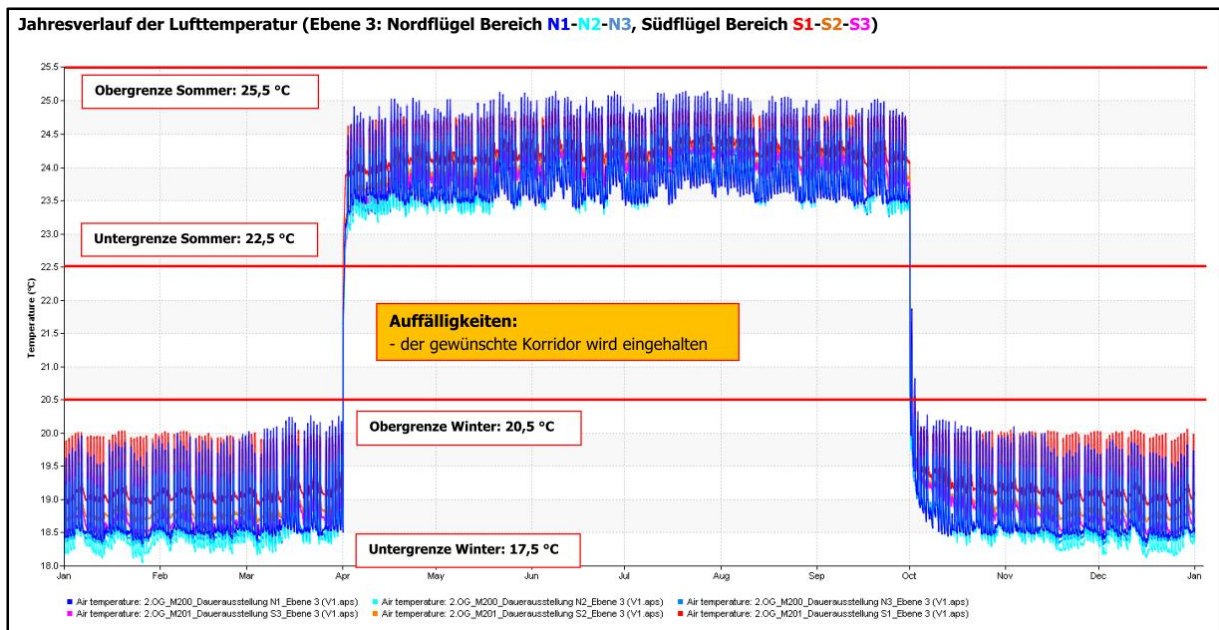
Figure 10: Air temperature over the year in the permanent exhibition
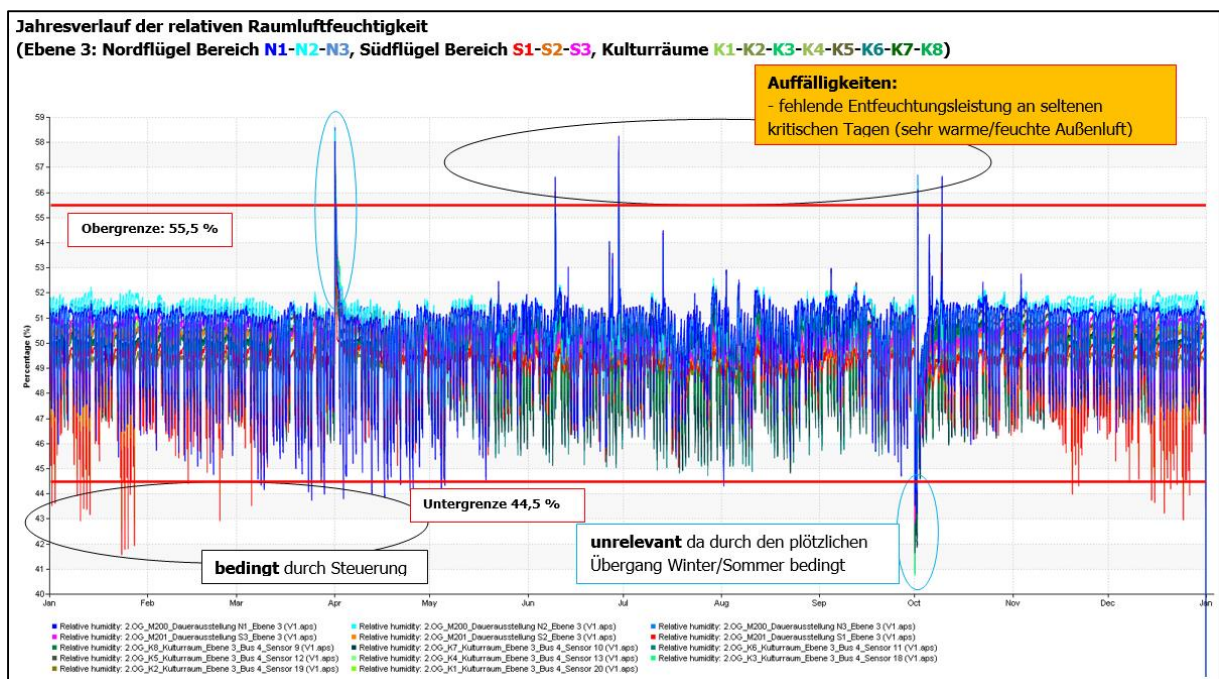*Source: Herz & Lang GmbH*

Figure 11: Relative humidity over the year in the permanent exhibition
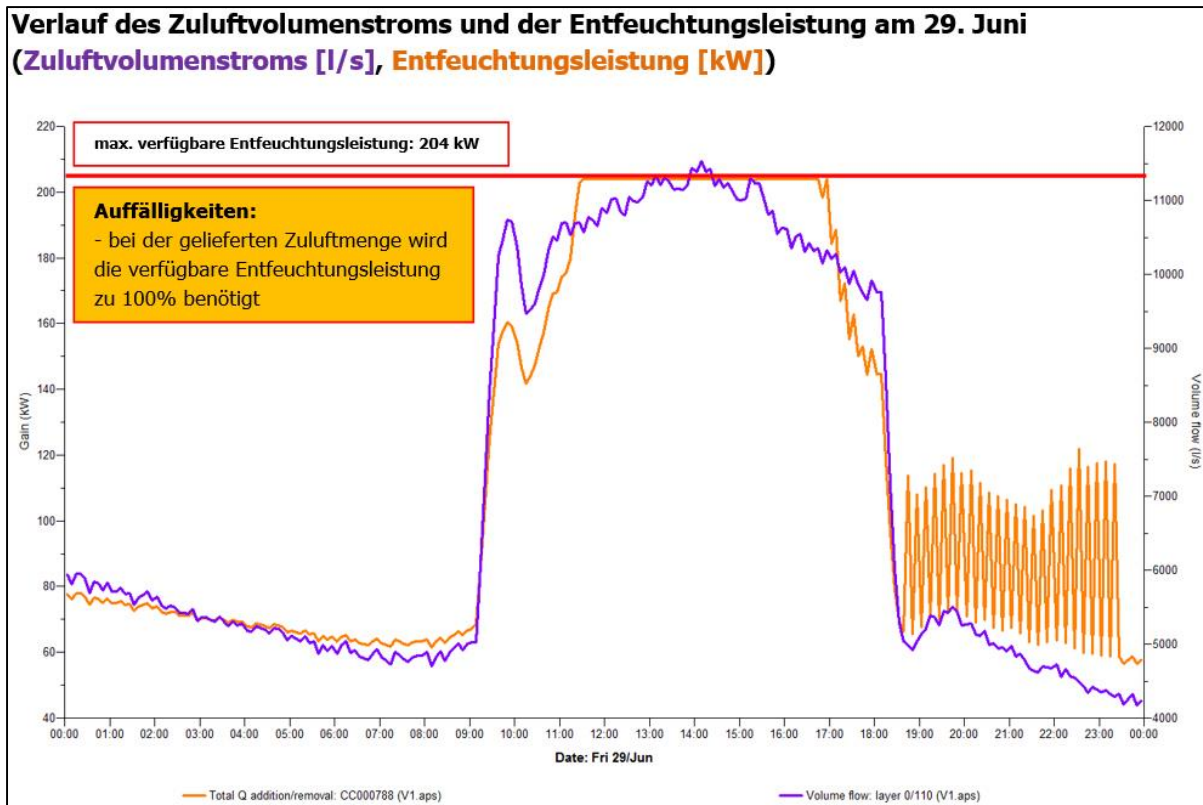*Source: Herz & Lang GmbH*

Figure 12: Power input of cooling coil for cooling and dehumidification on a day with exceedance of the required relative humidity
Source: Herz & Lang GmbH

Despite an extremely stable air temperature and relative humidity over the year (figures 10 and 11) there are still exceedances of the required relative humidity on a few days (by high absolute moisture content outside). The accurate division of the building and modelling of the HVAC-system allowed a quick identification of the causes (figure 12) and the investigation of the most cost effective solution.
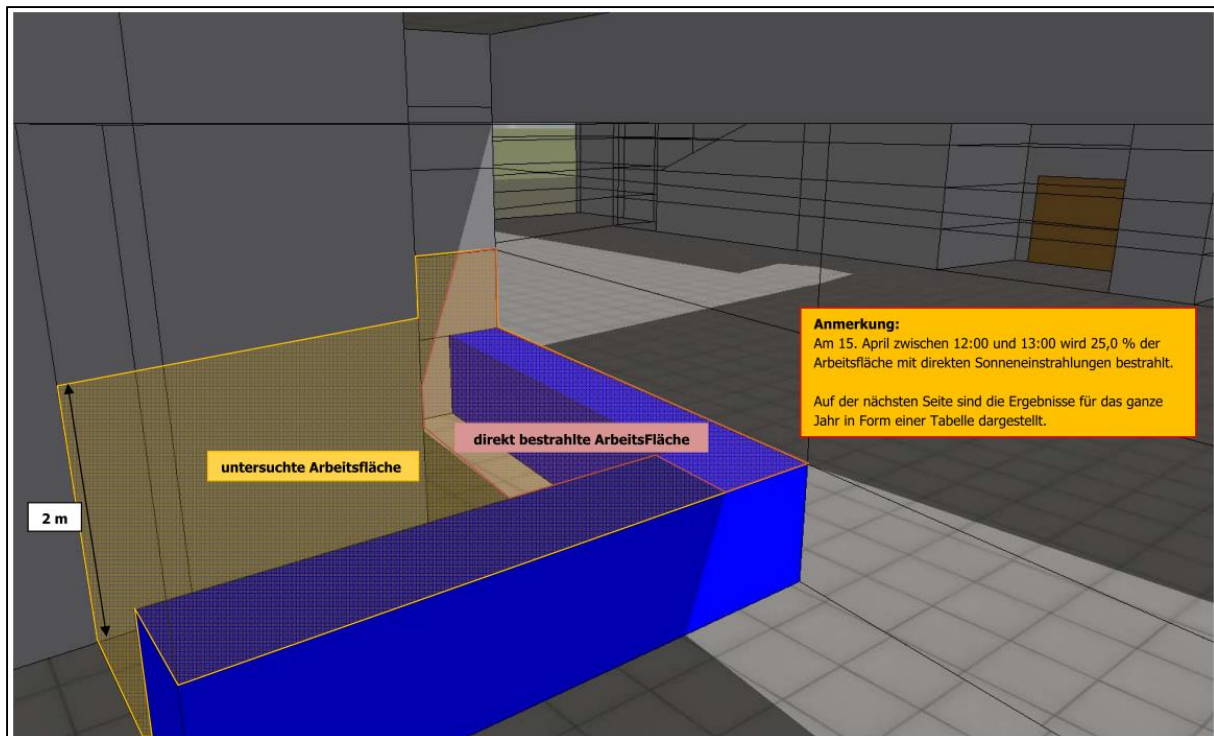
Figure 13: Analysis of direct solar radiations on work stations in the entrance hall
Source: Herz & Lang GmbH

As the 3D Model of the building was available for the main above mentioned purposes, it has also been used for additional investigations. Here (figure 13), for example, the investigation of direct solar radiations on work stations in the entrance hall was carried out, in order to optimise the comfort of work stations and comply with the German workplaces ordinance.

Final Statement

Despite a project team with no passive house background and mostly negative prejudices about dynamic building simulation, the combination between the passive house calculation and the accurate dynamic simulation offered by IESVE finally enthused the involved team members, as it turned out to be an extremely cost effective way of optimising the building.

The scepticism concerning dynamic building simulation is mostly due to the current ambiguity on the market which has resulted from quick and cheap solutions claiming to provide dynamic simulation but delivering accordingly low accuracy of results on the one side, with more powerful software solutions that offer highly detailed simulation, but are in fact more time consuming, on the other. The best way of dissipating any doubts is to evaluate the results of successful projects, such as this, which could only be achieved by using a powerful dynamic simulation tool, such as IESVE.