

General refurbishment to create an office building to the passive house standard




The office building on the site of the former Thiepval barracks was in a poor structural condition when it was bought. With the refurbishment of their new office building in Tübingen, ebök GmbH were able to considerably reduce the heating and electricity requirements and increase the comfort in summer. It is the first building worldwide to be awarded a passive house certificate for its refurbishment. The air-conditioning and ventilation are achieved solely via mechanical air supply and exhaust systems, and, if required, by opening windows. A brine-air heat exchanger cools the air as required and provides frost protection in winter. For structural reasons, the roof extension had to be built using a lightweight structure. For this reason, the ceilings of the top floor were clad with gypsum board impregnated with micro-encapsulated paraffin (PCM).



East elevation of the refurbished building on the site of the former Thiepval barracks
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Building summary

Project status	 Optimized
Location	Schellingstraße 4/2, 72072 Tübingen, Baden-Württemberg
Year of construction	1950er
Refurbished	2003
Building owner	Ing.-Büro ebök GbR
Gross floor area	986 m ²
Heated net floor area	833 m ²
Gross volume	3,724 m ³
Work places	30
A/V ratio after refurbishment	0.49 m ² /m ³
Key aspects	Heat insulation, Glazing + windows, Optimised lighting, Ventilation + heat recovery, Regenerative + passive cooling, Heat / cold storage, Optimisation of operations

Project description

In 2002, ebök Vermögensverwaltung GmbH purchased an ancillary building in the military conversion area belonging to the former Thiepval barracks. The building was constructed by the French garrison in 1954 for teaching purposes. It had not been used for some time and was in a very poor state of repair. Nevertheless, the requirements stipulated by the local conservation authorities had to be observed in terms of the outer appearance (listed protection as historic ensemble).

With the aim of achieving high quality and comfortable workspaces with minimum energy requirements, an energy concept was chosen that mixes proven state-of-the-art technologies, prototypes and experimental measures.

The location of the building on the site of the listed barracks in the immediate vicinity of Tübingen's main railway station is very attractive. Here there are optimum connections to local and regional public transport networks as well as the cycle path network. The setting is characterised by a public park, which is the former parade ground. The historic centre of Tübingen can be reached on foot.

Refurbishment concept

A new roof truss comprising double I-joists (TJI) was built on top of the old, monolithically built ground floor. The roof truss was also extended with two dormer windows so that more workspaces could be accommodated in the roof space.

In contrast to the thermal insulation for the walls and the roof, which were able to be carried out without creating thermal bridges, the thermal insulation for the base of the building presented the type of problems typical for old buildings. Higher thermal insulation thickness on the foundation slab would have made it necessary to raise the door lintels. A solution was found in providing increased insulation to the building's outer perimeter walls. With

the help of dynamic, two-dimensional heat flow calculations, it was shown that the insulated outer perimeter walls, combined with reduced floor insulation, enable a quality to be achieved comparable to the passive house standard. The flanking insulation has the effect that the temperature in the trapped ground volume beneath the building increases over the years. This creates a “heat sink” beneath the building, which reduces heat losses and leads to higher temperatures at the base point.

Energy concept

The high quality thermal insulation with passive house components enable the heating requirements to be reduced considerably below the statutory minimum requirements stipulated by the German Energy Saving Ordinance (EnEV).

In addition to low energy requirements, a pleasant indoor environment is also nowadays essential in non-residential and, in particular, office buildings. Work and meeting rooms are therefore supplied with a ventilation system that provides fresh air, whereby the exhaust air is extracted from the ancillary spaces such as the WC, kitchenette and server room. The corridors are transfer flow zones – only the meeting rooms receive a supply and exhaust air system. A time programme controls the ventilation in the office spaces. Depending on the number of occupants, the volume flow can be increased using an auxiliary fan. The mechanical night ventilation in summer is provided independently of the exhaust and outside temperatures. By deploying fans with integrated measurement and control functions (master/slave), the system is balanced in all operating situations.

The highly efficient ventilation system with heat recovery is a prototype that once again greatly exceeds the strict efficiency criteria for passive house ventilation systems. The pre-heating of the supply air and the frost protection for the heat exchanger are provided by a brine flat-plate collector laid in the ground around the building.

The building is conventionally heated with panel radiators (65/45 °C). A modulated gas condensing boiler provides any required supplementary heat. If required, a continuous-flow heater can also provide hot water across short distances in the kitchenette, shower and wash basins. Active solar energy use of the roof surfaces was not possible because of the group listing of the buildings as an historic ensemble.

In summer, internal solar shading reduces solar gain, supported by “soft” cooling. The overall measures ensure a pleasant indoor environment. The interior shading is a compromise solution between the need to provide solar protection and the listed building requirements. Internal loads are consequently avoided by using electricity-efficient devices and efficient lighting. The heat from large sources (server) is extracted directly in the equipment cabinet.

The free night cooling is implemented with support from the ventilation system (mechanical ventilation). New here is that the cool night air is fed with a large volume flow so that the ceilings, which provide the most important air-conditioning thermal capacities, specifically release heat. For structural reasons, it was not possible to construct the top floor using a solid structure. For this reason, the ceilings in the top floor were clad with gypsum board impregnated with micro-capsulated paraffin (PCM), which the manufacturer produced as a prototype. A brine geothermal heat exchanger cools down the outside air to around 4 kelvin.

A good working atmosphere requires optimum lighting of the workspaces – including with daylight. In order to ensure this, the design was supported with a simulation. Highly efficient and dimmable lighting was created, which is smoothly adjustable by means of daylight and motion sensors.

The energy quality was balanced according to the PHPP (Passive House Planning Package). The refurbished passive house requires approximately 20 kWh per square metre and year for heat (thermal heating and hot water), and approximately 7 kWh for lighting and building services equipment. Converted into primary energy, this corresponds to an energy deployment of 43 kWh/m² p.a. This means that the building requires only 15% of the primary energy used by typical existing office buildings, which is thus around 60% lower than the energy requirements for the key research area "Energy-optimised construction" (EnOB).

Performance

The mean energy consumption for heating and hot water across two years is 24.5 kWh/m² p.a. The measured value for the energy consumed by the building's heating includes losses in the heating system (generation and distribution losses). The heating requirement of 22.4 kWh/m² p.a. including losses, which was forecast during the planning, is therefore almost achieved.

The electricity consumption lies in the same magnitude as the heat energy consumption. In terms of the primary energy, however, the electricity consumption considerably predominates relative to the overall energy consumption as a consequence of the more unfavourable primary energy factor. This shows how important it is to deploy energy-efficient office equipment and building services systems in energy saving buildings.

The technical office equipment largely determines the electricity consumption, which at an average of 20.8 kWh/m² p.a., amounts to around 70% of the overall electricity consumption.

In 2004, the building became the first refurbished building to be awarded a passive house certificate from the Passive House Institute, Darmstadt.

Optimisation measures and possibilities

Combining the ventilation concept and temporary heat storage in the ceilings has had a positive effect in the realised form. The exterior air is pre-cooled with the ground collector and, together with the heat absorption by the ceilings, enables the internal loads and part of the solar loads to be compensated for. The mechanical night ventilation generally re-cools the heat capacities by a sufficient amount. The thermal discharge of the ceilings is achieved using an air current beneath the ceiling – here there is still room for improvement. During hot periods, there are increased room temperatures as a result of the limited output of the flat ground collector laid flat in the workroom together with the relatively low solar shading effect provided by the internal blinds. In some rooms, the excess temperature frequency amounts to around 10 per cent of the working time.

Construction costs and economic viability

The construction costs for the cost groups 300+400 amounted to 810,000 euros (net). These include additional costs for purely energy-based additional measures (without summer cooling and without lighting) relative to a functionally required minimum standard of 60,000 euros. The economic assessment was conducted following the annuities process.

Without taking into account subsidy measures, after 30 years this provides an excess present value of around 20,000 euros, while the payback time amounts to 26 years.

In this case, a grant was awarded by the Baden-Württemberg Ministry for the Environment and Transport as part of its Climate Protection Plus Programme, which amounted to 47,200 euros. This reduces the payback time to 6 years. For the assessed period of 30 years, this leads to an excess present value of around 112,000 euros.

Key energy data

Energy indices according to German regulation EnEV (in kWh/m ² a)	before refurbishment	after refurbishment
Heating energy demand		19.30
Overall primary energy requirement		52.50
Measured energy consumption data (in kWh/m ² a)	before refurbishment	after refurbishment
Site energy for heating and domestic hot water (dhw)		24.50
Source energy for heating and domestic hot water (dhw)		26.30
Total source energy		112.00
Lighting		8.00
Computing		61.00
Building services equipment		8.00
Hot water		0.00
Heating		25.00
Other (kitchen, etc.)		6.00

Implementation costs

Implementation costs in €/m ²	
Construction (KG 300)	680
Technical system (KG 400)	156

These figures represent established costs

Net construction costs (according to German DIN 276) relating to gross floor area (BGF, according to German DIN 277)

Operating costs

Operating costs in €/m ² a	before refurbishment	after refurbishment
Total energy costs		7.20
Heating and domestic hot water		1.34

Heating	1.31
Domestic hot water	0.03
Total electricity consumption	0.57
Lighting	0.57
Infiltration/ventilation/cooling	5.86

Project presentation fbta Uni Karlsruhe

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