Complete refurbishment of a block of flats to become a 3-litre house

EnSan

In the Mannheim Garden City, a two-storey residential building from the 1930s was refurbished to provide up-to-date and modern living conditions. Twelve attractive maisonette flats were created from the previous 24 small flat units. The building envelope of the monolithically constructed building, which has a gable roof, was clad in high-performance thermal insulation. Five different kinds of systems for heating and ventilating the building were tested with this project. Each flat was equipped with a central ventilation system as standard. The flats are to some extent exclusively air-conditioned via the ventilation system with different comfort temperature settings as well as via radiators or capillary tube mats in the room ceilings. A CHP plant provides the heating energy.


Building after refurbishment
© GBG Mannheimer Wohnungsbaugesellschaft mbH

Building summary

Project status	Optimized
Location	Freyastraße 42-52, 68305 Mannheim-Gartenstadt, Baden-Württemberg
Year of construction	1931
Refurbished	2004
Building owner	GBG Mannheimer Wohnungsbaugesellschaft mbH
Gross floor area	1,353 m²
Gross volume	6,560 m³
Heated living area	1,150 m²
Usable floor area (according to EnEV)	2,099 m²
A/V ratio before refurbishment	0.50 m²/m³
A/V ratio after refurbishment	0.50 m²/m³
Key aspects	Heat insulation, Glazing + windows, Ventilation + heat recovery, Regenerative + passive cooling, Thermo-active building element systems, Combined heat and power generation, combined heating and cooling

Project description

The 3-litre house research project in Mannheim was carried out in 2004 by the GBG Mannheim. The aim was to modernise an old building belonging to the building society's stock in an exemplary fashion in order to transform it into a 3-litre house. That corresponds to an annual primary energy requirement for the heating of 34 kWh/m² p.a., which is equivalent to 3 litres of heating oil per square metre of living space and year. The energy requirement is therefore considerably lower than the standard prescribed for new buildings under the former German Energy Saving Ordinance (EnEV).

The non-insulated exterior walls, constructed as solid brick masonry in combination with a non-insulated basement that extends beneath the entire building, were decisive for the massive heat losses. The flats only had individual ovens that were heated with oil, gas or coal. This meant that no overall heat consumption had been determined, since the individual tenants procured their own fuel. The hot water was heated using gas fired continuous-flow heaters or solid-fuel hot water tanks. The only means of providing ventilation was by opening the windows.

The flat and room sizes were adapted to modern requirements in order to make it easier to rent the flats. For this purpose, two vertically adjacent flats were joined together to form a maisonette flat.

Building / Refurbishment concept

3-litre houses require good thermal insulation and a sufficiently airtight building envelope. The building was insulated with extruded polystyrene insulation panels, which were 20 cm thick on the exterior side of the long elevations and 25 cm thick on the gable end walls. All windows were replaced with high quality windows with thermally insulating triple glazing. The roof structure was completely refurbished and clad with between-rafter

and over-rafter insulation up to a depth of 36 cm.
Besides the structural refurbishment measures, the concept of the 3-litre house in Mannheim is based on the use of different plant systems for ventilating and heating the flats. By comparing the five versions, this shall provide the building society with valuable information as to which system offers the maximum amount of convenience and comfort or the lowest energy requirements.

Energy concept

In order to achieve the desired primary energy requirement, a correspondingly efficient system for generating heat has been selected, whereby the primary energy assessment plays a significant role. Since the combined production of heat and electricity achieves a high degree of efficiency, a combined heat and power (CHP) unit with a Stirling engine is utilised, which is located in the central local heating plant in the neighbouring building. Even with the use of fossil fuel, this produces a primary energy factor of 0.7. This good primary energy assessment takes into account the additional electricity production. The electricity produced by the CHP plant is fed into the public grid. A heat storage tank stores the heat that is currently not required. If more heat is required in peak load times than can be supplied by the CHP plant and the storage tank, a gas condensing boiler provides sufficient additional power.
Five different system versions were deployed for the ventilation, which were measured and assessed over a period of two years. A common feature of all the versions is that the ventilation is provided by a central domestic ventilation unit with heat recovery in the top floor as well as a radiator in the bathroom.

Version 1: Standard air heating

The flat is heated and ventilated using a central domestic ventilation unit. The overall air volume can be regulated at three levels, while the temperature can be variably controlled. When heating, the air system is fed through a central reheater to add heat. The ventilation system is used in winter and is switched off in summer. The flats then have to be ventilated via the windows. This is a simple system that is frequently deployed in passive houses.

Version 2: Ground and first floor air heating

In contrast to version 1, separate reheaters have been installed for the ground and first floors so that different temperature levels can be set.

Version 3: Comfort air heating

In contrast to versions 1 and 2, both the air volume and the temperature can be controlled individually in each room.

Version 4: Air heating and radiators

In addition to the ventilation system with heat recovery and reheaters, a complementary system for heating the rooms is provided. The individual room control makes it possible to feed heat to each room as required.

Version 5: Air heating and capillary pipe mats

Analogous to version 4, a complementary system for heating the rooms is provided in addition to the ventilation system. The system comprises capillary tube mats, which are arranged close to the surface in the room ceilings. In addition to feeding heat loads when heating, these systems are also used for discharging heat loads when cooling. The coolness is extracted from the ground using a ground collector laid 1.2 metres deep in the garden.

Performance

The evaluation of the measurement data and surveys show that the single or double zone control does not make it possible to heat the living spaces as required. With versions 1 and 2, the tenants complained about the temperatures being too high in the upper floors during the heating period. In the flats that just have air heating, the tenants criticised the long warm-up time. The tenants, on the other hand, were very satisfied with the air quality when operating the ventilation system in winter. That is certainly one reason for the generally very high acceptance of the new building systems equipment. When comparing the energy consumption with flats using the same types of systems, this shows the considerable influence of users on the energy requirements in highly insulated buildings. The differences in the heating requirements between flats with the same types of systems are sometimes even greater than between flats with different system versions.

Optimisation measures and possibilities

The comparison of the temperature profiles in flats with and without cooling shows that room temperatures vary by as much as 7 kelvin. The room temperatures in the flats using version 5 are generally lower in comparison to all the other flats. The cooling via the ground collectors functions well. However, there are flats without cooling whose room temperatures are lower than in the cooled rooms. This reveals the considerable influence of the users' behaviour on the summer indoor temperatures. For good comfort in summer it is important that the rooms are only ventilated at night and that the exterior solar shades are used during the day.
The effect of the night ventilation can be increased in summer by switching on the air extraction fan, which

increases the air exchange rate. This possibility was not used by the tenants, although this function was frequently explained to them. A possible additional measure would be to automate this function.

Construction costs and economic viability

The construction costs for the 3-litre house are around 2,300 euros/m² of living area according to DIN 276 cost group 300/400. These comparatively high costs have mainly resulted from the large-scale intervention in the existing building fabric that was necessary in order to reconfigure the flats.

The construction costs include the additional costs for the 3-litre house standard relative to the corresponding EnEV version, which amounts to around 600 euros/m² of living area. These additional costs can be divided into 440 euros/m² for the ventilation technology and 160 euros/m² for the optimised thermal insulation.

The investments for the subsidised special technologies such as the capillary tube mats and the ground collectors are not included in these additional costs.

Key energy data

Energy indices according to German regulation EnEV (in kWh/m²a)	before refurbishment	after refurbishment
Heating energy demand	210.00	21.60
Overall primary energy requirement	389.10	34.00
Measured energy consumption data (in kWh/m²a)	before refurbishment	after refurbishment
Site energy for heating and domestic hot water (dhw)		29.80
Source energy for heating and domestic hot water (dhw)		20.90
Total source energy		54.80
Ventilation system		29.00

Refurbishment costs

Refurbishment costs in €/m²	
Increased heat insulation standard	135
Additional charge ventilation technology and special technologies (capillary tube mats, ground collectors)	370

These figures represent calculated costs

This project is funded within the framework »Energy Optimized Building« (EnOB) by the German Federal Ministry of Economics and Technology, on the basis of a decision by the German Bundestag. Get further information at www.enob.info.