MODERNISING OLDER HOUSES TO PASSIVE HOUSE STANDARD

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Abstract: This paper is intended to outline technical solutions for future modernisation of older buildings by the addition of heat pumps for homes and small businesses, using the example of an apartment building in Hanover. The apartment building underwent a thorough energy overhaul including replacing the old decentralised coal/oil/gas/electricity heating systems with a central heating system plus two groundwater heat pumps.
Brief design guidelines for use of the heat pumps in old buildings will then be outlined.

Key Words: ***heat pump, water/water heat pump, ventilation system, Cross-counterflow heat exchanger, photovoltaic system, passive house standards, heating, domestic hot water, primary energy balance***

1 INTRODUCTION

Approximately 87% of the total energy used in private households is used for central heating and domestic hot water. When the first Thermal Insulation Ordinance came into force in 1977, considerable improvements were made to thermal insulation of new buildings.
In addition to well-insulated new buildings, efforts in the field of energy efficiency and energy savings in the heat market need to focus much more on the huge potential for modernisation within existing housing stocks, with a view to achieving a 30% reduction in carbon dioxide emissions from buildings by 2020 by doubling the modernisation rate for existing heating systems and by thermal insulation.

9 Schaufelder Strasse in Hanover is an old residential building reconstructed in 1950, which has been renovated to become a comfortable, model energy-saving building.
The project was planned by the Hanover-based design consultancy, Passivhauskonzepte GmbH, together with the Stiebel Eltron design department.

Approximately every fourth new house built is constructed in accordance with passive house standards. Conversion to passive house standards as part of old building modernisation projects is in the very early stages of development. The project in Hanover-Nordstadt should highlight innovative opportunities, such as the outstanding residential quality of the passive house concept, the important role of apartment ventilation and the fact that heat pump technology is ideal for this purpose.

2 MODERNISATION

2.1 Initial position

The building at 9 Schaufelder Strasse was reconstructed after the Second World War. It was an empty residential building in need of modernisation in many respects. The heating, plumbing and electrical installations were out-of-date and the apartment layouts were old-fashioned. The lack of balconies and lifts also had a detrimental effect on convenience.

Before modernisation, the building had 5 floors with 21 residential units and one shop. The living area covered 1709 m^2. The heating and domestic hot water supply, comprising a decentralized mix of coal/oil/gas/electricity with a heating consumption of 230 kWh/m²a, was out-of-date.

Figure 1: Residential building at 9 Schaufelder Strasse before modernisation

2.2 Scope of modernisation works

In order to optimise energy use, the building's heat-conducting external wall area was minimised by closing off internal courtyards. This led to more useable internal space and simultaneously reduced heat losses.
The roof space was extended to include 3 maisonette dwellings. Balconies were added to the apartments on floors 1-4 facing the rear elevation. The basic layout of the apartments was redesigned to create more, smaller units. Apartments were made accessible to all by providing a lift. Four apartments were even adapted fully for disabled residents. Heating, plumbing and electrical installations were replaced in their entirety.
The result: 32 residential and 2 office units with a total living area of 2050 m^2 over 6 floors.

Figure 2: Residential building at 9 Schaufelder Strasse after modernisation

The crucial energy-saving elements, even in existing buildings, consist of very good thermal insulation, reducing thermal bridges, increasing airtightness, ventilation with efficient heat recovery, the use of high-insulation windows and efficient heat production.

The energy concept at 9 Schaufelder Strasse envisaged reducing heat demand by a factor of 10, using highly efficient heat pumps and creating an energy balance to produce heat over the course of the year with the aid of a photovoltaic system.

Thermal insulation was provided for the external walls by means of a composite thermal insulation system and by a completely new design of insulation in the roof space in accordance with passive house standards. The considerable height of the ground floor made it possible to apply a very thick layer of insulation within the floor structure above the unheated basement. High-insulation windows (U value = 0.8 W/m²K) were used throughout. Existing thermal bridges were minimised thanks to careful detailed design.

In order to increase heat recovery efficiency in the installed ventilation systems, great emphasis is placed on an airtight building shell and the design quality of this shell was ensured by use of blower door tests. This energy feature also led to a considerable increase in living comfort by excluding draughts and cold spots in front of windows. The very airtight windows also reduced the level of road noise that could be heard inside the building.

In the summer months, thermal insulation of the passive house shell is achieved by use of shading.

The specified measures ensure that, in future, the residents will only require about a tenth of the energy for heating and domestic hot water purposes.

3 BUILDING TECHNOLOGY

3.1 Ventilation system

Ventilation systems within the apartments ensure a comfortable living atmosphere.
To reduce design and installation costs, ventilation systems were provided individually for each apartment. These systems ventilate the apartments, filter external air, constantly remove pollutants and humidity (preventing mould growth) and recover up to 90% of the heat.
Each residential unit has a separate ventilation appliance. These ventilation appliances were designed specifically for single-storey apartments. They can be installed in a suspended ceiling and are thus particularly space-saving. The atrium and stairwell also have their own ventilation system.

3.1.1 Ventilation system operation

The ventilation appliance has two fans, which carry external air and exhaust air from rooms in the apartment that are prone to smells or humidity (kitchen, bathroom, WC) via separate ducts, each with their own filter pad. These two air flows are passed through a cross-counterflow heat exchanger, where the external air takes up heat and the exhaust air gives off heat. The heated ventilation air is passed into the apartments via the air ducts and the air outlets. The cooled escaping air is blown outside via an appropriate wall grating.

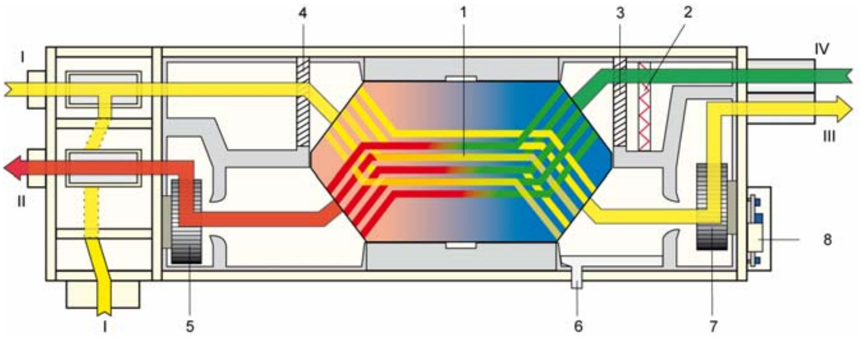

Figure 3: Ventilation system – operating principles

1 Heat exchanger
2 Preheating element
3 External air filter
4 Exhaust air filter
5 Ventilation air fan
6 Condensate discharge
7 Exhaust air fan
8 Control circuit board
I Exhaust air
II Ventilation air
III Escaping air
IV External air

3.2 Heat pump

Two heat pumps supply heating and domestic hot water and take their energy from a shared borehole water supply in the internal courtyard.

Figure 4: Installed heat pumps

However, due to inadequate water quality, only water/water heat pumps that pass the heat from the groundwater to the heat pump's intermediate circuit via an additional heat exchanger could be installed. These heat pumps were thus not connected to the groundwater, but still use the energy from the conveyed water. Although this led to a reduction in performance of approximately 5%, it also improved system safety.
The installed heat pump system comprises two separate appliances (13 and 18 kW output), which are used for different temperature ranges (underfloor heating and radiators).

It was possible to construct the borehole, comprising a supply and return well, in the building's internal courtyard.
The heat pump system is operated in mono-mode, i.e., without any additional direct electrical heating, even for heating domestic hot water up to a temperature of 60 °C.

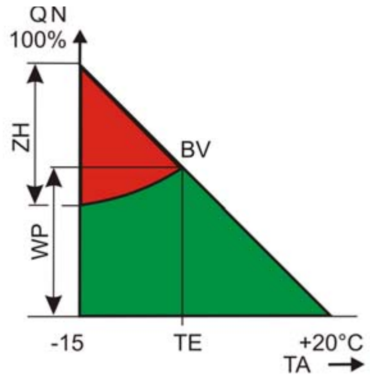

Figure 5: Mono-energetic operation

WP- Heat pump
Q_h- Booster heater
TU- Switch point
BV- Bivalent point
ZH- Booster heater
TE- Booster heater cut-in temperature

In summer, the 13 kW water/water heat pump is also used for passive cooling in the roof space and ground floor and thus provides additional levels of comfort.
In the case of passive cooling, the cooled groundwater is passed through an additional heat exchanger for the cooling trap, through which the heating water passes. Heat is transferred from the warmer medium to the colder medium. The heating water for the surface heating system flows through the floor of the rooms to be cooled and thus reduces room temperature.

3.3 Domestic hot water cylinders

Two series-connected cylinders with a capacity of 400 l and 1000 l are provided to store domestic hot water.
The 400 l pre-cylinder constantly heats the water to a temperature of 35 °C. The 1000 l main cylinder is responsible for the remaining heating process from 35 °C to 60 °C. For protection against legionnaires' bacteria [thermal pasteurisation], the 400 l cylinder is rinsed once a day with the 60 °C water from the 1000 l cylinder.

Figure 6: 1000 l DHW cylinder

3.4 Flow diagrams

The hydraulic and electrical systems were created by the Stiebel Eltron design department. A buffer cylinder or a low-loss header is required in order to separate the flows from the heat pump and heating circuit/cooling circuit by hydraulic means. A low-loss header was sufficient in Schaufelder Strasse. A buffer cylinder was not necessary. See figure 8.

3.5 Photovoltaic system

75 modules manufactured by a company called Solarnova (SOL 212 GT) were installed on the south and east-facing roofs of the building in Schaufelder Strasse. Each module has a peak output of 212 W. The inverter output of the PV system is 19.1 kW.

4 STATE AFTER MODERNISATION

No comprehensive assessment is available as the first heating season is not as yet over. Initial estimates indicate that the target values for the first year are not as yet being achieved due to building drying and controller optimisation. Significant are high distribution losses in the DHW circulation lines.

5 ENVIRONMENTAL SIGNIFICANCE OF HEAT PUMPS

Primary energy comparisons between heat pumps and oil or gas-fired heating systems are possible on the basis of power generation efficiency and the heat pump performance factor as compared with the energy content of the fuel and the efficiency of the heat generator. Figure 7 illustrates this comparison for German conditions.

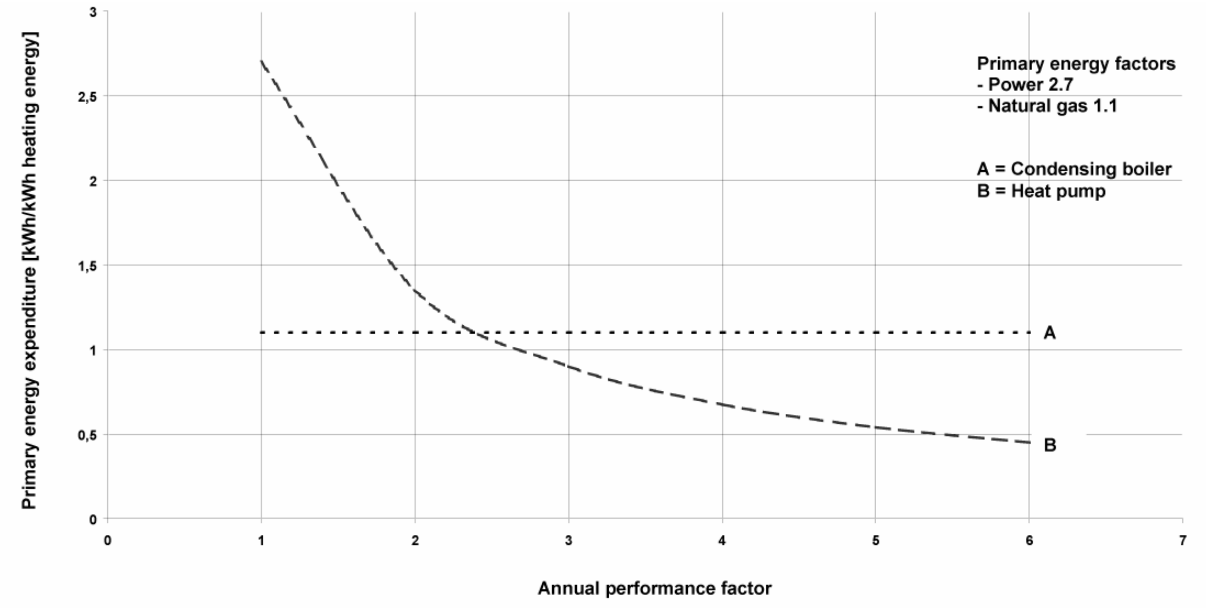

Figure 7: Comparison of the primary energy used by heat pumps with natural gas-fired heating systems

The power required to operate the heat pump is already at its optimum primary energy consumption level with annual performance factors of approximately 2.8. Current improvements in power generation by increasing the efficiency of power stations and increased use of regenerative power generating systems have a direct and positive effect on the primary energy balance for a heat pump and thus on the environmental balance. These improvements also have a lasting effect on existing heat pumps. [1]

5.1 Conditions of use for heat pumps

The efficiency of heat pumps is greatly dependent on the heating system temperature required in the heating system and this in turn depends on heat demand and the installed radiators. Heat pumps ideally operate with low system temperatures of 35 °C, as used in underfloor heating systems for example. However, heat pumps can also be used effectively with higher temperatures of up to 55 °C. In addition, the location and quality of the heating system can affect the annual performance factor.

5.2 Reduced heat demand and reduced system temperatures in buildings

The system temperature of the heating system is defined when the heating system is installed and the radiators are designed accordingly. If the heat demand changes, the system temperature also changes. Retrospective thermal insulation measures such as insulating glazing, thermal insulation of the facade, the basement ceiling and the roof space itself and the use of controlled ventilation systems with heat recovery reduce the heat demand for the building considerably. This also means that a lower system temperature is possible with the same radiators.

Table 1: Energy-saving measures

Measure	Energy saving
External wall insulation	20 – 40 %
Windows with thermal insulation glass	10 – 25 %
Roof insulation	10 – 25 %
Basement ceiling insulation	10 – 20 %
Ventilation system with heat recovery	15 – 30 %

The table shows the influence of thermally insulating a building, starting with a building with a heat demand of 150 W/m² and standard sizing for 70/55 (70 °C flow temperature , 55 °C return temperature) to the required system temperature.

Heating systems with a flow temperature of 70 °C and a return temperature of 55 °C were used routinely during the 1970s and 80s and were frequently oversized since the radiators were adapted to the size of the windows. Modern radiators can achieve a heat exchange surface which is about 50% bigger whilst using the same amount of space. Compared to a flow temperature of 70 °C, a reduction of approximately 10 °C to a maximum flow temperature of 60 °C can thus be achieved.
Buildings constructed between the 90s and the present day were also often wrongly designed with 70/55° systems. These buildings generally have relatively high thermal standards, so there is no need to upgrade the thermal insulation. As a general rule, larger radiators need to be used with a heat pump system. Alternatively, a considerable reduction in the heat load and maximum flow temperature can be achieved by using a central apartment ventilation system with heat recovery as the ventilation heat losses in well-insulated houses account for almost half the heat load. It is also possible to operate a heat pump if a low-temperature condensing boiler heating system is installed with temperatures of 55/45 °C. Surface heating systems can be used without restriction if the entire building is heated using this system. In the case of mixed systems, the maximum flow temperature for the entire system is crucial.
In order to check whether the existing heating surfaces can be used for heat pump operation, please consult the form entitled “Grundlage Raumliste: Heizflächenprüfung; Heizflächenauslegung” (*Basic room list: Heating surface checks; Heating surface design*) issued by the Bundesverband Wärmepumpe (Federal Heat Pump Association) (now known as the BWP) [2].

5.3 Selecting the heat source and the installation site

When selecting the heat source for the heat pump, local conditions are often the deciding factor. In a new build, the garden has not normally been laid out and construction work can easily be accommodated. It's a different matter with existing buildings, where years of effort have often been invested in the garden, which means that a geothermal collector, a geothermal probe or a borehole facility are not feasible. If conditions are favourable, boring a geothermal probe in the driveway is a possibility and not too expensive. It is essential that the brine pipes can be laid from the heat pump installation site to the driveway without any problem. The building heat load should also not be too high for the necessary probes to be constructed in the driveway. As a rule of thumb[1], the building heat load divided by 7 kW corresponds to the number of probes required. On the other hand, air/water heat pumps can be installed inside the house or even in the open air with minimal expense. In the case of air/water heat pumps installed inside the house, the external air is supplied and discharged

[1] Assumption: Probe length 100 m; specific extraction rate between 50 and 55 W/m

by two air ducts or tubes. In the case of heat pumps installed outside the house, the heating flow and return, a condensate drain and the electrical cables need to be connected to the house via a narrow trench. [1]

5.4 Energy and operating costs

The energy and operating costs for heat pumps are particularly low if the system is designed correctly. Energy supply companies (EVU in German) offer special heat pump tariffs because they reserve the right to switch off for a maximum of 3 x 2 hours per day in peak power generating periods. Stable electricity prices, which have risen more or less with inflation for the past 30 years or so, also suggest a reliable energy cost prognosis.

6 SUMMARY

The passive house standard can make an important contribution to climate protection, especially due to the increased use of highly efficient components when modernising old buildings. Even though much has yet to be done with a view to achieving appropriate and stable outline conditions for this sector in the world of politics, we can still hope that this example of a modernisation project will encourage other investors to follow our lead in the short term.

In general, air/water heat pumps are suitable for modernising heating systems, as these are easy to install retrospectively. It is generally possible to operate such systems with temperatures of no more than 55 °C or to achieve this relatively simply by use of oversized radiators and installing thermal insulation. The low electricity requirements of heat pumps result in low energy costs and sustained savings in terms of primary energy and CO_2 emissions.

7 REFERENCES

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[2] IWP Information on heat pump technology "Wärmepumpen für die Modernisierung älterer Heizsysteme" (Heat pumps for modernising older heating systems)

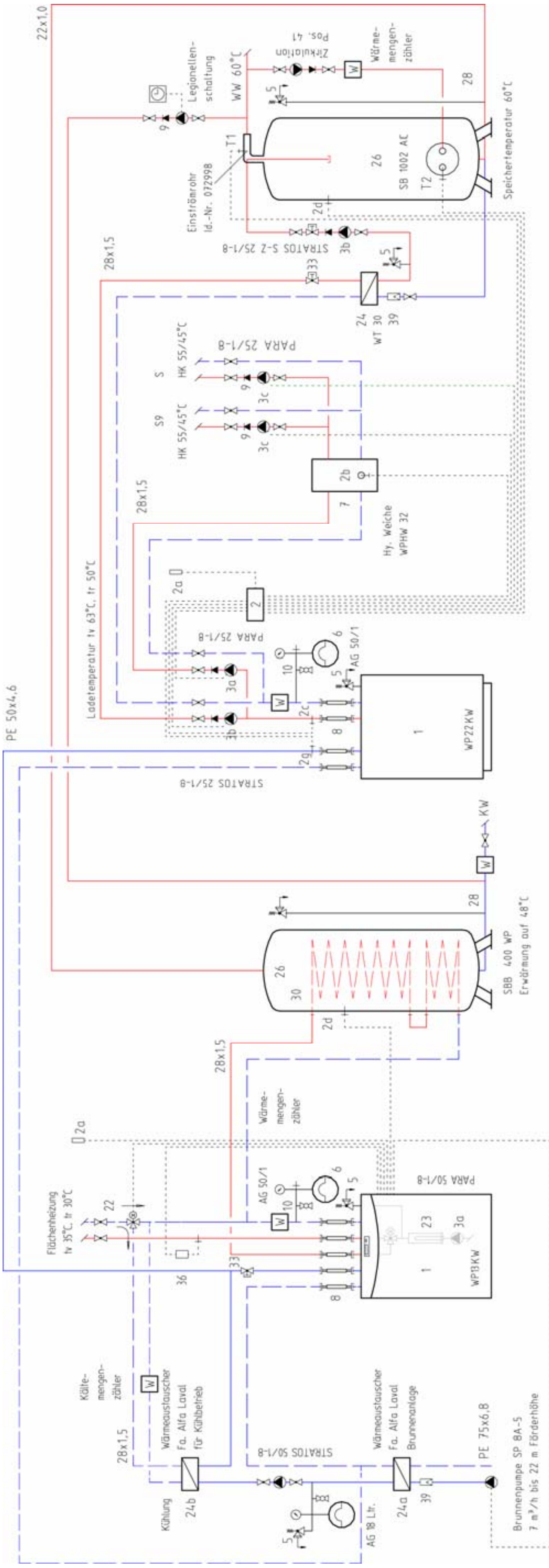

Figure 8: Hydraulic flow diagram