Progress in construction from the 1950s detached house to the EnerPHIT/Passive House Plus of today

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For a sustainable energy transition the energy consumption must be considerably reduced and the remaining energy demand must be met by renewable sources. A retrofit project in Aachen will demonstrate in a two-phase project with sub-steps, how this aim can be achieved efficiently. The project is supervised by the Büro für Nachhaltigkeitsmanagement BSMC and the Rongen Architekten.

Starting point

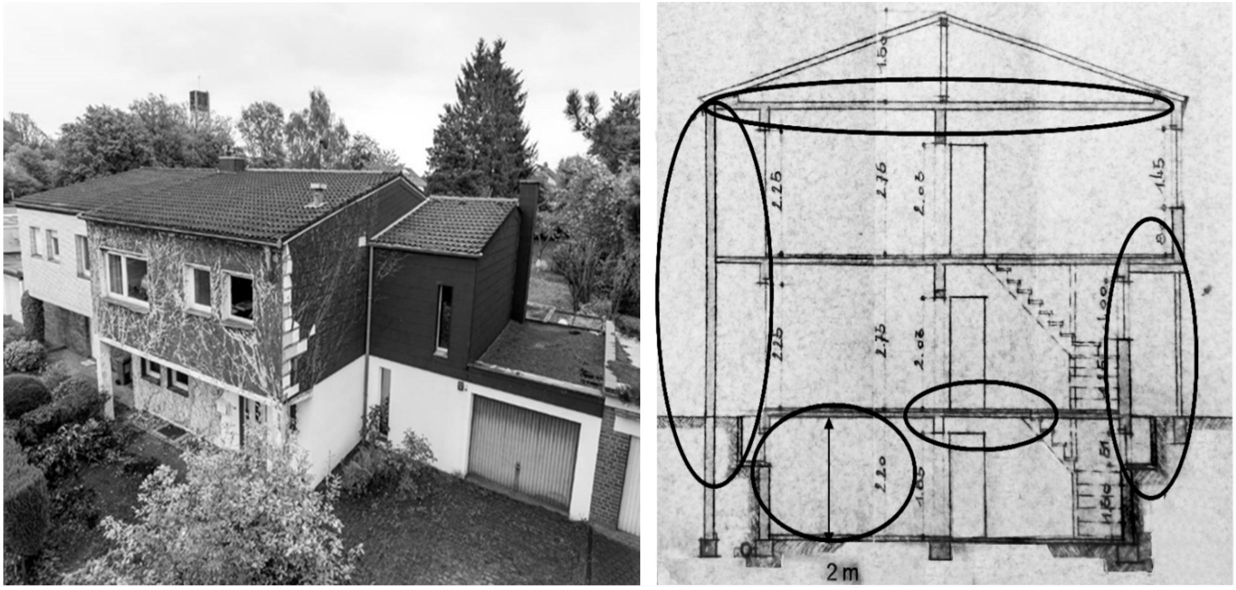


Figure 1: Street view and section with problem areas

The two-storey building (see Figure 1) is oriented to the north-west/south-east, and has been constructed in 1958/59 as part of a duplex. In 1983 an extension was added on one side. Additionally a floor heating, and around 10 years ago a gas condensing boiler has been installed. There was, however, hardly any insulation between the floor heating and the basement below so that the basement was heated as well, incurring high losses of heat.

Further losses adding up to a heating demand of about 250 kWh/m^{2}a and a primary energy demand of renewables (PER) of about 450 kWh/m^{2}a were caused by a branched, badly insulated heating and hot water circulation system, walls and upper storey ceilings with very little insulation, thermal bridges to the loggia and garage, and uncontrolled ventilation through joints and windows.

Retrofit boundary conditions and aims

The building was acquired by a young family at the end of 2015. Their primary objective was to move as quickly as possible into a healthy sustainable residential property, taking into consideration the family's limited funds.

In general, an empty building provides an excellent starting point for achieving this objective. However, the time required should not be underestimated. This is because there is often hardly any reliable documentation and little is known about the structural conditions in areas which are difficult to access (such as the soil, suspended ceilings, inaccessible areas in the eaves). Detailed information is only possible at great expense, or emerges once the work has started.

A two-stage retrofit plan was drawn up to enable the family to move in as soon as possible (2016), while ensuring a comprehensive retrofit as close as possible to EnerPHIT/Passive House Plus standard, leaving a time buffer in the calculations for any surprises and any additional work to be carried out by the family during interior work in the building.

In order to qualify for retrofit funding provided by the State of North Rhine-Westphalia and the German Federal Government, the relevant energy objectives had to be met.

Basic retrofit concept

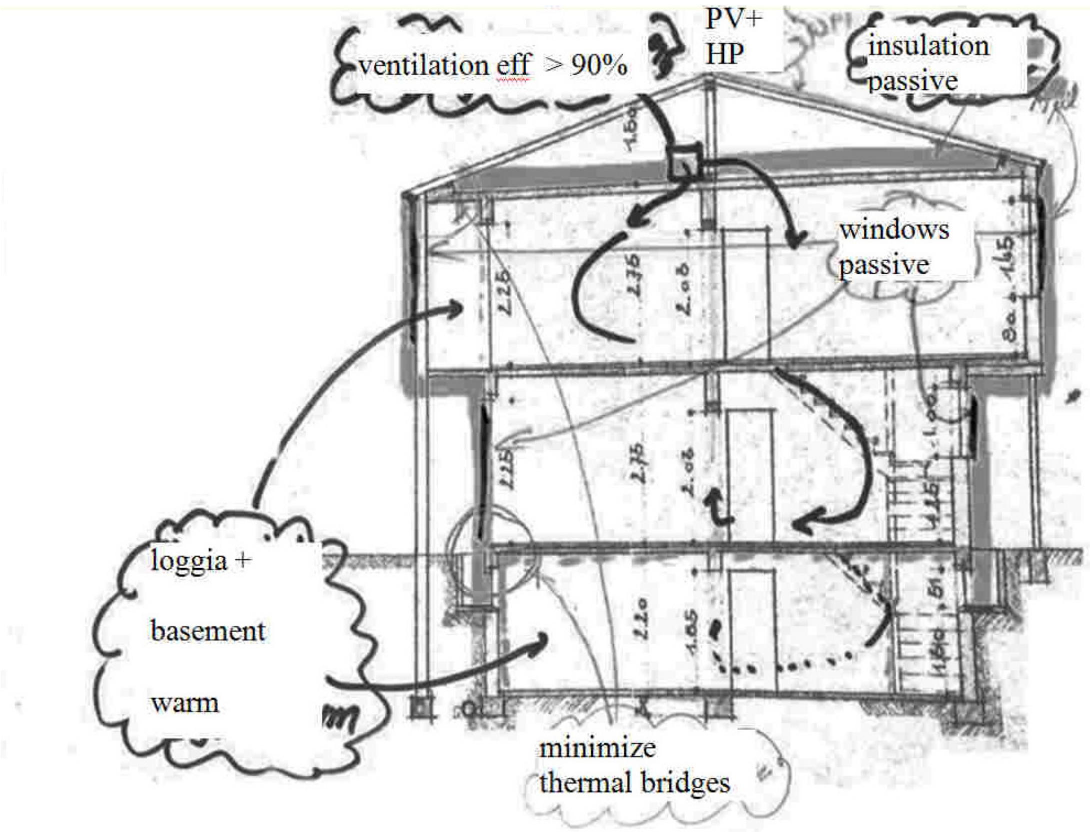


Figure 2: Basic retrofit concept

The retrofit concept was drawn up at the same time as the building was acquired. During Phase 1, the building envelope was comprehensively upgraded using efficient Passive House building techniques. These included Passive House windows, suitable insulation for facade, basement and roof, thermal bridge reduction as well as an airtightness layer and controlled ventilation with efficient heat recovery.

Insulating the lowest ceiling/flank walls to Passive House standard proved to be practically impossible because the basement ceiling was only 2 m high and there were numerous cables on the basement ceiling and on the inner walls above. It was therefore decided to include the basement – as well as the loggia – in the thermal envelope. This also improved the area-to-volume ratio, reduced the number of thermal bridges and created new useful areas, working areas and floor space with a controlled temperature, features that were much appreciated by the family.

A major challenge with old buildings is to draw up a simple efficient ventilation concept. The main objective was to accommodate the family's storey/floor space usage pattern, to re-use hardly polluted air several times, to minimise duct installations and to include existing free flow paths. The top storey ceiling of the old building tract offers not just a convenient location for the ventilation system but also a starting point for a cascade-like opening up of the storeys below with a minimum of ducts, using the stairwells as unobstructed overflow channels for the passage of air downwards. Efficient use can be made of an unobstructed flue draught flowing from the boiler room via the kitchen to the roof with the aim of recirculating extract air from the lower storeys to the ventilation system.

The integration of renewable energies (phase 2) rounds off the concept.

Fine-tuning and conversion of the basement

The most effective option for insulating the basement in the building stock is to insulate the exterior of the basement walls. To do this, a shaft has to be sunk to the foundations. The time and effort and costs involved in this operation vary depending on the conditions and on the excavating tools that can be employed. The advantage of this approach is that the cellar walls can be inspected and fixed where necessary from the outside.

As it was not possible to insulate the outer wall below the garage adjoining the extension, the decision was taken to insulate the adjoining basement area from inside. During the invitation to tender, it was found that a deep excavation was not possible at low cost for the garden-facing side of the old building's basement either, as access for large excavation machinery would be required. Also here, the decision was taken to fall back on the option of fitting insulation around the base (ca. 1.3 m) internally.

The external basement insulation and plinth insulation were the first measures taken in the second quarter of 2016. The internal insulation of the basement was carried out in 2017 after completion of the terrace and after checking/refurbishing additional damaged areas that had been found.

Windows and loggia

The existing window openings were maintained except for a few openings, but the design was thermally optimized by using the slim window profile Energeto 8000 Passiv with triple glazing.

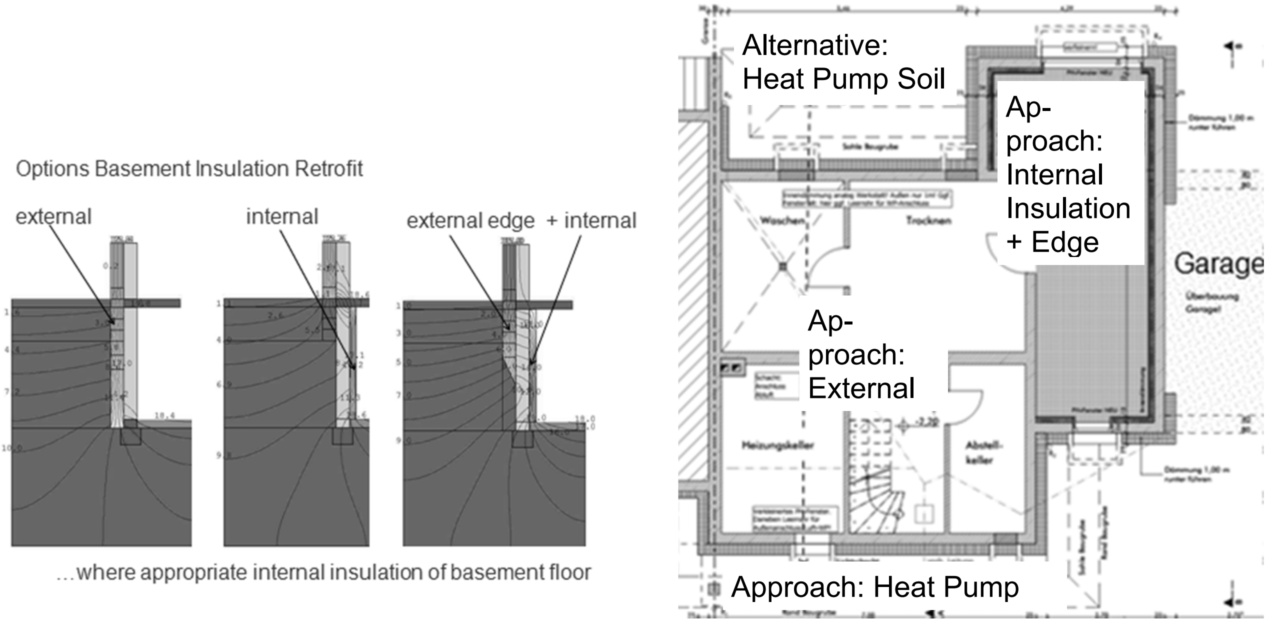


Figure 3: Conversion of the basement

The existing double-glazed windows together with roller shutters were retained in the rear loggia area, enabling the rooms behind to be decoupled from the loggia if required. The front was constructed from three fixed glazing elements and two door elements connected by slim coupling elements. An examination showed that the door elements may entail unexpectedly high losses. Fortunately, improved elements were provided by the manufacturer which, although not of Passive House quality, can collectively meet the high requirements.

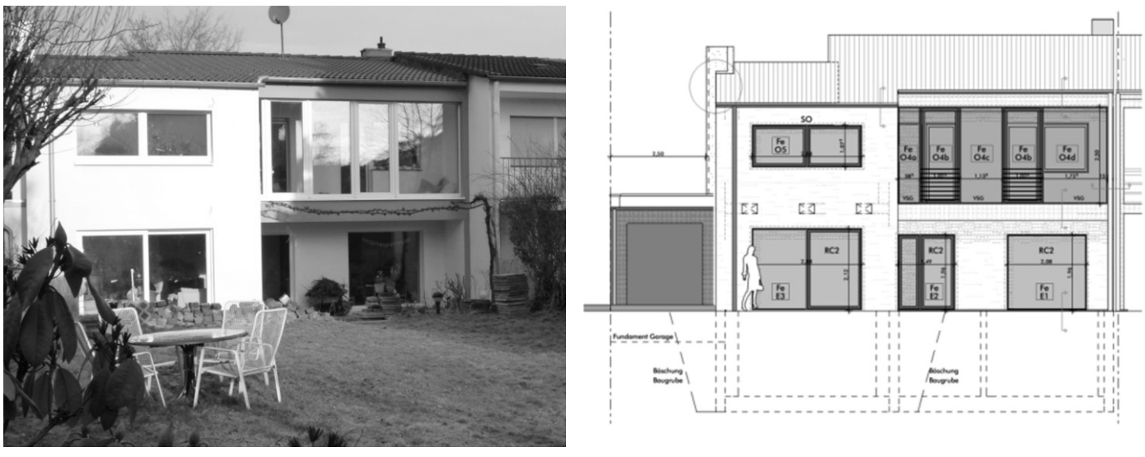


Figure 4: Conversion of windows and loggia

An additional thermal bridge was found when fitting roof tiles in the back of the eaves above the loggia ceiling. A continuous concrete filling that was difficult to break up was found here, which would act as a massive thermal bridge if left untreated. In addition to the original plan, an 8 cm thick internal insulation thermal conductivity group 022 was fitted on the loggia side and a 3 to 5 cm thick PU insulation was fitted on the roof.

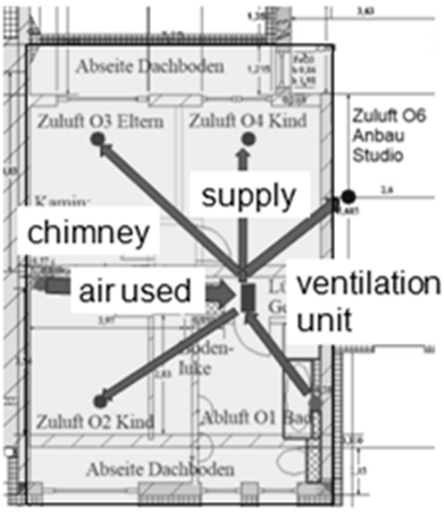
Facade

A continuous EIFS with a mean U-value of 0.12 W/m²K (generally 24 cm, thermal conductivity group 032) was installed along the facade on the basement/perimeter insulation. To save space, a high quality EIFS (generally 15 cm resol resin, thermal conductivity group 022) was chosen for special areas only (entrance, garage partition wall). The garage ceiling/floor will be fitted with additional flank insulation to reduce thermal bridges.

Roof and ventilation

The roof area is divided into the old building (1959) with an uninsulated attic about 1.5 m high and the extension (1983) with a rafter roof with about 12 cm of insulation. Both areas, including the verge and eaves, will be professionally insulated and made sustainable for the future.

A highly efficient ventilation unit (hot water heat recovery > 90 % was mounted in the old building on the top of the floor trap to facilitate access for inspections and was connected over a short distance to the outdoor air. Due to the vertical type of installation – suitable horizontal devices are unfortunately in short supply – the air ducts must first be routed downwards and insulated separately. However, air can conveniently be distributed horizontally to the individual rooms through flat ducts only 8 cm high, which are concealed under about 50 cm of attic insulation (U-value 0.07 W/m^{2}K). The ventilation unit and floor trap will be fitted with their own insulation collar made of EPS.



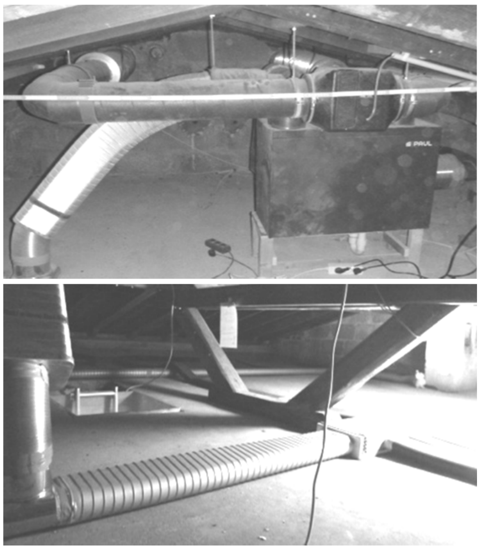


Figure 5: Ventilation diagram for attic **ventilation unit, duct laying**

The internal roof insulation of the extension was increased to 44 cm, thermal conductivity group 032, U-value 0.08 W/m^{2}K. It was found here that the structure did not have sufficient rear ventilation after the interior lining had been removed. Because the accessibility (Photovoltaic) would be restricted at a later stage, it was decided to replace the ageing roofing professionally both on the extension and on the old building. This led to an improvement in the insulation of the eaves and verge (Ψ-values generally between -0.05 and 0.1 W/mK).

Renewable energies

The above passive measures reduce the heating demand of the building effectively and considerably, to the extent that the low residual demand is now conveniently covered in small active subsequent steps (Phase 2) via a Photovoltaic-coupled small electric heat pump, making it possible to meet the demanding EnerPHit Plus or even the Passive House Plus standard for primary energy use (see diagram in Figure 6).

Suitable preparations have been made in the basement for the heat pump. Prompt execution is indicated in order to use all the funding (KfW/BAFA; English: Development Loan Corporation/Federal Office of Economics and Export Control). A later execution rather is indicated for the amortisation of the gas condensing boiler which is just 10 years old.

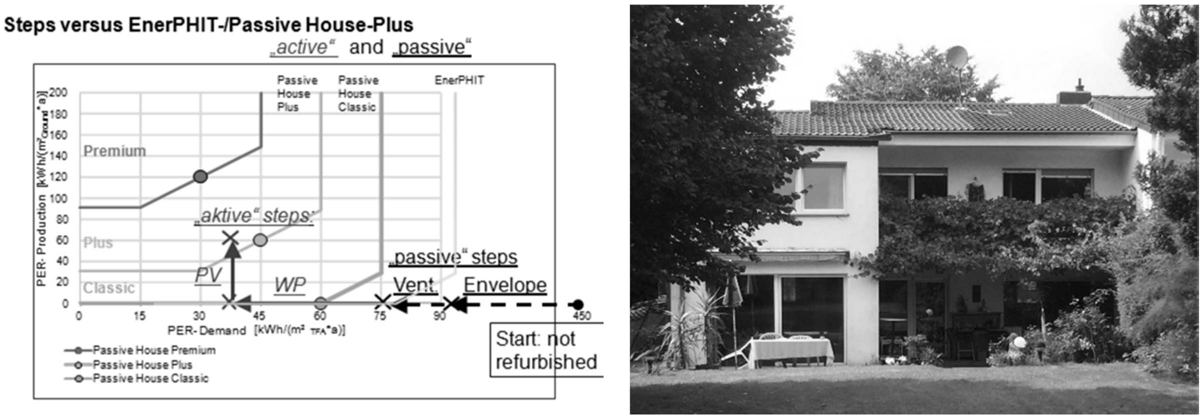


Figure 6: Progress in construction from the 1950s detached house to the EnerPHIT/Passive House Plus of today. (PV: Photovoltaic; WP: heat pump)

Acknowledgments and outlook

The project is sponsored by the German Federal Government (Phase 1: KfW, Phase 2: BAFA), supervised by the Energy Agency of North Rhine-Westphalia and used for further training and education events.

Inspired by this example, the owners of the other part of the semi-detached house are planning a similar retrofit for 2017, enabling all aspects of the house to be raised to a sustainable standard and encouraging others in the surrounding area to follow.

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