Step by Step **retrofits**

www.europhit.eu

Passive House Institute

with

Passive House **components**

EuroPHit

Scope of content/Disclaimer

This publication mainly deals with the energy-relevant aspects of step-by-step building modernisation, therefore it does not claim to cover all other aspects that are important for planning and realising a building retrofit project. The construction details shown here are meant as basic representations of the principles and cannot be applied on a one-to-one basis for implementation planning. The focus of the content is on solutions for the cool, temperate climate (e.g. of Central Europe). Instructions for other climates are also given in some places.

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Content

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Introduction

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The EuroPHit project

Retrofitting for the energy revolution, one step at a time

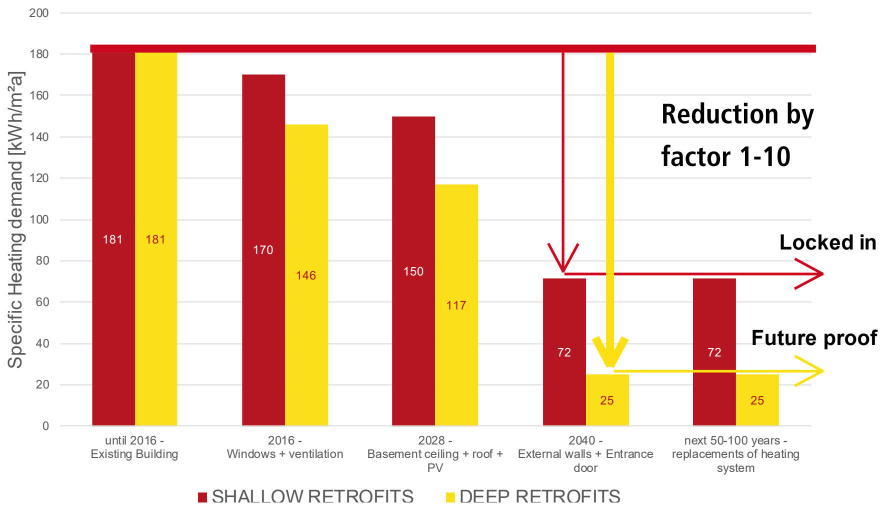
The EU has introduced legislation to ensure that buildings consume less energy. A key part of this legislation is the Energy Performance of Buildings Directive first published in 2002, which required all EU Member States to enhance their building regulations and to introduce energy certification schemes also for the existing building stock. At the same time, the refurbishment of existing buildings provides an opportunity to create local jobs, stimulate the economy and generate financial savings.

Taking into account that most retrofits are performed in a step-by-step manner, it is important to understand the consequences of lock-in effects: retrofit processes started now with shallow measures cannot achieve a high level of energy efficiency in 20-30 years. The risk is that by 2050, the reduction of the energy demand of the building stock will only be 50-60%.

As the life cycle of most building components, especially those of the building shell, is 40-60 years, no further improvements to this moderate efficiency would be expected in the next decades. It is thereby crucial to start with deep retrofit measures now in order achieve future-proof efficiency levels. Only by doing so will it be possible to make our building stock fit for a sustainable energy supply.

While the below diagram shows that the potential to reduce energy consumption through improving our building stock is very significant, many barriers remain to turn these policy goals and recommended steps into action.

The EuroPHit project and the accompanying capacity building activities undertaken throughout, looked to break down some of these barriers to provide a model to transform the existing building stock into one geared towards a sustainable energy future. One of the means for this is this handbook, which is intended to provide knowledge about and awareness of the special challenges of step-by-step retrofits. Furthermore, the project looked at implementing current know-how into pilot projects across the EU, including the development of a long-term retrofit planning tool and a certification scheme. The project consortium also supported manufacturers to develop suitable products, and engaged with the financial industry to study existing investment and funding best practices and potential future models.



1.1

Author: Jan Steiger

The project worked with 14 partners in 11 EU member State countries over a period of 36 months. In order to illustrate how highly efficient step-by-step retrofits can be designed and executed successfully, pilot projects were part of the project. The involved design and tradesperson teams were specifically trained. The projects included a selection of residential and non-residential buildings across the different climate zones throughout Europe to be retrofitted according to Passive House principles. A total of 20 pilot projects in 9 countries were involved, 11 of them with completed first retrofit steps within the project. Through the EuroPHit project a total of 40,000 m² of floor area have been retrofitted with a budget of more than 26 Million € for the first steps.

Furthermore, the experiences gained through these pilot projects have been displayed on the EuroPHit-website for others to learn from. Among these materials you will find recommendations for retrofit concepts, but also drawings for step-by-step connection details, product ideas and developments for such purposes, or videos documenting the implementation of the retrofit measures. In addition, completed examples of the Passive House Planning Package (PHPP) or the EnerPHit Retrofit Plan (ERP) can be downloaded to better understand the data entry of retrofit steps of such a long-term renovation process.

Check **www.europhit.eu** for further information.

Step-by-step retrofitting according to plan

In many western countries with stagnating population growth, building modernisation has replaced new construction as the most important construction task. In Germany over 70 % of resources in the housing sector flow into the maintenance and modernisation of existing building stock. 85 % of these funds in turn are invested in partial refurbishments. A major part of the investment in housing therefore goes into step-by-step modernisations.

The reasons for these are obvious. The building components, such as the windows, plasterwork, roof covering, boiler etc. have different life durations. The necessity for repairs or replacement of various components arises at different points in time. Inevitably, in the case of a complete retrofit building components that are still intact are renewed unnecessarily before time.

The high volume of investments in step-by-step modernisations however also means that the most important area for climate protection in the building sector lies here. Each repair or replacement measure for the building envelope or building services can simultaneously be used to bring the energy-relevant quality up to a future-oriented standard with moderate additional expenditure. If such an opportunity is missed, it will be decades before the next repair work becomes necessary again and cost-effective energy-related improvement is possible. Until then, the building component will have to remain in the inadequate state of thermal protection – which will be detrimental from the financial and environmental perspective.

The EnerPHit Standard offers guidelines for a reasonable level of thermal protection for existing buildings. It was developed in 2010 as an addition to the Passive House Standard which can often only be achieved with a lot of effort in the case of retrofits. It is now used worldwide. The EnerPHit Standard specifies minimum standards for all energy-relevant building components. These correspond largely with the requirements for Passive House components (for new constructions). On account of the residual thermal bridges and other problems often arising in existing buildings, the resulting energy demand will be slightly higher than that of a Passive House building. Beginning with the EnerPHit Classic Standard, it is also possible to achieve the more advanced EnerPHit Plus or Premium Standards with particularly efficient building services in combination with the generation of renewable energy e.g. with photovoltaic systems.

Buildings modernised to the EnerPHit Standard offer optimal thermal comfort, fresh air at all times and protection against damage due to moisture and mould growth resulting from condensation. In addition, a financial advantage can also be expected because these measures save considerably more energy costs over the service life than the total amount that has to be invested for their implementation.

Passive House components can be used for each measure in order to achieve these benefits in the case of step-by-step modernisation as well. However, this alone is not enough. When applying a step-by-step approach, at least a rough overall plan should be made for all measures including those

Figure 1:
Complete retrofits as for this single-family home are an exception.

Figure 2:
Single family home after a complete retrofit

which lie in the distant future, similar to the implementation planning carried out in the case of complete retrofits before starting the work. Only in this way can it be ensured that everything fits together exactly as with a complete retrofit and an optimal end result is achieved in terms of cost-effectiveness, climate protection and user satisfaction (see 2.3 The Retrofit Plan).

Figure 3:
Roof edge with insulation above rafters – the airtightness membrane still has to be connected to the exterior wall.

02

Basics

PAGE

Peculiarities of stepwise retrofit

Sustainable energy supply through efficiency and renewable energies

In many building retrofits the potential for reducing the energy demand through passive thermal protection measures is not fully utilised. The reason given sometimes is that the same objectives can also be achieved with the use of renewable energy, for example by the installation of a wood pellet boiler. However, this argumentation falls short of reality for the following reasons:

- The potential for acceptable and economic use of renewable energies is limited. Biomass utilisation competes with food production for a growing population, while the use of hydropower frequently has a major impact on the landscape and ecosystems, and even wind power and photovoltaic systems compete with other uses due to the large space demand and negatively affect the appearance of the landscape.

- In cool and cold climates the energy demand is significantly increased in the winter due to the necessity for heating buildings in the winter. At the same time, solar radiation is 7 times lower than in midsummer so that only a small amount of energy can be gained through photovoltaic and solar energy systems. The result is the so-called “winter gap” in which an above-average high energy demand stands opposite below-average energy production. In order to be able to make enough renewable energy available despite this, the surplus energy gained during the summer must be stored for the winter. This is possible e.g. by converting the solar energy into chemical energy which is stored in the form of a gas. However, the conversion of electricity into storable gas and reconversion into electricity later on is associated with losses, so that with seasonal storage, ca. 3 kWh of the original electricity is needed for 1 kWh of usable electricity in winter. This is why so-called zero-energy buildings which only generate the same amount of energy as the total amount that is used annually are inadequate for a sustainable supply of energy in the future because this concept does not take into account the "winter gap". It makes more sense to reduce the winter energy demand as far as possible so that a minimum amount of the valuable stored electricity and the biomass, which is only available to a limited extent, has to be used. This is achieved through modernisation using Passive House components which reduces the heating demand by up to 90 % compared with existing building stock

To achieve a sustainable standard of energy also in existing buildings, it is therefore expedient to combine highly efficient retrofits using Passive House components with the generation and use of renewable energy.

Modernisation: complete or step-by-step?

If a building is in need of refurbishment, the question that always arises is whether only individual measures should be carried out or whether the entire building should be modernised all at once. For instance, if the façade plasterwork is crumbling and the opportunity is taken to apply thermal insulation at the same time instead of just renewing the plaster, it may make sense to simultaneously bring the windows and roof up to a future-oriented standard even if the remaining service life of these building components has not expired.

Advantages of a **complete** modernisation:

- Synergistic effects arise as a result of the repair and renewal of different building components. For example, the same scaffolding can be used for the three measures exterior wall insulation, roof insulation and window replacement. Similarly, this also applies for construction site setup. As a rule, the total planning costs will also be lower if the whole building is modernised at the same time.

- The impact of the modernisation measures on the occupants and users is quite considerable due to the noise, dust and vibrations associated with this work. If all modernisation measures are carried out during the same period of time, then the overall duration of this impact will be shorter than it would be with step-by-step modernisation measures.

- If a building component is repaired or renewed but modernisation of the adjacent building component post-poned, then an intermediate state will have to be created which must also fulfil the functional and

2.1

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design requirements until the adjacent component can also be modernised. Ideally, airtight connection to the adjacent building component in a cost-efficient and thermal bridge free manner should also be possible during the subsequent modernisation measure. Creating such an intermediate state usually incurs higher expenditure for planning and execution. It is easier if both components are repaired or renewed simultaneously so that the final permanent connection can be achieved.

- If building components are not renewed simultaneously, there is the risk that a component that has already been renewed previously may be damaged during the work on another component. For example, this may be the case with window replacement when a compound insulation system (CIS/EIFS) has already been implemented.

Advantages of **step-by-step** modernisation:

- With limited financial resources, it may be necessary to spread the investment costs for modernisation measures over a longer period of time.

- The individual building components of a building have a different useful life duration. In general, not all building components will need to be repaired or renewed when building refurbishment is intended. With a step-by-step modernisation, one can normally avoid unnecessary renewal or repair of components that are still good in terms of appearance and function.

- The extra costs for improving the level of thermal protection will often be moderate if energy saving measures are carried out at the same time as repair work which is necessary in any case. This speaks in favour of energy-related modernisation of each building component only when it needs to be repaired anyway. Looking at the example of insulation for a sloped roof, if the roof covering is still in good condition but insulation is to be applied for reasons of comfort and energy efficiency, then this would be a relatively expensive measure. As a rule, scaffolding will have to be set up, and roofing tiles, battens and any existing sub-roof will have to be removed. The insulation will be installed, possibly with additional double rafters, and a new roof covering will be created. However, if the roof covering has to be renewed anyway, then only the costs for the insulation on and between rafters and possibly the adjustment of the edge connections of the thermal insulation measure will have to be included in the costs; all other costs would have been incurred in any case. Thermal protection measures are therefore always particularly economical when the affected building component is currently in need of repair or renewal. This fact is taken into account optimally with step-by-step modernisation.

Recommendations for sets packages of measures and the appropriate sequence

- For complete retrofitting of a building the individual measures will obviously be coordinated with each other, this means that functioning connection details will be developed and the building services technology will be optimised for the requirements of the building. With step-by-step modernisation, exactly the same measures are implemented – but with long time intervals in between. Here too, careful coordination of the individual measures with each other should go without saying. This is the only way in which an optimal result in terms of economic efficiency, climate protection and client satisfaction can be expected for all individual steps as a whole. The EnerPHit Retrofit Plan is available for this purpose, to be used as a basis, resource and guideline. The particular challenge here is to recognise the various interdependencies of the individual measures and to take these into account when preparing the retrofit plan.

- The most direct dependence arises with connection details between two building components which will not be modernised at the same time (e.g. exterior wall and roof). The connection of the building component that is modernised first must be carried out in such a way that connection of the subsequent component years later will be possible in a problem-free way. The position and connection of the insulation layer as well as the airtight layer must be kept in mind accordingly so that with very little effort, a connection that is as thermal bridge free and airtight as possible can be achieved. The basic function of the building components – e.g. protection from rain – must be ensured both in the final state as well as in the intermediate state when only one component has been modernised.

Peculiarities of stepwise retrofit

- Functional interrelationships between individual measures are less obvious. For example, the heating load will decrease if the exterior envelope is thermally insulated. An existing boiler will then be over-dimensioned.

- Constraints in relation to the chronological sequence of the individual measures may arise as a result of these interrelationships, which may make it necessary to renew a building component well before its useful life has expired. Some measures will have to be carried out before others, for example, for a ventilation system with heat recovery to function properly and economically, first the airtightness will have to be improved. With adjacent components it also makes sense to modernise these simultaneously even if one of them has not yet reached the end of its service life. This may be necessary in order to avoid the expense of creating a functioning intermediate state, or to avoid setting up the scaffolding twice. If the façade is insulated without renewing the windows at the same time, increased effort will be necessary for preparing the connection detail for thermal bridge free window installation later on.

- Each construction process is associated with expenses and encumbrances; these include organisational and planning effort, construction site setup (with a crane or scaffolding etc. where necessary), noise and dust due to the construction work, damage to the outside facilities etc. Measures that are closer together in time should therefore be bundled into sets packages of measures, each of which forms one modernisation step. To a certain extent, bringing forward of individual measures should also be accepted, even if this means that residual values will be lost.

- If the above-mentioned interdependences are not given consideration, then the effort for achieving an optimal level of thermal protection during later steps may be greatly increased, so that a thermal protection measure which actually makes sense can be implemented either inadequately, or not at all. For example, if the windows, radiators, heating pipes and electrical installations near an exterior wall have been renewed just a few years ago, then interior insulation which necessitates the removal and re-installation of all these components will not be very popular with the building owner. Such planning errors are referred to as lock-in effects because the building component is "locked into" a lower standard of thermal protection by these, and subsequent improvements are prevented. Also well-meant thermal protection measures, such as insulation of the exterior wall may lead to lock-in effects if only a moderate insulation thickness is used. Subsequent improvement of the thermal protection to the level necessary for climate-neutral existing building stock will then be uneconomical for the next few decades (see also the section on Economic Efficiency 2.5).

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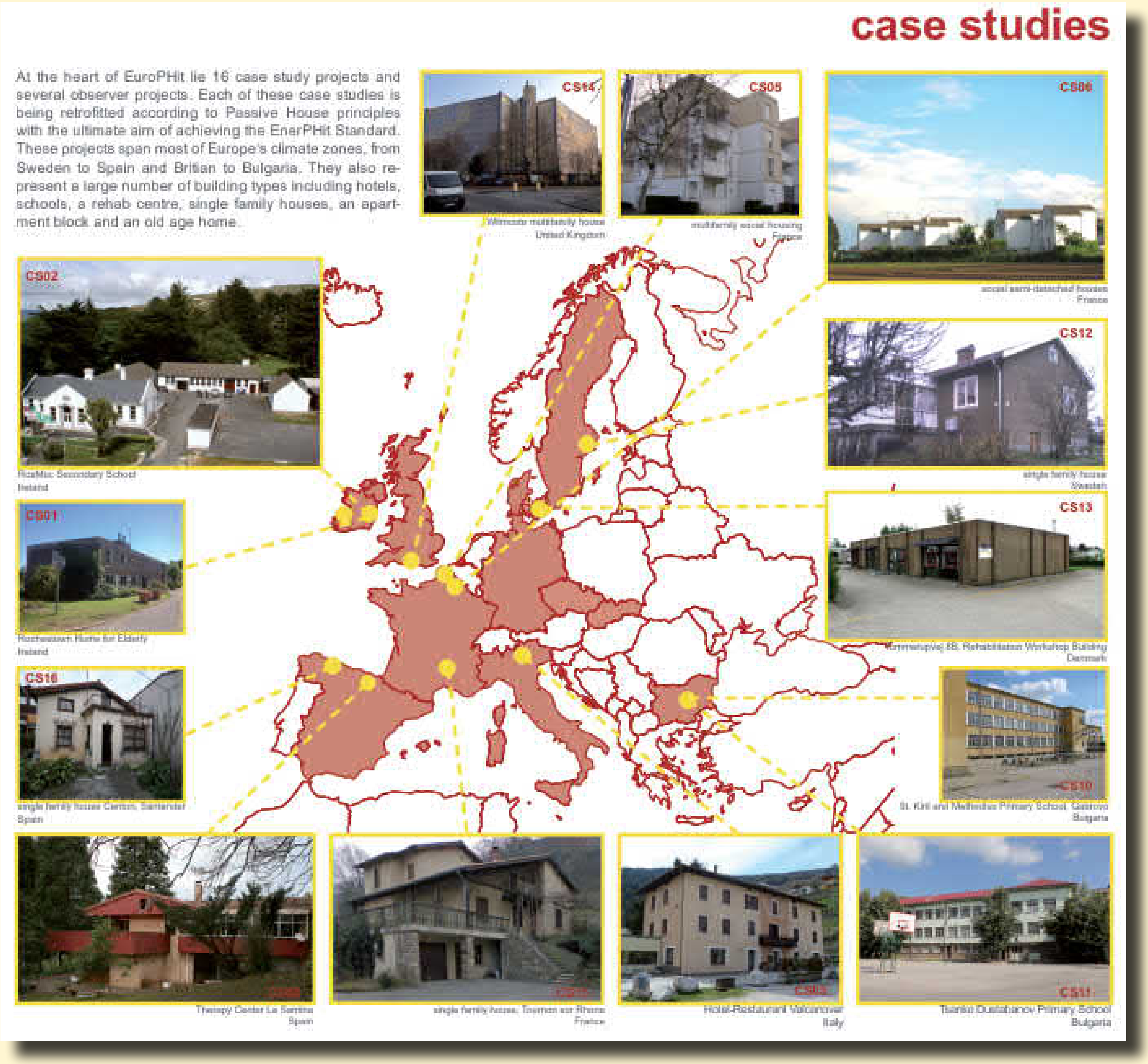


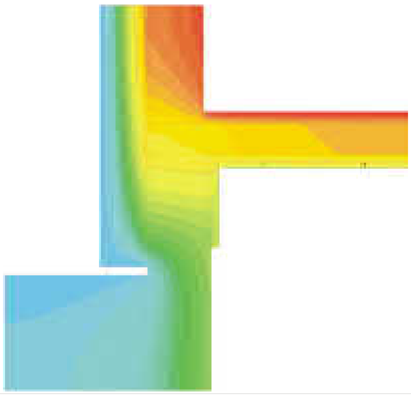
Figure 1:
Map of EuroPHit case studies

The EnerPHit Standard

Passive House Standard – also for existing buildings?

While the Passive House Standard is increasingly gaining popularity in the area of new constructions, the number of existing buildings which have managed to achieve the Passive House Standard after modernisation is comparatively small. An important reason for this is the various difficulties that are typically encountered in older buildings. These include the barely avoidable thermal bridges of basement walls, a building design that is not optimised with regard to compactness and passive solar gains, and the lack of space for optimal insulation thicknesses, e.g. on account of limited room heights in the basement. Beam penetrations and poor accessibility make it difficult to improve airtightness. In order to achieve the Passive House Standard despite all this, relatively extensive thermal protection measures would usually be necessary to compensate for the increased heat losses (or reduced heat gains) occurring in various places. In this case the economic efficiency of the entire modernisation often isn't certain.

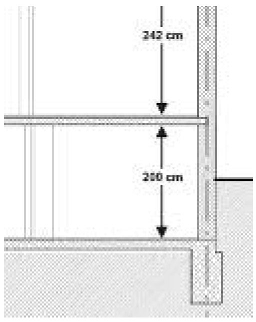
Unfavourable SA/V ratio



Thermal bridges

Airtightness
(e.g. penetrations by beams)

Unfavourable window orientation



No space for insulation

Historic building preservation requirements

Figure 1:
Typical "difficulties" which stand in the way of achieving the Passive House Standard in modernisations of existing buildings

2.2

Author: Zeno Bastian

Nevertheless, using Passive House components for modernising existing buildings offers some tangible benefits even if the Passive House Standard is not achieved in the end:

- Due to the excellent level of thermal protection, the interior surface temperatures are raised substantially during the heating period, so condensation and mould growth can be excluded with great certainty. In addition, temperature distribution on the inside is much more uniform, providing for an optimal level of thermal comfort.

- Due to the insulation of the heat storing wall, comfort is also improved during hot periods: once a pleasant interior climate has been achieved, (e.g. through night-time ventilation), it can be maintained for a longer time. The same applies in the case of improved windows.

- If the heating or cooling system is renewed later on, then a smaller output will be sufficient (more cost-effective and more efficient). At this point, even more money can be saved by these measures.

- Improving the airtightness prevents structural damage due to the entry of warm humid indoor air into the exterior building components. Unpleasant draughts due to infiltration of cold outdoor air are avoided.

- Installing a comfort ventilation system with heat recovery perceptibly improves air quality and has a positive effect on health. Ventilation via windows is no longer necessary, and mould growth is prevented due to reliable removal of moisture.

- Through modernisation using Passive House components, the heating demand in climates requiring heating can be reduced by up to 90 %. This is substantiated by calculations of the demand using the Passive House Planning Package (PHPP) as well as by consumption measurements in the context of monitoring in what is now a whole range of realised projects. CO_2 emissions for heating buildings are also reduced at least to the same extent. In climates requiring cooling, the cooling and dehumidification demand may be reduced by 50-80 %.

- The saved costs for energy offset the costs for investment and capital, so thermal protection measures to the Passive House standard result in financial gains for both owners and occupants.

In order to promote the achievement of an optimal standard of thermal protection in building modernisations as well, in 2010 the Passive House Institute developed the EnerPHit-Standard for retrofits with Passive House components. An "optimal" standard of thermal protection here means that significantly better energy efficiency compared to the legal requirements goes hand in hand with a good level of economic efficiency of the thermal protection measures as a whole. Implementation on a broad scale is only achievable in this way. The other advantages mentioned above should also be achieved in addition.

Figure 2:
EnerPHit seal

The EnerPHit Standard

The thermal protection requirements of the EnerPHit Standard [1)] constitute helpful guidelines for all planners and building owners who wish to carry out modernisations of existing buildings. The PHPP calculation for EnerPHit verification provides very precise energy-relevant characteristic values for the modernised building in an understandable way and with moderate effort.

In the context of quality control, modernised existing buildings can also be certified in accordance with the EnerPHit Standard. In this way the building owner can be sure that the stated optimal level of thermal protection has actually been achieved and the implemented measures do not fall short. This is especially important as subsequent "improvement" of inadequate thermal protection measures is almost always uneconomical.

EnerPHit requirements

For existing buildings, it would not make sense to specify energy-relevant building parameters which should apply equally for all buildings. On account of the greatly varying circumstances in the existing building stock with regard to the SA/V ratio, solar incidence, thermal bridges etc., some buildings may only be able to achieve such a characteristic value with excessively great effort, while in the case of a building with optimal conditions the saving potential to be raised economically would not be fully exploited.

That is why in the so-called building component method the EnerPHit Standard defines energy-relevant criteria for individual building components (window, roof, ventilation system etc.). The criteria correspond with the requirements for Passive House suitable components. In this case there are no requirements for the heating or cooling demand.

For buildings with favourable conditions, i.e. with few obstacles in the way of energy-relevant modernisation (due to the old building), the EnerPHit Standard can alternatively be achieved through compliance with limit values for the heating demand or the cooling and dehumidification demand. The requirements for individual building components will not apply in that case, and the same level of freedom will apply for dimensioning of the individual thermal protection measures as in (new) Passive House constructions.

1) EnerPHit stands for “Energy Retrofit with Passive House Components“.

Climatezone acc. to PHPP	Opaque building envelope towards				Windows (incl. entrance doors)					Ventilation	
	...ground	...outdoor air			Total			Glazing	Solar load		
	Thermal insulation	Exterior insulation	Interior insulation	Exterior paint	Max. thermal transmittance ($U_{D/W,installed}$)			Solar energy transmittance (g-value)	Max. spec. solar load during cooling period	Min. heat recovery efficiency	Min. moisture recovery efficiency
	Max. thermal transmittance (U-value)			Cool colours							
	[W/(m²K)]			-	[W/(m²K)]			-	[kWh/m²a]	%	
Arctic	Calculation in PHPP using project-specific heating and cooling degree days for ground	0.09	0.25	-	0.45	0.50	0.60	Ug - g*0.7 ? 0	100	80%	
Cold		0.12	0.12	-	0.65	0.70	0.80	Ug - g*1.0 ? 0		80%	
Cool temperate		0.15	0.35	-	0.85	1.00	1.10	Ug - g*1.6 ? 0		75%	
Warm temperate		0.30	0.50	-	1.05	1.10	1.20	Ug - g*2.8 ? 1		75%	
Warm		0.50	0.75	-	1.25	1.30	1.40	-		-	
Hot		0,50	0.75	yes	1.25	1.30	1.40	-		-	60% (humid climate)
Very Hot		0.25	0.45	yes	1.05	1.10	1.20	-		-	60% (humid climate)

Figure 3: EnerPHit criteria in the **building component method** in dependence on the climate zone of the building’s location (as of August 2016)

Author: Zeno Bastian

The EnerPHit Standard serves as a guideline for a reasonable standard of thermal protection for the modernisation of existing buildings worldwide. It can be applied for residential buildings and also for most non-residential buildings such as offices, schools, kindergartens etc..

Figure 4:
EuroPHit case study project „Svartbacksvagen" in Stockholm

Climate zone acc. to PHPP	Heating	Cooling
	Max. heating demand	Max. cooling + dehumification demand
	[kWh/(m²a)]	[kWh/(m²a)]
Arctic	35	Corresponds with Passive House requirement
Cold	30	
Cool temperate	25	
Warm temperate	20	
Warm	15	
Hot	-	
Very Hot	-	

Figure 5:
EnerPHit criteria in the **energy demand method** in dependence on the climate zone of the building's location (as of August 2016)

The Retrofit Plan

Buildings modernised to the EnerPHit Standard offer optimal thermal comfort, fresh air at all times and protection from moisture and mould damage caused by condensation. In addition, a financial profit can also be expected because the measures as a whole save substantially more energy costs over the useful life than the amount invested for their implementation.

Requirements for a Retrofit Plan

In order to realise these advantages also in the case of modernisations that are carried out in a step-by-step manner, Passive House components can be used in each individual measure, but this alone will not be enough. Just as an implementation plan is prepared before beginning a complete retrofit, at least rough planning should take place also in the case of a step-by-step retrofit for all measures including those which are still in the distant future. Only in this way will it be possible to ensure that everything fits together as in the case of a complete retrofit and so that an optimal final result is achieved in respect of cost-effectiveness, climate protection and user satisfaction.

The following points should be included in such forward-looking overall planning:

- **Chronological order** of the measures: besides the expected time-point for the renewal of the individual components this also depends on the functional context. For instance, for window replacement with airtight windows, the installation of a mechanical ventilation system will also be necessary at the same time. Similarly, a heat pump with low temperature heating can only be installed if the heating load has already been largely reduced by means of insulation measures.
- **Energy-relevant quality** of individual building components: if the future quality of thermal protection of all building components is determined in advance, then the energy standard of the building that is achievable in the future can be ascertained by means of an energy balancing software program. The future energy costs and savings can also be determined with this. The transparent final goal provides motivation for implementing the necessary building component quality at each step.
- Building envelope – **position of the airtight layer and insulation layer**: if the approximate location of the airtight layer and insulation layer in the building component structure is specified, then it will be possible to find out whether the two layers can be continued without any gaps at the component connections as far as possible – even in the case of adjacent components which are not being modernised at the same time. This is the only way to achieve a building that is airtight and thermal bridge minimised as a whole.
- For subsequent measures, clarify the points that must be given attention now: a good standard of thermal protection can only be achieved easily and cost-effectively if the **interrelationships** between measures that are not being implemented at the same time are kept in mind

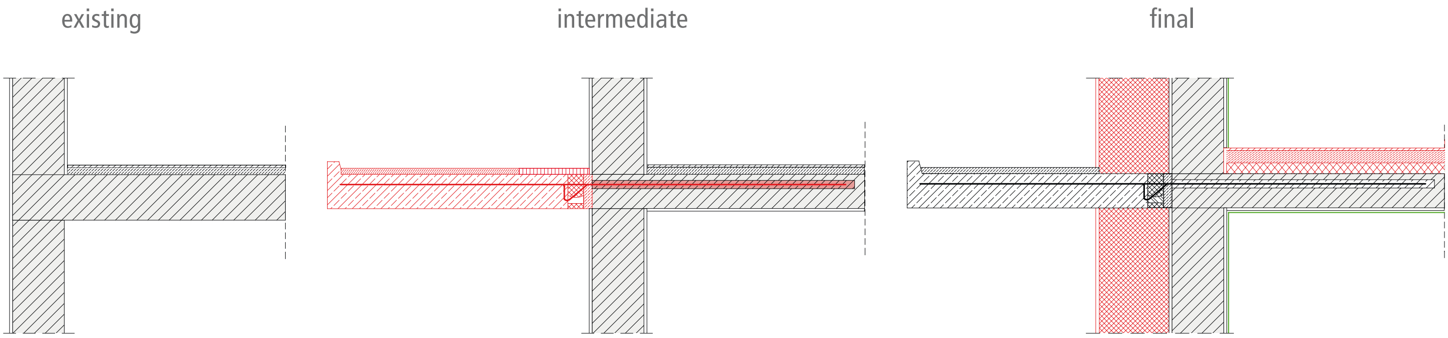


Figure 1:
Installation of a new projecting balcony with thermal separation. Thus, when the wall insulation is applied years later the thermal bridge remains minimal.

2.3

Author: Zeno Bastian

in advance. A typical example is that of a new balcony which is already joined to the (as yet) uninsulated wall of the house with a thermal separation. What at first does not seem to make sense in terms of construction prevents a massive thermal bridge at a later point in time when the wall insulation is carried out, and therefore makes it possible to realise the full potential for saving energy (see Figure 1).

- **Economic efficiency analysis** (optional): if the energy savings achievable over the useful life of the measure are compared with the investment costs which are necessary for improving efficiency going beyond the level for maintenance alone, then it will be easy to recognise whether a measure is successful in economic terms as well. As a rule, this may support the building owner's decision to implement ambitious efficiency measures. In addition, the building owner can already plan for the necessary investment funds in the long term.

The EnerPHit Retrofit Plan

Unfortunately, this kind of overall planning for step-by-step modernisation is uncommon. In the context of the EuroPHit project the Passive House Institute therefore developed a concept for a globally applicable retrofit plan based on the EnerPHit Standard; this is known as the EnerPHit Retrofit Plan.

The EnerPHit Retrofit Plan addresses building owners as well as the energy consultants, planners and craftsmen charged with carrying out the current and future measures. This plan in the form of a printout or PDF file is handed to the building owner for safekeeping by the originator. It is a simplified overview of the current and future sets of measures and contains all the information for forward planning as mentioned above.

The EnerPHit Retrofit Plan can be prepared by an energy consultant or Passive House Designer using the Passive House Planning Package (PHPP) and the associated output file based on MS Excel (included in the program CD from PHPP 9.6 onwards). The output file automatically adopts all relevant existing entries in the PHPP and summarises these in a clearly arranged form in a series of worksheets. Some entries which are not yet included in the PHPP are manually entered in the output file.

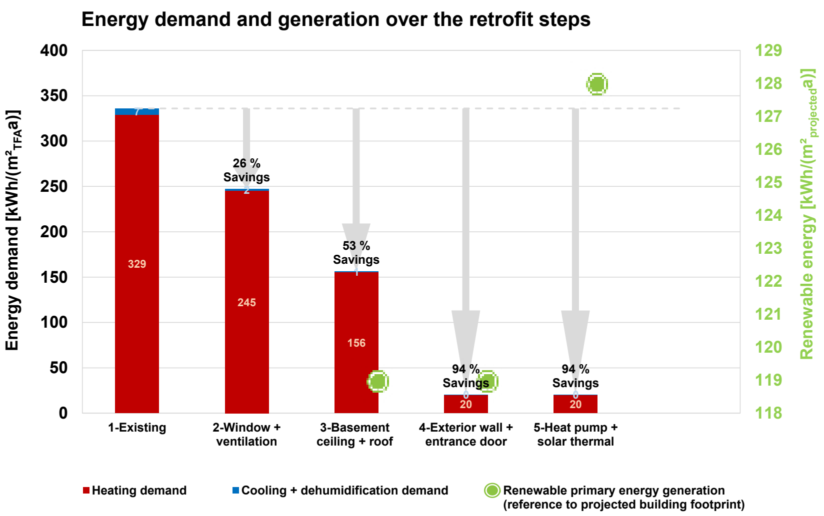


Figure 2:
Title illustration of an EnerPHit Retrofit Plan for an end-of-terrace house showing the heating demand and generation of renewable energy (right-hand axis) in the existing building and after the four steps.

The Retrofit Plan

Method for preparing the EnerPHit Retrofit Plan

First of all, several sets of measures can be put together in the output file from an overview of the time-points for repair work for the different building components. These are then entered in the PHPP with the aid of the variant function as a sequence of building variants. The PHPP displays the results such as the heating demand, heating load, primary energy demand, summer behaviour etc. for all modernisation steps next to each other and thus illustrates the improved efficiency of the building. From the PHPP data, the output file then generates the actual EnerPHit Retrofit Plan.

Constituents of the EnerPHit Retrofit Plan

The address of the building and the key players involved are mentioned in the Cover page. Additionally a diagram shows the main energy-relevant parameters for each step so that the achievable energy savings and generation of renewable energy are shown clearly. Right at the bottom there is space for the name and signature of the originator of the plan.

The cover **Letter** addresses the building owner and briefly explains the most important points relating to the EnerPHit Standard, the retrofit schedule and the preliminary certification. The text can be amended if required.

The **Scheduler** provides an overview of the chronological sequence of pending measures that are necessary anyway. Appropriate sets of measures can be put together based on this. It is filled in first, before the PHPP.

The main worksheet **Overview** displays the most important output for the following:

- Chronological sequence of the steps
- Measures necessary in any case and resultant energy saving measures
- Characteristic values of building components
- Building parameters
- Achievement of EnerPHit criteria
- Investment and energy costs

The worksheet can also be printed separately on DIN A3 paper and e.g. taken along to meetings with the bank.

The investment and maintenance costs for measures required anyway and energy saving measures are entered in the worksheet **Costs**. The obtained result is the total of the annuities for all measures. These values are also used in the worksheet "Overview".

The characteristic values of building components in the PHPP are presented in a simplified way in the worksheets opaque envelope **(Exterior wall, Roof, Basement ceiling), Windows, Ventilation, Additional vent, Photovoltaics, Heating & Cooling, Misc.** There is also space for adding (detail) drawings and explanatory notes.

Select the active variant here >>>>>>>		6-Passive House	Existing	Window + ventilation	Basement ceiling + roof	Exterior wall + entrance door	Heat pump + solar thermal
	Units	6	1	2	3	4	5
Heating demand	kWh/(m²a)	13,7	329,3	245,2	155,6	20,3	20,3
Heating load	W/m²	10,2	141,9	97,7	67,0	15,5	15,5
Cooling & dehum. demand	kWh/(m²a)	0,1	6,7	2,1	0,7	0,2	0,1
Cooling load	W/m²	3,5	32,6	17,4	10,2	5,5	3,7
Frequency of overheating (> 25 °C)	%						
PER demand	kWh/(m²a)	32,7	994,4	784,5	558,9	224,3	38,9
EnerPHit Premium?	yes / no	yes		no	no	no	yes

Figure 3:
Input of modernisation steps in the PHPP worksheet "Variants" and parallel representation of the results for all steps.

Author: Zeno Bastian

Attachments: overview of the documents attached to the retrofit schedule (plans of the existing building etc.).

The worksheet **Interrelations** contains a matrix with a description of the interrelationships which need to be kept in mind for later measures during a current measure. The texts are adopted in the component worksheets under the heading "preparation for subsequent steps". Some texts can be amended.

Building certification

Passive House and EnerPHit certification

The Passive House Institute and its global network of building certifiers have provided Passive House certification since the mid-nineties based on the published criteria. This was supplemented in 2010 with the EnerPHit certification for existing buildings that have been modernised using Passive House components. In both cases, the implementation planning is carefully and extensively examined by the commissioned certifier. Quality control is completed by further evidence of the executed work, such as the airtightness test. A certificate is only issued when the exactly defined criteria have been met without exception.

Advantages for the building owner

- certainty that the agreed energy standard will actually be achieved
- increase in property value through independent quality assessment
- certified Passive House/EnerPHit verification using the Passive House Planning Package (PHPP) can also be submitted for various subsidy programmes

Advantages for the planner

- prevention of errors due to thorough external checking of planning prior to start of construction
- recognition as a certified Passive House designer is possible by submitting a certified building

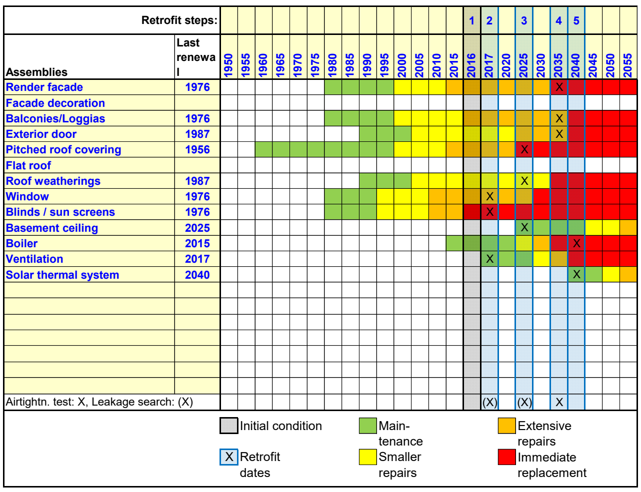


Figure 4:
Scheduler in an EnerPHit Retrofit Plan

The Retrofit Plan

Certification procedure

It is recommended that the certifier is contacted at an early stage of the planning. Any problems identified by the certifier can still be rectified easily at this point. However, in principle the certification can also be applied for after completion of the building. As a rule, all energy-relevant planning documents and technical data of construction products are submitted to the certifier before the work begins. After a careful examination and comparison with the energy balance calculation, the certifier will inform the client about any necessary corrections. After completion of the construction work, any changes to the planning will be updated during the final inspection, and verification of construction work (airtightness test, documentation of flow rate adjustment for the ventilation system, construction manager's declaration) will be checked.

If all criteria are met, the building owner will receive the

- certificate
- a supplement with the documentation of the energy balance calculation and all relevant characteristic values of the building
- a house plaque (optional)

Pre-certification on the basis of a EnerPHit Retrofit Plan

In the past, only those buildings could be certified which were completely modernised to the EnerPHit Standard. For this reason, there was no quality assurance system for the majority of modernisations that were carried out in a step-by-step manner. In order to close this gap, in 2016 the Passive House Institute introduced the pre-certification programme for step-by-step modernisations to the EnerPHit (or Passive House) Standard. A carefully prepared EnerPHit Retrofit Plan is a prerequisite for this. The certifier will check this for compliance with the EnerPHit requirements, and for completeness and consideration of all interrelationships between the measures. In this way, lock-in effects and unnecessary investment and energy costs can be avoided. After approval of the EnerPHit Retrofit Plan by the certifier, the first set of measures can be implemented. This will also be checked by the certifier for compliance with the Retrofit Plan. If this is the case and if energy savings of at least 20 % are achieved with the first step, then the building owner will receive a pre-certificate for the building. This pre-certification offers building owners and planners certainty that the standard being strived for will actually be achieved after the implementation of all modernisation steps according to plan. An online platform that was also launched in 2016 makes it possible to organise and store the necessary verifications over the long time periods.

Figure 5:
House plaque for a building that has been modernised to the EnerPHit-Standard

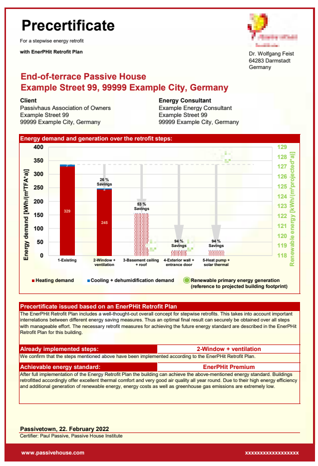


Figure 6:
Sample pre-certificate for step-by-step modernisation of a building to the EnerPHit Standard

Author: Zeno Bastian

Figure 7 and 8:
EuroPHit case study project „Rehab Workshop" in Naesved, Denmark, before and after retrofit

The Passive House Planning Package (PHPP)

Does energy-conscious design require sophisticated simulations?

This was indeed the case for the first Passive Houses that were completed in 1991. Calculating the energy balance of buildings with very low energy consumption is a demanding task - existing regulations and standards lack the required precision. Nevertheless, the Passive House Institute has identified the critical factors for preparing reliable balances - with a tool that is simple to use and with acceptable effort in terms of data input. The Passive House Planning Package (PHPP) is a clearly structured design tool that can be used directly by architects and designers.

The PHPP includes tools for

- calculating heating, cooling and dehumidification demand
- calculating heating and cooling loads
- calculating primary energy demand
- designing comfort ventilation
- summer comfort calculations
- calculating U-values

and many other useful tools for reliable design of Passive Houses and retrofits.

PHPP was presented for the first time in 1998 and has since been continuously developed further. New design modules have been added successively, e.g. in the course of the EuroPHit project.

The PHPP is continuously validated and refined based on measurements and new research results. As part of accompanying scientific research studies, measurements from more than 300 projects have so far been compared with calculation results. Of crucial significance was the CEPHEUS project undertaken as part of the European "Thermie" programme, during which housing developments were constructed according to Passive House standard and scientifically monitored at 14 different European locations (more).
The PHPP energy balance module was shown to be able to describe the thermal building characteristics of Passive Houses as well as less advanced low energy buildings surprisingly accurately.
The diagram below shows the results of a comparison between measurements and PHPP calculations for different Passive Houses at different locations. It is interesting to note that in all cases, irrespective of the thermal insulation standard of the buildings, there is high (relative) scatter due to user behaviour, but the calculations were in excellent agreement with the average measurement results.

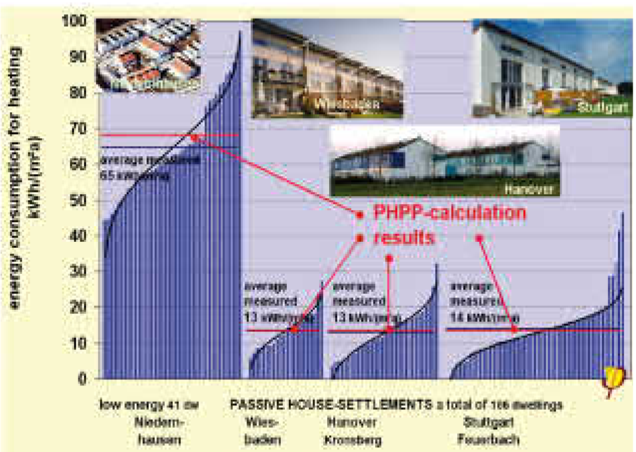


Figure 1:
Diagram: Comparison of PHPP calculation with consumption measurements in housing developments with low energy and Passive Houses.

2.4

Author: Zeno Bastian

PHPP features for step-by-step modernisations

Accuracy of the calculation results for non-renovated or partly modernised existing buildings

The PHPP was originally developed and optimised for Passive Houses. Within the framework of the EuroPHit project, a systematic investigation was carried out regarding its application for buildings with a poor level of thermal protection and accordingly a high energy demand.

The PHPP is a steady-state calculation tool that is designed to obtain results that are as realistic as possible with relatively little input and computation effort. For this study, PHPP results of buildings in different climates were compared with the results of the Dynbil program. Dynbil is a software program developed by the Passive House Institute for dynamic building simulations, which can reproduce the physical processes in buildings accurately and in high temporal resolution.

The results for the heating demand, heating load, cooling demand, cooling load and frequency of overheating were examined. It turned out that the PHPP results showed a reasonable accuracy even for non-renovated buildings with poor thermal protection and/or poor solar protection. A safety margin of 10 W/m² on top of the daily average heating or cooling load calculated in the PHPP was recommended only when dimensioning the heating or cooling system in non-renovated buildings. However, as a rule, a higher power is usually already foreseen in any case for meeting the necessary loads for heating up and cooling down in such buildings

EnerPHit verification

EnerPHit is the standard defined by the Passive House Institute for modernisation of existing buildings using Passive House components. Proof that the EnerPHit Standard has been achieved is often required, e.g. in the context of building certification for requisitioning of subsidies, due to (contractual) commitments to customers, or simply to ensure the achievement of self-defined modernisation objectives. Besides Passive House verification, EnerPHit verification can also be provided using the PHPP. The EnerPHit Standard is selected in the corresponding menu of the 'Verification' worksheet in the PHPP, as well as the desired verification method according to the building component or energy demand method. The corresponding required values will then be displayed next to the actual characteristic values of the building. PHPP shows for each requirement and for the requirements in total whether these have been met or not. The verification worksheet can then be printed out and signed by the originator/author, possibly supplemented with other PHPP worksheets.

For creating an EnerPHit Retrofit Plan (ERP) e.g. for pre-certification, in addition to the PHPP file, the ERP output file in which the PHPP data have been adopted is also necessary (see Section 2.3).

As with Passive House buildings, stringent requirements also

Specific building characteristics with reference to the treated floor area

	Treated floor area	m²	156,0		Criteria	Alternative criteria	Fullfilled?[2]
Space heating	Heating demand	kWh/(m²a)	20	≤	25	-	yes
	Heating load	W/m²	16	≤	-	-	
Space cooling	Cooling & dehum. demand	kWh/(m²a)	0	≤	15	15	yes
	Cooling load	W/m²	4	≤	-	10	
	Frequency of overheating (> 25 °C)	%	-	≤	-		-
	Frequency of excessively high humidity (> 12 g/kg)	%	0	≤	10		yes
Airtightness	Pressurization test result n_{50}	1/h	1,0	≤	1,0		yes
Non-renewable Primary Energy (PE)	PE demand	kWh/(m²a)	46	≤	-		-
Primary Energy Renewable (PER)	PER demand	kWh/(m²a)	39	≤	36	39	yes
	Generation of renewable energy (in relation to projected building footprint area)	kWh/(m²a)	128	≥	120	126	

[2] Empty field: Data missing; '-': No requirement

Figure 2: EnerPHit verification in the PHPP according to the energy demand method

The Passive House Planning Package (PHPP)

apply for the EnerPHit Standard in respect of thermal comfort and absence of condensation. Particularly in existing buildings there is a greater risk that these requirements will not be met by certain parts of the building envelope. The PHPP automatically checks whether the minimum interior surface temperatures for thermal comfort and absence of condensation are achieved and issues a warning if necessary.

Entering individual modernisation steps in the PHPP

From Version 9 (2015) onwards the PHPP offers the possibility of calculating in parallel several versions of the same building. Thus a separate PHPP file does not have to be created for each design variant or e.g. for several similar houses in a row of terraced housing.

This function is particularly suitable for calculations relating to step-by-step modernisations. The building only has to be entered once. The successive modernisation steps can then be created as separate building variants. For this, only the differences to the preceding step have to be re-entered again, e.g. the exterior wall insulation.

The PHPP then calculates the respective results for all steps and displays them clearly next to each other. The results are presented graphically in a bar chart that can be configured by the user.

Profitability calculation for individual modernisation and thermal protection measures

Besides improved comfort, in particular the energy costs that will be saved are also a motivation for carrying out energy-relevant modernisation. The profitability of individual energy-saving measures can therefore be calculated in an easy way in the PHPP. For example, a new coat of paint for the exterior wall which is a so-called `Anyway Measure' which is due in any case is compared with an alternative energy saving measure which is coupled with this measure – in the example here this is the insulation of the exterior wall. The debt service for the investment costs and the annual energy are calculated for both cases. The alternative where the total sum of the debt service and energy costs is smallest will obviously be more profitable. If the investment costs of the measures are not yet known, then it can at least be calculated how much the maximum costs for the more energy efficient alternative will have to be for this to be more profitable in comparison.
If the individual modernisation steps have already been entered in the PHPP, then this input can be adopted automatically for the profitability calculation.

	Select the active variant here >>>>>>>	5-Heat pump + solar thermal	Existing	Window + ventilation	Basement ceiling + roof	Exterior wall + entrance door	Heat pump + solar thermal
	Units	5	**1**	**2**	**3**	**4**	**5**
Heating demand	kWh/(m²a)	**20,3**	329,3	245,2	155,6	20,3	20,3
Heating load	W/m²	**15,5**	141,9	97,7	67,0	15,5	15,5
Cooling & dehum. demand	kWh/(m²a)	**0,1**	6,7	2,1	0,7	0,2	0,1
Cooling load	W/m²	**3,7**	32,6	17,4	10,2	5,5	3,7
Frequency of overheating (> 25 °C)	%						
PER demand	kWh/(m²a)	**38,9**	994,4	784,5	558,9	224,3	38,9
EnerPHit Premium?	yes / no	**yes**	no	no	no	no	yes

Figure 3:
Clearly arranged summary of the most important results of the modernisation steps in the PHPP worksheet 'Variants'

Author: Zeno Bastian

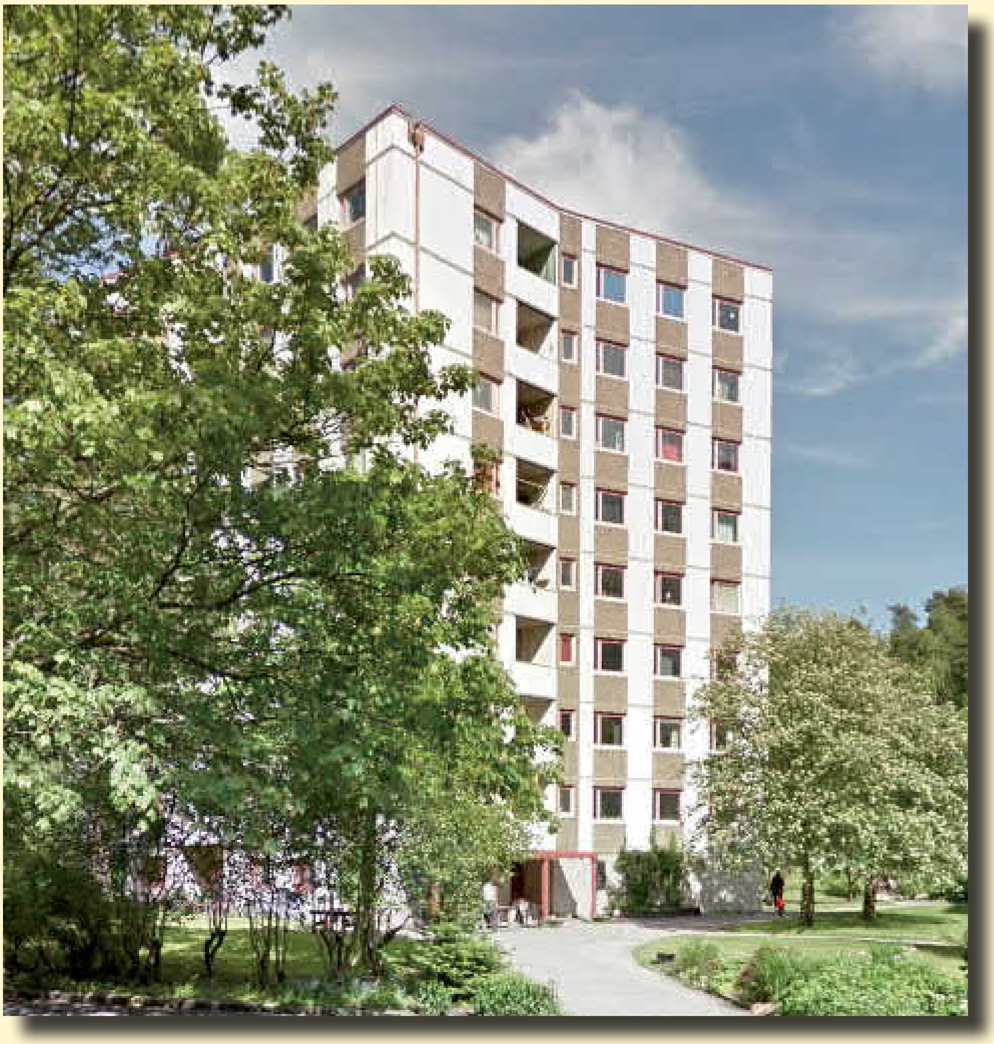


Figure 4:
EuroPHit case study project „Gothenburg Stacken“, Sweden, before retrofit.

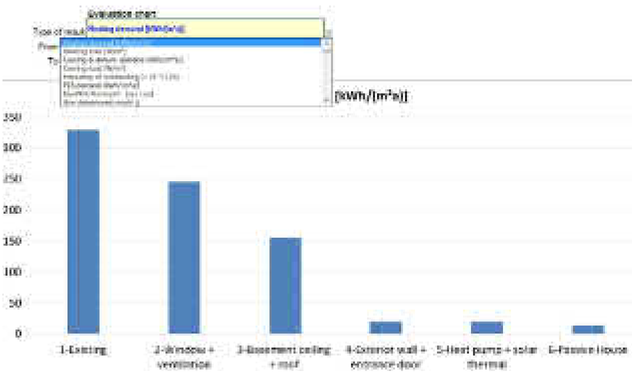


Figure 5:
Graphical representation of the results of the modernisation steps using a chart that can be configured by the user

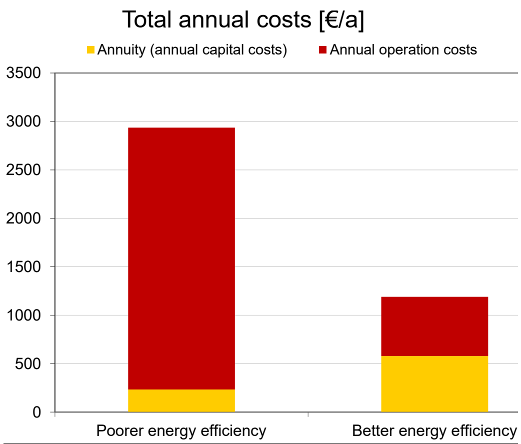


Figure 6:
Diagram showing the results of the profitability calculation in the PHPP for comparing the pending measure for a new coat of paint (left) and an alternative with simultaneous insulation of the exterior wall to Passive House quality (right).

Certified Passive House components

High quality products are essential for energy efficiency in buildings

It is evident that the energy efficiency of the building is directly related to its high quality components. Passive House criteria are usually much stricter than current regulations and as a result, it might be difficult to determine whether the performance of a given product is suitable for the Passive House standard or not. In many cases, product information is unclear or completely unavailable.

This is why the Passive House Institute certifies those components which have a performance that contributes to achieve the very high energy efficiency established in the Passive House and EnerPHit standard as well as in all other high energy efficient and comfortable buildings. In other words, the certified components have been tested regarding specific criteria, making available performance values that can be easily compared and that allow to make the precise energy balance calculation of the building. During the certification process, the Passive House Institutes experts are guiding manufacturers optimizing their products in order to meet the standard. In addition, the Passive House Institutes component seal is a well-recognized quality label which is used gladly by manufacturers advertising their products.

When a designer uses certified Passivhaus components together with careful design and planning, it is much easier to achieve not only the Passive House standard but to reach the energy targets during the service life of the building.

Which products or components can be certified?

The Institute certifies those building components which have a direct impact on the energy efficiency of the building. These are classified in three main categories:

- Opaque components: such as wall, roof or floor slab systems, anchor systems, balcony connections, attic staircases, among others.
- Transparent components: windows, skylights, curtain wall systems, shutters, doors, glazing, spacers, etc.
- Building services: compact heat pump units, ventilation systems, and drain water heat recovery systems.

Why certify?

For the Institute, certification is a way to ensure quality control during the design and planning processes. It is also a way to make it easier for the designer to specify adequate components, since they have been independently tested and certified. But the advantages are also clear for manufacturers, since the use of the seal "Certified Passivhaus Component" is the entry to a rapidly growing market and an increase in visibility and recognition of the certified product. When a product is certified:

- It is included in the online database (www.componentdatabase.org)
- It is listed in the Passive House Planning Package to be used in the calculations.
- It appears in the newsletter of the International Passive House Association (iPHA), where all new certified products are published.
- The Passive House Institutes component seal can be used for the purpose of advertisement by the manufacturer.

2.5

Author: Benjamin Krick

International does not mean one-size-fits-all

The criteria for component certification were developed based on two main requirements: to guarantee hygienic and comfort in the building with minimal energy consumption. Thus, the principle and requirements are the same, but are translated into different criteria if the building is in a cold climate, for instance in Norway or if it is in a warm climate like Portugal. As a result, a component is certified for a specific climatic region, which is specified in the certification seal.

The logic behind it is, the established values represent the optimal relation between performance and life-cycle cost efficiency. Let's look at this using a window as example. For the cold climate, the requirement is a U-value (before installation) of 0.60 W/m²K. This can be achieved with low-e quadruple glazing or excellent quality low-e triple glazing, possibly with hard coating on the outside. But in a warm or hot climate, the requirement is a U-value of 1.20 W/m²K. This can be achieved with double glazing, possibly with a solar protection coating. As a matter of fact, using triple glazing in a warm climate would be an unnecessary additional investment that might not be payed back by energy savings during the life-cycle of the product. In other words, details are important. The criteria are international, but there is no "one-size-fits-all" solution.

Summary

It is essential to have high quality components available in the market to guarantee the success of the Passive House concept. By offering the certification of components, the Passive House Institute contributes to making available such products in the market. For the manufacturer, this is a great opportunity to make key improvements to the product, thanks to the recommendations issued by the experts in the Passive House Institute and to enter an increasingly growing market. The very end of the certification and its main advantage is that it enables the link between the designers and those manufacturers who offer high quality components.

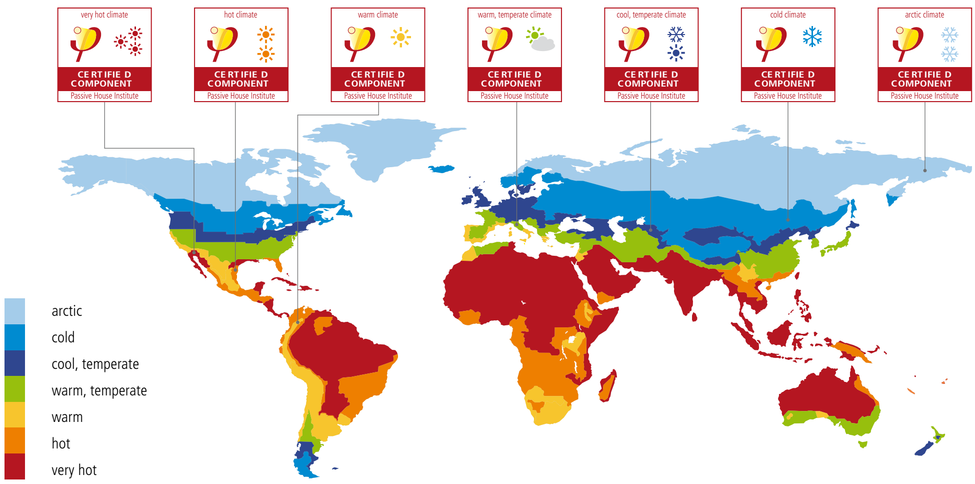


Figure 1:
The certification of a component implies that such product/system is suitable to use in a given climatic region.

Economic efficiency

Introduction – Motivation – Explanatory note

The most important **basic rule** when considering the economic efficiency of a measure for a building is **that it is not only the current expenditure for the investment which should be taken into account.** The "benefit" of a measure must always be considered and taken into account in the calculation at the same time. This applies generally and not only for energy efficiency measures:

- we build houses to protect us from wind and weather, houses in which we can live and work
- we build beautiful houses in which we feel comfortable
- we install a beautiful bathroom… we use beautiful colours …
- we install a heating system so that it is warm in winter and hot water is available all year round
- we use thermal insulation so that keeping warm in winter is easier
- we improve the level of airtightness so that there are no cold draughts through gaps in winter
- we get a ventilation system with heat recovery so that we do not have to ventilate via windows in winter
- we … the list may be continued easily…

This list purposely mixes those measures which can be assessed in monetary terms and those for which it is very difficult to assess the monetary value. However, it is undisputed that for the construction of a building, each component is produced only at the request of the building owner or customer. And it is equally clear that the building owner associates a specific benefit with each wish, i.e. each desired component or measure has a point and purpose, otherwise it would not be considered.

Some of the measures mentioned – namely all `energy efficiency measures' – usually also result in an objective economic advantage besides the subjective benefit, because as soon as they are applied they reduce the energy-related and financial effort required for keeping the building warm and well-ventilated and consequently comfortable.

Tangible energy efficiency – assessing the expenditure and benefit

The energy-efficiency measures for the building usually have an economic advantage because the heating costs will be greatly reduced. This is true especially if the original state of a building from a construction year with no thermal insulation is compared with the building after energy-relevant modernisation measures have been carried out.

This statement is relativised for newer buildings which already have more or less thermal insulation: if the initial state before the modernisation is already very good, then the savings effect of an additional layer of insulation will accordingly be smaller.

There may actually be situations where the initial state is `too good', so that the effort for an additional layer of insulation or some other measure such as new windows will not be worthwhile in strictly economic terms.

This is also known as the `lock-in effect': additional insulation that is actually necessary for energy efficiency reasons is no longer financially viable. Because it will not be financially worthwhile to add an extra 10 cm insulation to the 15 cm already present at a later point in time, the building will have only 15 cm of thermal insulation for the next 50 years and the energy costs will be high accordingly. The same applies for other measures such as improved U-values of windows. Many building owners are laypersons and cannot easily assess the financial consequences of such decisions.

2.6

Author: Berthold Kaufmann

For assessing economic viability the financial advantage of an energy saving measure, i.e. the saved heating energy, must be determined and compared with the expenditure for investment in the measure in a reasonable way. After that it can be checked whether the advantage or saving over the lifetime of the respective component balances out the expenditure for the necessary investment. In addition, it may make sense to compare different variants of the measures with each other, e.g. the expenditure and savings of thermal insulation measures with a thickness of 20 cm or of 25 cm. From this comparison it will then be possible to decide which variant is more economically advantageous in theory.

However, one must note that cost ascertainment and also the calculation of the saved energy include a certain degree of uncertainty. Differences of less than 10 % in the life-cycle costs of two variants of the measures are therefore insignificant. In this case the variant that is better in terms of energy efficiency (25 cm thickness instead of 20 cm in the example) should definitely be chosen in order to avoid the above-mentioned predicament with the lock-in effect. An energy saving measure should always be carried out according to the principle: "if it has to be done at all, then properly": e.g. thermal insulation should be implemented with a thickness of 25 cm instead of only 20 cm, windows should have a U-value of 0.8 W/m²K instead of 1.3 W/m²K whenever possible – see also the notes regarding the coupling principle.

Cost calculation – Assignment of costs for energy saving measures

The costs of the individual measures or sets of measures should certainly be determined and listed. Additional measures that are required later on should always be documented in the list immediately together with their costs so that the building owner is able to keep an overview of all costs.

Besides the investment costs, the calculation of cost efficiency must also include other costs such as the costs for servicing, heating, chimney sweep, tank insurance, solar energy system, ventilation system and possibly the costs for the auxiliary electricity for circulating pumps and the ventilation system. However, these can also be ascertained from typical maintenance contracts.

Energy-related investment costs – direct costs of measures

Determining the investment costs that are directly attributable to an efficiency measure is more difficult: This is illustrated by the example of a compound insulation system (EIFS) for insulating an exterior wall: the costs that are directly associated with the measure are the material costs for the insulation and the adhesive and possibly additional fastenings. The new exterior plaster needed in addition will usually have to be renewed in any case because the old plaster on the uninsulated wall was in need of repair. As so-called "anyway costs", the costs for the new plaster coat are therefore not included in the investment costs for the measure "thermal insulation of exterior wall".

Coupling principle and “anyway costs“

However, differentiating between the purely maintenance costs, also known as "anyway costs", and the costs directly relating to the measures must be well justified, or is admissible only in certain cases: the costs for new plaster may only be differentiated as "anyway costs" if the measure "EIFS" is carried out in combination with the measure "new exterior plaster". This leads directly to what is known as the "coupling principle": as a rule, measures for thermal protection can only be presented as being cost-effective if the measure is directly coupled with a retrofitting measure that is necessary in any case, such as renewal of the old crumbling exterior plaster. In general it is therefore apparent that ascertaining the costs is especially important and crucial for the economic efficiency analysis and must be done with great care. Planning of the chronological sequence and coupling of measures also have a big influence on whether measures are cost-effective.
Other modernisation costs such as a new bathroom will not be considered in this connection, but if necessary they must be discussed with the building owner with regard to the total budget.

Learning curves … the prospect of lower costs in case of mass production

The term "learning curve" is used to describe the effect that the cost of measures may decrease in the future because the prices for innovative products are particularly high directly after introduction on the market. However, as soon as the production

Economic efficiency

quantities increase and the unit costs can be reduced, prices can be expected to fall. For example, currently (2016) the price for low-e triple glazing is only slightly higher than that of the earlier insulated double glazing. The same applies for window frames and is expected for ventilation systems with heat recovery. However, on the other hand this development requires a market demand. Competent energy consultancy plays a key role in this respect; interest in this can only be raised if the high standard of components is adequately communicated to building owners and a corresponding market demand is generated, which in turn will help to reduce costs in the medium term. However, as a rule current prices should be used for the economic efficiency analysis of future measures since anything else would be speculative.

Another example: if a window fitter has never installed a window in the insulation layer before, he will demand an especially high price for this to cover the risk of something going wrong unexpectedly, and to pay for the time his colleagues will have to spend becoming familiar with the new procedure. The more the planner and the workers are familiar with a certain activity, the faster and more reliable the work will be and the costs will be accordingly lower.

Being aware of these effects may also be important for subsequent charging of costs and evaluation of tenders. For example, particularly high prices for insulated window frames and low-e triple glazing are no longer justified today, therefore high-priced offers in particular should be critically scrutinized.

Examples for costs of individual components up to the year 2015 (for Germany), with only the costs associated with the measures
themselves given here:

Thermal insulation	1 €/cm/m² cost for 1 cm of additional insulation thickness
Mitigation of thermal bridges	100 €/m
Windows	250 €/m² (legal minimum standard) 350 €/m² (Passive House standard)
Airtightness	5 €/m² floor area
Ventilation system with HR	50…80 €/m² floor area

Full cost of an energy-relevant modernisation

sum total of the costs for repairs or "anyway costs" and the costs for energy-related measures. If the full cost of both measures is used for the calculation when comparing the economic efficiency of a measure that is necessary in any case and an alternative energy-saving measure, then division into costs incurred anyway and additional costs for energy-related measures will not be necessary.

Ongoing costs for energy

Energy costs for each planning variant can be determined from the annual energy demand (delivered energy!) calculated in the PHPP. As a rule, these consist of costs for heating energy or fuel and the expenditure for auxiliary energy for operating the ventilation, heating and solar energy systems.

Determining saved energy costs using the PHPP

For determining energy savings, the energy demand of the building to be calculated in theory can be used "with" and "without" the energy saving measures. The potential saving results directly from the difference.

Seen statistically for a large body of identical buildings, on average the theoretical demand with the standard boundary conditions in the PHPP agrees very well with the actual average demand of these buildings. However, for individual buildings the consumption before the measure is often lower than the theoretically calculated demand on account of different user behaviours (desired temperature, ventilation behaviour etc.) This should be taken into account appropriately in the PHPP through modification of the boundary conditions e.g. a reduced average indoor temperature of just 18° C for the unmodernised building.

For a very well-insulated building after completion of the measure (target state), the potential statistical fluctuations due to user behaviour are significantly smaller so that the theoretical energy DEMAND according to the PHPP will be used for the energy-related assessment of the target state.

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It is important to provide the building owner with the best possible basis for making decisions for future modernisation steps. This means two things: the energy-related assessment should take place in an objective manner i.e. independently of the specific user behaviour. Secondly, the economic efficiency analysis should be carried out as realistically as possible. For this, it is necessary for the experts to determine the energy consumption of the building in the original state or "without" the measure, and in comparison to that the expected energy consumption after the modernisation.

The PHPP worksheet "Variants" can be used for this purpose. If the costs are entered in the worksheet "PHeco" then it is possible to quickly perform the economic efficiency calculation and see the effect of each measure, see Figure 1. Individual measures can be assessed even more easily in the PHPP using the worksheet "comparison".

Ongoing maintenance costs

The costs for maintenance and repairs to the technical systems are incurred annually like the energy costs. They must therefore be included as ongoing costs in the calculation.

Costs of planning and additional construction services: allocation is difficult.

It is not always easy to properly separate the costs for planning and additional construction because these include a large number of additional construction services which are necessary for the preparation and implementation of the measures properly and according to regulations. These are usually the fees for architects and engineers, fees for structural analysis inspections or verification of compliance with legal requirements. As a rule, these are allocated as costs that will be incurred in any case. In an initial step, planning costs can be set as 10 % of the investment costs for the measures.

On the other hand, costs such as those for increased planning effort for avoiding thermal bridges are more appropriately classified as energy-related additional costs

Cost effects with step-by-step modernisation

With step-by-step modernisation, the costs are spread over a longer period of time and are therefore easier to bear for the building owner. A step-by-step modernisation may therefore be realised even without taking out a loan, i.e. only equity may be used. For many building owners, this is the most important reason for carrying out modernisation measures in succession. Apart from that, full use can still be made of the remaining service life or residual value of components if necessary. Example: if plaster renewal and therefore thermal insulation are to be carried out today, but the windows are only 10 years old, then for economic considerations there is no sense in replacing these at present.

However, bringing forward measures that are not yet due in order to implement these more easily as part of a set of currently due measures has a reducing effect on the

building: 156 m² (TFA) |
credit: 20 years,
real interest rate: 2% |
delivered energy (heating): 0,1 €/ kWh |
energy (el.): 0,29 €/ kWh

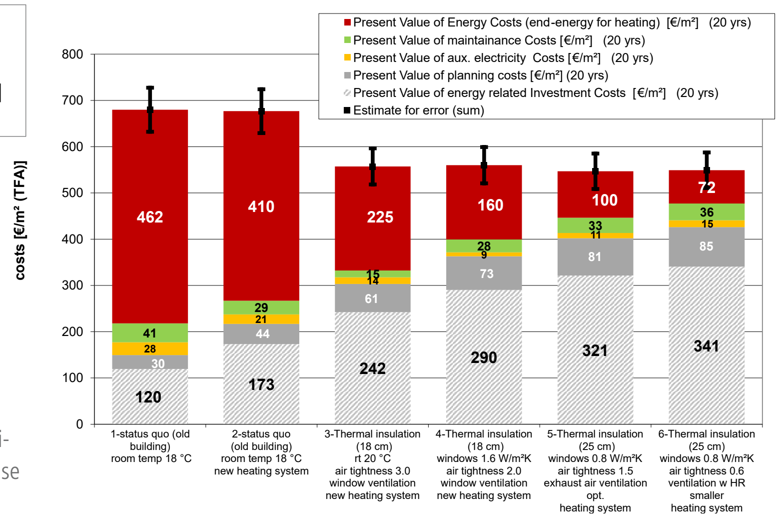

Figure 1:
Example showing the total life-cycle costs for different typical modernisation variants. Cash/present values for the cost of a single-family house with 156 m². The planning costs are given separately.

Economic efficiency

construction costs where applicable, because elaborate intermediate states will not have to be created and maintained.

In this way one can avoid unnecessary additional investment costs. Apart from this, by bringing a measure (new windows, smaller and fewer thermal bridges) forward, one can benefit even earlier from the higher energy savings.

The scenarios mentioned here show that planners should carefully explore the procedure in detail together with building owners. Senselessly implementing single measures without a concept (EnerPHit Retrofit Plan) is usually expensive and results in little energy savings.

Economic efficiency – Total life-cycle cost

So how can the economic efficiency of a measure be determined specifically? For this purpose, both types of costs, the one-off investment costs (today) and the ongoing energy costs that are incurred annually over the consideration period must be converted so that they can be compared with each other, or so that a total can be obtained from both. This total is known as the total life-cycle cost of a component or measure.

Dynamic net present value calculation

This conversion of the two cost categories can be broadly described as follows: with the aid of a dynamic net present value calculation, the (constant!) payment or "annuity" payable each year can be calculated using the interest rate for the loan and the rate of repayment and the loan period. With the formula (1) given below, the one-off investment (also called the cash value or present value) can be directly converted into an annuity. The formula gives the "annuity factor".

Conversely, an annual payment – in this case especially the energy costs and maintenance costs – can also be converted into a present value. Both cost categories can therefore be expressed fully equivalently either as present values or as annuities.

At least to some extent the methods for a dynamic present value or net present value calculation should be explained to the building owner, because most building owners are familiar with the conversion of one-off investment costs into an ongoing annual instalment; in order to finance a major investment in a measure for a building, a one-off loan is obtained from a bank which can then be repaid in annual instalments over the agreed loan period (annuities). For many building owners, major investments are only possible in this way, but businesses also finance their investments in this way through their current

A = a * K	**with**	**(1)**
A = annuity	or annual payment	
K = capital	or investment, one-off payment, cash value or present value	
a = p/(1-(1+p)-n)	**annuity factor with**	
p = interest rate	as a decimal number (0.03 = 3%) or 1+p = interest factor (1.03)	
n = loan period	or consideration period in years (as a whole number)	

How is the annuity calculated from the loan volume? With the aid of a dynamic net present value calculation, the (constant! annual) payment or "annuity" payable each year can be calculated using the interest rate for the loan and the rate of repayment and the loan period.

As one can easily see from the formula (1), conversely a present value for this annual payment can be calculated from an annual Payment A with the aid of the reciprocal b = 1/a

b = 1/a = (1-(1+p)-n)/p	b thus means the present value factor	(2)
K = A/a = b * A =B	net present value (K) or present value (B) both are frequently used.	

An annual payment such as the amount for the annually due heating bill can be converted just as easily using the "present value factor": the annual heating cost annuity can simply be converted into a "present" value.

Now the description of the procedure for the economic efficiency analysis is almost complete; in order to calculate the total life-cycle cost (LCC) of a measure, one must now only

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calculate the present value of the heating costs (afterwards, $B_{HeatingCost}$, afterwards) plus the investment costs (invest) of a measure: $B_{HC,\ 'with'} + B_{invest} = LCC'_{with'}$. This must be compared with the present value of the heating costs ($B_{HC,\ before}$) before the implementation of the measure.

If applicable, any costs arising annual for maintenance, chimney sweep, tank insurance etc. $A_{maintenance}$ must also be added on both sides i.e. "with" and "without", but these can also be converted into a present value $B_{maintenance}$ with the aid of the present value factor.

$$B_{invest} + B_{HC,`with'} + B_{maintenance,\ `with'} = LCC_{'with'} \leq LCC_{`without'} = B_{HC,\ `without'} + B_{maintenance,\ `without'} \qquad (3)$$

The measure will be economically advantageous or at least, would not be disadvantageous, as soon as the sum "total afterwards" $LCC_{`with'}$ becomes smaller or equal to the ongoing costs ($LCC_{`without'}$) before.

Selecting boundary conditions correctly

For an accurate economic efficiency analysis, the correct average boundary conditions (interest rate, energy prices etc.) must be selected for the consideration period:

- Interest rate: 2 % (real interest rate, as of 2016)
- Energy price 0.1 €/kWh as an average price throughout the entire consideration period. An energy price increase exceeding the general inflation rate is not assumed.
- Consideration period is 20 years.
- Average useful lives of different components are predefined in the PHPP. These can be adjusted by the user if required.
- If the useful life of a component or the average useful life is known and it is longer than the consideration period, then a residual value of the measure after 20 years is automatically calculated in the PHPP. This is deducted from the investment costs in the economic efficiency analysis.
- For simplification, in the economic efficiency analysis it can be assumed that all measures are implemented at the same time (present value 'today') although they may be implemented over several years in the case of a step-by-step modernisation. This simplification makes sense for reducing the calculation procedure and the input required in the PHPP.
- If these exist, subsidies can be taken into account in the economic efficiency analysis by decreasing the costs accordingly.

Important note: the annuities for the investment costs calculated according to the methodology described above usually do not correspond with the actual annual costs for interest and repayment by the building owner. This is due to the deduction of the residual value for one thing. Another difference results if only the additional costs due to energy-related reasons are used in the calculations instead of the total cost. The above mentioned calculation is ideal for an economic efficiency comparison. However, for calculating financing (bank savings plan), the total investment for the total cost of the measures are generally used, i.e. including the "anyway costs" and without deducting residual values.

The method for the economic efficiency analysis which was only described briefly here can be studied in more detail in the Passive House resource Passipedia (www.passipedia.org). Figure 1 below shows a diagram with the life-cycle costs for different modernisation variants.

Economic efficiency analysis in the EnerPHit Retrofit Plan (as of 2016)

The EnerPHit Retrofit Plan (ERP) contains a simple economic efficiency analysis. The annual energy costs for the individual energy sources are automatically calculated for this on the basis of the basic PHPP calculation. The total costs of measures that are due anyway and the energy saving measures must be entered in the ERP file. Based on this, the annuities for the energy-related investment costs will be output and added to the annual energy costs. It will then be possible to see how the total consisting of the investment costs and energy costs becomes smaller and smaller with each modernisation step, i.e. the annual costs will decrease – at least if the sets of measures are cost-effective.

Minimal monitoring

Minimal monitoring

When carrying out energy-related retrofit measures, a frequent issue that arises is how high the envisaged savings in the form of a reduction in consumption actually are in reality. With as little effort as possible, the total consumption of the building can be determined so that it can be compared with the consumption before the retrofit measure. For this, it is necessary to be able to differentiate between heating, hot water and electricity use. In this connection the term 'minimal monitoring' should be understood to mean '**an efficiency review of a building regarding its energy consumption using minimal effort**'.

Only the already existing consumption meters for billing purposes are available for this purpose. As a rule, detailed values such as the consumption for 'heat distribution' in the building can only be estimated with this method. The other – equally important – effects of energy-relevant retrofit measures such as a higher surface temperature of an interior wall and increased living comfort can only be ascertained and evaluated by means of other measurements.

The method for 'minimal monitoring' is designed to evaluate the overall consumption of a building. With simultaneous implementation of several individual measures, only the total savings achieved through all the measures can be determined. For example, if the windows are renewed in a retrofit step and the top floor ceiling is insulated at the same time, it is not possible to ascertain the influence of window renewal on its own simply through measurement of the consumption.

Influencing factors

After a successful retrofit, the amount of energy consumed depends on the type of retrofit on the one hand, and the usage and climatic conditions on the other hand. The main influencing factors for energy consumption compared with a previously prepared demand calculation are as follows:

1. **Construction work:** The executed work deviates from the planning (material, type of assembly, airtightness etc.).

2. **Indoor temperature:** Normally an indoor temperature of 20 °C is calculated for residential buildings. The actual indoor temperature of the building is typically different.

3. **Climatic conditions:** The average climatic conditions (outdoor temperature and global radiation) in a calculation always differ from the actual conditions.

4. **Type of operation:** Running times and volumetric flows of ventilation systems, unintentional heating in the summer, incorrect operation, etc. often result in boundary conditions that differ from the calculation.

Due to the total sum of the influences mentioned above, the difference in the energy **consumption** and a careful **demand** calculation, e.g. with the PHPP, can be quite considerable. In energy efficient buildings this can reach a scale similar to that of the calculated demand value. However, on account of the extremely low consumption level, this doesn't have to be a problem.

Procedure

The heat consumption (space heating and hot water) of a building is considered in a simplified way in the method described here; electricity and water consumption will remain unconsidered. More comprehensive information can be found in [Peper 2014].

The energy-relevant influences of a retrofit that is carried out step-by-step can be verified with minimal monitoring. At least the monthly meter readings are available as a starting point and basis, from which the monthly consumption e.g. for space heating will be determined. An annual total can then be calculated from 12 months initially. Based on the corresponding treated floor area of the building, the specific annual total consumption will be obtained.

2.7

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Depending on the type and position of the meter (heat meter at the outlet of a gas boiler or a gas meter), different measured values will result. Conversion and storage losses etc. are accordingly included or not included. The measured value (pellets/wood in kg or m³, electricity for heat pump, gas) must accordingly be converted into a corresponding heat quantity. The recorded heat quantity does not equate to the pure heating energy even if it can be measured after conversion and storage in exceptional cases. It still includes at least distribution losses within or/and outside of the thermal envelope, therefore this cannot simply be compared with the heating energy value calculated in the PHPP.

For example, if an equivalent of 70 kWh/(m²a) results for the total gas consumption of a building after retrofit, the question arises as to whether the building is functioning 'as planned'. For instance if 25 kWh/(m²a) is expected for space heating and 22 kWh/ (m²a) is expected for hot water, that is 47 kWh/(m²a) in total, then the 70 kWh/(m²a) cannot be put into perspective at first. As explained above, there can be several reasons for this.

The procedure for minimal monitoring with the issues `does the building function as planned?' or 'what did the retrofit steps bring?' will be described here in steps. After the main steps, there will be some further optional steps so that the result can be refined even further. However, further measurements will usually be necessary for this.

There is no difference between the basic procedure for new constructions and that for retrofits. The consumption values for a sufficiently large number of months are necessary in all cases. To shorten the measurement duration that is required, only the **heating period** (for heating operation alone in Central Europe, e.g. from October to April) or the **cooling period** for cooling energy (in Central Europe, e.g. from May to September) can be used for simplification.

Step 1:
Initial value of final energy

The monthly consumption is calculated from the monthly readings of the meters for delivered energy (e.g. gas, district heat, heat pump electricity) of the building or corresponding measurement units (in case of oil, wood etc.). If the delivered energy is measured directly e.g. as the gas volume (m³) instead of in energy units (kWh), then conversion will be necessary. For simplification, calculation can be carried out using the conversion rule `1 m³ natural gas roughly equals 10 kWh'. A separate electricity meter must be available in case electric heat pumps are used.

Step 2:
Position of the heat generator

The location of the supply and heat storage facilities must be taken into account in the evaluation: If the technical installations for energy supply or conversion of energy (district heat transfer station, gas boiler, heat storage) are situated outside of the building envelope (e.g. basement), the heat output from conversion and storage is not (directly) used to heat the building, therefore these conversion and storage losses must be taken into account as an overall amount.

The amount of **conversion and distribution losses** depends on many technical circumstances. As a rough but acceptable approach, an **overall amount of 12 %** of the total delivered energy can be deducted for conversion and storage losses (this does not apply for heat pumps). These are not released within the thermal envelope of the building and therefore cannot be used for heating. The interim result with the remaining 88 % is the quantity of heat which was used within the thermal envelope of the building. No reduction will take place if the technology is located within the thermal envelope.

Minimal monitoring

Step 3:
Solar thermal system

If a **solar thermal system** is used in the considered building, then the energy gains which are supplied to the building additionally must be measured separately. General deductions will not lead to any useful results.

Step 4:
Separation of energy for space heating/hot water

Since space heating and hot water generation usually takes place jointly with only one device (boiler, heat pump, district heat), these two consumption parameters must be separated. An easy way to do this is to ascertain the so-called 'hot water base'. This refers to the amount of energy consumed throughout the year for generating hot water, to which the heating energy consumed in winter is added. This can easily be inferred from the graph (Fig. 3). The heat consumption in summer (e.g. June to August) is extrapolated to the whole year. The hot water consumption determined thus is deducted from the annual consumption.

Normally there is a slight fluctuation in the summer/winter consumption of hot water in residential buildings; slightly more hot water is used in winter than in summer; energy expenditure in winter is thus slightly higher. This fluctuation is not taken into account in the simplified kind of evaluation of energy expenditure for hot water generation described here. However, a maximum addition of 10 % can be made to the values calculated from the three summer months.

Care is necessary in the case of holidays or other periods of absence: (in summer) these cause minimal consumptions (`summer slumps'); sometimes these can also occur during other times (e.g. winter holiday periods). This may be especially relevant in the case of small buildings (single-family and semi-detached houses). These periods must be taken into account if the energy expenditure for hot water generation is determined in the simplified manner described here.

Step 5:
Result for heat consumption

For a single-family house the amount of energy which is reduced by the consumption value amount for hot water generation represents the **estimated consumption value for space heating**. Further adjustments are not realistically possible without exact knowledge of the boundary conditions etc.

Additionally for multi-storey buildings: deduction of non-utilisable distribution losses

In an apartment block with central heat distribution outside of the thermal envelope, further deductions can be made for the non-utilisable heat quantity for heat distribution (pipes). Here too, there are fluctuations due to many influencing parameters (duct lengths outside of the thermal envelope, quality of the insulation etc.). Based on the multi-storey buildings with typical heat engineering that were monitored by the PHI ([Peper/Feist 2008], [Peper 2009]), an overall **deduction of 17 %** of the calculated heat quantity is applied here.

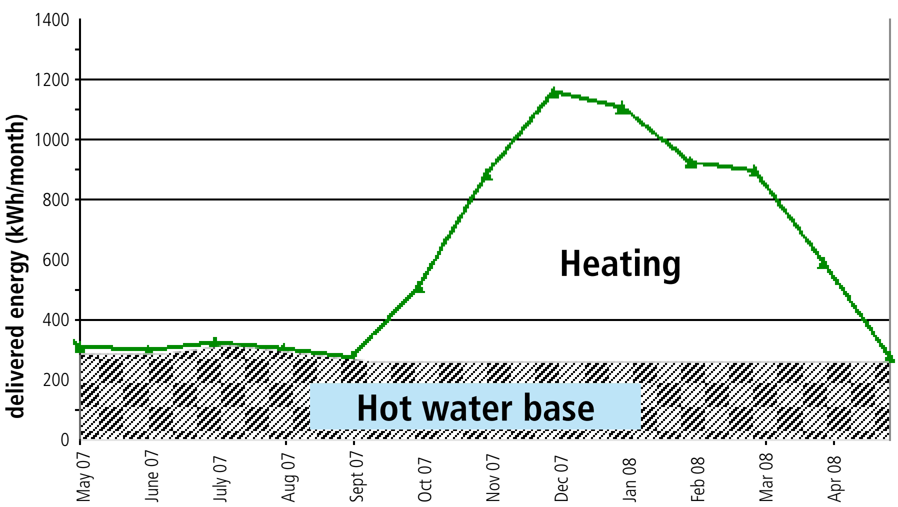

Figure 3:
Determination of the scale of the so-called hot water base for the annual consumption by means of evaluation of the adjusted monthly final energy consumptions. [Peper 2012]

Step 6:
Temperature adjustment (optional)

If the monthly average indoor temperatures of the building in winter are known, then adjustment of the heat consumption can be carried out optionally. As a rule, the actual temperature differs from that used in the calculation. Here what matters is:

- that the **temperature is representative** of the entire building and not just a single room with a specific use (kitchen, living room or bedroom),
- that the temperature measurement is not exposed to influences such as **direct sunlight** or cold air from open doors or windows and
- that the temperature measurement has a **reasonable level of accuracy** ($\leq \pm 0.5$ K).

Adjustment can take place if a temperature measurement has been carried out which corresponds with the requirements given above. In order to be able to estimate the difference in the heating demand, the safest way is to use the measured temperature in the current PHPP calculation. This value can then be applied in a simplified way for the consumption (measured value) as well (the change is calculated for the demand, but it is applied to the consumption).

If the PHPP is not available, or not available in digital form, then the difference between the measured winter temperature and the balance temperature (standard 20 °C) can be calculated first. A moderate overall deduction of 2 kWh/(m²a) for each kelvin of temperature difference can then be applied for energy efficient buildings.

Result for space heating

The outcome obtained is an estimation of the heat consumption of the building **without other detailed adjustments e.g. for climate data**. This estimation can be compared directly with the heating demand in the PHPP calculation. The calculated value can be used as an initial estimate in order to check whether further, more exact and complex investigations of the building would be expedient or necessary. However, assessment of the reasons for any increased consumption values (technical malfunction etc.) cannot take place with this. Since this is a rough general method, the results should accordingly be treated with caution. Nevertheless, a valuable estimate of the heat consumption of the building can be achieved in this way. Comparisons of different buildings can be carried out using the same method (benchmarking).

Step 7:
Adjustment of outdoor climate (optional)

For further, more exact evaluation of the consumption data, adjustment of the balance calculation (PHPP) to the actual outdoor climatic conditions during the measurement period can take place optionally as a next step. This will increase the effort and will exceed the context of simple `minimal monitoring'.

For this, climate data for the relevant location during the studied period will be necessary: global radiation (horizontal) as well as the outdoor temperature as monthly average values. Values from the nearest weather station should be used. A separate climate data set for the measurement year can be created with this data in the PHPP. The calculated result of the theoretical heat demand determined in this way is used for comparing the result in the PHPP for the previously used standard climate of the location. The difference in the heating energy due to the varying weather conditions can thus be determined. The method for adjusting the climate conditions by means of heating degree days alone is not useful for energy efficient buildings, as has been explained in [Peper 2012-A].

Minimal monitoring

Summary of minimal monitoring

The most important points regarding minimal monitoring are as follows:

- Monthly meter readings of all essential meters (electricity, gas, district heat) or specification of the procured quantities of firewood, wood pellets or crude oil.
- An additional heat meter is necessary in case of a solar heating system.
- Distribution and conversion losses are taken into account as a simplified overall value.
- The energy consumption for hot water generation is calculated from the consumption data for the summer months. An overall adjustment can be made here additionally in order to take into account the summer/winter fluctuation in the consumption of hot water.
- In the case of apartment blocks, the non-utilisable distribution losses are taken into account as an overall value.
- Adjustment of the consumption values on account of a different indoor temperature can take place optionally if this is known (standard 20 °C).
- The influence of the actual weather conditions on the heat consumption during the measurement period can be determined optionally with the aid of the balance calculation (PHPP). The difference between the standard weather of the location can be calculated in this way.

Despite the limited accuracy of this method for **estimating heat consumption** and disregarding the various influencing factors, this provides a valuable overall picture for an initial assessment of the building. Further `refinement' such as taking into account of the indoor temperature and the climatic conditions during the measurement period can be added with more effort.

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03

Building envelope – General principles

PAGE

Thermal Bridges

During the heating period, thermal bridges lead to increased heat losses. In moderate to cold climates, thermal bridges in an existing building are problematic especially because of their reduced interior surface temperatures and the associate risk of moisture-related structural damage. In climates where cooling is required, the influence of thermal bridges on the cooling demand is less relevant on account of the smaller temperature difference between the inside and the outside. However, in hot and humid climates condensation may form on the outside at thermal bridges when the interior space is cooled. While mould growth often occurs in unmodernised existing buildings, it can largely be ruled out after an ambitious energy-relevant full modernisation.

The situation is different in the case of partial modernisations where due to poorly coordinated modernisation steps the risk of mould may even be temporarily increased in the heating period. The reason for this is measures that reduce air exchange, i.e.

- increased airtightness, e.g. after window replacement
- changing the heating system from non-roomsealed individual stove to central heating

If the occupants do not adjust their winter ventilation behaviour to the changed circumstances (e.g. four times daily airing with windows opened wide) and if a ventilation system is not installed, then the relative humidity levels of indoor air will often increase to much higher than 50 %. The risk of mould will increase, particularly if the thermal protection of the exterior envelope is not also improved at the same time.

For preparing an EnerPHit Retrofit Plan, the following recommendations apply for the prevention of moisture damage at thermal bridges during the heating period:

- Reduction of uncontrolled air exchange (leaks, combustion air) must take place simultaneously with the ensuring of adequate controlled ventilation. This applies particularly if thermal protection of the building is not improved at the same time. For reasons of thermal comfort and saving energy, the installation of a ventilation system with heat recovery is recommended if the conditions for this are already present at the time of the respective modernisation step (sufficient airtightness of the entire building envelope).
- In the case of individual measures, mitigation of thermal bridges may become necessary for an intermediate state. For example, if a new window is installed in an uninsulated wall, then a thin layer of reveal insulation or comparable measures for preventing mould will usually be necessary (see section on windows, 3.2). In the case of a complete retrofit with simultaneous insulation of the exterior wall, these measures would not be necessary and therefore they constitute an extra expenditure which must be taken into account when considering whether or not it would be better to combine both measures.

Figure 1:
Onset of mould growth at the connection point of a window and an uninsulated wall

3.1

Author: Zeno Bastian

- Because damage due to mould constitutes a serious defect and can also affect the health of the occupants, measures which serve to remedy this damage must already be foreseen in the first set of measures in the EnerPHit Retrofit Plan even if no pending measures for the affected building component are yet due. Thus, if mould growth occurs in the corners of the room, then the exterior wall should be insulated even if the exterior plaster does not need to be renewed yet.

Figure 2:
Connection of the basement wall to the basement ceiling: continuing the exterior wall insulation down to and well below the basement ceiling connection, and flanking insulation on the inside of the exterior wall of the basement mitigates the thermal bridge and provides for sufficiently high interior surface temperatures in order to safely prevent mould growth on the ground floor.

Airtightness

Airtightness

The step-by-step retrofit of buildings represents a special challenge for airtightness of a building. In order to achieve a sufficiently airtight building ultimately as an overall outcome, airtightness must be taken into account at each individual step. The final result and not only the individual step must always be considered in the process. In order to ensure this, the procedure is divided into five steps:

Preliminary measurement for a building survey

To define the correct retrofit steps in relation to airtightness, the structure must be assessed to this effect before planning takes place. In doing so, the focus must be on the following questions:

- Which materials form the airtight layer in the existing state?
- Where are the weak points located in the existing envelope?
- What will be changed by the retrofit steps?

In order to answer these questions, a preliminary measurement of the airtightness (pressure differential measurement) should be carried out if appropriate. The entire structure is examined at negative pressure, leakages are detected and assessed. In the process, leaks or problematic areas usually come to light which were not noticed previously. This information is incorporated into the planning for airtightness. The measurements can be performed in the inhabited or uninhabited state. A welcome side-effect of this preliminary measurement is that the airtightness of the building is obtained as an n_{50} value before the retrofit for use as a comparative value for the success of the measure.

Rough concept

For the EnerPHit retrofit plan, an overall concept for airtightness which takes into account all planned retrofit steps must be defined **before** the first retrofit step using the findings from the preliminary test of the building. Only then will it be ensured that the individual steps will enable an overall solution that is airtight. In doing so, it must defined which materials will form the airtight layer all throughout for **all** building components (old and new). In ordinary cases, only four types of materials are suitable for surface sealing:

- Plastered over masonry walls
- Concrete
- Membrane/reinforced building boards
- Hard wood composite boards

The `pencil rule' is advised for this procedure: it must be possible to outline the building envelope with a pencil in all cross-sections of the building without lifting it from the paper. The only exceptions are the ventilation opening of the fresh air

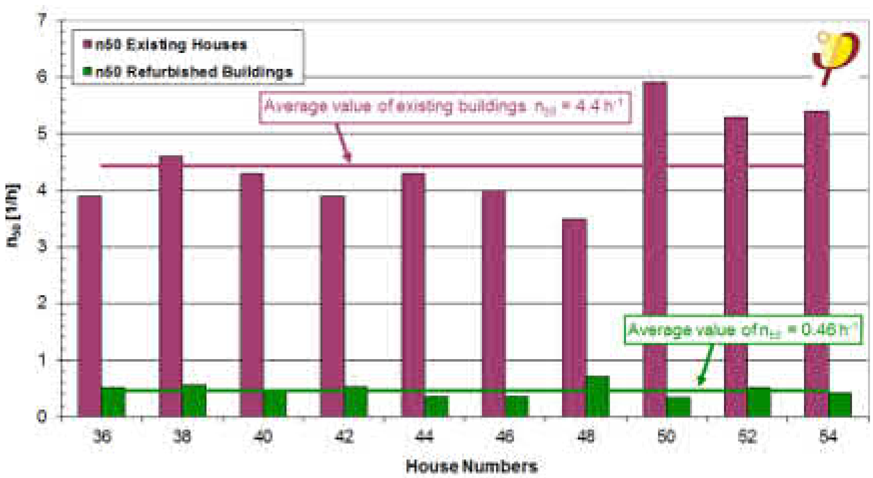


Figure 1:
Comparison of measured values for airtightness in the 10 entrance stairways before and after the retrofit of the buildings in Tevesstraße in Frankfurt a.M. [Kaufmann et al. 2009]

3.2

Author: Søren Peper

and exhaust air pipes. The airtight layer for each area must be indicated.

For the retrofit plan, simple schematic sketches must also be prepared for showing the connection of the airtight layer and building components (e.g. connection of the roof to the exterior wall). Only then can it be ensured that a building component that is modernised later on is airtightly connected in a reliable way and with little effort.

Detail planning

Once the airtight layer has been specified for all building components all throughout, the connections of these areas with each other and the penetrations (cables, pipes) must be planned in detail. Exact planning for implementation will take place directly before the execution of the respective steps. Simple joining of two plastered wall surfaces (no other measures necessary) must be taken into account just like more complicated connections between a window and wall or between the roof membrane and wall surface. Suitable materials must also be specified for the surface sealing connections. With step-by-step retrofit, in particular accessibility of the connections for subsequent steps must be kept in mind and planned for accordingly: for example, the joint in the membrane of a building component must be prepared and secured in such a way that implementation of a secure connection is still possible during a later retrofit step.

In the case of penetrations, the `avoidance rule' must be applied primarily: it should always be checked whether the specific penetration is really absolutely necessary. This may seem a trivial thing, but is surprisingly relevant. As far as possible, penetrations by cables and pipes must be concentrated at a few points because sealing will then be easier and more reliable. In the case of horizontal penetrations, pouring thin gypsum plaster or expanding mortar is often best.

Execution

Implementation of the planning can take place in a targeted manner only through a direct review of the implementation during the individual retrofit steps. In particular it must be ensured that specially selected products suitable for airtight sealing are used. If other materials of a different quality or different properties are used, then it must be checked whether it is equally possible to achieve the overall objective with these. In doing so, the focus must not only be placed on the current retrofit step; future steps must always also be considered.

During a retrofit, it should always be expected that despite a review and detail planning, other old materials will come to light in the wall or roof build-up, in which case readjustment of planning may become necessary. A flexible response must be possible while bearing in mind the objectives of the airtightness concept.

Airtightness

Step-by-step airtightness measurement

Airtightness should normally be checked after each retrofit step that affects the airtight layer. In the process, thorough leakage detection is advised at a time when changes can still be made to the airtight layer directly. If all cladding, window ledges etc. have been attached, then it is usually no longer possible to carry out corrective work at all the appropriate points. However, a full airtightness measurement is not absolutely necessary after each step. Alternatively, leakage detection by means of a so-called `craftsman's Blower Door' is sufficient. This is a simple exhaust fan for installation in window or door openings. The negative pressure produced inside the building makes it possible to feel the air currents caused by the leaks easily with the hand.

Overview of the procedure

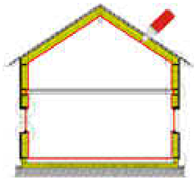
The five individual steps and the times for these are shown here in the form of a table:

1 **Review of the existing building**
all relevant areas connections and transitions
Recommendation: airtightness measurement in existing building

Timepoint: before the measure

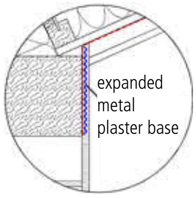
2 **Rough concept for airtightness:**
Specification of the airtight layer in all cross-sections and floor plans (apply the **pencil rule**), and schematic sketch of the connection details

Timepoint: before the first step



3 **Implementation planning:**
Detailed specification of the work to be executed including specification of the materials to be used for each joint, connection and penetration.

Timepoint: before the respective measure



4 **Execution**
Implementation of planning with supervision of the work. If necessary, adjustment of the planning.
Use of suitable products for airtightness

Timepoint: during each retrofit step

5 **Airtightness measurement**
Checking of the work (leakage detection) and ascertaining of the n_{50} value for the energy balance

Timepoint: Leakage detection just before completion of each individual measure or full airtightness measurement after completion of the last retrofit step

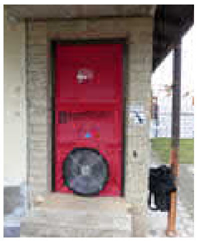


Figure 2:
Procedure for implementing a successful airtightness concept in modernisation projects

Author: Søren Peper

Figure 3:
EuroPHit case study project „Home for Elderly" in Dún Laoghaire, Ireland
View of airtight layer being applied on new roof metal deck
(Photo: Mariana Moreira)

Minimum requirements for thermal comfort and prevention of mould

If Passive House components are used exclusively for modernising a building then impairment of comfort or mould growth can be ruled out with great certainty on account of the excellent level of thermal protection. Nevertheless, there is often some reason why building components cannot be retrofitted to achieve an optimal standard of thermal protection, e.g. due to historic building preservation requirements or simply because there is not enough space for thermal insulation. In addition, in the case of step-by-step modernisation, it is not always possible to bring all building components up to an optimal standard right at the beginning. In order to safeguard against mould growth and problems relating to comfort also in these cases, the criteria for Passive House buildings and EnerPHit retrofits include simplified minimum requirements for thermal protection which are considerably less stringent than the requirements for Passive House components.

Comfort

A poor level of thermal protection impairs thermal comfort particularly during the heating period due to the cold interior surfaces of the exterior components arising as a result. As a rule, the windows have the poorest U-value in the exterior envelope, and therefore are especially crucial for the perceived thermal comfort. The interior surface temperature of windows, exterior walls and ceilings should not fall more than 4.2 K below the operative indoor temperature (average value obtained from air and radiation temperatures, i.e. perceived temperature) even in deepest winter. The surface temperature of the floor should not fall below 19 °C (with 22 °C indoor temperature). In the Passive House Planning Package (PHPP) the requirements relating to comfort are automatically checked based on the temperatures contained in the climate data set for the respective location.
Exemptions in the requirements may only be possible if single, small areas (less than 1 m²) do not comply with these or if the radiation asymmetry is compensated by additional heat sources (usually radiators e.g. under windows).
Because humans react less sensitively to excessively warm interior surfaces, radiation asymmetry due to poorly insulated building components is less critical during the cooling period. In this respect, impairment of comfort will only occur in the case of extremely poorly insulated roofs.

Protection against moisture

Moisture-related problems due to condensate occur with insufficient thermal insulation and ventilation during the heating period, particularly at thermal bridges and at the glazing edge of windows. In its building criteria, the Passive House Institute has defined requirements for the temperature factor $f_{Rsi = 0.25\ m^2K/W}$ which ensure that such problems are highly unlikely. The temperature factor lies between zero and one and expresses the ratio of the interior surface temperature at the coldest point to the outside and to the indoor temperature. With a temperature factor near one, the interior surface temperature is close to the indoor temperature and moisture-related problems are not likely. For simplification, there is a temperature factor criterion for the climate zones throughout the world as defined by the Passive House Institute. For the hot and very hot climate zones there are no requirements since moisture-related problems on the inside

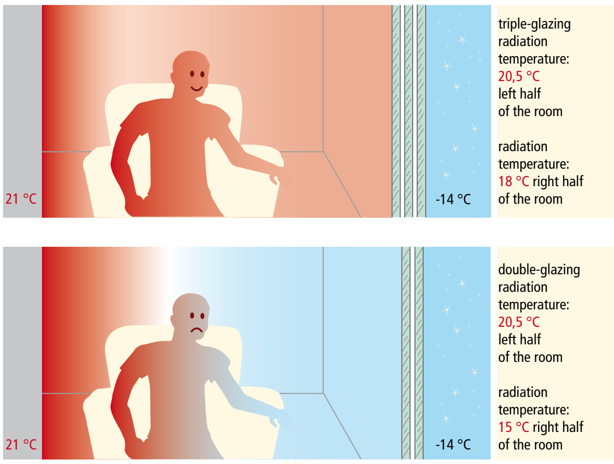


Figure 1:
Well-insulated Passive House windows improve comfort drammatically by keeping average inside surface temperatures above 17 °C, even in the coldest of outdoor conditions. This, of course, also prevents condensation and mould growth.

due to lack of thermal protection are not likely (adequate dehumidification is a prerequisite if necessary).

Besides the criterion for the temperature of the interior surface of building components mentioned in Table 1, all standard cross-sections and connection details must of course also be planned and executed so that with the intended utilisation, excessive moisture accumulation in the component build-up can be ruled out. For this, careful planning and execution of the airtight layer is necessary because otherwise warm and humid air may flow into the building component through leaks during the heating period. In climates requiring heating, interior insulation must be planned and executed skilfully in order to prevent excessive moisture accumulation.

Climate zone	Min. temperature factor $f_{Rsi=0.25\,m^2K/W}$ []
Arctic	0.80
Cold	0.75
Cool-temperate	0.70
Warm-temperate	0,65
Warm	0.55
Hot	-
Very hot	-

Table 1:
Criteria for protection against moisture

04

Building envelope – Connections in detail

PAGE

This section describes the preparations that should be carried during the implementation of individual energy saving measures for the thermal building envelope so that adjacent building components that are not being modernised at the same time can also be renovated to a high efficiency standard in an easy and cost-effective manner at a later point in time. The separate sub-sections are arranged according to the currently pending modernisation measure. The preparations which should already be carried out at this point in time for the subsequent measures will then be described for each current measure. Instructions for preparing for the subsequent window installation in the insulation layer are therefore given in the section "Wall insulation on the outside" and not in the section "Windows and doors".

Wall insulation on the outside

Wall insulation on the outside

When?

- Insulation of the exterior wall is often financially worthwhile on its own even if this is not due to be modernised, particularly in cool temperate to cold climates.
- When a new coat of paint or plaster renewal are necessary
- When scaffolding is to be set up in any case, e.g. for roofing work
- Simultaneously with necessary window replacement because windows can then be positioned optimally in the insulation layer with little effort.
- Immediately if a poor level of thermal protection of the exterior wall leads to mould growth on interior surfaces.

Where?

Location of the insulation

- In climates mostly requiring heating, the wall insulation should always be applied on the outside if possible. The exterior insulation here is unproblematic in terms of building physics and usually saves significantly more energy.
- Interior insulation is always much better than no insulation at all, but only if insulation on the outside is not possible (e.g. in the case of decorative façades of historic buildings, see Section 4.2).
- In hot climates the interior insulation can be the less problematic option in terms of building physics, but project-specific reasons (the building is continuously inhabited; reduction of the useable area is undesirable) may also speak for exterior insulation here.

Location of the airtight layer

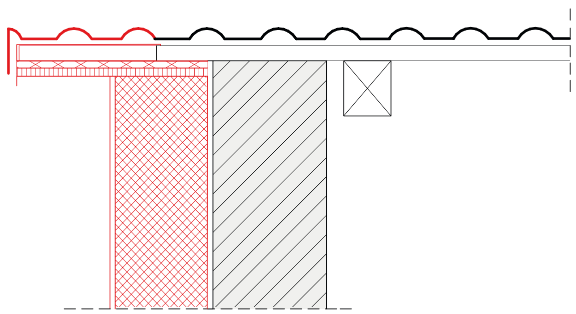
- In climates that require heating, the airtight layer is positioned on the room side of the thermal insulation. In solid constructions, this is usually the interior plaster. As a rule, it must be repaired for this purpose (e.g. at the power sockets) and joined to adjacent components without any gaps. Airtight connection to unfinished (reinforced concrete) ceilings is often only possible if the floor build-up is also renewed at the same time.
- Alternatively, the airtight layer may be in the area of the existing exterior plaster – that is between the existing wall and the new thermal insulation. However, because the existing plaster is not completely airtight on account of long-term weathering, additional plastering across the entire surface will also be necessary for this. This incurs extra costs and possible difficulties with quality assurance (as it will be covered by the insulation later on). This variant can therefore only be recommended if one of more of the following prerequisites are given:
  - Levelling plaster will be necessary in any case for creating an even surface for the thermal insulation.
  - It is very difficult to create a continuous airtight layer on the inside, e.g. due to ceilings with wood beams.
  - The airtight layer in the roof is located above the rafters and can therefore be joined comparatively easily to the exterior plaster.
  - Airtight connection of the exterior airtight plaster layer to the basement ceiling is possible (this is made difficult e.g. if the exterior wall in this area consists of hollow bricks).

4.1

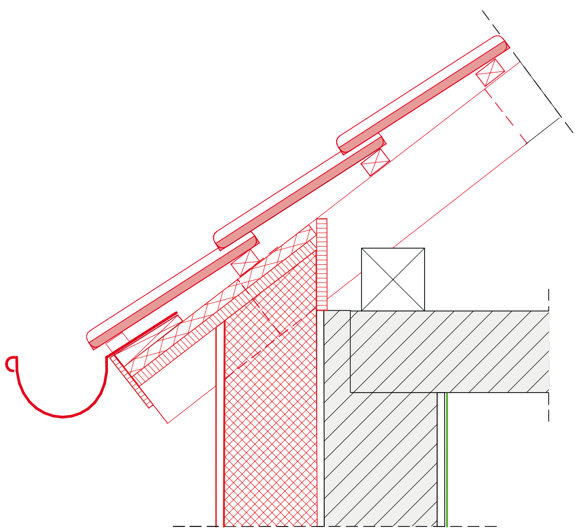
Author: Zeno Bastian

How?

Wall insulation / **pitched roof that is not yet renovated**



Verge
A roof overhang that is too small should not stand in the way of insulating the gable wall with an optimum thickness. The roof battens can simply be extended by attaching extension battens at the sides or by special U-shaped profiles.

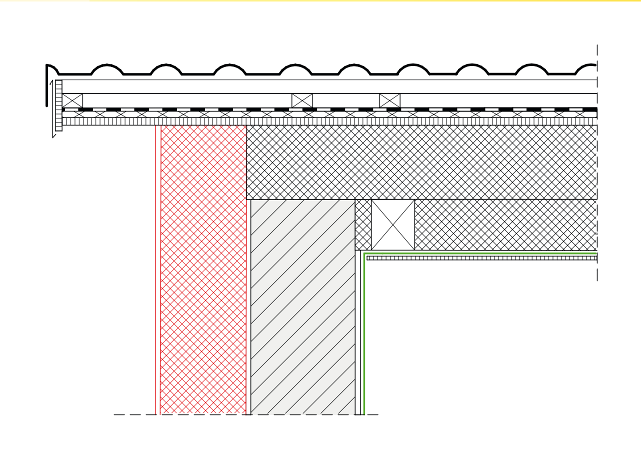


Eaves
A roof overhang that is too small can be extended by fastening rafter extensions at the sides. The roof end with the rainwater gutter etc. will have to be re-built.

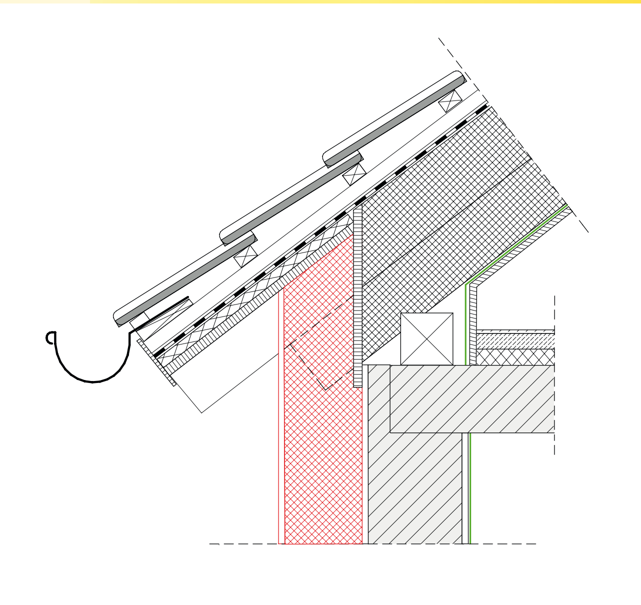
- hochfester Dämmstoff
- Dämmung
- Massives Bauteil
- Holz
- Luftdichtheitsebene

Wall insulation on the outside

Wall insulation / **insulated pitched roof**



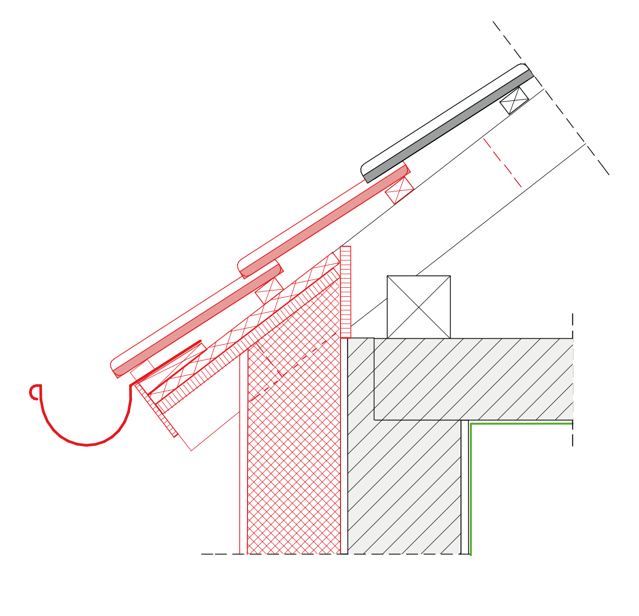
Verge
If the roof overhang has been prepared correctly in the preceding step, the wall insulation can simply be continued up to the lower edge of the roof overhang without any further modifications. The front-facing cladding of the insulation above the rafters can be removed prior to this.



Eaves
The thermal wall insulation at the edge of the roof must be worked around the protruding rafters. No other modifications will be required at the eaves if the preceding step has been properly prepared. Only the rainwater pipes will have to be moved and re-joined to the existing rainwater gutter.

Author: Zeno Bastian

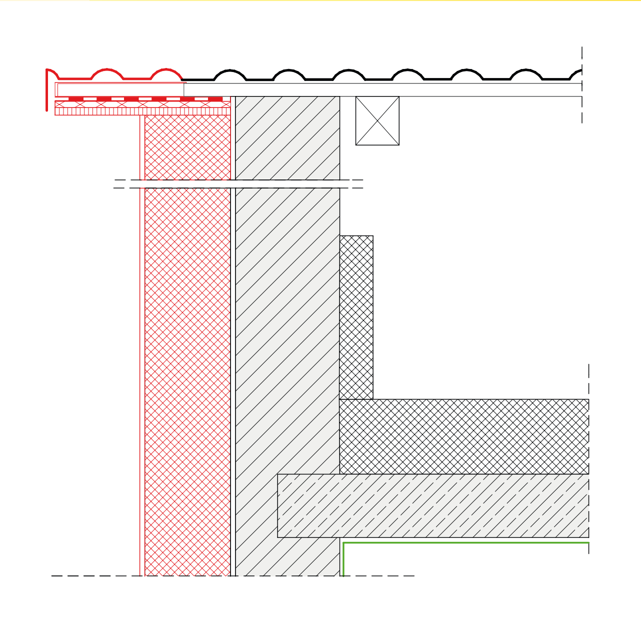
Wall insulation / **top floor ceiling which is to be insulated at a later point in time**



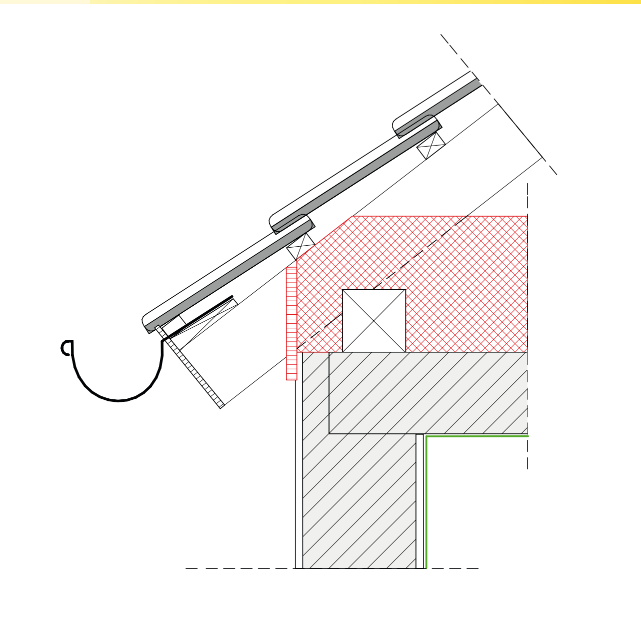
Eaves
If the roof overhang is insufficient, it can be extended by means of rafter extensions attached at the sides of the rafters. The roof edge with the rainwater gutter will have to be re-built again. The wall insulation should be continued as far upwards as possible.

Wall insulation on the outside

Wall insulation / **insulated top floor ceiling**



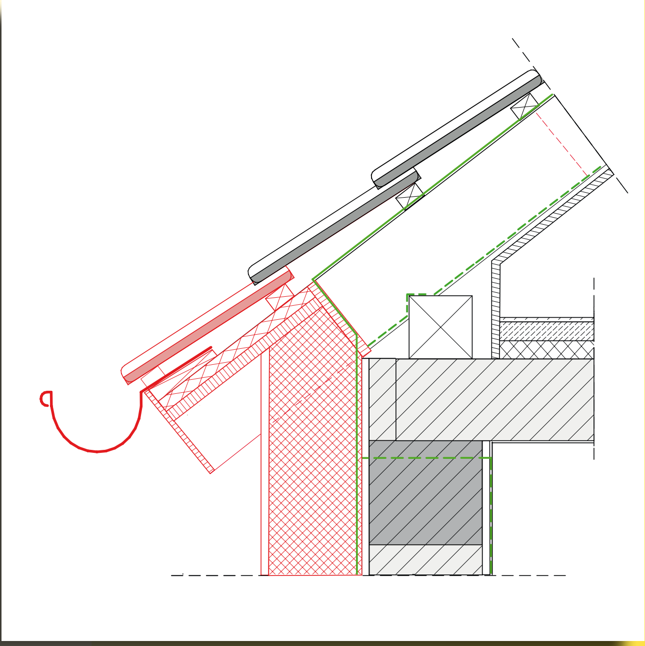
Verge
The wall insulation is continued up to the lower edge of the roof overhang if a consistent design of the gable wall is desired. If this is not large enough, the roof battens can simply be extended by attaching extension battens at the sides or by special U-shaped profiles. If other solutions are possible in terms of design, it is sufficient to extend the insulation up to about 50 – 100 cm beyond the upper edge of the top floor ceiling.



Eaves
If the roof overhang is inadequate, it can be extended by means of rafter extensions attached at the sides of the rafters. The roof overhang with the rainwater gutter will have to be re-built again afterwards. Wall insulation should be extended upwards as far as possible.

Author: Zeno Bastian

Wall insulation / **modernised attic floor that is not insulated or only minimally insulated**

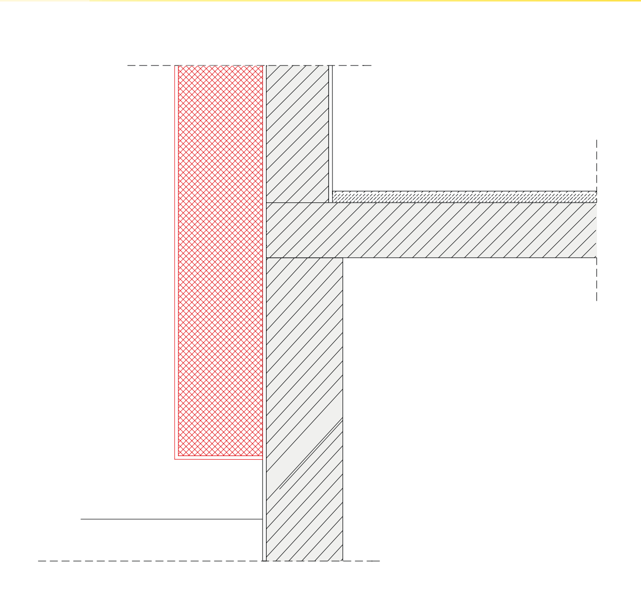


Eaves

If the attic floor is already modernised, then subsequent thermal protection measures will usually take place from the outside so that cladding etc. on the inside is not destroyed. The airtight layer in the roof will then also be installed from above, i.e. it will run above the rafters. The protruding rafters at the eaves will then make connection to the airtight layer of the wall difficult, therefore it may be expedient to saw off the existing rafter protrusions flush with the existing wall. A wide strip of membrane is then laid wavelike over the rafters along the roof edge. The roof overhang be extended again only after that by attaching rafter extensions at the sides of the rafters. The membrane runs between the original rafters and the extensions. The strip of membrane should be so wide that at the top it extends far enough over the brackets to allow subsequent connection to the air-tight layer of the roof without any problems. At the lower end the strip of membrane is joined with the old exterior plaster which has been repaired as the airtight layer. If a ring beam is present, the airtight layer here can also merge into the interior plaster over the airtight ring beam. The roof edge with the rainwater gutter etc. must be re-built for the intermediate state as well as for the final state. The shortening and subsequent extension of the rafters should be checked in advance by a structural engineer.

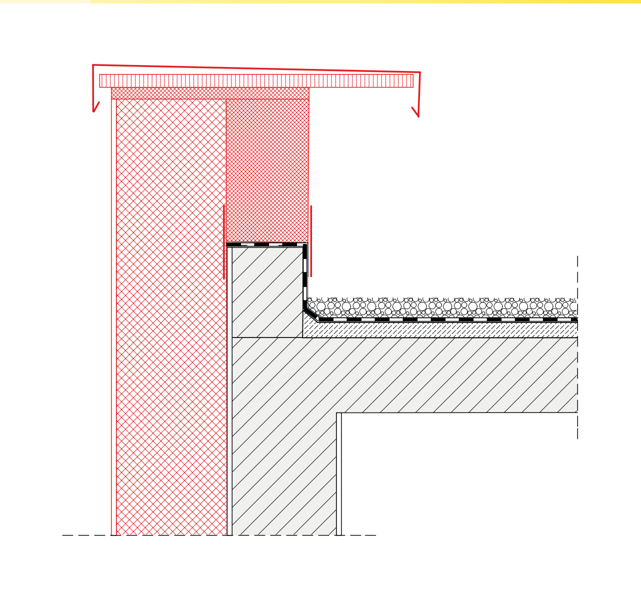
Wall insulation on the outside

Wall insulation / **top floor ceiling that is to be insulated later on**



The wall insulation should only end ca. 50-100 cm below the lower edge of the basement ceiling, so that the thermal bridge at the basement wall connection can be mitigated.

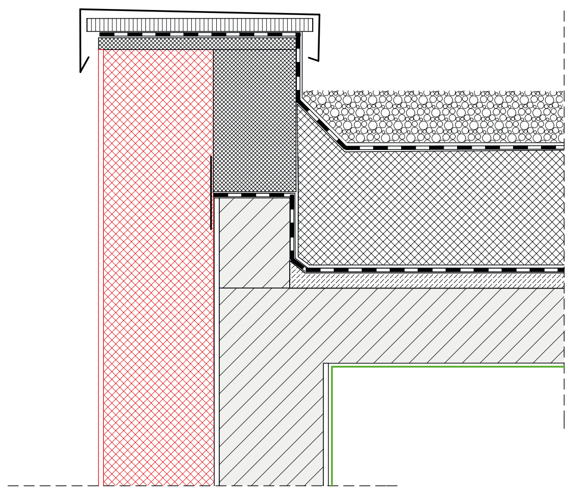
Wall insulation / **flat roof that is to be insulated later on**



The parapet must be raised to the extent that the subsequent flat roof insulation plus the gravel or green roof build-up will still be at an adequate distance from the upper edge of the parapet. In order to avoid thermal bridges, elements made of high-strength insulating material or wooden boxes filled with insulation material should be used. If it is expected that subsequent flat roof insulation will not overlap far enough with this insulation element (thermal bridge) then the flat roof insulation should even be continued up to the upper edge of the parapet later on. An adequate overhang of the parapet cover should be foreseen for this purpose.

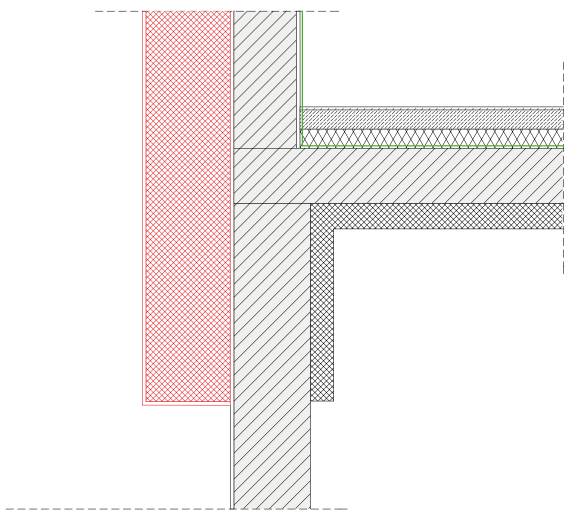
Author: Zeno Bastian

Wall insulation / **insulated flat roof**



Any existing cladding on the outside of the parapet should be removed. The wall insulation continues up to the parapet cover overhang prepared in the previous step.

Wall insulation / **insulated basement ceiling**

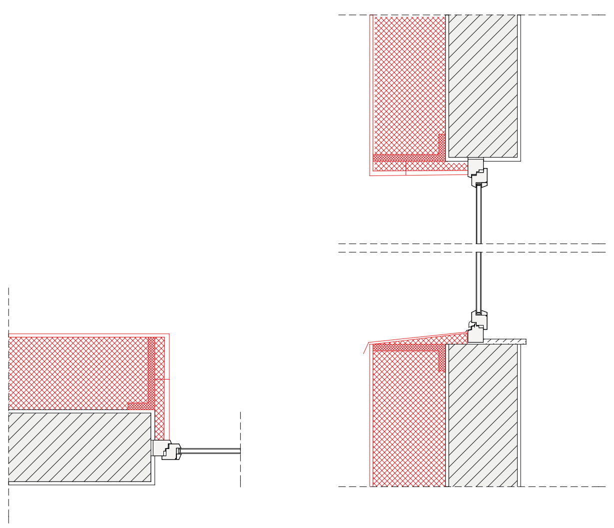


The wall insulation should only end ca. 50-100 cm below the lower edge of the basement ceiling so that the thermal bridge at the basement wall connection can be mitigated.

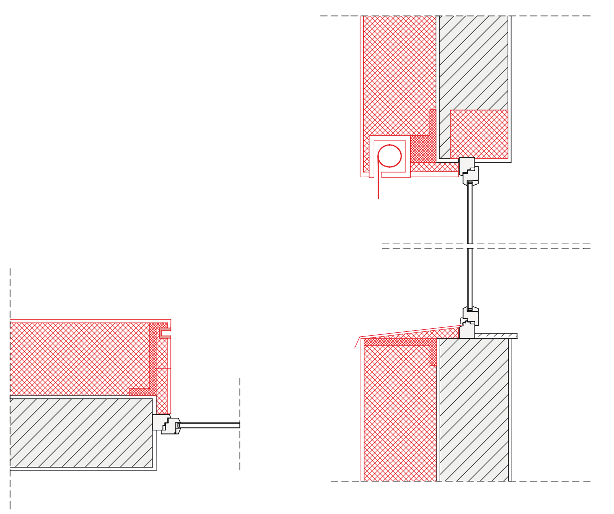
Wall insulation on the outside

Wall insulation / **existing window**

Without roller shutter



With roller shutter



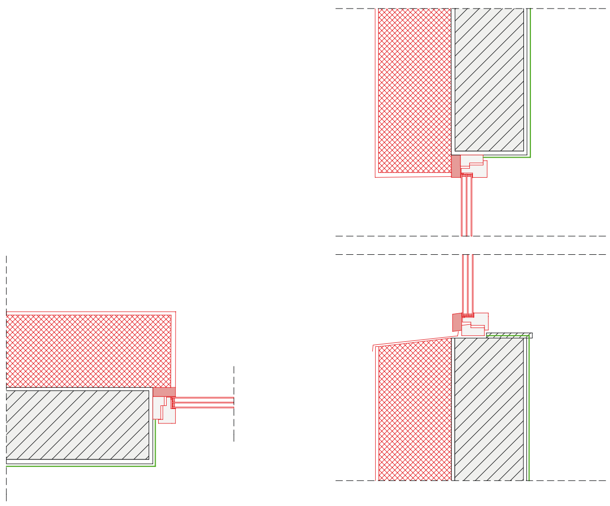
When installing the wall insulation, preparations should be made for subsequent thermal bridge minimised installation of the new windows in the insulation layer of the wall. For this, mounting frames consisting of high-strength insulation material are available which can be affixed on the outside around the window reveal. In order to avoid problems with condensation also during the intermediate state, and to limit heat losses, the outer window reveal should also be insulated up to the window frame. Subsequent window installation will be facilitated even further if the outer window ledge is already implemented in two parts and the plaster in the exterior reveal at the future exterior of the new window frame is separated by plaster profiles.

Existing roller shutters should be disman-tled and the roller shutter boxes filled with insulation material. New roller shutter boxes can then be mounted in the insulation layer under consideration of the future position of the new window. The mounting frame for the window can also be used for attaching the roller shutter box if necessary.

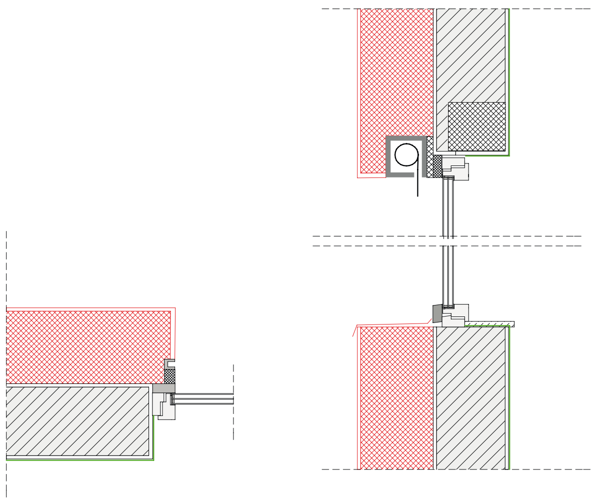
Author: Zeno Bastian

Wall insulation / **Passive House windows that have been installed previously**

Without roller shutter



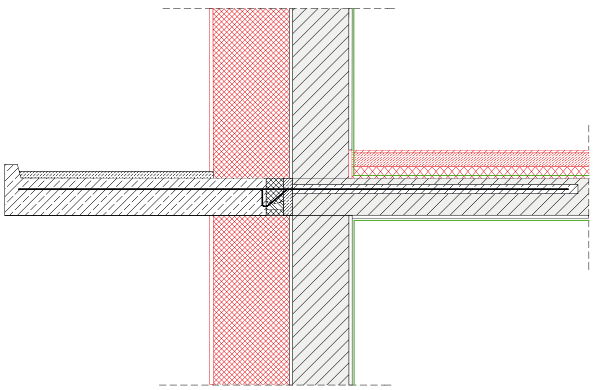
With roller shutter



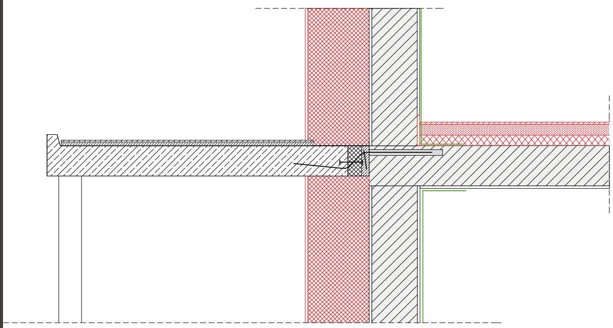
Insulation should extend over the window frame as far as possible. Any aluminium angle profiles affixed on the inside of the window frame for the intermediate state should be removed again if possible when the exterior insulation is applied, because these are no longer required for avoiding mould growth and also increase the heat losses slightly.

Wall insulation on the outside

Wall insulation / **existing balcony mounted with thermal separation**

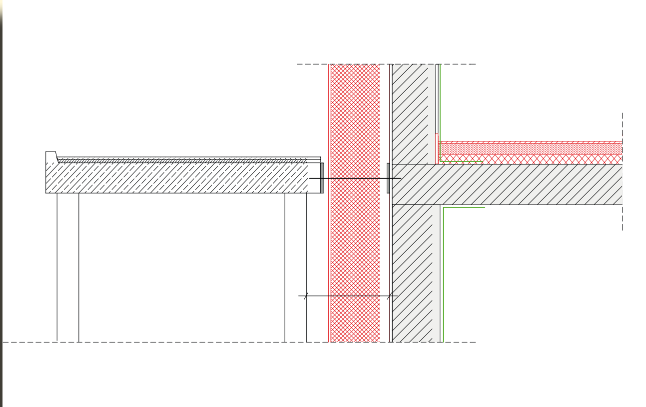


Any covering on top of the thermal separation that was installed for the intermediate state must be removed before installing the wall insulation (except at French windows) because otherwise they will constitute a thermal bridge.



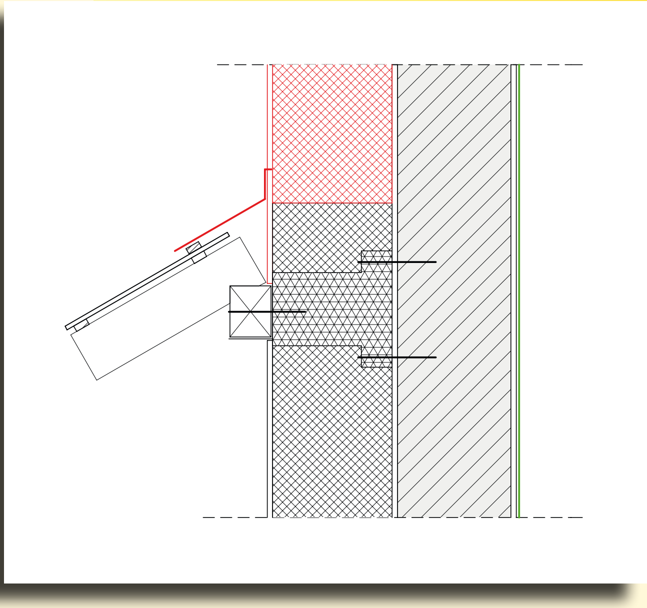
Author: Zeno Bastian

Wall insulation / **existing self-supporting balcony**



Any covering above the space between the balcony slab and the existing wall that was installed for the intermediate state must be removed before installing the wall insulation (except at French windows) because otherwise they will constitute a thermal bridge. The wall insulation must be applied around the anchoring elements carefully and without any gaps.

Wall insulation / **conservatory**



The existing water-carrying layer (flashing) at the connection of the conservatory to the wall must be removed before installing the insulation and then re-installed as otherwise this will create a thermal bridge

Exterior wall with interior insulation

General recommendations

In cool and cold climates interior insulation is recommended as a solution for energy retrofits of buildings which cannot be insulated on the outside. In step-by-step retrofitting with interior insulation, in addition to particularly careful planning and execution, attention should also be given to structurally faultless connection details to windows, interior walls and ceilings, and also to uninsulated exterior building components.

The following prerequisites must exist for the installation of interior insulation:

- the existing interior plaster must be firmly connected with the subsurface
- loose areas, heavy soiling of the surface, and oily paints or tiles should be removed
- it must be ensured that the wall is free of rising damp

For implementation without any defects, it should be ensured that

- the airtight layer (e.g. new interior plaster or membrane) is clearly and unambiguously identified and executed carefully, and meticulously joined with the adjacent building components in a way that is free of gaps, and power sockets are installed in an airtight manner,
- air currents behind the insulation layer are avoided e.g. by applying adhesive all over the surface of insulation panels.

Furthermore, heaters should be moved. For frost protection reasons, distribution pipes must not remain in the exterior wall and should be laid in the insulation layer, or in front of it.

Corner of exterior wall with interior insulation only on one side

If interior insulation is only applied on single walls or for single apartments, then particular attention should be given to the connection points where the interior insulation ends. In cool temperate climates a functioning solution for interim states is to install an L-shaped aluminium profile with a side length between 5 and 10 cm at the place where the interior insulation ends. The temperature at this place will be increased to the extent that there will not be a higher risk of structural damage with normal indoor air humidity levels. This only applies if pieces of furniture are not placed next to the wall. With an increased heat transfer resistance of 0.25 $(m^2K)/W$ due to furniture or curtains etc., even with a heat conducting profile the surface temperature may be too low.

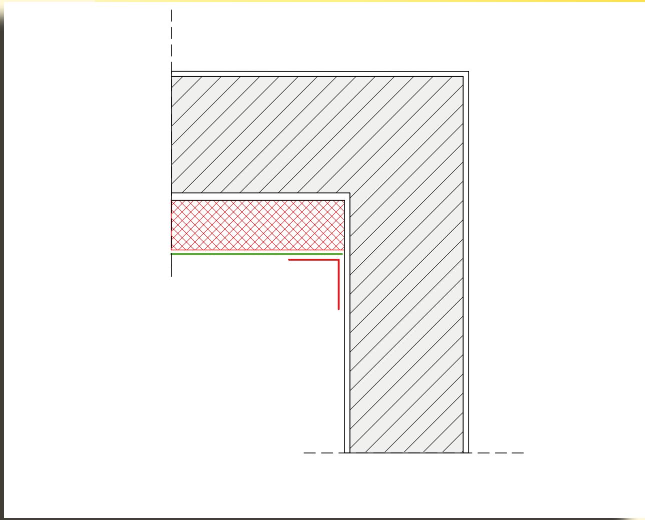
There will be considerable additional heat loss due to the use of the L-shaped heat conducting profile. Therefore insulation of single walls is inadvisable and only makes sense as a temporary solution. The L-profile should be removed when the adjacent wall is insulated later on.

4.2

Author: Tanja Schulz

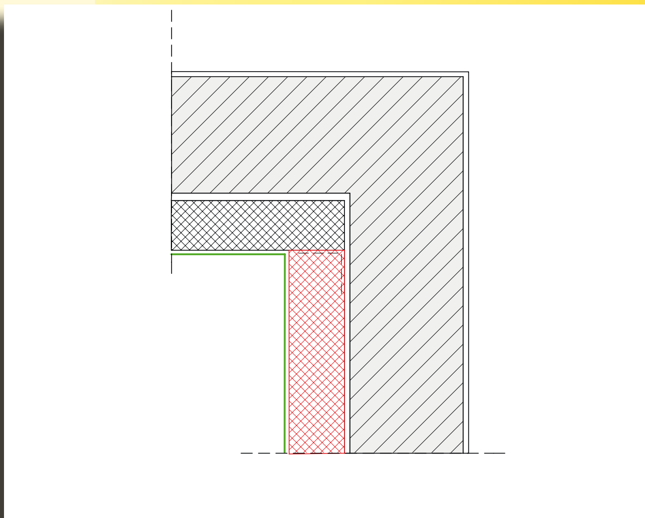
How?

New interior insulation ends at an exterior corner



An L-shaped heat conducting aluminium profile should be installed in the corner, in order to avoid critically low surface temperatures.

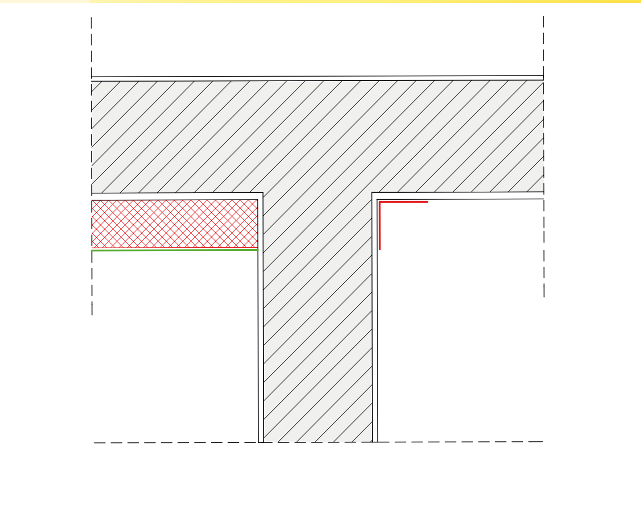
Connection to existing interior insulation at an exterior corner



The L-shaped aluminium profile should be removed, when the new interior installation is installed. The airtight membranes of the new and the existing interior insulation should be connected carefully.

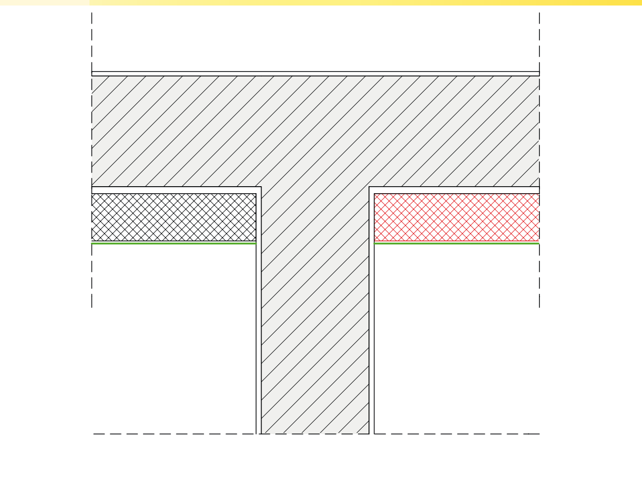
Exterior wall with interior insulation

New interior insulation in a single apartment



An L-shaped heat conducting aluminium profile should be installed in the corner of the apartment with no insulation, in order to avoid critically low surface temperatures.

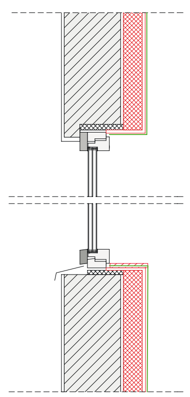
Interior insulation also installed in the adjacent apartment



The L-shaped aluminium profile should be removed, when the new interior installation is installed.

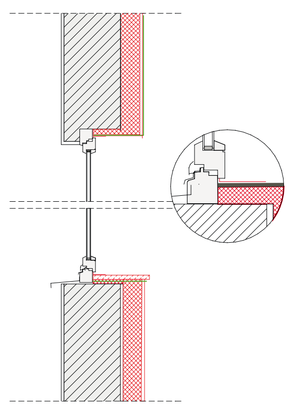
Author: Tanja Schulz

Interior insulation / existing Passive House window



The insulation layer and the airtightness layer of the new interior insulation should be connected to the existing reveal insulation without any gaps.

Interior insulation / existing Passive House window



The window reveal should be insulated as thick as possible. The insulation layer and the airtightness layer of the reveal insulation should be connected to the existing window without any gaps. In order to avoid mould growth in the interim state, an L-shaped aluminium profile should be installed at all four sides of the existing window. The reveal insulation will probably have to be destroyed again for installation of a new window later on.

Windows and doors

In practice, windows, doors and façades are seldom retrofitted at the same time, even though doing so would save costs, reduce thermal bridges and optimise solar gains. There are many reasons why retrofits are done step-by-step. Often, new windows are installed in-between tenants, or a window may be in such bad shape that it cannot wait until the next full building refurbishment to be replaced. If a façade is then renovated at a later date, any windows renewed "in the meantime" will still be in good condition and not need replacing.

Wherever possible, windows and façades should be retrofitted simultaneously. Where it is not possible, the following recommendations will help in optimising energetic performance as well as affordability.

All recommendations made here on the subject of windows can also be applied to terrace doors and entrance doors.

First windows, then insulation

In retrofit cases where windows are installed before the insulation, the U-values of the new windows are often better than those of the original walls. The windows are improved so much that the coldest point is no longer somewhere at the window, but rather at the existing wall. Also, old windows are generally not airtight, so there is uncontrolled air exchange; while this results in decreased comfort and high energy losses (and unnecessary heating costs), the leakage also allows moisture to be transported out of the room, keeping indoor air relatively dry. If the old windows are replaced with airtight ones, hygiene issues could actually worsen. Because the new windows reduce the rate of air exchange, users must actively increase ventilation levels in order to remove humidity from the room – but they don't always change their ventilation behaviour when faced with this new situation. As a result, humidity increases, leading to conditions that are problematic for health, including condensation at the coldest points in a room. The actual issue here is the change in how ventilation is managed, not the thermal quality of the windows. The process of replacing windows must include information on a new ventilation concept, or at least users and building owners must be made aware of the issue. Options such as increasing ventilation by cutting out gaskets, or installing window-integrated ventilation systems without heat recovery or volumetric controls is a bad option due to low comfort levels and high energy losses. Ideally, a ventilation system with heat recovery should be installed, since it reliably solves the hygiene problem and improves indoor air quality without high energy costs.

When planning the replacement of windows, several factors should be taken into account, including airtightness and thermal bridges generated during the intermediate period and following installation of the insulation layer. Therefore, the location of the window in the window reveal should be carefully chosen. With regards to airtightness, the window must be connected to the airtightness layer of the building; the connection can be made with plasterable airtightness tapes, approved compression tapes or permanently elastic joint sealant.

New windows in the same position as the old ones?

Frequently, new windows are installed in the same position as the old ones. This approach reduces investment costs, as existing window sills and any shading fixtures do not need to be changed; the work is done quickly, and residents are not disturbed much. There are, however, high follow-up costs from unnecessary heating energy consumption; in the end. Once the wall is insulated, it will have thermal bridges from installation, and solar gains are lower because of reveal shading. Additional insulation of the window reveals raises costs further; the application of exterior wall insulation and reduced exterior aperture sizes due to reveal insulation can easily lead to an `embrasure' effect, especially when windows are small.

Recommended solution

For the EuroPHit project's 2015 Component Award "Windows in step-by-step retrofits", the focus was on solutions that are as affordable and functional as possible, considering investment and energy costs for the window's entire service life.

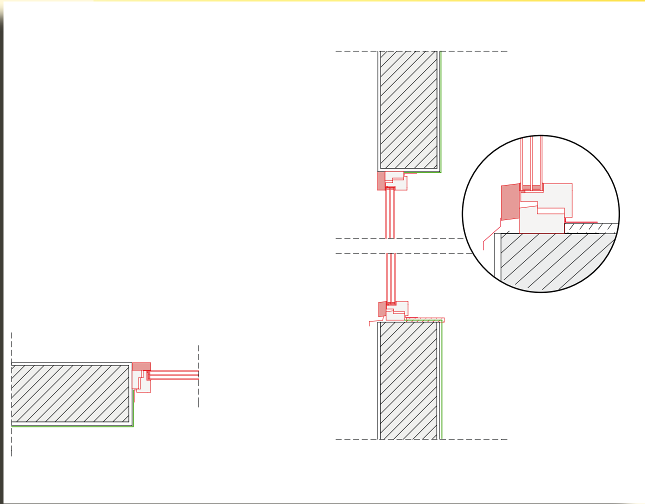
The result is surprisingly simple; the window, preferably with an integral frame (where the frame covers the casement), is installed flush with the exterior masonry, and the resulting gap is carefully sealed with a permanently elastic sealing agent (see below). Well-insulated Passive House frames are required for this situation; if standard frames are used, the temperatures at the interior window connection can be too low, and may lead to hygiene issues. Later, when the façade is renovated, the window frame can easily be externally insulated. All other solutions turned out to be detrimental: if the frame is installed deeper in the reveal, the installation thermal bridge in the final state is much greater. Insulation of the reveal is more costly

4.3

Author: Benjamin Krick

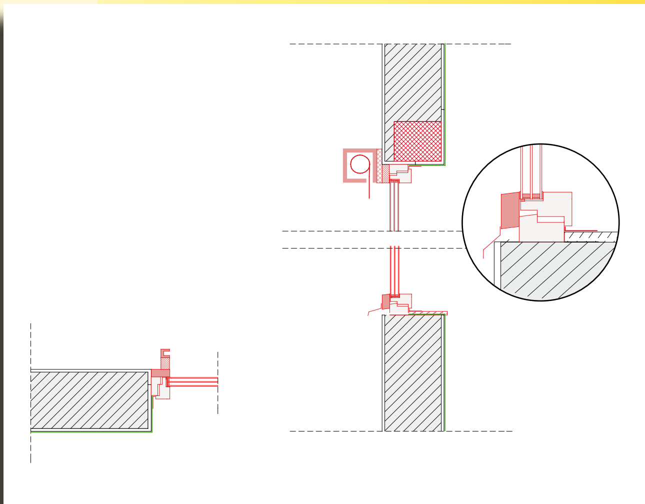
and increases reveal shading. A position in-line with future insulation may be beneficial in terms of installation thermal bridges and reveal shading, but installation in front of the wall leads to additional costs, and sealing off the resulting bays has been found to be difficult. In addition, the jury for the 2015 Component Award found this "bay solution" to be unacceptable in terms of design.

Window without roller shutter / exterior wall that is to be insulated later on



The frame is mounted flush with the exterior plaster. Accurate sealing as a weather protection is crucial. An L-shaped aluminium profile might have to be installed at all four sides of the window to mitigate the risk of mould growth depending on the geometry and thermal properties of the frame.

Window with roller shutter / exterior wall that is to be insulated later on



The old roller shutter box is filled with insulation. The frame is mounted flush with the exterior plaster. The new roller shutter is installed in the future insulation layer. A strip of high performance insulation creates a thermal break between the roller shutter box and the existing wall. Extra care should be taken regarding the weather protection sealing at the joint between the wall and the shutter box.

Windows and doors

First insulation, then windows

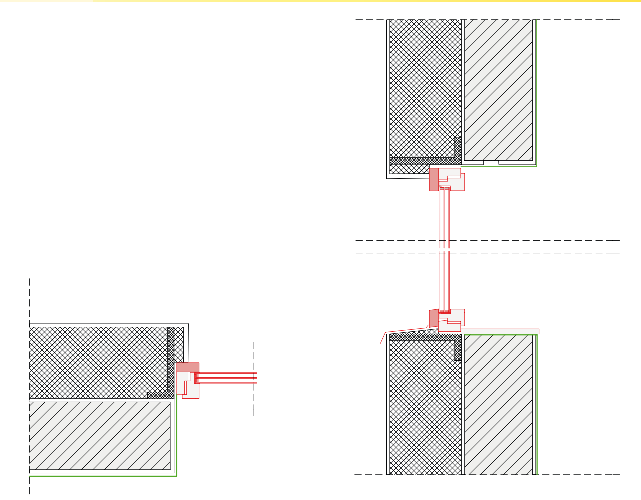
Common inadequate solution

In the best case, where a façade is retrofitted, insulation is applied to the reveals up to the window frame. Often, however, the reveals are not insulated, especially when roller blinds are used. This results in a massive thermal bridge. If the window is to be renewed in a second step, it is generally installed where the old window was, so that the new plaster and insulation are not damaged. The situation is hardly improved: the installation thermal bridge remains large, as does reveal shading.

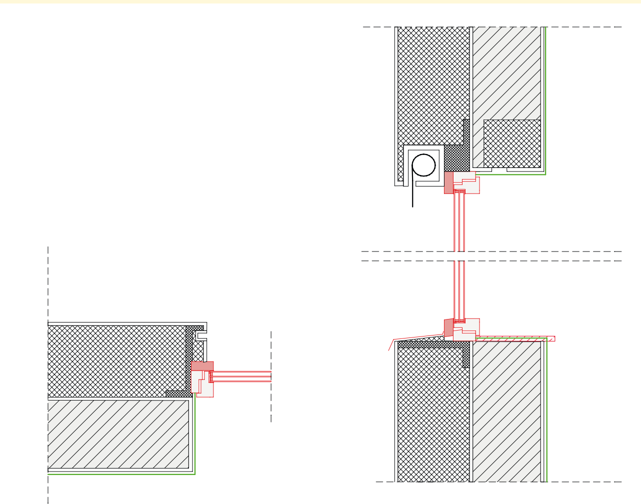
Recommended solution

When installing the wall insulation provisions should be made so that the new windows can be installed in the new insulation layer. Surface mounting systems can be used for this purpose, such as those from Iso-Chemie, Hanno or Illbruck. Another option is a self-made assembly frame, constructed from timber or hard insulation materials (such as CompacFoam, Purenit or similar products/ materials). The Passive House Institute is currently working on a certification scheme for such products.

New window (without / with roller shutter) / existing wall insulation



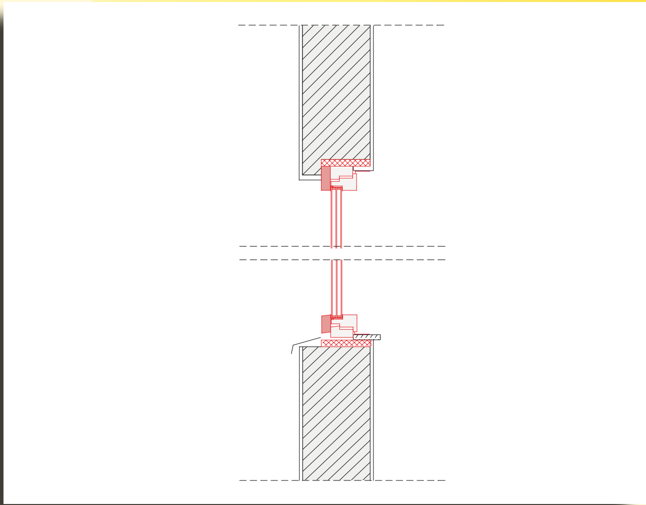
If everything has been prepared correctly in the previous step, the interior part of the insulation in the reveal can be taken off up to the plaster slat, and the new window placed in the planned position without requiring any other work to the thermal insulation composite system. The airtightness layer of the wall (e.g. interior plaster) should be connected to the new window frame without any gaps. The inside reveal is repaired and a new window sill is mounted, or the old one is covered by a new finish.



Author: Benjamin Krick

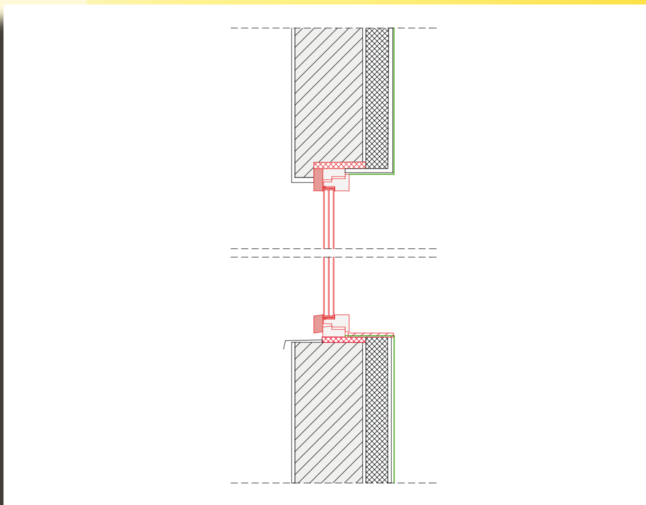
Windows in walls with interior insulation

New window / wall so be insulated from the inside later on



In order to reduce the risk of mould growth the reveal should be insulated before installation of the new window. The reveal insulation should extend between wall and window frame all the way to the insulation layer of the frame. An easy connection of the airtight layer of the reveal insulation to the airtight layer of the future interior wall insulation should already be prepared.

New window / wall with interior insulation



Any heat conducting aluminium profiles from the interim state should be removed together with the old window. The reveal insulation should extend between wall and window frame all the way to the insulation layer of the new frame. The airtight layer of the interior insulation should be connected carefully to the window frame.

Windows and doors

Shading/blinds

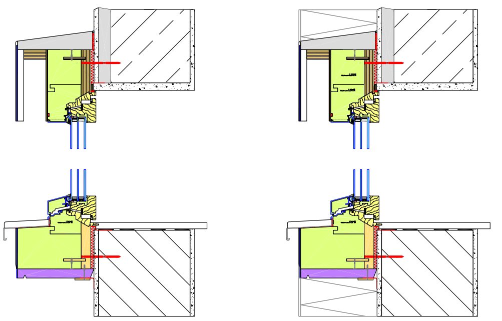
Roller shutter boxes are one of the major weak points in a building envelope. Generally, roller shutter boxes are not airtight, and it is difficult to make them so in existing buildings. This results in high levels of heat loss, even when the roller shutter box is insulated. Because if the roller shutter box contains cold outdoor air, insulation does not have any advantages.

It is therefore recommended that the old roller shutter be removed along with the window; the roller shutter box should then be insulated and made airtight from the room side, and a new darkening / shading option should be provided. A front-mounted box, or blinds that can be integrated in the new insulation later are a good option. In these cases, the window frame and the front-mounted box should be thermally separated to reduce installation thermal bridges.

An even better option (shown at the 2015 Component Award) is shading integrated into an air gap between an exterior single window pane and interior heat-insulating glazing. The award showed that the investment costs for such shading are less than half those of blinds. Additional benefits include weather protection for shading / darkening, reduced thermal bridges and simpler, faster installation. The drawback is that the slats or the screen can slightly enlarge the visible frame width at the top, and dirt may collect on the panes in the air gap, which would then require cleaning. If this additional cleaning is to be avoided, filters must be used. This solution is generally offered for side-hung windows only. However, some manufacturers are working on solutions for fixed glazing as well. Shading elements placed in a hermetically sealed gas gap between low-e coated glazing is said to be more affordable regarding the investment costs. It must be noted however that in cases of shading malfunction, the whole glazing unit has to be changed, resulting in high costs.

Replacing glazing

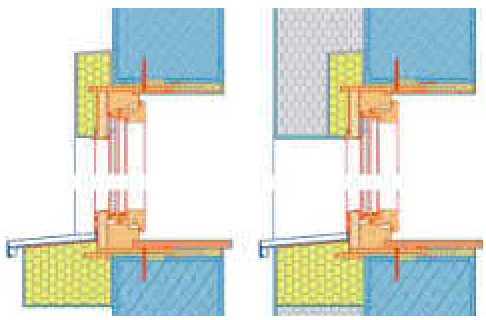
If the window is in good condition and the wall insulation will cover the frame in order to extend the window's service life, the casement can be retrofitted with triple glazing. This option is particularly favourable with timber frame windows. To reduce weight and avoid unnecessarily overloading the casement, partly pre-tensioned, thin-layered panes should be used. A 3/x/2/x/3 (3 mm of glass outside, 2 mm inside) pane design is recommended. The new glazing will then be exactly as heavy as the original old glazing with two panes and a thickness of about 4 mm each and 16 mm of space between the two panes (total of 24 mm). In terms of thermal quality, the optimum for glazing filled with krypton is 2 * 12 mm of space between the panes for a total of 32 mm. Generally, this should be possible if the old window's pane-holding strip is reduced. Krypton, however, is much more expensive than argon, and also the losses at the glass edges are much lower if the gaps between the window panes are larger. The optimum for argon-filled glazing is 2 gaps of 18 mm between the panes for a total of 44 mm. For such glazing for a standard IV 68 mm timber frame, the pane-holding strip should be reworked as shown in Figure 7. The airtight connection between the old casement and the new glass should be made by using an adhesive tape that is as



Stage 1:
Window is installed in front of the old wall

Stage 2:
Insulation is added around the window

Figure 8:
Window Installation in front of the façade, exemplary solution of the participant dPHT, Deutsche Passivhaus Transfer.
Source dPHT



Stage 1:
The new window is installed, some insulation is added around the frame.

Stage 2:
The insulation layer is added with no changes to the window.

Figure 9:
Window installation partially in front of the façade, exemplary solution of the participant Pazen Fenster und Technik.
Source Pazen

Author: Benjamin Krick

diffusion-tight as possible so that condensation does not build up as so often happens with old windows, thereby preventing the frame from rotting and extending the window's service life. When the glass is renewed, old sealants can also be replaced if necessary.

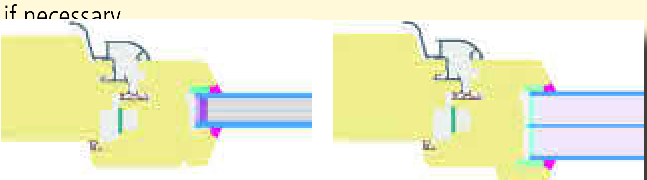


Figure 7:
Old window frame (left) with new triple glazing (right)

Solutions from the Component Award 2015 (samples)

The Component Award 2015 was run as part of the EuroPHit project.

Manufacturers of certified Passive House windows were invited to submit a quote for windows including shading (interior shading was not accepted), assuming a 1.23 x 1.48-meter window. The windows would be installed as part of a step-by-step retrofit of an apartment building, originally built in 1975. The new windows were to be fitted to the building in 2015, and the façade insulated ten years later. The windows were required to work well in both situations. The quotes were compared in terms of lifecycle costs, consisting of investment costs and energy costs for heating and cooling over 40 years; this aspect counted for 40 percent of the overall score. A jury of window specialists, architects, and trade journalists also gave scores for aesthetics, innovation, and viability, with each aspect being given a weight of 20 percent. More information on the competition is available at http://europhit.eu/component-award-2015.

Installation Solutions

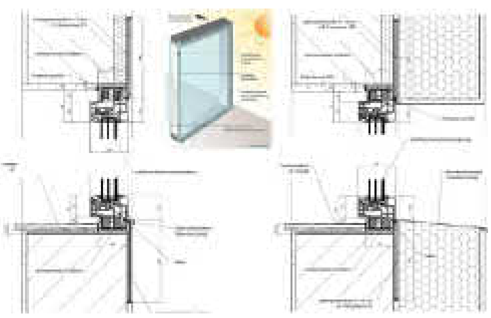
Several installation solutions exist, in which the window connections work both with- and without the new insulation layer. Installation in the same position as the old window is not recommended, since it would lead to massive thermal bridges when the insulation layer is added, and high levels of shading by the deep reveal.

To the surface of the façade

Windows are installed in insulated assembly frames to the surface of the façade, and the insulation is later added around the window. This solution has the advantage of extremely low thermal bridges, but may create issues with the durability of the airtightness layer, as well as noise, weather protection and façade aesthetics.

Partially in front of the façade

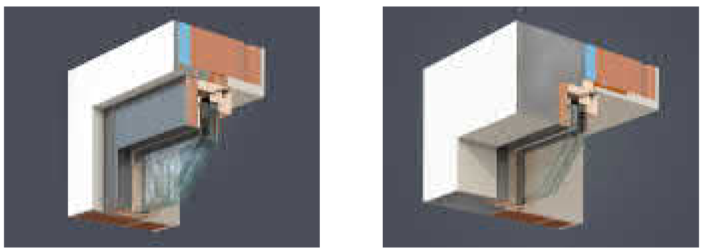
Windows are attached to the wall, but partially exposed to the exterior. When the next step of the retrofit occurs, the insulation layer is added around the protruding frame. It should be noted that very high levels of thermal bridging may occur



Stage 1:
The new window is installed with the insulated jamb panel.

Stage 2:
The insulation layer is added over the plaster board.

Figure 10:
Window installation in existing wall, with insulated jamb panel, window installation partially in front of the façade, exemplary solution of the participant Aluplast.



Stage 1:
The new window is installed in a similar location to the old one.

Stage 2:
The window is relocated when the insulation layer is added.

Figure 11:
Moving windows, solution provided by Pro Passivhausfenster.

Windows and doors

with this installation solution during the first stage. Additional insulation may be added to prevent surface temperatures around the reveal from dropping too much. Other concerns were resistance to weather and aesthetics.

At the edge of the wall

The plaster around the window opening is removed and replaced with an insulated jamb panel that extends into the window opening. It is used as a bearing and insulating surface for the window, which is installed at the edge of the wall. The insulation layer is then added over the plasterboard. This solution is relatively inexpensive compared to the others, but may result in a massive thermal bridge in the first stage. This can be reduced by way of the insulated plasterboard, which also improves weather protection.

Relocate windows

Another option is to install the new window in the same location as the old one, and then when the insulation layer is added, the window is relocated to the ideal installation situation. The advantages of this solution are that during both stages, there are low levels of heat loss via thermal bridging, high levels of daylight and adequate weather protection. But it turns out, that this measure is too expensive for standard application.

Exemplary solution: smartshell reno

Smartshell reno is a timber based renovation system, partly developed in the EuroPHit project. The system was certified as a wall and construction system for the cool, temperate climate by the Passive House Institute. The main developer of the system is the window-cooperative pro Passivhausfenster, see www.smartwin.eu.

In the position of the ceiling, planks are fitted to the existing wall, all around the building. Then vertical planks are mounted and clad by a special rigid wood fibreboard. The gap between the old wall and the new cladding is filled with cellulose.

Step one: The window reveal is also made by way of planks. The fibreboard will extend beyond the planks and will be specially arranged in order to serve as a part of the new window later. The emerging gap between the old window and the new fibre board will be filled with another piece of wood fibreboard, leading to acceptable thermal bridges and hygienic conditions, see Figure 13.

Step two: The fibreboard and the window is taken away and the new window is mounted at the very edge of the construction, see Figure 14.

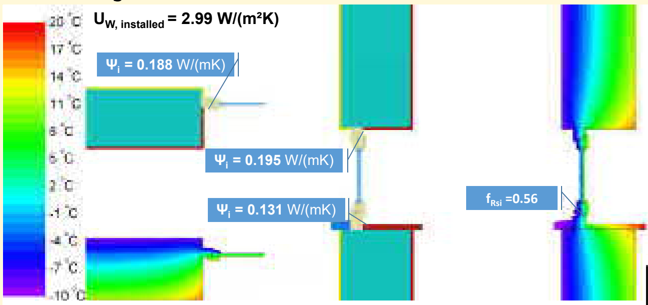


Figure 12:
Initial state with a wooden window frame and double glazing. Thermal bridging levels are very high and there is an extremely high risk of condensation and subsequent mould growth.

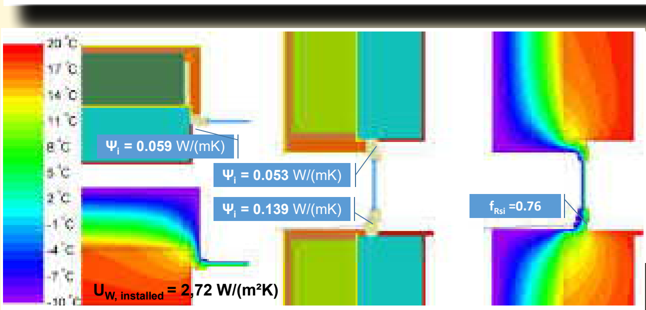


Figure 13:
Step 1: Wall is insulated, window frame is covered by insulation. The thermal bridges are significantly reduced and the hygienic risk at the window junction is mitigated.

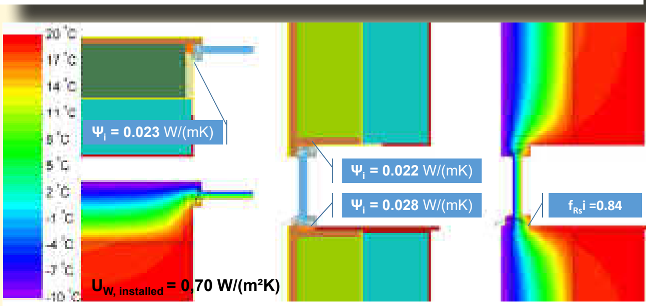


Figure 14:
Step 2: The old window as well as the interim insulation is taken away, the new window is mounted at the very edge of the new insulation layer. The results are small thermal bridges and perfect hygiene conditions. Because of the position of the window at the very edge of the insulation layer, there is nearly no shading cast by the wall or insulation itself.

Author: Benjamin Krick

Figure 15:
Europhit Case Study project „Community Center" in Pergine Valsugana
Photo: Studio Bombasaro

Insulation of a pitched roof

When?

If new roofing is to be carried out or the attic floor is developed or renovated, it is possible to insulate the roof at the same time with moderate additional effort. It is worthwhile to consider simultaneous insulation of the roof even if the exterior wall is to be insulated, because scaffolding will be set up in any case. Apart from that, the final connection with the roof edge can then also be created at the same time. There may also be an opportunity to take action if occupants complain of poor comfort on the attic floor in winter and summer. Roof insulation should preferably be implemented before the installation of a solar thermal/PV system. If the solar thermal/PV system is planned for a later point in time, then mounting points and cable/pipe feedthroughs may already be prepared during the course of roof insulation.

Where?

Location of the insulation

The available height between existing rafters is insufficient for meeting the EnerPHit or Passive House requirements in many climates. Besides this, in the case of insulation between rafters only, the rafters weaken the insulation due to their thermal bridge effect; an additional layer of insulation above or below the rafters will therefore be necessary.

Insulation above rafters is recommended if the attic floor is already developed and any existing interior cladding etc. would have to be removed – and also when new roofing is necessary in any case and the roof has to be opened from the outside anyway. A small room height in the attic area may also contraindicate insulation below rafters as the available space should not be reduced even further.

Insulation below rafters may make sense if the roof covering is still intact and the attic floor is to be redeveloped on the inside. Sometimes raising the roof covering could also lead to problems with connections of the roof dormers etc. in which case below-rafter insulation would be easier. If gable walls are present then below-rafter insulation has the disadvantage that in contrast with above-rafter insulation, it does not cover the wall coping at the verge, so that a considerable thermal bridge remains at this place.

Location of the airtight layer

In terms of building physics, it is safest to install the vapour retarder on the room side of the insulation, i.e. below the rafters (in cool to cold climates). This may be covered over on the room side by means of a few centimetres thick installation level which is filled with insulation material, in which cables etc. can be laid without damaging the vapour retarder. The vapour retarder will be laid on the outside if the renovation work is to be executed from the outside only, i.e. wavelike above the rafters, or in some systems between above-rafter and between-rafter insulation. When deciding the location of the airtight layer, the connection to the airtight layer of wall at the eaves and verge must also be kept in mind in particular. Routing the airtight layer through ceiling beams or rafter tiers should be avoided as far as possible because the necessary sealing at each individual beam is complicated and prone to errors.

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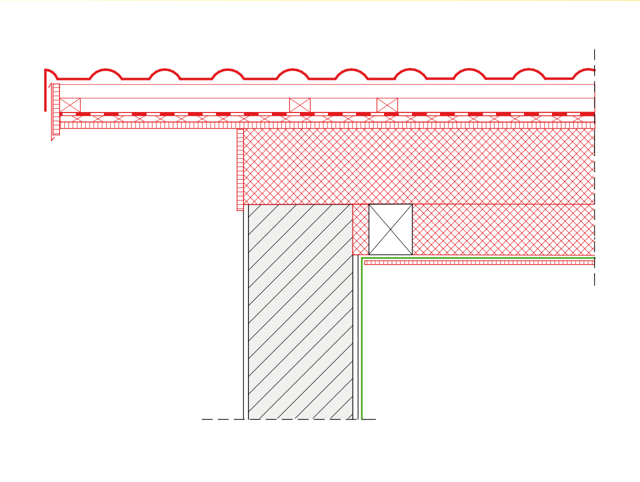
Author: Zeno Bastian

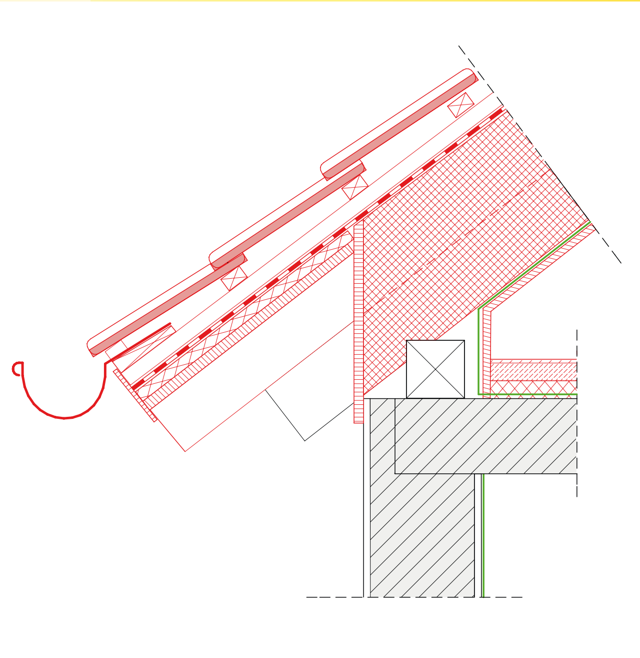
How?

Pitched roof insulation / **exterior wall to be insulated later on**



Verge

The insulation above rafters covers the wall crest and thus prevents a thermal bridge at this point particularly in the final state when the wall is also insulated. For the intermediate state, the front side of the above-rafter insulation is plastered over or covered with cladding. The roof overhang needs to be extended so far that it provides sufficient space for later wall insulation with an optimum thickness. Special U-shaped profiles are available for extending the roof battens. The airtight layer in the roof (vapour retarder) is joined to the interior plaster without any gaps.

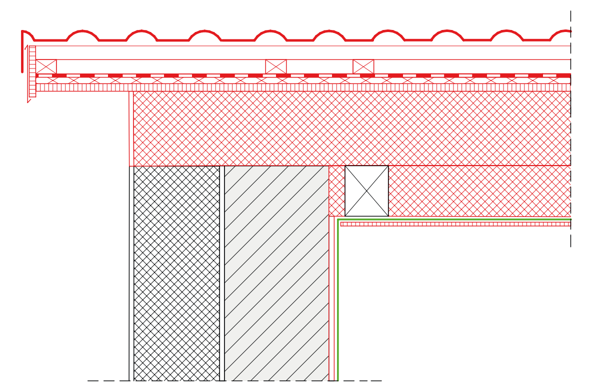


Eaves

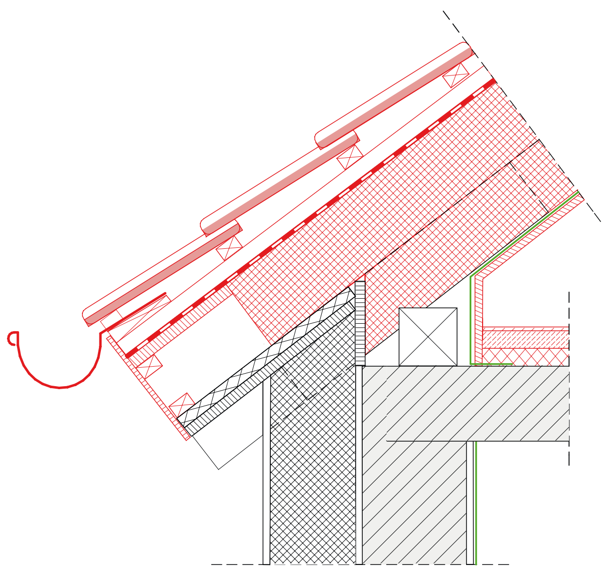
In the event that the existing roof overhang is inadequate for the planned wall insulation thickness, it may be extended by means of rafter extensions on top of the existing rafters. The roof edge and the rainwater gutter must be installed again, but they may remain unaltered when the wall insulation is installed later on. The airtight layer (vapour retarder) is joined without any gaps to the top floor ceiling consisting of reinforced concrete. This should take place before laying the floor build-up.

Insulation of a pitched roof

Pitched roof insulation (airtight layer below the rafters) / **insulated exterior wall**



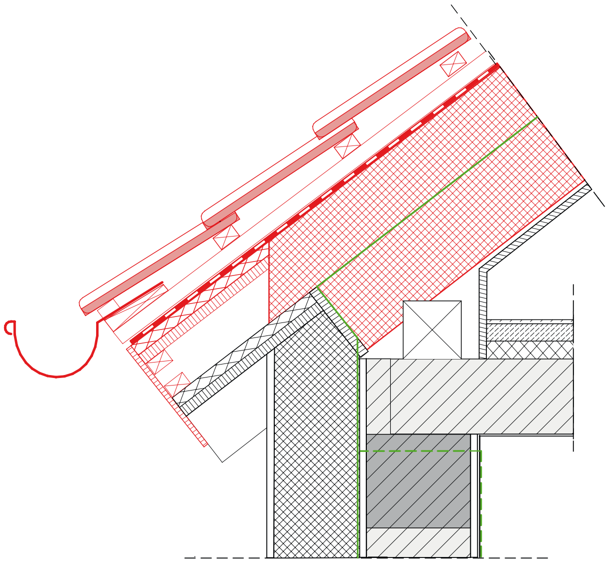
Verge
The above-rafter insulation covers the wall crest and thus prevents a thermal bridge at this point. It joins with the existing wall insulation without any gaps. The front side of the above-rafter insulation may be in a colour contrasting with the existing wall render or it may be covered with cladding. The airtight layer in the roof (vapour retarder) is joined to the interior plaster without any gaps.



Eaves
After removing the existing roof covering, the between-rafter and above-rafter insulation is joined to the wall insulation without any gaps. The airtight layer (vapour retarder) is also joined without any gaps to the top floor ceiling consisting of reinforced concrete. This should take place before laying of the floor build-up.

Author: Zeno Bastian

Pitched roof insulation (airtight layer above the rafters) / **insulated exterior wall**



Eaves
The airtight layer in the roof is joined without gaps to the strips of membrane that are present along the roof edge and laid wave-like above the rafters. The between-rafter and above-rafter insulation is joined to the existing wall insulation without any gaps.

Insulation of the top floor ceiling

When?

Insulation above the top floor ceiling is easier and more cost-effective than pitched roof insulation. Compared to roof insulation it also results in lower heat losses with an identical U-value due to the resulting smaller thermal envelope area. Insulation above the top floor ceiling is therefore recommended if the attic floor will not be used as a living area even in the long term.

Insulation of the top floor ceiling does not require any triggering modernisation measures and should therefore be implemented right at the start with the first modernisation step.

Where?

Location of the insulation

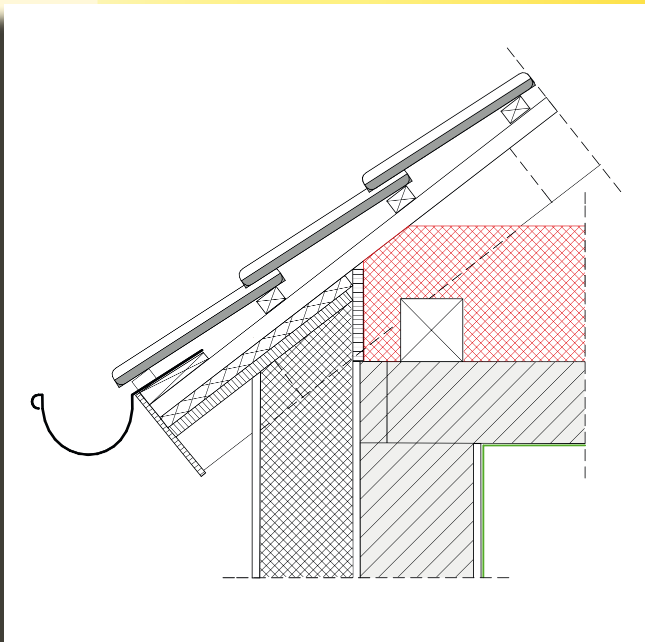
The insulation is usually laid on the flooring of the top floor ceiling.

Location of the airtight layer

Existing reinforced concrete ceilings can assume the function of the airtight layer. In the case of wood beam ceilings, a vapour retarder is laid between the existing ceiling and the new thermal insulation and joined on all sides.

How?

Insulation above top floor ceiling / **insulated exterior wall**



Eaves
Insulation on the top floor ceiling is continued up to the end board without any gaps (also behind the eaves purlin).

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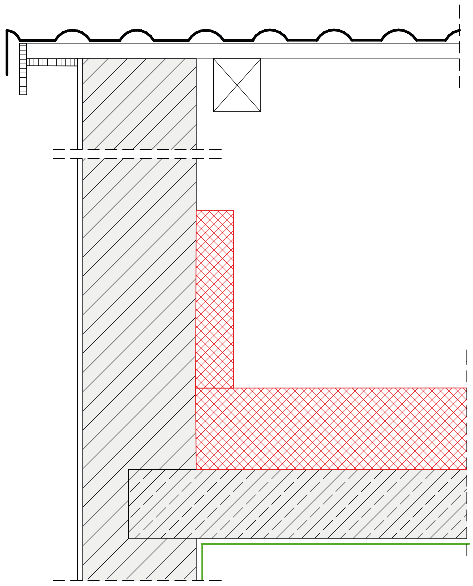
Author: Zeno Bastian

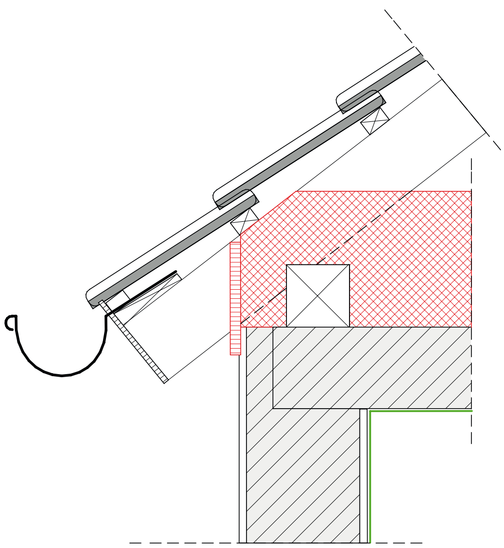
Insulation above top floor ceiling / **exterior wall to be insulated later on**

3b



Verge
Flanking insulation along the gable wall (and any existing house partition walls) mitigates this thermal bridge if the exterior wall is also insulated, particularly in the final state.

8b



Eaves
Insulation on the top floor ceiling is continued up to the end board without any gaps (also behind the eaves purlin).

Flat roof insulation

When?

Insulation of the flat roof can be coupled with due renewal of the roof waterproofing. If the exterior wall is to be insulated, it will be worthwhile to consider implementing flat roof insulation at the same time because scaffolding will already be set up in any case. Besides, the final connection to the roof edge can then take place. There may also be an opportunity to take action if the building users complain of poor comfort beneath the roof in winter and summer. The roof insulation should take place preferably before the installation of a solar thermal/PV system; if a solar thermal/PV system is planned for a later point in time, then mounting points and cable/pipe feedthroughs can already be prepared during the course of the roof insulation.

The design of the new roof build-up, particularly that of warm roofs, should be checked by an expert against long-term moisture accumulation.

Where?

Location of the insulation

In the case of solid ceilings, the insulation is usually positioned above the existing construction. If thermal insulation with an inappropriate thickness is already present then it may be retained and supplemented with an additional layer of insulation. If closed-cell insulation material is used, the water carrying layer may then be safely situated between the old and the new insulation layers.

In timber constructions, the intermediate space between the beams is generally used for the insulation. If the beam height is insufficient, these can be doubled accordingly.

Location of the airtight layer

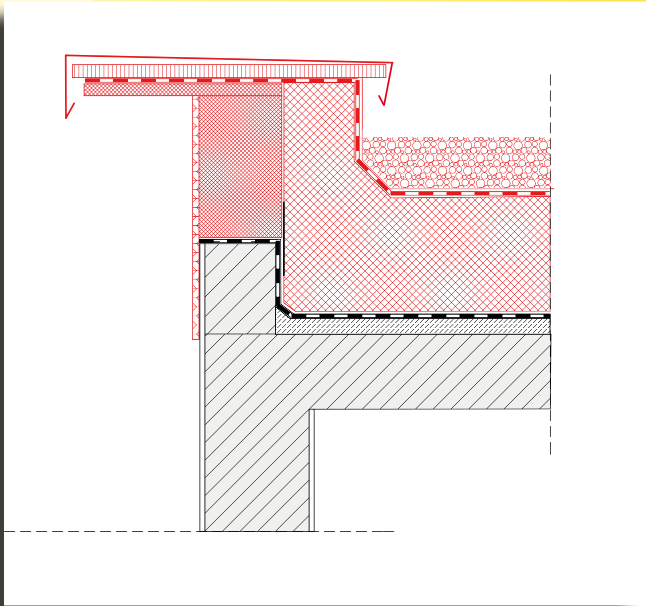
In solid ceilings, the reinforced concrete ceiling or the interior plaster can assume the function of the airtight layer. In this case attention should be given to gap-free connection to the wall plaster on all sides (e.g. also above suspended ceilings). With timber constructions the airtight layer is positioned on the inside of the beams. Depending on the roof build-up, the use of a moisture-adaptive vapour retarder is advisable.

4.6

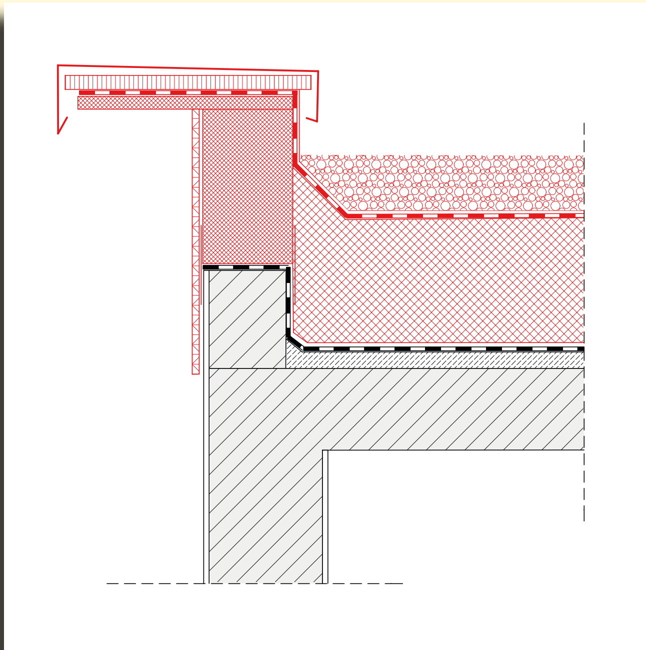
Author: Zeno Bastian

How?

Flat roof insulation / **exterior wall to be insulated later on**

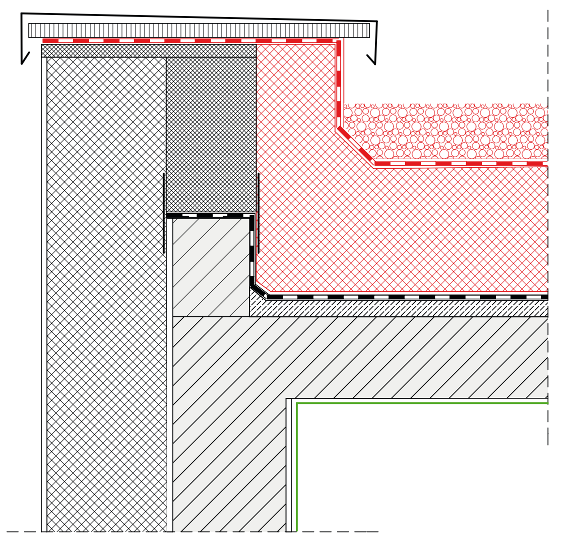


In order to allow roof insulation with an optimal thickness, first the parapet should be raised. In order to avoid thermal bridges, elements made of high-strength insulating material or wooden boxes filled with insulating material should be used. The parapet covering should project outwards far enough to allow the subsequent wall insulation to be covered as well. The insulated parapet element can be temporarily cladded on the outside according to the optical requirements. The roof insulation is joined to the insulated parapet element. If this results in insufficient overlap, the flat roof insulation should be continued up to the upper edge of the accordingly prepared parapet element in order to avoid thermal bridges (see upper drawing).

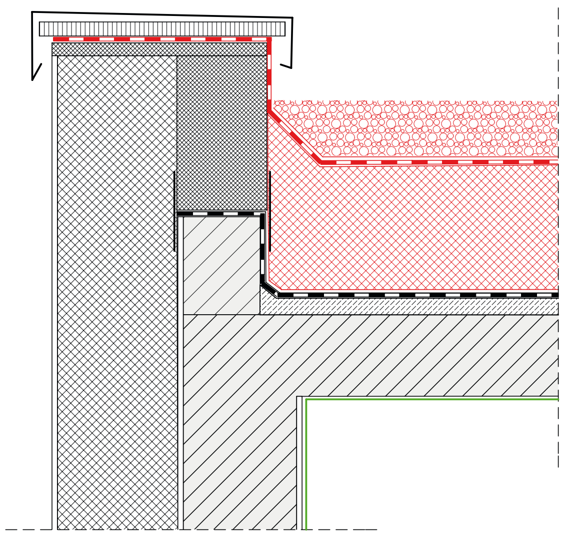


Flat roof insulation

Flat roof insulation / **already insulated exterior wall**



The roof insulation is joined to the insulated parapet element. If this results in insufficient overlap, the flat roof insulation should be continued up to the upper edge of the accordingly prepared parapet element in order to avoid thermal bridges (see upper drawing).



Author: Zeno Bastian

Figure 1 and 2:
Construction sites of EuroPHit case studies in France
Photo 1: Pollet Ingéniere
Photo 2: Tillieux Menuiseries

Insulation of the basement ceiling and floor slab

When?

Insulation of the basement ceiling from below is a simple measure which potentially can also be carried out by the homeowner. Because the basement ceiling usually does not have to be renovated, this work does not have to be coupled with any other pending measures. It can therefore be implemented with the first step. Apart from this, it is ideal if this measure is coupled with pending renewal of the heating, water and electrical installations below the basement ceiling because

- the heating and hot water pipes can be integrated into the insulation, which would reduce the heat losses even further.
- the installations will no longer be easily accessible after the insulation has been applied, and
- existing installations make it quite difficult to apply the insulation in a gap-free manner.

Insulation of the basement ceiling from above or insulation on the floor slab is usually only possible in the case of extensive interior renovation, e.g. following a change of tenants. Besides the new build-up of the flooring, the heights of staircases (step dimensions), door lintels and French windows must also be adjusted if necessary, and built-in furniture (fitted kitchen, fitted wardrobes) etc. must be dismantled.

Where?

Location of the insulation

As a rule, insulation is applied from below; insulation above the basement ceiling comes into question only if this is not easily possible, e.g. due to very low ceiling heights or vaulted ceilings. Alternatively, it is also possible to apply the insulation half above and half below the basement ceiling depending on the space available.

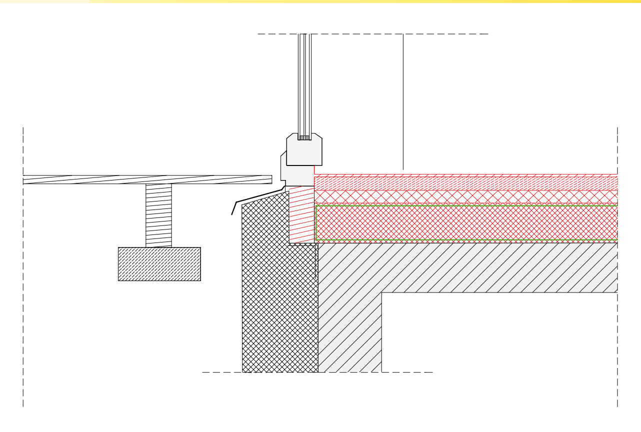
If the basement ceiling or the floor slab cannot be insulated at all, then alternatively the wall insulation can be extended into the ground horizontally or vertically ("insulation skirt"). A heat reservoir is thus formed in the ground under the building particularly in the case of buildings with a large base area, which reduces heat losses even without continuous insulation.

Location of the airtight layer

An additional airtightness layer (e.g. anhydrite screed on the bare ceiling) is usually necessary in the case of composite constructions such as vaulted ceilings and steel-reinforced brick ceilings and of course for wood beam ceilings. Reinforced concrete ceilings can be used as an airtight layer and only have to be sealed in the case of penetrations by pipes etc.

How?

Insulation above floor slab / **French window installed previously**

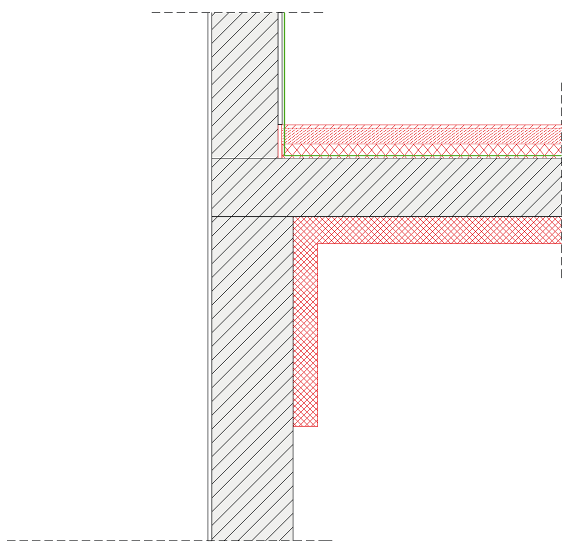


The previously installed frame extension at the threshold of the French window now allows an optimal insulation thickness. The reinforced concrete floor slab or the moisture barrier applied on this can serve as the airtight layer.

4.7

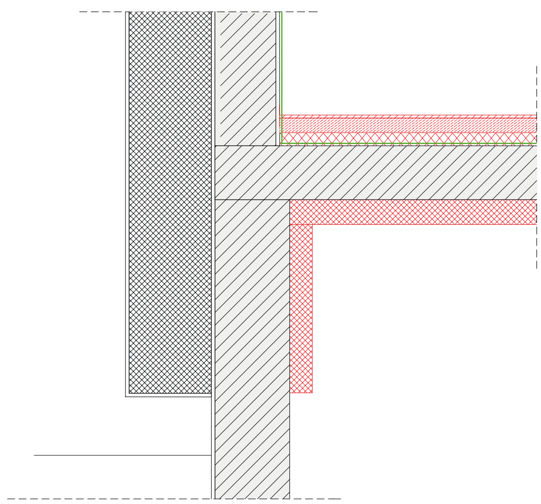
Author: Zeno Bastian

Basement ceiling insulation / **exterior wall to be insulated later on**



Insulation below the basement ceiling is supplemented with flanking insulation alongside the exterior wall. In combination with the subsequent wall insulation on the outside, this reduces heat losses and prevents mould growth on the top surface of the basement ceiling. Flanking insulation along both sides of the interior walls of basements also reduces heat losses; however, the interior surface temperatures at this point are usually already high enough to prevent the formation of condensation even without any flanking insulation. If the floor build-up on the ground floor is renewed, the wall plaster of the exterior and interior walls should be continued down to the bare floor at the same time in order to achieve a continuous airtight layer.

Basement ceiling insulation / **existing exterior wall insulation**



Insulation below the basement ceiling is supplemented with flanking insulation alongside the exterior walls. In combination with the existing wall insulation, this reduces heat losses and prevents mould growth on the top surface of the basement ceiling. Flanking insulation along both sides of the interior walls of basements also reduces heat losses; however, the interior surface temperatures at this point are usually already high enough to prevent the formation of condensation even without any flanking insulation. If the floor build-up on the ground floor is renewed, the wall plaster of the exterior and interior walls should be continued down to the bare floor at the same time in order to achieve a continuous airtight layer.

New balconies and conservatories

When?

Balconies, conservatories and other additions at exterior walls are easiest to install simultaneously with the exterior wall insulation. If they are to be installed in advance then the subsequent wall insulation must already be taken into account in order to avoid thermal bridges in the final state.

Where?

Location of the insulation

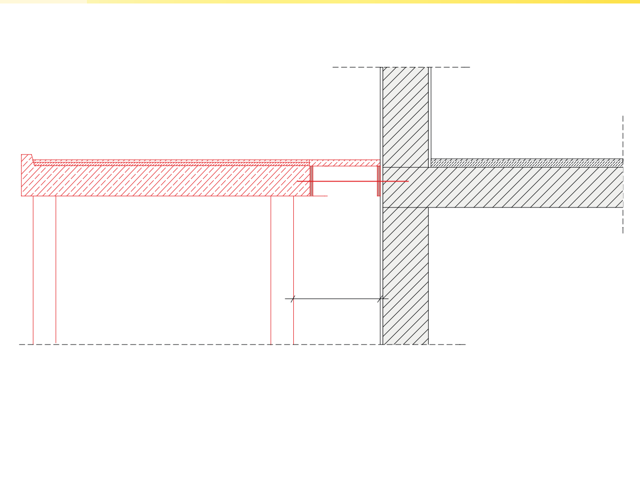
The instructions in this section are only relevant for exterior insulation. In the case of interior insulation, additions on the outside naturally will not result in any thermal bridges.

Location of the airtight layer

If the (renewed) existing exterior plaster is to serve as the airtight layer for subsequent wall insulation, then it must already be repaired in the area of the additions in case these areas are no longer accessible later on.

How?

New self-supporting balcony / **exterior wall to be insulated later on**

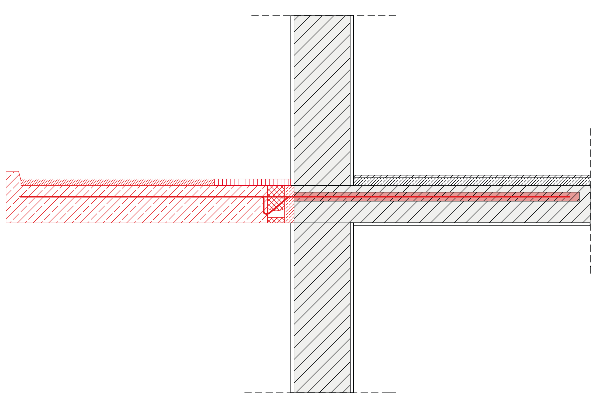


As a rule, the balcony construction must be back-anchored to the building. The anchors in the later wall insulation layer must have thin cross-sections and should preferably consist of high-grade steel (instead of construction steel), because this has a significantly lower thermal conductivity. The balcony slab should be at a further distance from the existing wall than the outer edge of the subsequent wall insulation. If the supports on the wall side are shifted a further 10 cm outwards then later on the new wall insulation can be neatly plastered over even behind the supports. Due to the risk of falls, the gap between the balcony and the existing wall must be covered over temporarily until the wall insulation is installed.

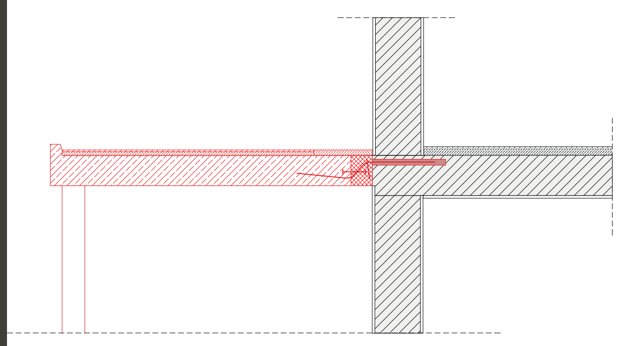
4.8

Author: Zeno Bastian

New projecting balcony or balcony supported on one side / **exterior wall to be insulated later on**

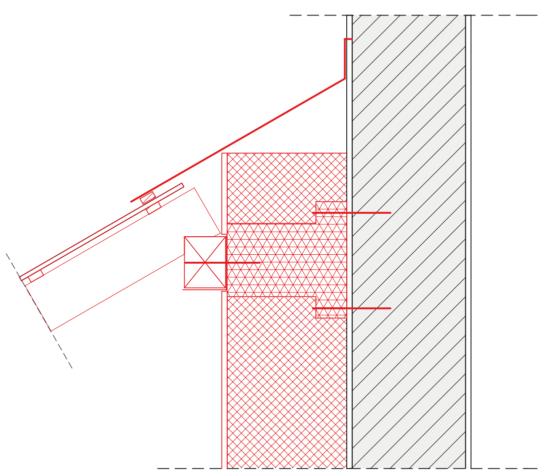


The new balcony slab may only be connected with the existing wall or ceiling by means of a load bearing thermal insulation element, which must be situated at the level of the subsequent wall insulation. The insulation element can be cladded temporarily on the top and underneath for the intermediate state.



New balconies and conservatories

New front-mounted conservatory / **exterior wall to be insulated later on**



The load-bearing construction of the new conservatory should be decoupled from the existing wall by means of thermal bridge minimised mounting brackets at the level of the later wall insulation, particularly in the case of metal constructions. If the exterior wall inside the conservatory is insulated at the same time, then the interior space of the conservatory can be spared during the work for later installation of the wall insulation.

Author: Zeno Bastian

Figure 1:
Conservatory at the EuroPHit case study project „Family Home in Wicklow"

05

Building services

Ventilation

Ventilation – properly!

An adequate ventilation concept is indispensable for improving the airtightness of the building envelope. For step-by-step retrofits, different ventilation options are available; however not all concepts are suitable for energy retrofits:

- Free ventilation concepts (installation of trickle vent or separate outdoor air inlets)
- Mechanical ventilation (exhaust air system)
- Mechanical ventilation with heat recovery

Window ventilation is not sufficient for providing the minimum air change rate that is required for hygienic indoor air. Concepts for free ventilation through defined openings in the thermal envelope are not an adequate measure for providing the necessary air flow either, as the air change rate depends greatly on temperature differences and wind pressure and can vary significantly.

Reliable air change rates can only be achieved with mechanical ventilation.

From the energy relevant point of view, devices providing efficient heat recovery are the most appropriate solutions. Heat recovery not only reduces ventilation heat losses significantly, it is also an especially important measure for thermal comfort that simultaneously provides ventilation and comfortable air conditions. The only exceptions are warm climates where Passive Houses can be realised relatively easily due to comparably low heating and cooling loads. Even exhaust-only systems without heat recovery may work in this climatic zone. However, this zone only represents a very limited area (in Europe only some Mediterranean regions and Portugal).

According to [PHI 2009], the following energy requirements are specified for ventilation devices with heat recovery:

heat recovery rate $\geq$ 75%; specific electric power $\leq$ 0.45 Wh/m^3 at an external pressure difference of 100 Pa.

Furthermore, the ventilation devices should provide the following functions:

- Filtration of outdoor air (F7 or better according to EN 779)
- Controllability (minimum of 3 ventilation settings) in order to allow reduction of the air flow rate during the winter season and avoid dry air conditions
- Summer by-pass of the heat exchanger
- Frost protection of the heat exchanger (depending on the respective climatic conditions)
- Acoustic requirements:
  - sound pressure level in living areas </= 25 dB(A)
  - sound pressure level in functional areas </= 30 dB(A)

With reference to the overall life cycle costs, the performance of a well-designed ventilation device may even be more cost-effective than exhaust-only systems. The life cycle costs are determined from the investment costs and the operating costs. With an improved air distribution concept and integration of the device, the investment costs can be reduced significiantly. Low operation costs are achieved especially with efficient fans and low pressure drops of the duct system.

Step-by-step retrofits usually take place while the buildings are inhabited. The following aspects are especially important in this context:

- Fast installation within the dwelling with minimum disruption for inhabitants, achieved with
  - a compact duct system
  - prefabricated components
  - duct components and devices suitable for visible installation in order to avoid costly additional casing or suspended ceilings
- Least possible construction dust, achieved through
  - a reduced number of wall openings due to an optimised air distribution concept (e.g. extended cascade ventilation)
  - implementation of wall openings using a suitable core drilling machine with integrated dust removal

5.1

Author: Kristin Bräunlich

When is the best time to install ventilation devices?

Mandatory installation of ventilation devices along with other retrofitting measures

A concept for controlled ventilation becomes necessary as soon as the **airtightness of the building envelope improves substantially**, because air exchange due to free air infiltration is significantly reduced.
The following measures that are due in any case necessitate the installation of a controlled ventilation system at the same time:

- New windows
- New entrance door or doors to unheated cellars or attics (this may have a relevant influence especially in the case of small buildings such as single-family houses)
- Implementation of an airtight layer under the roof

The installation of interior insulation is another retrofitting measure where the simultaneous installation of a controlled ventilation system is highly recommended, as this will reduce indoor air humidity so that the risk of condensation due to uncontrolled flow of indoor air behind the insulation layer is greatly reduced.

Advantages of installing ventilation devices along with other retrofitting measures

While implementing some retrofitting measures, it might be a good idea to combine these with the installation of a ventilation device. This can be especially advantageous when:

- the installation costs can be reduced and
- the disruption can be reduced significantly for the inhabitants

Due retrofitting measure	Possible synergy effects of combining with the installation of a ventilation device
Installation of exterior insulation	• installation of ventilation units integrated into the façade (single room ventilation or ventilation of a small group of rooms) • integration of ducts within the thermal envelope
Insulation of the top storey ceiling	Provision can be made for the implementation of a planned ventilation concept at a later date (e.g. a centralised system located on the roof or within the attic) by way of integration of horizontally distributed ducts into the insulation layer
Interior finishing (e.g. new bathroom, kitchen or paintwork)	It is appropriate to consider the air distribution concept within the dwelling now because ductwork can be installed at the same time at a low cost
New floor construction	Integration of ductwork

Ventilation

When is the installation of a controlled ventilation system rather unfavourable?

If airtightness of the building is rather poor (e.g. due to old windows), operation of heat recovery ventilation will not lead to high energy savings as the potential reduction in ventilation heat losses will be quite limited due to high infiltration rates. The power consumption (even though low because of efficient devices) however remain the same.
Synergy effects should be used when possible (e.g. for installation of ductwork). The ventilation device itself could also be installed at a later point in time.
Important aspects to be considered when installing the ductwork before the ventilation device:

- Ensure the ductwork remains clean until the device finally starts operation: keep the ducts sealed. Manufacturers provide suitable caps for this purpose.
- The installation of the ductwork should not affect later connection of the duct to the device. The ductwork in the installation room can be installed later on together with the ventilation device.

Integration of ventilation devices in retrofits

Recommendations for installing ventilation devices in inhabited flats

The following aspects must be considered in the case where the ventilation device is installed while the flats are inhabited:

- Often there are only poor documentation and plans available for old buildings. For that reason it is advisable to inspect each flat and re-measure important dimensions.

- Fixed furnishings (e.g. fitted kitchen or built-in cup boards) must be recorded in detail in advance.

- In case of centralised ventilation devices, it is important to check the availability and usability of shafts in advance. Any built-in components in existing shafts may require considerable effort for dismantling.

The right ventilation concept for each floor

Different floor plans and boundary condition require varying ventilation concepts. The following table provides some examples.

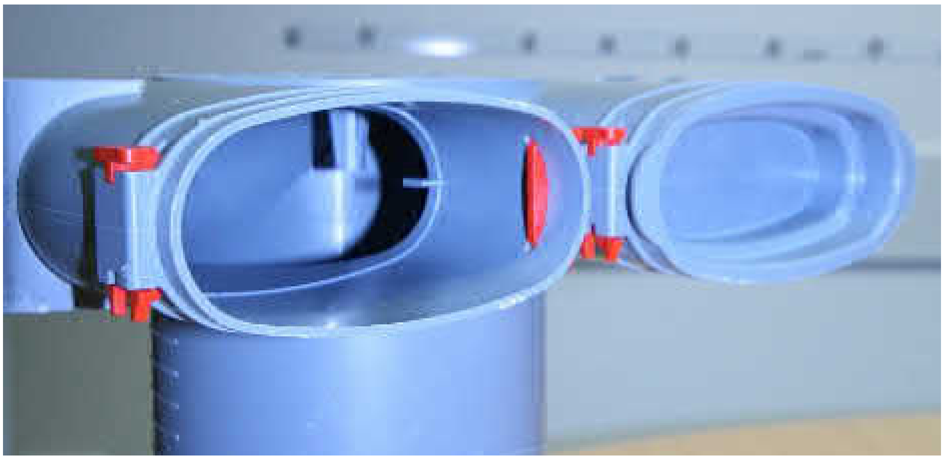
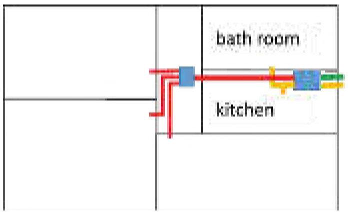
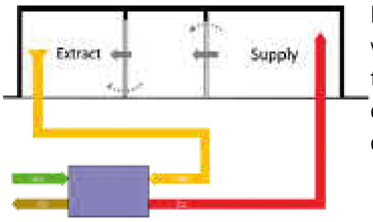
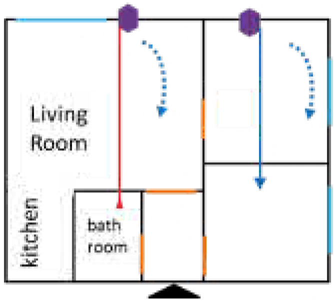


Figure 1:
Cover for protection against dust

Author: Kristin Bräunlich

Boundary condition	Possible ventilation concept
Central corridor connected to all supply air and extract air rooms 	Cross-flow ventilation (cascade ventilation) from supply air rooms to extract air rooms via the corridor: short ductwork is possible; duct distribution inside the suspended ceiling of the corridor.
One or several corridors 	Extended cascade ventilation: corridors become transfer areas; minimised effort for installation of ductwork

Boundary condition	Possible ventilation concept
Central corridor connected to all supply air and extract air rooms 	Façade integration of ventilation unit for ventilation of the installation room and optionally one or two connected rooms. Depending on the installation room, it is necessary to ensure that sound emission from the unit is low (recommended sound power level for continuous operation: ≤ 25 dB(A) in living areas und ≤ 30 dB(A) in functional areas)
Distant single rooms that are difficult to connect to a centralised ventilation device	Single room ventilation can be an alternative

The ventilation concept with active transfer [Sib 2015] is a new option (see below): the corridor or common area becomes part of the air distribution concept itself. Fresh air is supplied to the central area and passes into the adjacent rooms via active transfers, i.e. openings in the internal partitions, fitted with powered fans. A very short duct system (extract air only) is required.

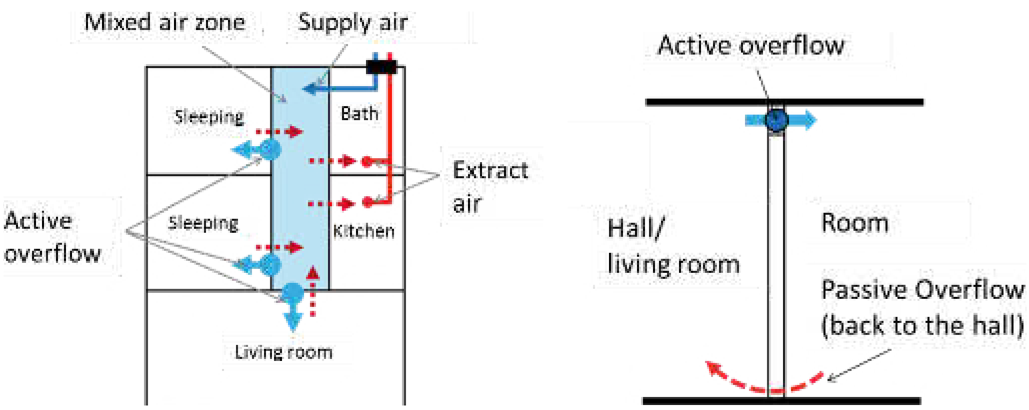


Figure 2 and 3:
Active transfer concept
(source: University of Innsbruck)

Ventilation

Integration of ventilation unit and ductwork

Many different ventilation devices for several integration variants are available today e.g. for:

- ceiling installation
- wall installation
- integration into kitchen furniture
- façade integration

It is important to choose the device which is most suitable for the specific situation under the given boundary conditions.

Another aspect is the ducting system: manufacturers now provide different solutions (different forms and materials) so that the most suitable option can be chosen (depending on the effort for installation, the retrofitting measures that are due anyway and any additional measures that may eventually become necessary such as dry wall construction).

- Flat ducts for integration in the suspended ceiling or in the floor build-up.
- Ducts suitable for visible installation: no additional measures are required to cover the ducts.

Centralised ventilation concepts

For centralised building ventilation concepts, an important question is where to install the ventilation device. In existing buildings, often there is no room available that can serve as an installation room for a centralised unit. A good alternative could be roof top installation. Some manufacturers already provide good solutions for outdoor installation. A special focus is placed on good supply air flow and extract air flow ducting: good design options have only very small duct sections outside the thermal envelope, and a good level of thermal insulation.

A similar issue arises in connection with the installation of centralised ducts; old shafts can be used for vertical ducts for centralised distribution provided that the effort for dismantling any old installations is manageable.

Author: Kristin Bräunlich

Sources

[PHI 2009] Requirements and testing procedures for energetic and acoustical assessment of Passive House ventilation systems < 600 m³/h for Certification as „Passive House suitable component“, Passive House Institute; Darmstadt 2009

[AkkP 30] Lüftung bei Bestandsanierung (Ventilation in retrofits); Protocol Volume No. 30 of the Research Group for Cost-effective Passive Houses Phase III; Passive House Institute; Darmstadt 2004

[Sib 2015] Sibille, E.: Optimised Integration of ventilation with heat recovery in residential buildings through the implementation of innovative air distribution strategies and pre-fabricated components; University of Innsbruck 2015

Left page (from left to right):
Figure 4: Ceiling installation (source: paul Wärmerück-gewinnung GmbH)
Figure 5: Facade integration (source: Vaventis)

Figure 6:
Two examples of suitable duct solutions for visible installation top: prefabricated duct with expandend polystyrene cover (source: Helios Ventilatoren) bottom: prefabricated cover for round spiral duct (source: Swegon)

Figure 7:
Roof-top installation of building-centralised ventilation devices (source: Lüfta GmbH)

Heating and DHW systems

Renewal of heating and DHW systems (heat generation, distribution, and transfer)

For step-by-step retrofits, the question arises regarding the best point in time for renewal of the heating system. Besides efficiency of the existing heating system, the development of the heating load over the retrofitting steps also plays a significant role in this respect.

In the case of modulating systems it must be ensured that the heating device is suitable for the current load as well as for the future load (during its useful life).

Boilers (especially gas boilers) allow a great range of the heating power at almost the same efficiency. The heating power can adapt well to the declining energy demand in the case of modernisations that are carried out step-by-step. The time for replacing the boiler is flexible.

- Attention should be given to the modulation range of the boiler, especially if the boiler is to be used for hot water generation as well. While the output for space heating is often the decisive factor in a non-modernised existing building, for an energy retrofit it is the hot water generation which matters.

- Other reserves can be mobilised by increasing the forward flow temperature.

- Hydraulic balancing of the radiator thermostats is advisable if significant changes in the heating demand result due to a retrofitting step.

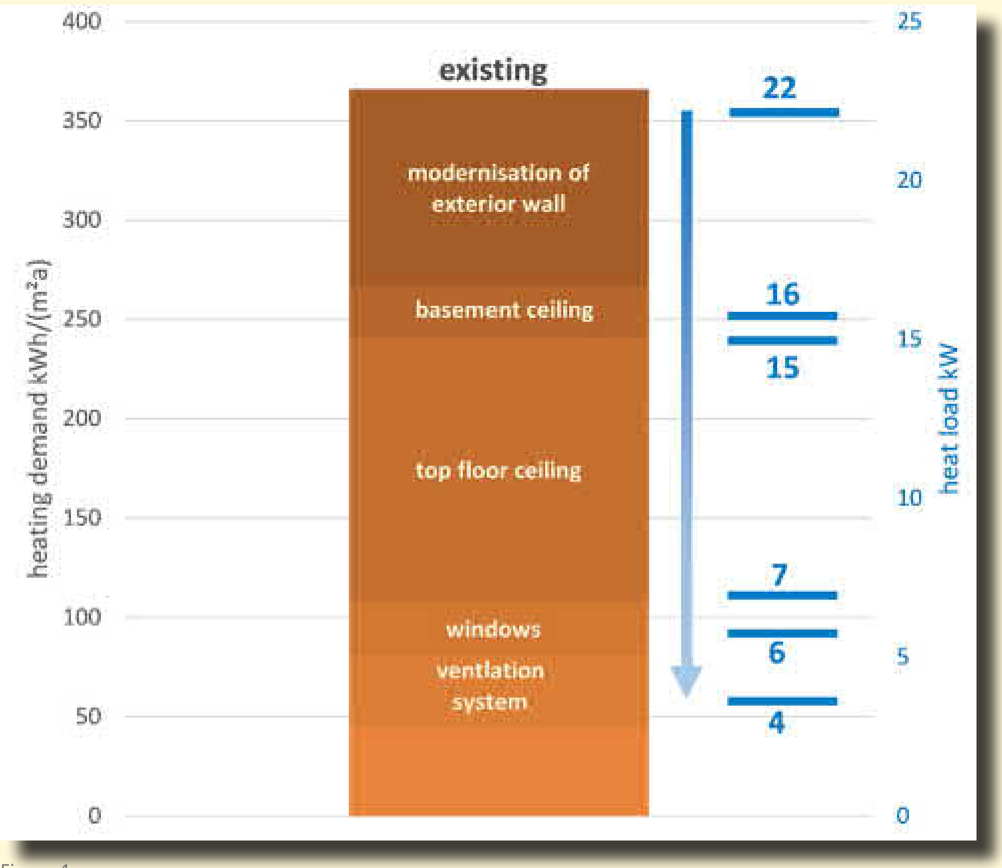


Figure 1:
The heating demand decreases with each step of the retrofit. At the same time, the necessary heating load is reduced from 22 kW to 4 kW (example values for a single-family house). About 10 kW or more of heating power are necessary for hot water generation in single-family houses.

5.2

Author: Tanja Schulz

Manufacturer	Type of heating	Name of product	Rated thermal output [kW	Modulation range
Viessmann	Gas condensing boile	Vitodens 333-F	1.9 – 19	1 : 10
Brötje	Gas condensing boiler	EcoCondens BBS EVO	2.9 – 20	1 : 6
Rotex	Gas condensing boiler	ROTEX GSU 520S-e	3.7 – 20	1: 5
Oertli	Gas condensing boiler	GVR 140-15 Condens	3.2 – 14.8	1 : 5
Giersch	Gas condensing boiler	GiegaStar 11 GiegaStar 15	2.6 – 10.6 3.0 – 14.5	1 : 4 1 : 5

Table 1:
Exemplary overview of currently available boilers with a large modulation range (German market)

Heat pumps in monovalent operation by contrast must be tailored to the actual heating power range. Unsuitable operating parameters will decrease the performance factor. The achievable output depends on the heat source among other things:

Air/air or air/water heat pumps are suitable for buildings with a very small heating load, such as for modernisations with Passive House components. The advantage is that accessing air as a heat source is easy and cost-effective.
Systems which use the soil as an energy source can generate higher heating power. The number and depth of the boreholes depends on the demand. Small heating loads result in an investment cost advantage.

Monovalent operation is well-suited for constant heating loads over the useful life of the heat pump, therefore it makes sense to dimension and install the heat pump at the end of the retrofitting measures.

If a heat pump is to be used at an early point in time, then bivalent operation is recommended. Here the heat pump is operated in combination with a second heating system – this can be the existing boiler. The heat pump will then be used for covering the base load, while the „still" existing old heating system can cover peak loads. At the end of the retrofitting measures, the heat pump can then cover the loads on its own and the old boiler will become redundant. If it is likely that the more important thermal protection measures will only be implemented after about 15-20 years, then a new condensing boiler can be installed initially for a further cycle. This will be substituted for a heat pump only after the thermal protection measures have been implemented.

Recommendations for heat pumps:

- Most heat pump systems are designed for low forward flow temperatures. If the existing distribution network is to be retained, it should be checked whether there are sufficient heat transfer surfaces (usually radiators).
- If an existing boiler heating system is replaced with heat pumps then the chimney which is no longer used can be prepared for vertical duct distribution for the ventilation system
- Combined systems which simultaneously provide hot water are already available on the market. However, usually two heat pumps are provided here which are optimised for different temperature requirements.
- Façade-integrated systems for ventilation and heating on the basis of a heat pump are emerging as a new solution. These are space-saving and can be installed while the building is inhabited. A connection for the condensate drain will be necessary.
- A larger hot water tank can already be installed if a solar thermal system will be used in the future.

Heating and DHW systems

Renewal of the heat distribution system

It should be ensured that for renewal, the distribution lines are laid in the heated part of the building to the greatest possible extent. Pipes that are laid in the cold part must be very well-insulated.

Subsequent insulation of heating pipes is a simple and very effective measure which has a direct impact. The insulation thicknesses mentioned in the table below may appear large, but they have the lowest life cycle costs and should therefore be recommended to the building owner provided that sufficient space is available in the existing building.

With the renewal of hot water distribution pipes, a hot water connection for washing machines and dishwashers can also be suggested even if the currently used appliances do not support this. A suitable appliance can be acquired later on with the next renewal.

Pipe diameter DN [mm]	Minimum insulation thickness [mm]
15	40
20	40
25	50
32	50
40	60
50	60
100	100

Table 2:
Economically optimal insulation thicknesses depending on the nominal diameter of the pipe. Recommended for heating pipes in the unheated part and for circulation pipes carrying hot water regardless of the location (derived from the "Guidelines for economical construction 2014" of the City of Frankfurt am Main, Germany).

Dependencies with later insulation measures may need to be considered. This could be the incorporation of the heat distribution pipe into the insulation of the basement ceiling or interior insulation measures. If the distribution pipe penetrates the airtight layer (basement ceiling or membrane of the interior insulation) then special attention must be given to airtight connections. Before mounting installations near the exterior wall, if the interior plaster is to form the airtight layer, a layer of plaster should be applied in an airtight manner to the affected area of the wall which will no longer be easy to access later on.

Author: Tanja Schulz

Figure 2

Figure 3

Figure 4

Figure 5

Figure 2-5:
EuroPHit case study project „Home for the Elderly" in Dún Laoghaire, Ireland, (3) previous view, (4) finalized project, (5) new window fitted and taped, (6) external insulation on existing concrete panel,
Photos: Mariana Moreira

Cooling and dehumidification

Cooling and dehumidification

Most buildings which are to undergo a step-by-step refurbishment are not equipped with air conditioning. Instead, their designers originally relied on passive strategies to keep the building comfortable in summer. North of the Alps only some non-residential buildings will require an active air-conditioning, given that a certain fraction of overheating can usually be accepted. For optimal thermal comfort, temperatures should not exceed 25 °C for more than 5 % of the year (Passive House requirement: max 10 %).

As a general principle, designers should bear in mind to minimise loads and to provide means for heat removal:

- Reduce internal heat loads
- Reduce solar loads
- Allow for night ventilation

Adding insulation or minimising window heat losses will not only reduce the heating demand, it will also affect the summer temperatures and cooling loads. Insulation reduces the solar load through walls and roof but, on the other hand, reduces heat losses during cooler summer periods and may therefore even increase the overheating frequency or the annual energy demand of an air conditioning system. When insulating the thermal envelope, consider providing other measures of passive cooling simultaneously.

Peak cooling load, as a general rule, is reduced by insulation. Well-insulated buildings with night ventilation will provide superior thermal comfort also in summer.

Should I use insulation even if it's not time for other passive measures yet? With regard to energy consumption, yes, because winter savings are almost always higher than summer penalties. For passively cooled buildings make sure to check the summer comfort of this intermediate refurbishment stage by means of the PHPP.

In some applications and climates active cooling (air-conditioning) is inevitable. Adding an active cooling system should ideally be the last step after insulation, exterior shading, night ventilation, and reduction of internal heat loads. The cooling system can then be properly sized (oversized systems are inefficient and don't provide sufficient dehumidification!) or may not be required at all, cf. Figure 3 for the difference in cooling load of old and fully retrofitted buildings. Obeying this order, part of the investment for passive measures can be recovered by choosing a smaller cooling system.

If only certain rooms get an active cooling system, e.g. only those flats of a multi-family apartment building where the residents are changing, mind that heat flows from the adjacent, hot rooms contribute to the cooling load.

Figure 1 and 2:
The most important means of passive cooling are movable shading and night ventilation

5.3

Author: Jürgen Schnieders

If split units are retrofitted before an exterior insulation is installed, sufficient space for a later insulation between the exterior part of the split unit and the wall should be provided. Also, consider to install a sufficient thermal break between the wall and the exterior unit right from the start.

Figure 3:
EuroPHit case study project „Centon" underway in Spain, Photo: VAND arquitectura

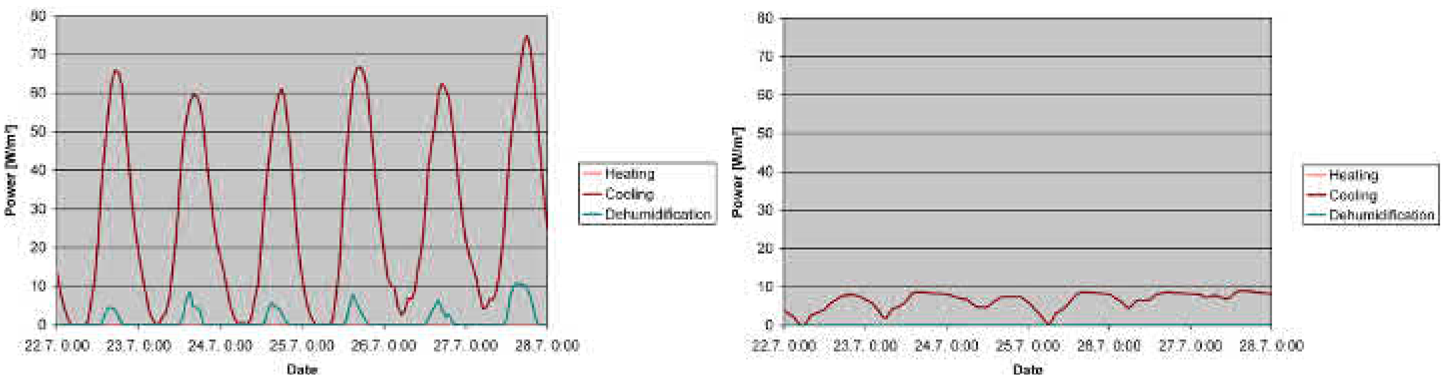


Figure 4:
Simulation results for Seville, Spain: Existing buildings in warm climates need high cooling powers during the afternoon hours (left). Refurbished buildings make do with considerably less cooling power (right).

Active utilisation of solar energy

Introduction

The energy revolution can only succeed with an interplay of increased energy efficiency and widespread use of renewable energies. Buildings are predestined as facilities for solar energy systems as electricity or heat can be produced in addition to the original function of a roof or a façade. Solar energy systems should always be installed where this is justifiable and permitted in the economic, cultural and usage-specific context.

Utilisation of solar energy should always take place AFTER thermal insulation measures

If a system for active utilisation of solar energy is installed on a building component, insulating this component makes economic sense again only at the end of the utilisation phase of the solar energy system, therefore it is essential to insulate the building component first. Solar installations can be foreseen additionally following this measure.

In the course of thermal efficiency improvements to roofs and façades, it may make sense to foresee subsequent installation of solar energy systems by installing mounting brackets and cable feedthroughs in advance.

Solar thermal system

A solar thermal system consists of a collector (flat plate collector or vacuum tube collectors), a storage tank, pumps, a control unit and an expansion tank.
Solar thermal systems make sense particularly in combination with biomass heat generators. Solar thermal systems function particularly efficiently if they do not produce more heat than required in the summer months. A contribution of around 40-60 % of the solar installation, equating to a collector area of ca. 1-2 m² per inhabitant, is appropriate. If the specific collector area becomes greater, especially the surplus energy in summer will increase, while the contribution towards the heating demand will only increase slightly in winter and in the transitional seasons due to less solar radiation. For this reason, supplementary installations for solar heating are less economical compared to those for solar hot water generation. In order to increase the heat gains in the cold season, the installations can be inclined more steeply (e.g. 60-70 degrees) so that the gains are optimised for the low winter sun.

Solar thermal systems are particularly economical in case of a high heating demand per installation, as in the case of multi-storey buildings for example.

Supplementary heating using a solar thermal system may make sense in buildings with a lower efficiency standard because the solar radiation that is available during a major part of the heating period in the months from April to May and from September to October is sufficient. In the case of extremely energy efficient buildings the heating period is limited to the main winter period in which there is very little solar radiation.

Investing in an improved standard of thermal protection towards the EnerPHit Standard will lead to much higher energy and cost savings than with solar heating systems.

Photovoltaic system

A photovoltaic system consists of a PV module (with monocrystalline cells or amorphous cells), an inverter and a (feed-in) meter. As a general rule, photovoltaic systems are connected with the power grid (grid-connected systems). Stand-alone/off-grid systems which are not connected to the power grid only make sense in exceptional cases in locations remote from the grid. These have electricity storage (rechargeable batteries) and an additional power generator (diesel generator, wind power plant) as additional components. Grid-connected systems with additional storage are becoming more popular because the degree of on-site use is increased due to the storage. In certain cases, this may be interesting from the economic point of view, particularly where the costs for power from the grid are high with simultaneously low or no feed-in remuneration.

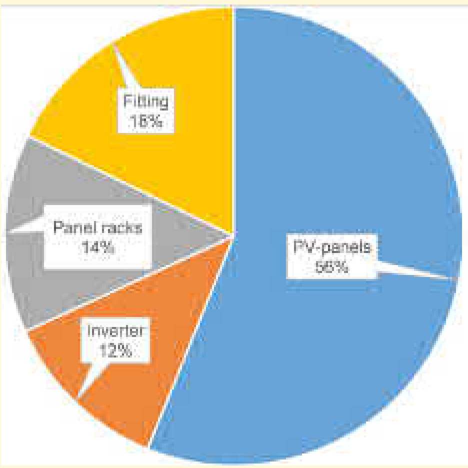
Due to grid-connection, photovoltaic systems can be regarded independently of building services. The cost of generating electricity with PV is often much lower than buying power from the grid. PV systems are of economic interest particularly where there is high on-site consumption. If heating, cooling and hot water generation in the building takes place via heat pumps, then on-site consumption can be increased significantly. It may therefore make sense to couple the installation of a PV system with a change of the heat supply to heat pumps. In some countries, PV generated electricity that is fed into the power grid is remunerated. The system will certainly be cost-effective if the electricity generation costs of the PV system are lower than the feed-in remuneration.

5.4

Author: Benjamin Krick

The installation costs for a PV system are a major cost factor, see Figure 1. Cost-efficiency can be improved significantly if the coupling principle is applied here as well. In this way, costs for mounting racks and the roof covering or façade cladding can also be saved.

In Germany, costs of around € 1200/kWp or ca. € 200/m² (net, including installation) can be expected currently (Summer 2016) for a photovoltaic system with ca. 30 kWp. The costs for a solar module (without installation, mounting rack and inverter) are around € 105/m². Compared to this, the costs for covering a roof with tiles are ca. € 20/m², while prices between € 55/m² for basic quality and over € 200 for high quality products can be expected for façade cladding with cement fibre boards. This example makes it clear that a photovoltaic façade does not have to cost more than a façade which has cladding of different materials; the decision for or against a PV system is thus a question of the design.



Solar thermal system or PV?

The comparison between a solar thermal system and a PV system usually shows an economic advantage in favour of the PV system if there is adequate feed-in remuneration. As a rule, solar thermal systems usually have a higher overall efficiency than PV systems as they produce more energy per m². A solar thermal system is particularly recommended in combination with a wood pellet stove or firewood stove.

Instructions for installation:

It is still common to use aluminium brackets for attaching the support system of façade claddings and PV. Due to the high thermal conductivity of the aluminium, thermal bridges may result which may double the U-value of the wall and thus also the heat losses and energy costs. It is therefore particularly important to draw attention to thermal bridge minimised fasteners. Where permitted by the fire safety provisions and statics, these can be made of fibre-reinforced plastic or wood. Failing this, high-grade steel supports have proved successful, particularly those consisting of metal stabs rather than metal plates.

Figure 1:
Typical distribution of the costs for a solar energy system. Fitting includes installation of the module and the inverter as well as the cost of scaffolding and connection to the power grid.

Figure 2:
Example of a roof with solar installations

06

Example project

The EuroPHit observer project "Sonnenstrasse"

A detached Franconian house from 1959

The single-family house Sonnenstrasse 39 in Zellingen/Main, Germany, was originally constructed in 1959. It is one of many detached homes built in new developments after WWII for working-class families in Franconia (region in Southern Germany), with a big garden to grow food and adjoining secondary buildings to house small animals, a laundry room and a garage.

Those developments provided electricity and later natural gas. In the unheated basement of each house, the building services consist of a domestic hot water (DHW) storage tank, gas boiler, in former times: oil tanks, and a chimney. A second chimney serves the living room where a wood stove could be installed as a back-up heating system. The main building is designed for four persons and has a treated floor area of 127 m² (according to PHPP). This Sonnenstrasse building type was reproduced in nearly every Franconian settlement. Thus, demonstrating sustainable solutions for it will be beneficial for many other potential retrofits. It features a variety of Franconian details, typical for the time period and region.

Over time, the houses from this period were usually modernized and extended.

In recent years, further changes can be noticed in some houses such as

- External wall insulation
- New double- or triple-glazed windows installed in the old position
- New heating system installed

All in all, the house in Sonnenstrasse 39 underwent the following interventions in chronological order:

- 1974: Concrete balcony and access door as well as enlargement of the former window and use of glass bricks, entrance porch added. Living room extension added with larger window areas (1974), see Figure 3. New double- or triple-glazed windows installed in the old position

- 1999: In addition to changes on the exterior (some windows replaced by PVC windows with double-glazing) the interior was modernized: new gas boiler, new floor finishes, new and bigger bathrooms.

- 2004: The rest of the house received new windows (with the exception of the attic windows)

- 2014: new gas boiler, solar DHW panels and storage tank, external wall insulation, new entrance door, new radio-controlled external blinds, new triple-glazed attic windows, ventilation system with heat recovery, basement ceiling insulation, internal basement access: insulation, airtightness improvements (named "step 1" of the EnerPHit requirements)

- 2050: In theory, as part of the EnerPHit Retrofit Plan: New Passive House windows (named "step 2" of the EnerPHit requirements)

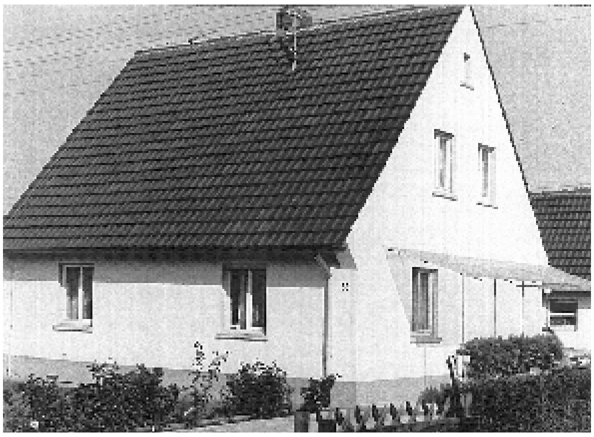


Figure 1:
Photo of the original 1959 building "Sonnenstrasse 39, Zellingen", taken around 1970

Figure 2:
recent photo (2015) showing EnerPHit step 1 completed. Source: Karl Theumer

6.1

Author: Susanne Theumer

- 2070: In theory, as part of the EnerPHit Retrofit Plan: Airtightness improvement along the eaves, additional roof insulation, better heat recovery efficiency of the ventilation unit (named "step 3", achieving the EnerPHit requirements)

All interventions until 2009 were carried out without an independent energy consultant. In the year 2009, a mandatory energy label was being completed, combined with an intensive energy assessment by architectural office Werner Haase, Karlstadt, see [Haase_2009, in German]. In 2013, this architect was hired to plan and supervise the next intervention ("step 1", 2014), in close collaboration with the Passive House Institute.

The existing double-glazed PVC windows have an Uw-value of 1.45 W/(m²K) (for size 1.23x1.48 m). Inspired by illustrations on page 37 and 38 of a step-by-step solution in [PHI-RG39], they were not replaced during the retrofit 2013/2014 but integrated into the new external wall insulation so that they can be uninstalled in the future, see Figure 5 and full photo series on http://www.europhit.eu/op17-sonnenstrasse-39-zellingen-am-main.

Existing window during the retrofit, before the thermal insulation has been installed: The timber frame in the insulation layer is required to fix the new window frame to it in future. The external, lower window sill will then remain, the second window sill will be removed. (Photo: Architect's office Werner Haase)

Interim solution with EIFC: Also the external blind is installed in the insulation layer. This way, it can remain even after the future installation of new windows and no works are required from the outside of the building. (Photo: Architect's office Werner Haase)

Figure 6:
Window sill detail during and after completion of the retrofit

Figure 3:
Additions to the original design. Balcony and glass block element. Source: Karl Theumer

Figure 4:
Additions to the original design. Entrance porch. Source: Karl Theumer

Figure 5:
Additions to the original design. Living room extention. Source: Karl Theumer

The EuroPHit observer project "Sonnenstrasse"

The detailed PHPP calculation carried out with PHPP 8 shows a primary energy demand of approx. 320 kWh/(m²a). The gas costs for DHW and heating consumption were on average 1900 €/a. Electricity costs are not known because the tenants pay the energy supplier directly.
The main challenge of this particular project was the application of the step-by-step EnerPHit approach in a project were past interventions did not address any of the EnerPHit recommendations such as achieving an airtight building envelope and the principle "If you do it, do it right from the start".

Another challenge was the project's short time frame. Due to new tenants moving in at the end of January, the retrofit had to be completed within the two winter months December 2013 and January 2014. The unpredictable weather conditions were a risk that was taken. It has to be mentioned that the project's success depended largely on the huge personal contribution of the investor, the building owner.
To assess the thermal bridge influence on the energy balance in such a Franconian detached house, was the main topic of a master thesis by the author [Theumer_2015].

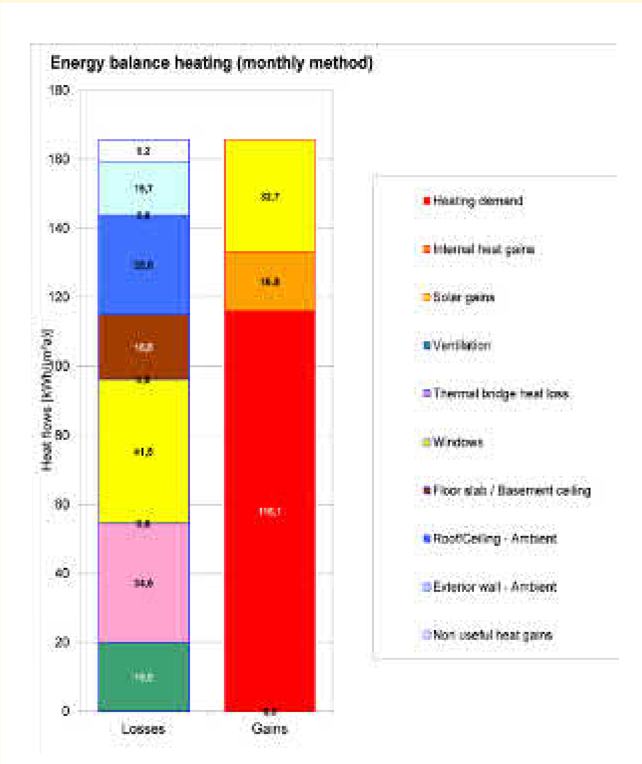


Figure 7:
Heating energy balance for the retrofit step 1. The contribution from thermal bridges to the losses are approx. 35 kWh/(m²a)).

The role which thermal bridges play in this deep retrofit can be illustrated using the graph from the PHPP heating worksheet, see Figure 7.

It can be observed that 35 KWh/(m²a) of heat loss comes from the various thermal bridges balcony slab, thermal bridges towards unheated basement and ground, windows and door installations, chimneys to mention the most important ones. As a result, it is important to address thermal bridges in a proper way. They should be reduced as far as possible at the same moment when the respective building component is being enhanced.

Also, the cost side has to be briefly mentioned. The total investment costs of the retrofit were 110 000 euros. The home owner received approx. 20 000 euros in funding from the municipality and KfW bank. The rent was increased by 200 euros/month and the increased comfort will probably have the effect of being able to retain the same tenants for a long time.

The first gas bill proved that the building is already on its way towards "Nearly Zero Energy" with total annual costs for heating and DHW of 467 euros in 2014/2015 instead of 2159 euros incl. 19% VAT in 2012/2013 which is approx. 5 times less than before the intervention, a real cost saving of >70%. The current annual electricity costs are 653 euros incl. 19% VAT and translate into a low electricity consumption compared to similar German households. The following year showed even lower bills.

During project implementation, several possibilities for developing retrofit components for simplifying the step-by-step approach were identified. Among them are, for example, an airtightness kit for small houses and ventilation units integrated into the external wall insulation or the window interim solution with two window sills, see EuroPHit website.

Conclusions

The Sonnenstrasse project was, all in all, a success for the home owner as well as for the tenants.

However, due to many obstacles such as recently carried out retrofit steps without an EnerPHit Retrofit Plan, a decision to follow a step-by-step approach, lack of rigorous airtightness planning, the building's performance can be understood as an intermediate result which will improve over time. Although it has not achieved the EnerPHit targets yet, it will eventually do so in the future. It is a pioneer project and acts as a case study project for the step-by-step refurbishment of single-family houses.

Of course, many lessons can be learnt from this step-by-step retrofit and will be done better, faster and more cost-effectively next time.

The optimization potential was shown in a master thesis and client and designers of a similar project have to calculate more time for the planning process to use this potential to the maximum. They can avail themselves of a number of off-the-shelf solutions and reliable component certificates, see [PHI_EnerPHit-Systems], which are welcomed by clients. These are a huge relief as well as support for investors and architects alike. The EU project EuroPHit is a great means to communicate this to a wider audience.
Moreover, the PHPP 9 (2015) should be used to set up a sound EnerPHit Retrofit Plan. This is vital as it can be used to display and compare various scenarios with each other to derive the best solutions for the individual situation.

Having said this, the most surprising and rewarding lesson learnt for the home owner and tenants comes from the first energy bills received. They prove a significant cost reduction of more than 70%. Coupled with higher comfort (warm surfaces, fresh air, neat appearance) this house is on the right path towards climate protection.

Last but not least, several possibilities for developing retrofit components were identified.

Acknowledgement

This text is based on the master thesis "Step-by-step towards EnerPHit-Standard retrofit. Relevance of typical thermal bridges in a detached Franconian house from 1959" [Theumer_2015].

Sources

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[Markt_Zellingen] 1. Bürgermeister Dr. Wieland Gsell, Geographic data, "http://www.markt-zellingen.de/sites/gensite.asp?SID=cms110220152232437993585&Art=240", accessed 11.02.2015.

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[PHPP] Passivhaus Institut: Passive House Planning Package, April 2015.

[Theumer_2015] Susanne Theumer: Master thesis "Step-by-step towards EnerPHit-Standard retrofit. Relevance of typical thermal bridges in a detached Franconian house from 1959", Hochschule Hannover / University of Applied Sciences and Arts, February 2015.

07

Further information

Further Information

EuroPHit:

EuroPHit Website

Online information resource on
www.europhit.eu

Implementing deep energy step-by-step retrofit Increasing the European potential

An informational booklet about EuroPHit and stepwise retrofit
www.europhit.eu

Ventilation concepts for energy retrofits

Component Award 2016: Brochure with detailed results of the competition and general information about ventilation concepts for retrofits
www.europhit.eu

Built projects:

Passive House database

A large database with built Passive House buildings
www.passivehouse-database.org

Passive House project documentation

Detailed technical documentations of built Passive Houses and EnerPHit retrofits project documentation
www.passivhausplaner.eu

Events:

International Passive House Conference

The International Passive House Conference is the year's premium Passive House event, where about 1000 thought leaders and innovators from around the world gather.
www.passivhaustagung.de/en

International Passive House Days

Visit Passive House buildings or showcase your own projects
www.passivehouse-international.org

Tools:

Passive House Planning Package (PHPP)

The energy balance and planning tool for Passive Houses and EnerPHit retrofits including the EnerPHit Retrofit Plan for stepwise retrofit.
www.passivehouse.com

designPH

designPH is set to revolutionise the way we use Passive House Planning Package (PHPP).
www.designph.org

EnerPHit and Passive House – General information

Passipedia

The ever-expanding knowledge database on energy efficient building and Passive House, comprising over two decades of research. Articles relating to step-by-step energy retrofit and deep retrofit in general are also found here.
www.passipedia.org

Active for more comfort: Passive Houses

An informational booklet with basic information about Passive Houses and retrofit with Passive House components.
www.passivehouse-international.org

Criteria for the Passive House, EnerPHit and PHI Low Energy Building Standard

Passive House Institute building criteria and certification procedure
www.passivehouse-international.org

Certification and Training:

Passivehouse building certification

Information about the Passive House Institute's quality assurance program.
www.passivehouse.com

Component Database

Large database of certified products suitable for Passive Houses and EnerPHit retrofits.
database.passivehouse.com

Passive House Designer

Information about Passive House Institute's international education program incl. large database of Certified Passive House Designers.
www.passivhausplaner.eu

Passive HouseTradesperson

Information about Passive House Institute's international education program, large database of Certified Passive House Tradespersons.
www.passivehouse-trades.org

Organisations:

Passive House Institute

An independent research institute that has played an especially crucial role in the development of the Passive House concept.
www.passivehouse.com

International **P**assive **H**ouse **A**ssociation

A global network for Passive House knowledge working to connect international stakeholders.
www.passivehouse-international.org