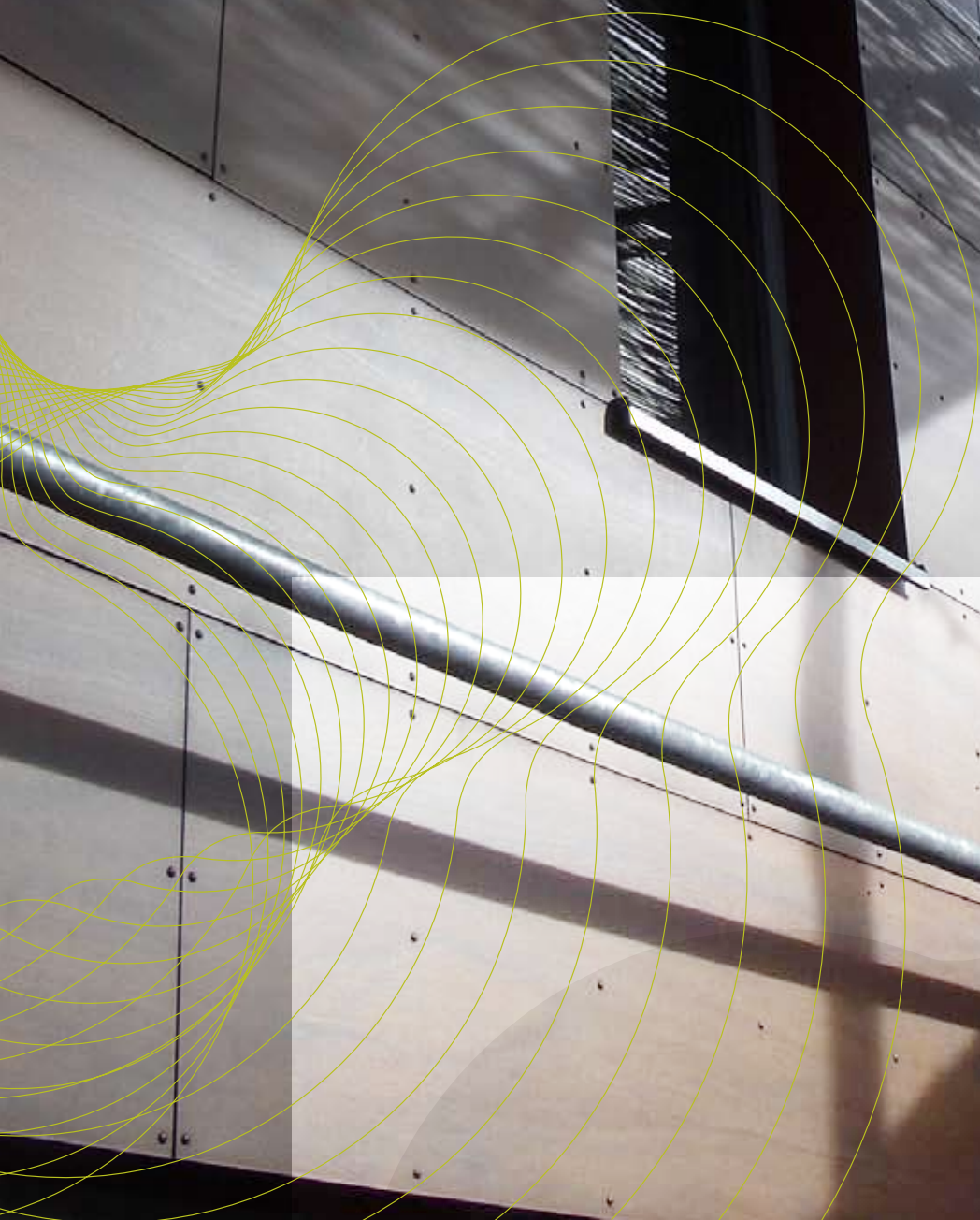


# PASSIVHAUS PRIMER

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# BACKGROUND

This primer is an aid to developers, architects and aspiring self-builders in understanding the key principles of PassivHaus design. The term 'PassivHaus' refers to a voluntary, ultra low-energy construction standard first developed over a decade ago by Dr Wolfgang Feist of the Passivhaus Institut Germany.

The core focus of PassivHaus design is to dramatically reduce the requirement for space heating and cooling. This can be achieved without compromising comfort or needing to rely on the falling costs of renewable energy technologies.

The first dwellings to be completed to the PassivHaus standards were constructed in Darmstadt in 1991. The Passivhaus Institut subsequently monitored the performance of these dwellings with another 250 PassivHaus projects around Europe eventually being monitored as a part of the European CEPHEUS project ([www.cepheus.de/eng/](http://www.cepheus.de/eng/)).

Since the completion of the CEPHEUS project, the concept of PassivHaus design has become mainstream and has seen

widespread adoption around Europe. To date over 7,000 dwellings have been constructed in accordance with PassivHaus principles, with several projects now nearing completion and certification in the UK.

PassivHaus represents one approach the industry can take as we move towards the aspiration of zero-carbon buildings. Whilst a PassivHaus is not zero-carbon in itself the reduced energy requirements allow potentially smaller and cheaper quantities of renewable technologies to be specified to achieve zero-carbon standards.

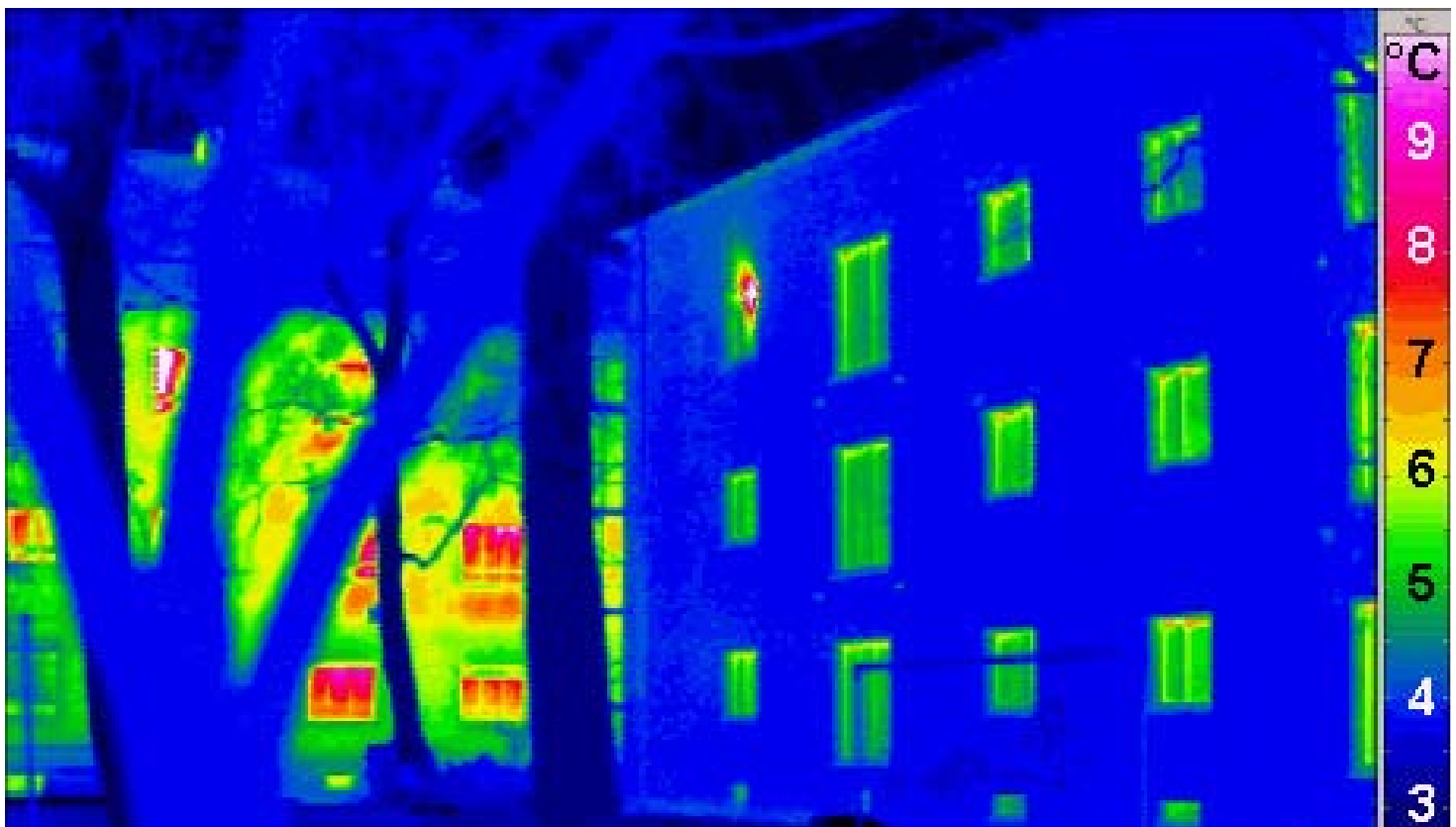
The PassivHaus design principles can be applied not only to the residential sector, as the name suggests, but also to commercial, industrial and public buildings.

"Ten years ago, no-one believed us that houses can manage with less than a tenth of the heating energy used by average old buildings"



Image courtesy PassivHaus Institut Darmstadt

**Professor Wolfgang Feist  
of the PassivHaus Institut  
Germany**



A typical thermal image of a block of flats constructed to the PassivHaus standard (right) versus a more traditionally built design (left). Dwellings constructed to PassivHaus standards can have space heating energy requirement up to 90% less than existing building stock. (Image courtesy of PassivHaus Institut Darmstadt.)

# 'PASSIVE HOUSE' OR 'PASSIVHAUS'?

A German 'PassivHaus' is different to a traditional 'Passive house'. The term PassivHaus relates to a well defined standard, whereas a 'Passive house' typically relates to a house with passive design features (e.g. passive solar design).

## PASSIVE HOUSE

Passive design minimises the energy requirements of a building by making best use of assistance from natural factors; typically passive buildings will have a passive solar strategy (highly glazed south façade, a sun space or conservatory) combined with a high level of thermal efficiency to reduce heating and artificial lighting requirements. Commonly these buildings are also specified with a natural ventilation system.

The benefit of this approach is that there are fewer or no active mechanical and electrical systems to maintain. However the success of this approach is highly reliant upon the building orientation and format. In addition to this heat may be lost through natural ventilation and some passive solar designs have also been known to suffer from overheating problems during the summer.



The Integer House at BRE is an example of what could be considered 'traditional' passive design.

## PASSIVHAUS

A PassivHaus incorporates some features of passive design, however the key difference is that a 'PassivHaus' is designed so that the heating requirement of the dwelling is met by pre-heating the fresh incoming air. This is an 'active' approach.

The fact that the ventilation system is used to provide the heating, means that the German definition of a 'PassivHaus' is different, ideologically, from a traditional 'passive' house.

One of the benefits of this approach is that the use of active building services can allow the designer more flexibility with the building design. However to achieve this a specific space heating requirement must be achieved and the ventilation system must be correctly specified, designed and commissioned.



A PassivHaus in Austria – this house incorporates some passive solar features such as south facing glazing and also external shading devices, but the overall build format and internal layout is not necessarily that different from a standard house.

# PASSIVHAUS REQUIREMENTS

To achieve the PassivHaus standard the energy required for space heating must not exceed 15 kWh/m<sup>2</sup>/yr – this is the overarching requirement<sup>1</sup>.

The figure of 15kWh/m<sup>2</sup>/yr has been arrived at from calculating the maximum amount of heat that can be delivered by heating air supplied at the minimum required ventilation rate.

It is limited to 15kWh/m<sup>2</sup>/yr for two reasons:

- 1 The temperature of the fresh incoming air cannot exceed 50°C – if the fresh air is delivered at a higher temperature than this problems can occur with the indoor air quality (e.g. burning smells caused from the air scalding dust within the ductwork).
- 2 A comfortable indoor temperature (20°C) needs to be achieved in areas with low ventilation rates – this means that only a certain amount of heat can be supplied without exceeding the 50°C temperature limit.

<sup>1</sup> In addition to this the total primary energy demand must not exceed 120kWh/m<sup>2</sup> – in the UK however this requirement is deemed to be satisfied provided that provided that A-rated appliances and lighting are specified.

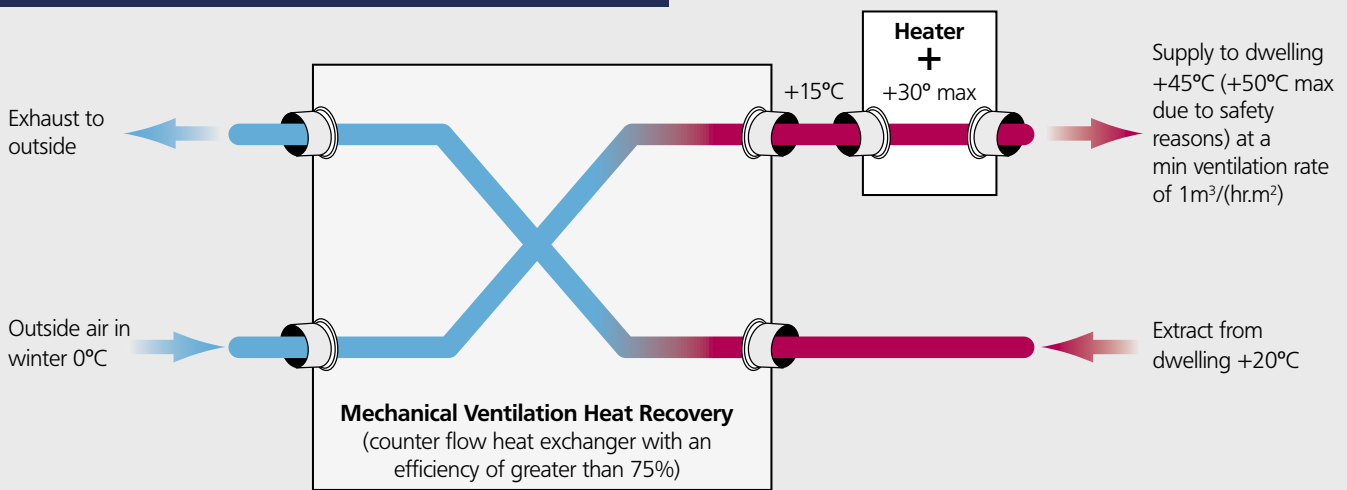
Without achieving the PassivHaus space heating requirement of 15 kWh/m<sup>2</sup>/yr or less, criteria 1 & 2 provided will not be achieved and, the above two criteria will not be achieved and thus it is not recommended to try and heat a dwelling using the fresh incoming air.

Achieving a space heating requirement of 15 kWh/m<sup>2</sup>/yr or less means that the following headline features need to be achieved as a minimum:

- Super-insulation: opaque U-values must be less than 0.15 W/m<sup>2</sup>K
- U-values for windows and doors need to be 0.8 W/m<sup>2</sup>K or less (for both the frame and glazing).
- Thermal bridging needs to be minimised, and ideally eliminated
- Airtightness: 1m<sup>3</sup>/(hr.m<sup>2</sup>) @ 50 Pa or less
- Whole house mechanical ventilation with heat recovery (75% efficient or better, with a low specific fan power).

Further advice on these requirements is provided overleaf.

## The technical basis of PassivHaus



To enable heating to be provided solely by the fresh incoming air (as per the diagram above) the heating load must be 10 W/m<sup>2</sup> or less:

$$1 \text{ m}^3/(\text{hr.m}^2) \times 30^\circ\text{C} \times 0.33 \text{ Wh}/(\text{m}^3\text{K}) = 10 \text{ W/m}^2$$

↑ Min. ventilation rate    
 ↑ Maximum heat input which can be provided via the fresh incoming air    
 ↑ Specific heat capacity of air

**This translates to a maximum heating requirement of 15 kWh/m<sup>2</sup>/yr**

## PASSIVHAUS PLANNING PACKAGE (PHPP)

The elemental specification provided above is a good starting point, however the PassivHaus space heating requirement of 15 kWh/m<sup>2</sup>/yr can only be verified by modelling the proposed design within PHPP. PHPP is a Microsoft Excel energy calculation tool, it is based around the same core

energy calculation methods used throughout Europe (including SAP here in the UK) however it includes certain enhancements based on the results of monitored PassivHaus dwellings within the CEPHEUS project. This allows PassivHaus specific features to be modelled (e.g. 'compact service units').

BRE provides PassivHaus certification using PHPP and it can also be purchased as a design tool (please visit [www.passivhaus.org.uk](http://www.passivhaus.org.uk)).

# HOW CAN PASSIVHAUS REQUIREMENTS BE ACHIEVED?

## Insulation and thermal bridging

External walls, slabs to the ground, and roofs are within 0.1 to 0.15 W/m<sup>2</sup>K.

All significant thermal bridges should be designed out.

The most important principle of a PassivHaus is insulation applied continuously around the building envelope without thermal bridging – this significantly reduces heat losses. As a consequence the heat losses during winter are negligible. Another consequence is that the temperatures of the internal surfaces are almost the same as the indoor air temperature. This leads to a very comfortable indoor climate and avoids damage caused by the humidity of indoor air.

During hot periods in summer, a high level of thermal insulation is a protection against heat. To ensure high thermal comfort during summer, well designed shading and sufficient ventilation are important, too. All construction methods can be used for PassivHaus and have been tested successfully: masonry construction, lightweight construction, prefabricated elements, insulating concrete formwork construction, steel construction, and all combinations of the methods above.

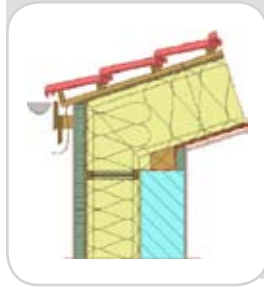
## Airtightness

1 m<sup>3</sup>/(hr.m<sup>2</sup>) @ 50 Pa or less.

Unwanted air leakage can significantly increase the space heating requirement of a dwelling, cause localised discomfort due to draughts and possibly cause moisture to build up within the building fabric which may eventually reduce the performance and lifespan of the building. Achieving PassivHaus levels of airtightness can eliminate these problems.

Achieving this level of airtightness requires a strategy to be developed at the design stage, with the final result also being sensitive to the quality of workmanship.

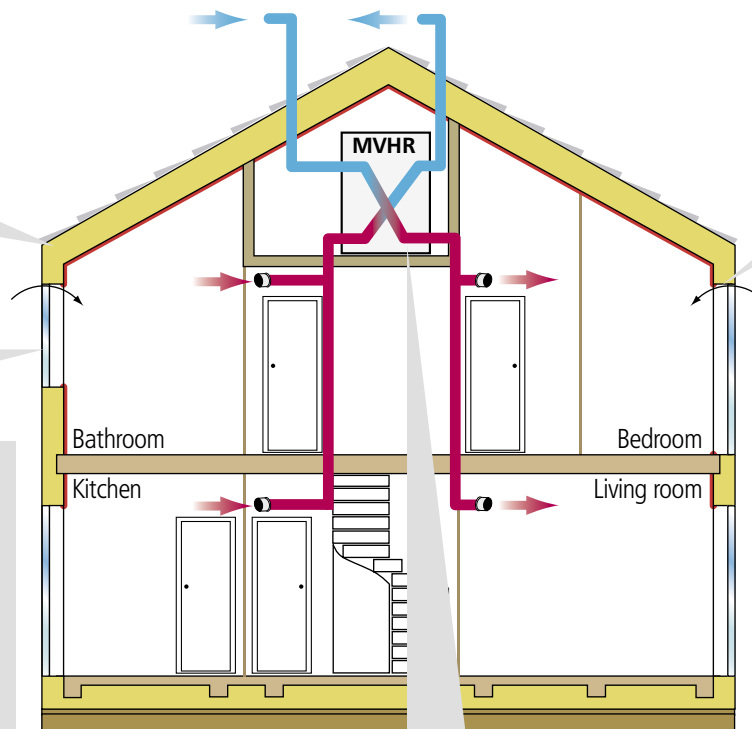
Achieving airtightness onsite requires careful use of appropriate membranes, tapes, wet plastering and/or vapour membranes to form a continuous airtight barrier.



## PassivHaus windows and insulated doors

Windows to be triple glazed and achieve 0.8 W/m<sup>2</sup>K for both the glazing and the frame. Doors must be insulated.

Even in the milder UK climate triple glazed PassivHaus windows need to be specified if the supply air is to be used to heat the dwelling – without triple glazing the heat loss is too high and it is not possible to achieve the PassivHaus standard. A benefit for triple glazing is that the surface temperature of the windows is similar to that of the surrounding internal surfaces – the occupants will not experience any discomfort, even on the coldest winter day, when seated near a PassivHaus window. Triple glazing also reduces sound transmission from outside.



## Other design considerations

**Utilisation of passive solar gains:** An optimised design can reduce space heating and day-lighting requirements which helps achieve the PassivHaus design target.

**Internal gains and overheating:** All energy consumption ends up as heat. This means that all appliances and lighting which use energy contribute to heating the house. Whilst this is useful, the main issue for a PassivHaus is to reduce internal gains as this can increase the risk of overheating. Thus low-energy lighting and appliances should be fitted.

**Renewable and low-carbon technologies:** Specifying renewable energy technologies is not a core requirement of the Passivhaus standard, however implementing renewable energy technologies can further reduce running costs and carbon dioxide emissions – it is also readily possible to achieve the zero carbon requirements of level 6 of the Code for Sustainable Homes.

## Mechanical Ventilation and Heat Recovery (MVHR)

Heat recovery efficiency of greater than 75% and a low specific fan power is required.

The health and comfort of the inhabitants are the most important objectives of PassivHaus design. The necessity for an extremely airtight building fabric means that MVHR is required to maintain the quality of indoor air by replacing unwanted odours, moisture and carbon dioxide generated by the occupants with oxygen rich fresh air. Occupants can still freely open and close the windows as they see fit, however to achieve adequate ventilation rates in such an airtight building the occupant would be required to open all the windows at least once every three hours for some 5 to 10 minutes at a time – even during the night. This would obviously be impractical and would cause unacceptable heat loss during the winter.

Since MVHR can be closely controlled, it ensures that the correct levels of ventilation can be achieved in all rooms and provides excellent indoor air quality when specified and installed correctly. The heat exchanger does not mix the fresh incoming air with the exhaust air, but simply exchanges heat to reduce the heating requirement. In a PassivHaus – and only in a PassivHaus – there will be another advantage when specifying an MVHR system: The opportunity to heat the dwelling by heating the supply air.



# WHAT IS THE RELATIONSHIP BETWEEN PASSIVHAUS AND THE CODE FOR SUSTAINABLE HOMES?

The PassivHaus standard is measured in terms of absolute energy use for space heating only, whereas building regulations and the Code for Sustainable Homes set standards according to reductions in carbon dioxide emissions for space heating, water heating and lighting. Because of this the two standards cannot be compared like for like.

However, a new-build PassivHaus can typically be expected to achieve the energy requirements of Code level 4 (a 44% reduction in carbon dioxide emissions) without renewable technologies being specified. It is not possible to go beyond code level 4 without specifying renewable energy technologies.

The fabric performance requirements (Ene.2 credit) required for level 6 of the Code are based upon the PassivHaus standard. With the exception of flats, it is not generally possible to achieve Code Level 6 without adopting a performance specification similar to PassivHaus.

## WHERE CAN I SEE A PASSIVHAUS?

There are a variety of PassivHaus projects reaching completion in the UK, the BRE Innovation Park also hosts several innovative housing projects which have similar features.

In addition to this BRE also runs study tours for industry groups and also excursions to the international PassivHaus Conference.

For more information please contact us:

W: [www.passivhaus.org.uk](http://www.passivhaus.org.uk)  
E: [passivhaus@bre.co.uk](mailto:passivhaus@bre.co.uk)  
T: 01923 664 161

BRE Innovation Park



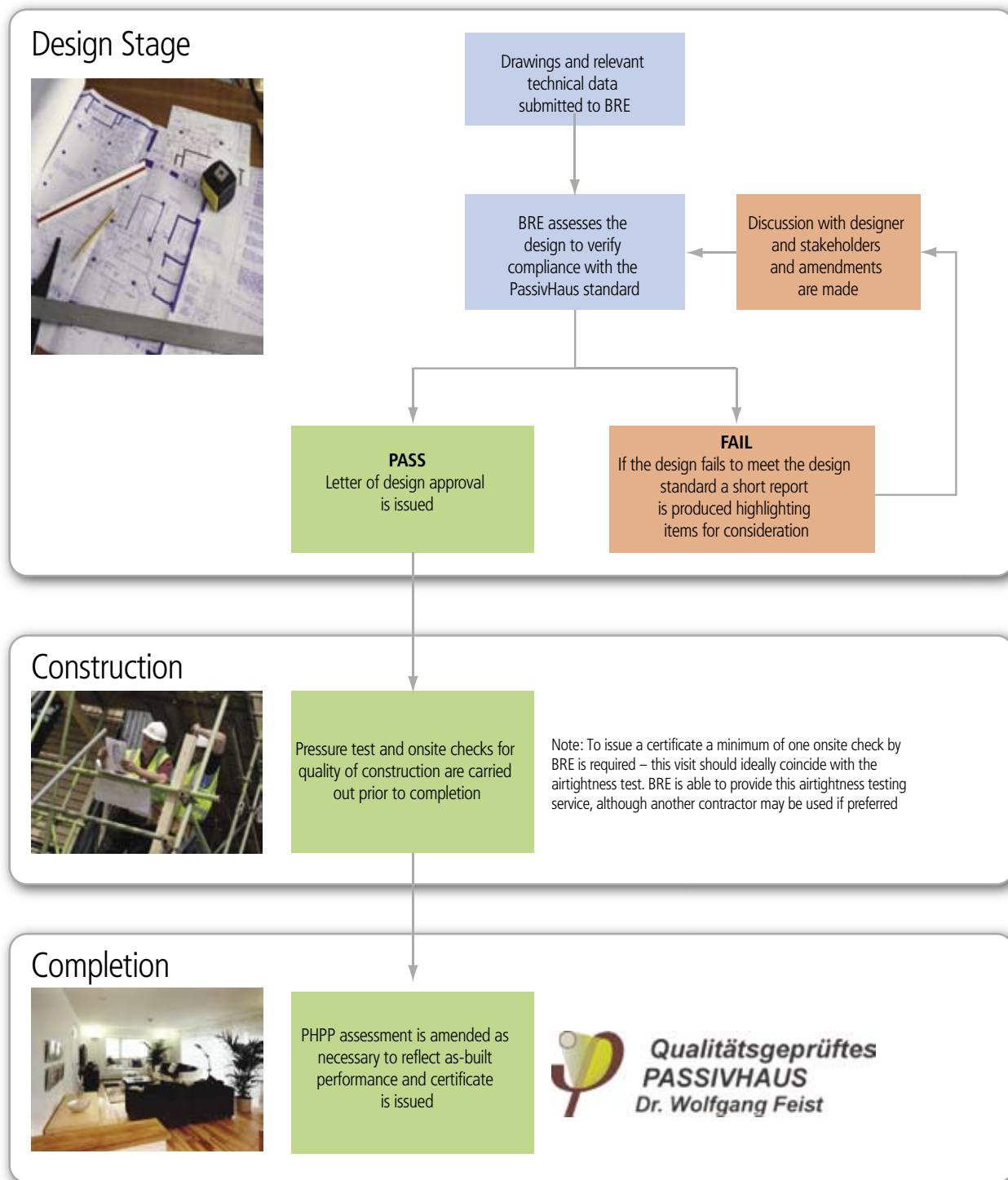
# CONSULTANCY AND CERTIFICATION

BRE is registered with the Passivhaus Institut Darmstadt to issue PassivHaus Certificates for domestic dwellings, offices, schools and industrial buildings. Compliance with the PassivHaus standard is assessed using the PassivHaus Planning Package.

As a result of our partnership with the Passivhaus Institut in Darmstadt we are able to provide a complete PassivHaus design advice service and can tap into a wealth of design experience from Europe. Assistance can also be provided to help overcome

specific problems when validating proposed designs. BRE provides consultancy throughout the UK, to either one-off buildings or entire communities.

The certification process is outlined below:



# PASSIVHAUSUK

PassivHausUK is run by the Building Research Establishment and provides information on:

- The concepts of PassivHaus design.
- Information regarding consultancy and certification services.
- Examples of PassivHaus dwellings in Europe and the UK.
- Practical information, such as building product listings and design guides.
- A forum for discussion.
- Updates on national workshops, study tours and the annual international PassivHaus conference.

DON'T FORGET WE ALSO  
PROVIDE CODE CONSULTANCY  
[www.bre.co.uk/codeconsultancy](http://www.bre.co.uk/codeconsultancy)

## CONTACT US

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Energon Building - Worlds Largest Office constructed to PassivHaus Standards



Flats refurbished to the PassivHaus standard in Nuremberg Germany



PassivHaus - Private residence in Oost-Vlaanderen Belgium