PASSIVHAUS PRIMER

bre

PASSIV HAUS INSTITUT

PassivHausUK is registered with the PassivHaus Institut Darmstadt as their official UK certifier for PassivHaus projects

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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 standard 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/).

Since the completion of the CEPHEUS project, the concept of PassivHaus design has become mainstream and has seen widespread adoption around the world. To date over 17,000 dwellings have been constructed in accordance with PassivHaus principles, with several projects now nearing completion and certification in the UK.

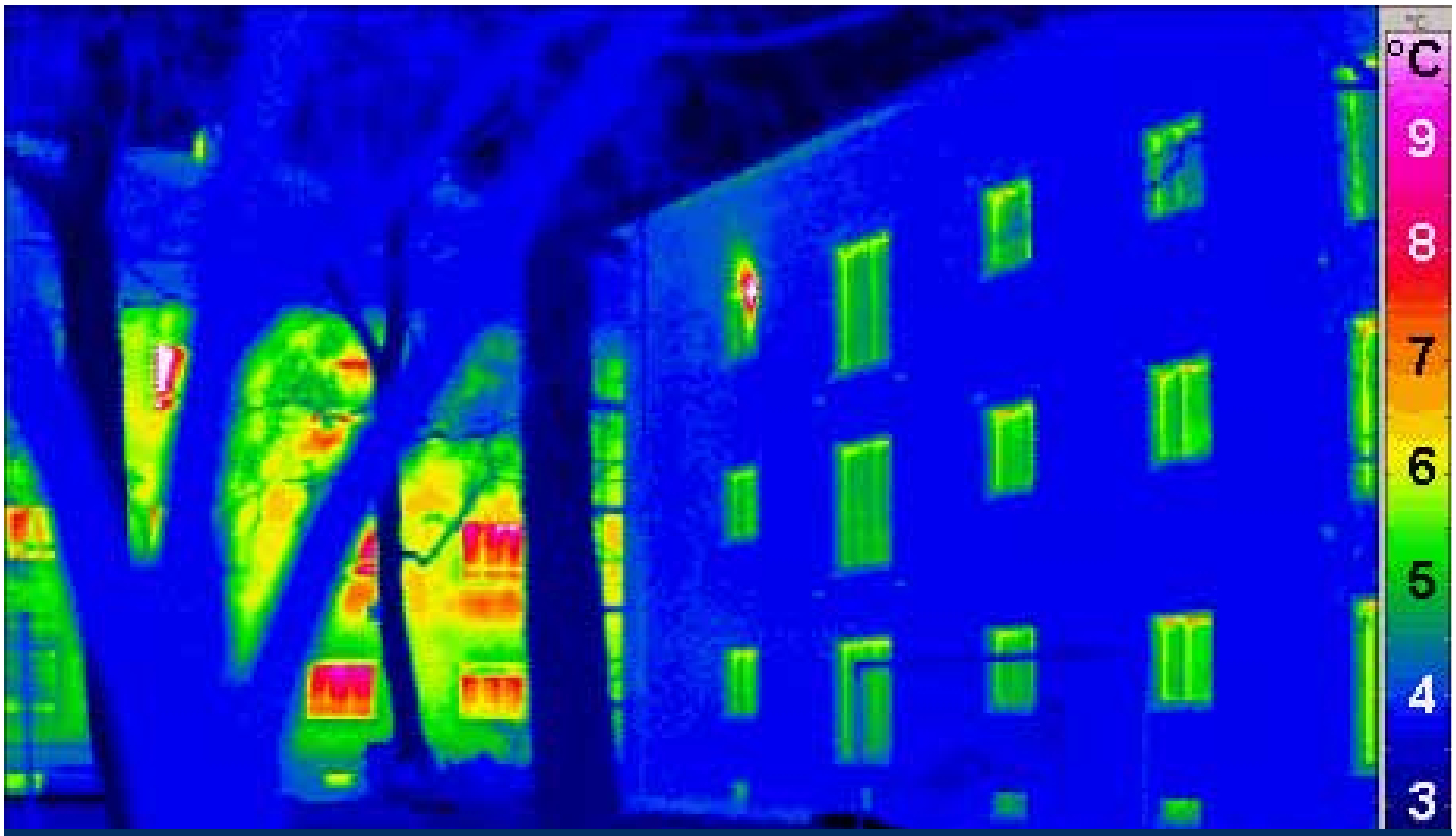
PassivHaus represents one approach the industry can take as we move towards the aspiration of zero-carbon buildings. Whilst a PassivHaus is not zero-carbon in itself the reduced energy requirements allow potentially smaller and cheaper quantities of renewable technologies to be specified to achieve zero-carbon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

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

Image courtesy PassivHaus Institut Darmstadt

"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"

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.

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 very low specific space heating requirement of 15 kWh/(m^2 a) must be achieved and the ventilation system must be correctly specified, designed and commissioned.

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

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/(m² a) – this is the overarching requirement[1].

The figure of 15kWh/(m² a) has been arrived at from calculating the maximum amount of heat that can be delivered using the fresh supply air at the minimum required ventilation rate.

It is limited to 15kWh/(m² a) 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.

Without achieving the PassivHaus space heating requirement of 15 kWh/(m² a) or less, criteria 1 & 2 will not be achieved and thus it is not recommended to try and heat a dwelling using the fresh incoming air.

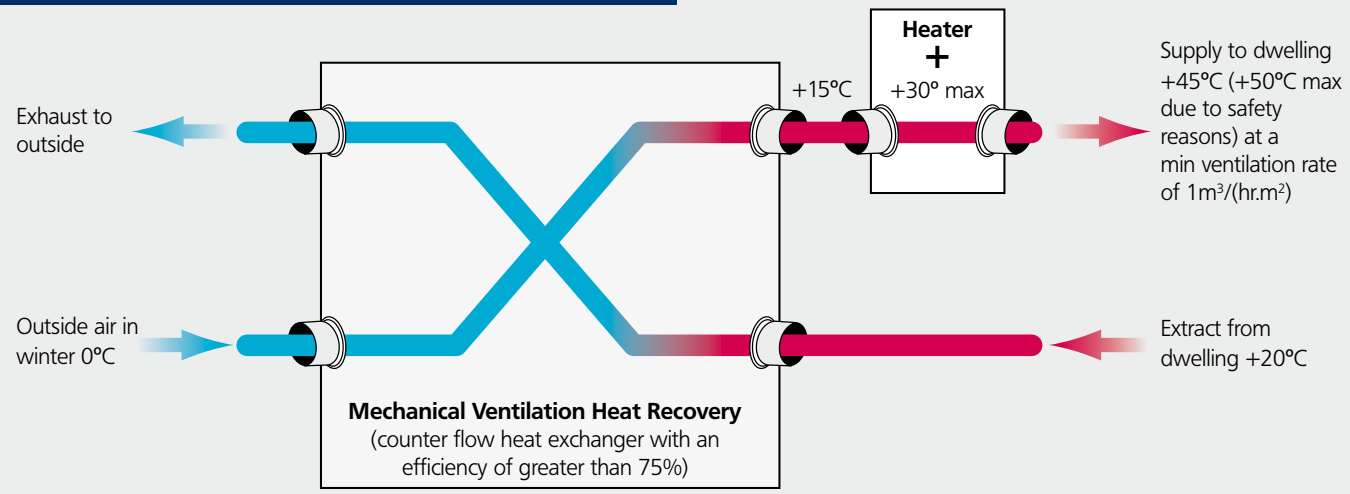
Achieving a space heating requirement of 15 kWh/(m² a) or less means that the following headline features are specified:

- Super-insulation: opaque U-values must be less than 0.15 W/m²K
- U-values for windows and doors need to be 0.8 W/m²K or less (for both the frame and glazing). This requires the window frame to incorporate insulation and triple glazing
- Thermal bridging needs to be minimised, and ideally eliminated
- Airtightness: n_{50} of 0.6 h^{-1} @ 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. In addition to this there are further criteria for projects undergoing "Quality Approved" certification. (Please contact BRE.)

1 In addition to this the total primary energy demand must not exceed 120 kWh/(m² a).

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/m² or less:

$$1\,m^3/(hr.m^2) \times 30°C \times 0.33\ Wh/(m^3K) = 10\ W/m^2$$

- 1m³/(hr.m²): Min. ventilation rate
- 30°C: Maximum heat input which can be provided via the fresh incoming air
- 0.33: Specific heat capacity of air

This translates to a maximum heating requirement of 15 kWh/m²/yr

PASSIVHAUS PLANNING PACKAGE (PHPP)

The elemental specification provided above is a good starting point, however the PassivHaus space heating requirement of 15 kWh/(m² a) 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).

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/m²K.
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.

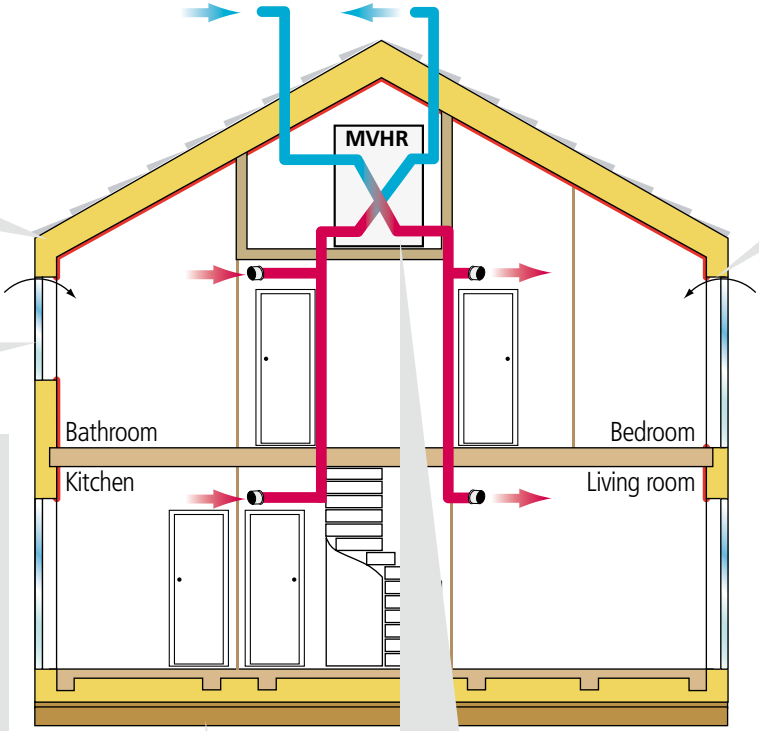
During hot periods in summer, a high level of thermal insulation is a protection against heat. To ensure high thermal comfort during summer, well designed shading and sufficient ventilation are important, too. All construction methods can be used for PassivHaus and have been tested successfully: masonry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

Airtightness

n_{50} of 0.6 h^{-1} @ 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/m²K 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 of 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.

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 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 an MVHR unit runs continuously, 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.

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.

COMPLETED PASSIVHAUS IN THE UK

FIRST CERTIFIED NON-DOMESTIC PASSIVHAUS

Canolfan Hyddgen is a new 410 m^2, £1.2m training, education and customer service center situated in the Dyfi Valley in Wales. The eco-friendly building has been co-funded by the Wales Assembly Government's Pathinder Programme and Powys County Council.

JPW Construction set out to achieve BREEAM excellent and PassivHaus certification concurrently and as a result achieved 84.4% Excellent (best to date in Wales) and won the Welsh BREEAM 2009 award, and through this route achieves a rating in band A.

It is also the first building in the public sector to be certified by the PassivHaus Institute in the UK.

JPW's mixed building approach included:

- A recycled central masonry core with GGBS in situ GF slab and external solid timber frame (using MMC) and I-beam cassette roof.
- Recycled material from an abandoned school canteen was integrated into the oversite, landscaping and new building.
- An air-tight/breathable membrane together with excellent on-site quality control ensured a compliant n_{50} air tightness result of 0.249 h^{-1} @ 50Pa (requirement is 0.6 h^{-1}).
- A decentralised ventilation system with timer and PIR controls was preferred due to the multiple and varied tenancy.
- Primary energy use and standby losses were reduced by using a combination of natural daylighting combined and artificial lighting controls, timers for IT sockets and instantaneous domestic hot water.
- A simplified Building Energy Management System linked to the county hall allows the building to be controlled and monitored remotely. This circumvents expensive and CO_2 demanding travelling by maintenance personnel across the most vast county in Wales.

TECH SPECS

Walls	0.16 W/m^2k
Roof	0.11 W/m^2k
Windows	PassivHaus certified
Thermal Bridging	Negligible (< 0.01 W/m^2 K)
Air tightness (n_{50})	0.249 h^{-1} @ 50 Pa
Overheating chance	0.6% (> 25°C) Night time secure cooling via ventilation system in summer bypass mode
Heating/ ventilation	Decentralised MVHR (five units) and gas auxiliary space heating
Appliances & lighting	T5 LEL and PIR controls
Hot water	Instantaneous 15L DHW gas heaters at point of use; low flow taps
Renewables	7 kWp of PV; the planned 2nd phase will add a wind turbine
Costs	**Basic building - £1537/m^2** • with PV and green roof - £1721/m^2 • plus canopy - £1784/m^2 • to meet BREEAM Excellent - £1858/m^2

FIRST CERTIFIED DWELLING

The PassivHaus certified project of Y foel set out to achieve an energy self sufficient carbon neutral home that does not compromise comfort. Two guiding objectives led the project:

- to reduce water and energy consumption
- to utilize energy generated on-site via renewable sources

The 2/3 bedroom private dwelling consists of an external I-beam timber frame with an internal earth block floor (ground floor). Welsh slate floor slabs were used on an in-situ 60% GGBS Slab. Further resource efficient features include a dry composting toilet, external cold store, breathable paints, MVHR with frost protection and preheat system for the ventilation unit. Silencers were used on the AHU to achieve inaudible noise levels from the unit (<25db). 100% LEL and 4m^2 of solar thermal collectors were installed, further enhancing the home's sustainability credentials.

CONSULTANCY AND CERTIFICATION

BRE is registered with the Passivhaus Institut in Darmstadt, Germany 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 BRE is able to provide a complete PassivHaus design advice service and can capitalise on 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:

Design Stage

Drawings and relevant technical data submitted to BRE

BRE assesses the design to verify compliance with the PassivHaus standard

Discussion with designer and stakeholders and amendments are made

PASS
Letter of design approval is issued

FAIL
If the design fails to meet the design standard a short report is produced highlighting items for consideration

Construction

Pressure test and onsite checks for quality of construction are carried out prior to completion

Note: To issue a certificate a minimum of one onsite check by BRE is required – this visit should ideally coincide with the airtightness test. BRE is able to provide this airtightness testing service, although another contractor may be used if preferred

Completion

PHPP assessment is amended as necessary to reflect as-built performance and certificate is issued

Qualitätsgeprüftes PASSIVHAUS Dr. Wolfgang Feist

Clients designing buildings to the PassivHaus standard should obtain a full and comprehensive copy of the certification requirements from the website: **www.passivhaus.org.uk**

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

CONTACT US

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Leeds Metropolitan University - Student Residence
Sheppard Construction / University Partnerships Programme

OTHER UK PROJECTS AIMING FOR PASSIVHAUS:

Racecourse Estate, Houghton-le-Spring, Gentoo / Devereux Architects

Ebbw Vale – The Works, Wales,
HLM Architects

New-build dwellings, London,
Matrix Bau Ltd / Kaufmann

Office Development, Kent, Van Developments