1 Introduction

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This guide highlights the key aspects of designing to the Passivhaus standard and the dos and don'ts for how to successfully build a Passivhaus.

CLIMATE AND COST-OF-LIVING CRISIS

If we are to prevent climate breakdown, we need to radically reduce energy demand and drive building energy efficiency. We cannot simply generate more zero-carbon energy supply, because of the limitations of grid capacity, peak load, and demands for renewable energy from other sectors.

EFFICIENCY FIRST

When determining the most impactful way to cut emissions in the built environment, we must consider embodied and operational carbon holistically. Passivhaus prioritises efficiency, of both energy and material resources. Passivhaus buildings are optimised for net zero, providing the best route to minimise whole life carbon. Outstanding levels of building performance minimise operational carbon, while the Passivhaus design methodology can also be used to encourage optimisation of embodied carbon. This can be through the optimisation of the building's form factor leading to a more efficient use of materials and through reducing the heating and cooling systems.

> *"I was working as a physicist. I read that the construction industry had experimented with adding insulation to new buildings and that energy consumption had failed to reduce. This offended me – it was counter to the basic laws of physics. I knew that they must be doing something wrong. So I made it my mission to find out what, and to establish what was needed to do it right."*
>
> **Prof. Dr. Wolfgang Feist**

Passivhaus delivers outstanding levels of energy efficiency, typically using half the energy of a new build home. It enables the levels of demand reduction that we will need to achieve net zero nationally and globally. Passivhaus also provides exceptional levels of interior comfort, health, wellbeing, affordability, resilience, and durability.

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pht.guide/claimingPassivhaus

PASSIVHAUS BUILDINGS

- Are optimised for net zero
- Consistently perform to design targets
- Are the best fit for a decarbonised grid
- Deliver health and wellbeing benefits
- Tackle fuel poverty

PASSIVHAUS SOLUTIONS

Passivhaus is an international tool, backed by 30 years of evidence, that provides us with a range of proven approaches to deliver new and existing buildings optimised for net zero. The Passivhaus standard provides solutions to the current hurdles to achieving net zero in the UK. This is no time to reinvent the wheel – the tools we need to deliver on our climate pledges exist today, so let's get to work!

What makes Passivhaus different from the plethora of other standards out there is its design and construction quality. This effectively eliminates the 'performance gap', delivering excellent performance in-use. The 'performance gap' is the difference between the assumed energy performance of a building based on its design and the energy performance a building actually achieves. From the monitoring of thousands of built Passivhaus buildings, energy use on average is extremely close to the amount that the modelling predicts. An average non-Passivhaus new home, by contrast, can have a heating demand of 60% more than that forecast using SAP modelling.

Certified Passivhaus projects demonstrate that performance is delivered through high quality design and construction, rather than just through adding more insulation or a high-performance component or two.

Passivhaus is not a trademark. However, if someone claims that a building is a Passivhaus, they are claiming that it meets the standard's strict energy and comfort requirements. Unlike 'eco-home' or 'sustainable building', to describe a building as a Passivhaus is a strong and verifiable claim under Trading Standards. The Passivhaus Trust document *Claiming the Passivhaus Standard* (PHT, 2022) clarifies this.

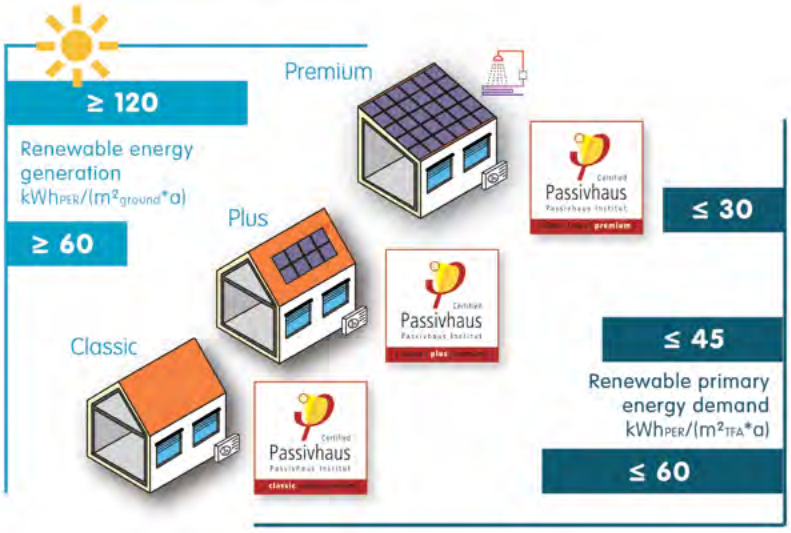
Passivhaus buildings provide a high level of occupant comfort while using very little energy for heating and cooling. They are built with meticulous attention to detail and rigorous design and construction quality according to principles developed by the Passive House Institute in Germany and are certified through an exacting quality assurance process.

PASSIVHAUS STANDARDS: CLASSIC, PLUS & PREMIUM

As Passivhaus continues to grow in the UK and the rest of Europe, many projects are using the Passivhaus Standard to deliver against net zero targets. A robust way to achieve this is to reduce energy demand to the Passivhaus Classic standard level and source renewable energy to meet the remaining demand. The renewable energy might be generated on-site or at a more economic scale; large scale renewables have the potential for a much lower life cycle cost and lower embodied carbon than domestic building-mounted PV.

For those who wish to demonstrate compliance with emerging definitions of net zero at the building level, **Passivhaus Plus** and **Passivhaus Premium** offer a rigorous methodology. These standards include the use of renewable energy generation in the certification assessment. They also require a further reduction in demand, making them suitable for more ambitious projects.

The **Passivhaus Plus** standard not only drastically reduces energy use, but for a typical two storey family home it will also produce, from renewable sources, as much energy as occupants consume, turning them into Passivhaus powerhouses. By most UK definitions, these would be considered net zero buildings, although this is not the most efficient way to meet national or global net zero targets.



The Passivhaus classes

For a typical two storey family home certified to the **Passivhaus Premium** standard, far more energy is produced than needed, even once storage losses are accounted for. It is therefore a goal for the particularly ambitious: building owners and designers who want to go beyond what economic and ecological considerations already propose. The Passivhaus Classic standard along with these additional classes make the Passivhaus standard the most appropriate target for our net zero future.

Top left: Chiswick Eco Lodge, Passivhaus Classic
Bottom left: Bristol Passivhaus Plus
Below: Erne Campus, Passivhaus Premium

Passivhaus criteria	Classic (new build)		EnerPHit (retrofit)	Plus (new build + retrofit)	Premium (new build + retrofit)
Airtightness n_{50}	**≤ 0.6** ACH @ 50 Pa		**≤ 1** ACH @ 50 Pa		
Space Heating Demand (SHD)	**≤ 15** kWh/m².a	–	**≤ 25** kWh/m².a (variable)		
Heating load	–	**≤ 10** W/m²	–		
Primary Energy Renewable (PER)	**≤ 60** kWh/m².a		**≤ 60** kWh/m².a (variable)	**≤ 45** kWh/m².a	**≤ 30** kWh/m².a
Renewable energy generation	–			**≥ 60** kWh/m².a	**≥ 120** kWh/m².a
Summer overheating	Max **10%** at > 25°C				
Surface temperature	**> 17°C**				
Ventilation	**> 20** m³/hr.person				

PER varies by building use, and, in retrofit, by allowance for larger heating and cooling demand compared to a new build.
In addition, all classes allow for ±15 kWh/m².a deviation from the PER criteria, with compensation through additional generation.

HEADLINE CRITERIA

The table above shows headline criteria for all Passivhaus classes. Readers must refer to the full criteria to ensure they have the correct values for their specific project – variations may apply.

As a measure of energy efficiency, Passivhaus offers a choice from two alternative criteria for heating – peak heating load in W/m² or space heating demand in kWh/m².a. By reducing heating and cooling load to a very low level we achieve excellent comfort, simplified building services and very low energy use.

For EnerPHit, the heating demand target varies according to climate zone, of which the UK spans three, most falling into 25 kWh/m².a.

As well as heat demand, Passivhaus also has strict limits for total energy demand. This is evaluated using the Primary Energy Renewable (PER) metric, which takes into account the characteristics of a future fully renewable grid, including distribution and storage losses and seasonality. It thereby incentivises optimum building fabric performance and energy efficiency. Read the in-depth explanation on Passipedia, the Passive House Institute's online encyclopedia for all things Passivhaus.

On-site renewable energy generation is assessed in terms of m² of building footprint, so multi-storey buildings which have less roof space in relation to internal floor area are not excluded from the Plus and Premium standards.

Other criteria address comfort, including ventilation. Here, we recommend supply air is set at 30 m³/h.person. The 20 m³/h.person basic criterion is a minimum, but it is not expected to be sufficient for UK homes because of our mild and damp climate.

Overheating is limited to no more than 10% of the year at over 25°C for certification. However, best practice is <2% of the year, and additional risk assessments and stress testing to take into account future climate and occupant behaviour are recommended, following the guidance in *Avoiding summer overheating* (PHT, 2021).

The surface temperature criterion not only addresses indoor comfort – eliminating the sensation of cold from chilly spots – but also protects the building fabric from the dangers of condensation and mould, with their detrimental impact on occupants' health.

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pht.guide/summer

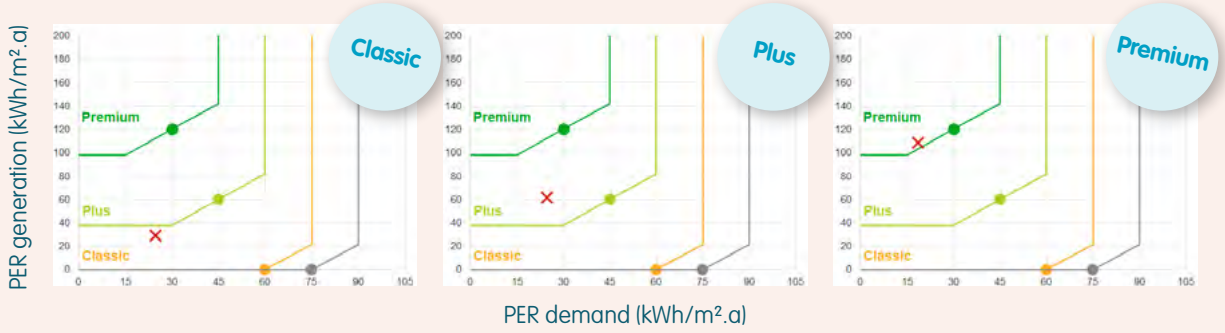
"As contractors, the Passivhaus approach is a quality standard helping us to deliver projects profitably by avoiding costly defects and callbacks. At Makar, we prioritise getting things right first time, and to a high standard of quality. This is why we follow Passivhaus principles."

Neil Sutherland, Architect & Director, MAKAR

Certified Passivhaus plaque, Lucy Cavendish student accommodation. Image: Tom Foggins

CLASS AMBITIONS

Get the basics right, and upgrading your Passivhaus Classic to Plus or Premium could be as easy as adding solar power and improving your appliances. The graphs below show the energy demand of a 2-storey detached dwelling (the red x) against the Classic, Plus and Premium criteria. To meet Passivhaus Classic, the house is already optimised for building performance and is heated with an efficient heat pump. Simply filling the south roof with PV upgrades the house to Passivhaus Plus, and a hypothetical step up to Passivhaus Premium would need only the addition of more PV on the north roof, best efficiency appliances and shower water heat recovery. This is one example - there are many ways to meet the higher classess.



CASE STUDY: Agar Grove

Above: Agar Grove Phases 1a and 1b aerial photo
Below: Phase 1b with Phase 1c under construction in the background.
Images: Architype

Agar Grove is set to be the largest Passivhaus development in the UK so far. Replacing existing 1960s H-shaped housing blocks, 345 affordable Passivhaus homes are being built for new and existing tenants in the London Borough of Camden.

Delivered over a total of 6 phases, each iteration is offering scope for learning and improvement for the delivery teams. A different approach to services and heating systems has been developed to respond to both post occupancy evaluation (POE) from earlier phases and to the wider decarbonisation of the UK's electricity supply. Phase 1A saw a communal MVHR system, while Phase 1B provided individual MVHR units for each apartment. Phase 1C is currently under construction (projected for completion in 2024) and will be all-electric, using an innovative ambient loop heat pump system.

Monitoring data on the first phase has shown that internal temperatures rarely dropped below 21°C in winter, and only rose above 26°C in peak summer months, with temperature peaks being rare. All respondents felt the air quality was good. The feedback on summer temperatures was more mixed and has prompted Camden to help residents understand how to best keep their flats cool.

Agar Grove exemplifies the collaborative approach and knowledge sharing that is typical of Passivhaus projects. Its success proves the relevance of Passivhaus in the UK at scale, and as an approach that aligns with local authority requirements on creating sustainable neighbourhoods, not only one-off sustainable developments.

RETROFIT

We need to massively reduce operational energy in our buildings, but it is essential that we think retrofit first, new build second. Retrofitting will play a vital role in mitigating the climate crisis. There are substantial embodied carbon savings made in repurposing existing buildings, compared with the ultra-high embodied energy costs of demolition and rebuilding.

LEARN MORE

pht.guide/retrofit

RETROFIT PAPER AND PRIMER

EnerPHit has a well defined process, very similar to the Passivhaus new build process, which helps to avoid the energy performance gap. The process is helpful, even when a lower standard is being targeted. It is a whole building approach which sets an exemplar standard for the energy and comfort performance of retrofit.

How far should our retrofit strategy go? Achieving net zero, improving health, eliminating fuel poverty and realising broader societal benefits are most likely to be achieved by a deep level of retrofit resulting in significant energy demand reduction.

> *"Despite having emissions reduction targets, government action is still lagging behind the policy ambition, and progress on retrofitting of existing buildings is flagged as 'significantly off track'"*
>
> **CCC**

There are two ways to meet the EnerPHit standard, the **heating demand method** or the **component method**.

The heating demand method uses the same criteria as Passivhaus Classic new build, but with a small relaxation for certain metrics. Achieving EnerPHit using the heating demand method will result in a retrofitted building with a space heat demand 80% lower than the national UK building stock average. The component method is an alternative approach that sets limits for the thermal performance of the building elements alongside the same targets for airtightness, ventilation, and surface temperatures. The component method option was developed to cater for buildings where the orientation, form factor, and glazing preclude achieving the required space heating demand, even when the fabric has been upgraded to levels commensurate with Passivhaus performance.

ENERPHIT OPTIONS

- **Heating demand method**
  This approach typically delivers buildings with a space heating demand of ≤25 kWh/m².a in the UK
- **Component method**
  This approach typically delivers buildings with a space heating demand of 30-40 kWh/m².a in the UK
- **Step-by-step approach**
  Work carefully planned & spread over multiple stages. Suitable for both heating demand and component methods

Shallow retrofit

30% space heating demand reduction leads to:

Reduced carbon emissions
Large renewable energy demand
Large peak demand
More grid storage required
Little change in energy bills
Limited health benefits

Deep retrofit

75% space heating demand reduction leads to:

Reduced carbon emissions
Reduced renewable energy demand
Reduced peak load
Less grid storage required
Significantly lower energy bills
Improved health & comfort

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pht.guide/largeandcomplex

NON-DOMESTIC AND LARGE & COMPLEX BUILDINGS

As the adoption of Passivhaus continues to grow in the UK, we are seeing more sizeable projects emerge with increasing complexities and challenges. This guide is aimed at those new to the delivery of Passivhaus projects and is not expected to cover the complexities of large-scale Passivhaus projects. Experienced Passivhaus Designers and Consultants are on hand around the UK to assist with these more challenging projects.

St Sidwell's Point, Exeter – Gale and Snowden © Tom Hargreaves

WHOLE LIFE VALUE

Lower heating running costs mean that Passivhaus homes offer significant whole life cost savings over a current building regulations home. A Passivhaus building is already optimised for net zero and will not need future retrofitting to meet zero carbon targets. By contrast, a building constructed to current building regulations compliance may need substantial investment in often disruptive fabric upgrades over time. Additional financial benefits such as better mortgage rates and lower maintenance costs result in even quicker payback periods and larger whole life benefits for Passivhaus buildings.

> *"The City of Edinburgh Council has adopted certified Passivhaus as a proven approach. It provides clarity around design and construction expectations, thereby ensuring building performance and user comfort expectations are delivered."*
>
> **Patrick Brown, Head of Capital Programme Team, City of Edinburgh Council**

PASSIVHAUS BENEFITS

With outstanding levels of building performance, Passivhaus delivers exceptional levels of comfort, health and wellbeing, affordability, resilience and durability, as explored in detail in *Passivhaus benefits* (PHT, 2021).

Individual homeowners will be interested in comfort and the excellent indoor air quality, as well as the lower energy bills.

Local authorities may focus on tackling fuel poverty, improving health outcomes, and meeting zero carbon pledges.

Government and energy suppliers may be attracted to the sound economics of lowering peak demand, minimising budgets for large scale infrastructure costs, and amplifying the resilience of a national grid that is fit for the 21st century.

SUMMARY

Passivhaus is a tried and tested 'fabric first' building standard and methodology, backed by over 30 years of international evidence. It produces buildings with a high level of occupant comfort that use very little energy for heating and cooling.

Analysis shows that reducing energy demands to Passivhaus levels is the only realistic way to achieve zero carbon without massive renewable energy expansion coupled with a significant, and expensive, investment in grid capacity and storage.

LEARN MORE

pht.guide/benefits