THE CONTINUING PROFESSIONAL DEVELOPMENT PROGRAMME

CPD

Fundamentals

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Passivhaus: delivering transformational buildings

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The UK is targeting a 78 per cent reduction in GHG emissions by 2035, leading towards Net Zero by 2050. Our built environment will play a pivotal role in delivering these targets, as the UK's building stock currently produces 27 per cent of our GHG emissions. Delivering on our GHG reduction and energy efficiency ambitions for the built environment would[1]:

- make our overall climate mitigation ambitions feasible, given the large proportion of emissions which come from buildings;
- deliver the most cost-effective route to reducing GHG emissions from buildings, since investments in energy efficiency are typically more attractive than those in renewable capacity;
- support the transition to a grid powered by renewables by significantly reducing the total demand for electricity, and the peak loads which the grid must be sized to meet;
- enable the transition to heat pumps as gas boilers are phased out, by delivering efficient buildings which have the low and steady heat demand profiles that best suit heat pumps;
- create business opportunities and jobs. It is estimated that the energy retrofit sector will create 2m new jobs as we deliver our GHG emission reduction targets for buildings;
- reduce fuel bills, improving competitiveness for industry and addressing the fuel poverty faced by 3.3m UK households;
- transform our built environment, delivering fresh air year-round via mechanical ventilation with heat recovery, plus stable temperatures for warmth in the winter and avoiding summertime overheating; and
- radically improve health and wellbeing by tackling the millions of cold, damp and uncomfortable buildings which impact the population's productivity and wellbeing at work and health and comfort at home. For example, treating conditions related to poor quality housing is estimated to cost the NHS £1.4bn each year.

While the technologies exist to deliver new build and retrofit projects to net zero emission levels of performance, there is a need to accelerate and formalise the means of delivering these projects at scale. This is where the Passivhaus standard provides an excellent insight as to what is possible and how it might be delivered.

First developed in Germany

The first Passivhaus was developed in Germany in 1990 and since then approximately 60,000 buildings have been delivered to this outstanding level of performance. The BRE states: "The core focus of Passivhaus is to dramatically reduce the requirement for space heating and cooling, whilst also creating excellent indoor comfort levels. This is primarily achieved by adopting a fabric first approach to the design …which can be applied not only to the residential sector but also to commercial, industrial and public buildings"[2].

Although Passivhaus is a voluntary standard, it is fast becoming the reference point for those looking to deliver on climate ambitions, to help tenants avoid fuel poverty, and to deliver health and wellbeing via excellent levels of thermal comfort and air quality. The standard has been successfully applied to a wide range of building types, including residential, schools, offices, hospitals, sports halls, industrial buildings, museums, supermarkets, and other commercial settings. The Passivhaus database holds examples of different applications within many sectors and from around the world, also promoting Passivhaus open days for those who wish to take a closer look[3].

One common concern is that building to the Passivhaus standard is too expensive to be applicable in mainstream circumstances. However, this is far from the case, for example as evidenced by the success of 'Exeter City Living' in championing Passivhaus in various forms of social housing[4]; or the Goldsmith Street development which won the 2019 Stirling Prize awarded by RIBA, plus the Neave Brown Award for the best examples of affordable housing[5]. The cost of delivering Passivhaus projects has rapidly fallen as experience of the 60,000 or so Passivhaus projects delivered to date has supported innovation and learning. In 2015, a cost uplift of 15-20 per cent was to be expected when building to the Passivhaus standard, this was assessed to have fallen to 8 per cent in a study reviewing 2018 data, with a projection that the cost uplift could be reduced to 4 per cent as Passivhaus is adopted at scale[6]. Certainly, project teams are reporting that if Passivhaus is adopted at early stages of a development, so that optimisation of the design can be used to manage costs, then cost need not be a barrier to the adoption of Passivhaus standard.

Core Passivhaus Criteria

METRIC	PERFORMANCE THRESHOLD	OBJECTIVE
Space heating demand	<15 kWh/m².yr	Manages building fabric losses.
Primary energy demand (PER) including all energy uses	<60 kWh/m².yr	Manages total energy use within the building to ensure an efficient fabric is not compromised by high levels of energy use within the building. Reduces internal gains, helping to manage summer comfort / overheating and rewards the use of efficient sources of heat generation and onsite renewables.
Airtightness	<0.6 ACH @ 50 Pa	Avoids uncontrolled losses through draughts and enables the use of mechanical ventilation with heat recovery, saving energy and giving excellent air quality year-round, even in the winter when windows are typically closed. Protects the building fabric from moisture damage.
Frequency of overheating	Internal temperature below 25°C for at least 90 per cent of the year, with a 95 per cent threshold typically applied as best practice.	Ensures that the building is comfortable year-round, e.g. guiding glazing design and the management of internal gains.

(NB: UK values shown, other localities use different values based upon regional climate data)

'Agnostic' construction type

The Passivhaus standard is 'agnostic' in terms of construction type and has been successfully applied to a wide range of systems. Passivhaus can be achieved with all standard construction techniques and shouldn't impinge upon design creativity, especially if considered from the project outset. Rather than being prescriptive in how the targets are met, Passivhaus sets some basic performance parameters, leaving how they are achieved to be decided on a project-by-project basis.

Rather than describe these criteria in more detail here, the summary in the table above gives a sense of their purpose, while the full list of the certification criteria for Passivhaus is available online.[7]

In terms of delivery, the Passivhaus standard provides a set of performance thresholds, a calculation tool, and a certification/quality control process which ensures that a project clears three hurdles: design, construction, and commissioning. The Passivhaus standard has consistently closed the historic 'performance gap' between the performance of a building as anticipated at the design stage, versus their actual performance in use.[8]

The concepts underpinning Passivhaus designs are discussed below and covered in more detail by the Passivhaus Easi Guide, which does an excellent job of demystifying the process of designing to the Passivhaus standard and is suggested reading to complement this CPD article.

- **free heat in winter from solar gains. Orientate predominant facades south, or at least ideally no more than +/- 30º from south.** Locate living and other primary spaces with larger windows on the south facade, shade these using horizontal shading to protect from high angle summer sun. Limit overshadowing by considering how buildings will impact each other in terms of developing a site plan.
- **simple building form (i.e. shape) for the building's warm spaces, reducing heat losses by presenting a low exposed surface area.** Be clear about the line of the thermal envelope of the building. Delineate and cluster cold spaces such as bike and bin stores early on, and ideally locate them on the north facade, since they do not make use of solar gains. Use thermally independent elements to add character to the design without compromising performance. For example, porches, balconies, and other external features can be made free standing and independent of significant interaction with the thermal envelope of the building. This approach helps to avoid unnecessary heat losses without compromising project aesthetics.

The 'form factor' of 'exposed external surface area' divided by 'internal floor area' is a useful metric for comparing options and optimising designs.

- **high levels of insulation and significantly reduced thermal bridges.** The U-values required will depend to a certain extent upon the building's orientation, form factor and other design decisions. See section 7 of the Passivhaus Easi guide for typical values and build ups of different building elements. It is important to maintain a continuous thermal envelope, avoiding 'thermal bridges' which break the insulation layer with non-insulating materials.

This is best done by clearly delineating a 'structural' zone of the construction, separate to an 'insulation' zone as far as possible. Utilising standard details and construction systems can help in these efforts.[10]

- **an extremely airtight building fabric coupled with efficient background mechanical ventilation with heat recovery (MVHR).** Avoids energy losses and comfort issues associated with draughts and enables the use of mechanical ventilation with heat recovery, saving energy and giving excellent year-round air quality, even in the winter when windows are typically closed. Protects the building fabric from moisture damage caused by uncontrolled movement of moist air. It is suggested that MVHR units should not be located in a living room or bedroom to help with noise management. Whatever the location, Passivhaus sets sound level thresholds which are verified via measurement post construction to ensure that MVHR does not cause any noise issues.
- **high-performance triple glazed windows with window proportions that are based on orientation.** Windows are an important part of the energy balance of a Passivhaus and should be sized and managed across each elevation to maximise solar gain during the heating season and to minimise summertime overheating.

With these ambitions in mind, suggested glazing ratios for each elevation are: north - 10-15 per cent (minimise losses as there are few solar gains here); east/west - 10-20 per cent (losses less of an issue than north facing, also needs careful consideration to manage overheating due to low angle sun); south - 20-30 per cent (making the most of solar gains, perhaps with horizontal shading to avoid overheating by blocking high angle summer sun).

Window installation details require careful consideration to avoid thermal bridging defeating the performance of high-quality triple glazing. Windows should be installed in line with the insulation layer, ideally with insulation overlapping the frames

Finally, Passivhaus specifies that windows should open to provide purge ventilation and to support the management of overheating via night time ventilation in the summer. The opening windows will ideally work together to provide 'cross ventilation' across the floorplan, or 'stack ventilation' which is achieved when the

The concepts underpinning Passivhaus design and delivery are summarised extremely well in the Passivhaus Easi Guide. It focuses upon medium density housing, but the principles discussed apply to all Passivhaus projects.[9]

windows are at different heights.

• **accurately predicted energy use modelling via the Passive House Planning Package (PHPP).** The PHPP tool creates an energy balance for the project. Total losses are tallied by source: i.e. from controlled ventilation, infiltration (uncontrolled draughts), thermal bridges, plus heat losses via the walls, floor, roof and windows

These losses are then referenced against the total solar gains from the sun, plus internal gains from occupants and equipment in the building. The difference is made up by the heating system and this value per unit of floor area defines one of the fundamental performance metrics of the Passivhaus standard. The model tracks the design from early stages, where it can be used to assess options during design optimisation, through to post completion where it is updated with 'as built values' such as the air test result and any changes to insulation products used.

The PHPP model therefore acts as the backbone for the quality assurance process, since certification is based upon the final 'as built' PHPP model.

• **appropriate allowances and frameworks for retrofit projects.** The Passivhaus methodology and associated PHPP modelling is applied to retrofit projects via the EnerPHit standard.[11] The standard makes some allowances for reduced performance when dealing with existing buildings, for example reflecting that building orientation and glazing ratios are already largely fixed.

The standard also makes allowance for 'difficult-to-treat' buildings, via the component route which instead of setting an absolute performance standard for the building as a whole, sets performance criteria which each element must meet, effectively acknowledging that the building has reached the best it could be.

Finally, it is possible to undertake a staged EnerPHit project, whereby a whole building design is developed, and the work is undertaken as part of an ongoing asset management programme as building elements such as the roof, or windows reach a natural point where replacement is due. This staged EnerPHit helps to ensure a holistic design is developed, avoiding any false starts and conflicts between early work and following steps.

• **robust quality assurance processes during construction and commissioning, plus independent certification.** The Passivhaus standard requires the submission of a detailed set of construction evidence and commissioning results to confirm that the design intent has been upheld at these later stages of the project.

Collation of this data and preparation of the PHPP model for the project is undertaken by the Passivhaus Designer, whose work is checked against supporting evidence by an independent Passivhaus Certifier. The status of Passivhaus certifiers and designers can be verified via a central database.[12] Examples of the site evidence required, and a typical site manager's declaration are available online, for example via Passivhaus certification providers.[13]

It is essential that the construction team understand and are onboard with the requirements of Passivhaus. It can help to either hire certified Passivhaus tradespeople, or to have key members of the team take this qualification. It is also recommended to appoint an Air Tightness Champion for the project to oversee connections between trades and the delivery of key details. Site training upfront, toolbox talks, and subsequent visits by the designer and sometimes also the certifier give important opportunities to engage the site team and spot any issues early on, while they can still be rectified.

There are several courses which would represent logical next steps if you want to learn more about the Passivhaus standard and contribute to the opportunity to decarbonise the built environment as part of our response to climate change.[14] For example, the Certified Passivhaus Designer course requires a commitment of roughly 100 hours, at a cost of around £2,000.

REFERENCES

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14) https://passivhaustrust.org.uk/certified_training_events.php

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ENTRY FORM

Please mark your answers below by placing a cross in the box. Don't forget that some questions might have more than one correct answer. You may find it helpful to mark the answers in pencil first before filling in the final answers in ink. Once you have completed the answer sheet, return it to the address below. Photocopies are acceptable.

Questions

1. What is the significance of emission reductions in buildings to the UK's climate targets?
- ☐ Marginal, there are few energy savings to be made within our building stock.
- ☐ Pivotal, the UK's building stock currently produces 27 per cent of our GHG emissions.
- ☐ Zero, savings are available but prohibitively expensive to deliver.
- ☐ Small, savings are available, but buildings represent a small proportion of the UK's total GHG emissions.

2. Why are Passivhaus levels of energy efficiency essential when seeking to decarbonise the UK's building stock?
- ☐ Because energy efficiency represents the most cost-effective route to reducing GHG emissions from buildings.
- ☐ Because the savings delivered support the transition to a grid powered by renewables.
- ☐ Because efficient buildings support the adoption of heat pumps as gas boilers are phased out.
- ☐ All of the above

3. Isn't delivering buildings to the Passivhaus standard prohibitively expensive?
- ☐ Yes, Passivhaus is a standard for 'Grand Design' type projects only.
- ☐ Yes, the relatively modest certification fees involved are not recouped by the robust quality assurance process which improves project quality.
- ☐ No, the uplift for achieving Passivhaus has fallen rapidly, from 15-20 per cent in 2015, to 8 per cent in 2018, and is projected to settle at ~4 per cent as the standard is adopted at scale.
- ☐ No, delivering the Passivhaus standard is now always entirely cost neutral.

4. Which of the following best describes Passivhaus construction options?
- ☐ Passivhaus is easiest to achieve when using timber frame construction.
- ☐ Passivhaus is easiest to achieve when using insulated concrete formwork (ICF) construction.
- ☐ The Passivhaus standard is 'agnostic' in terms of construction techniques and has been applied to all standard construction types.
- ☐ Passivhaus is easiest to achieve when using traditional masonry construction.

5. Which of the following is a simple metric for comparing the 'form factor' of different design options?
- ☐ Form factor = exposed external surface area / internal floor area
- ☐ Form factor = exposed external surface area x internal floor area
- ☐ Form factor = internal floor area / exposed external surface area
- ☐ Form factor = energy demand / internal floor area

6. Which of the Passivhaus standard's performance thresholds helps ensure that an efficient building fabric is not compromised by high levels of energy use?
- ☐ Space heating demand: <15 kWh/m^2.yr
- ☐ Primary energy demand (PER): <60 kWh/m^2.yr
- ☐ Airtightness: <0.6 ACH @ 50 Pa
- ☐ Frequency of overheating: Internal temp. < 25°C for at least 90 per cent of the year

7. What is the upper limit for a facade to count as South facing, therefore maximizing solar gains during the heating period?
- ☐ +/- 5 degrees from South
- ☐ +/- 10 degrees from South
- ☐ +/- 30 degrees from South
- ☐ +/- 40 degrees from South

8. The thickness of insulation required to deliver Passivhaus....
- ☐ .... is not impacted by other design decisions on a project-by-project basis.
- ☐ .... is the same as that required by Building Regulations.
- ☐ .... can be looked up in standard tables and is fixed for all projects.
- ☐ .... varies project to project, for example depending upon the building's orientation, form factor, and other design decisions.

9. What is the airtightness threshold value for certification in new build projects?
- ☐ <0.6 ACH @ 50 Pa
- ☐ <0.5 ACH @ 50 Pa
- ☐ It isn't possible to say without first examining the building's form factor.
- ☐ >0.5 ACH @ 50 Pa

10. Why is it important to manage glazing ratios for each facade?
- ☐ Because North facing windows do not see much sun.
- ☐ Because East / West facing windows receive low angle morning and evening sun, making them harder to shade.
- ☐ Because South facing glazing receives good levels of sun and therefore offers net energy gains during the heating season.
- ☐ All of the above

Please complete your details below in block capitals.

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MARK THROWER Managing Editor

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