MISUNDERSTANDING PASSIVHAUS PRINCIPLES

BEING AWARE OF THE RISKS

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Misunderstanding Passivhaus Principles
Being Aware of the Risks

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> *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

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EXECUTIVE SUMMARY

As awareness of the Passivhaus standard has grown, some knowledge of the fundamental building principles which all such high-performance buildings have in common - for example, appropriate levels of continuous insulation and air tightness together with Mechanical Ventilation with Heat Recovery (MVHR) - has also spread throughout the industry. This must be seen as a positive. However, this has led to projects that have declared that they are following "Passivhaus principles" because they incorporate some or all those five building principles, while neglecting to follow an integrated approach that also encompasses the principles of detailed performance and comfort criteria, accurate performance modelling in PHPP, and rigorous quality assurance across design, construction, and commissioning. Taken together, these are the eight principles that enable certified Passivhaus projects to reliably deliver so many health, comfort and energy benefits.

This paper shows how attempting to incorporate some Passivhaus building principles without also following the principles of approach introduces significant risks. If looking to achieve the benefits delivered by Passivhaus buildings, clarity about the standard being targeted should be established early. Use of the Passivhaus Planning Package (PHPP) to produce an energy and comfort model from the earliest stage of design, followed by implementation of robust quality assurance, is fundamental.

"Based on the evidence to date and within the constraints of measurement uncertainty, Passivhaus buildings perform as predicted."

Far from being an onerous academic exercise, the use of PHPP is key to designing and building successfully. It encourages the integrated approach which is so central to buildings which function as designed. The final ingredient is robust quality assurance during the construction phase that ensures, on average, there is no performance gap. Based on the evidence to date and within the constraints of measurement uncertainty, Passivhaus buildings perform as predicted.

INTRODUCTION

The Passivhaus standard is arguably the world's most widely adopted as well as most rigorous standard for energy efficiency and comfort in buildings. One of the original drivers for developing the Passivhaus standard was to close the large gap between how buildings were designed to perform and how they perform once occupied. At the time, just like now, many buildings already had insulation and good glazing, but failed to perform as expected.

The Passive House Institute (PHI) in Darmstadt, Germany, developed the Passivhaus standard based on rigorous scientific research and testing. The term "Passivhaus" or "Passive House" is often used colloquially when referencing a building that has been designed to this internationally recognised standard. To support the quality that is offered by the standard, the PHI has defined requirements for Passivhaus buildings, products, designers and consultants. Quality assured Passivhaus buildings have a reputation, not only for energy efficiency, but also comfort and quality. This has led to a rapid growth in the adoption of the Standard and global interest in the buildings that result.

Within the UK, there have occasionally been claims that buildings meet or exceed the Passivhaus standard simply because they might meet one or more of the requirements of the Passivhaus standard. More frequently, claims have been made that buildings are designed using "Passivhaus principles" without meeting all of the requirements. For example, they may target (but not achieve) the airtightness criteria. Commonly, some construction details inspired by Passivhaus projects might have been incorporated while others, such as quantifying thermal bridging or correctly designing for optimum window installation, might have been neglected. Insulation may be included to levels that are akin to the frequently adopted U-values for Passivhaus, particularly as these are not far above those now required for Part L of the Building Regulations in England and Wales[1] or Section 6 of the Building Standards in Scotland, but without adequate attention to installation quality and avoiding thermal bypass on site. Alternatively, they may have been shown to have a space heating energy demand of less than 15 kWh/m^2.a using the UK's regulatory compliance tools SAP and SBEM. It is incorrect to claim that such a building satisfies the Passivhaus standard or that it adheres to the principles that underpin the standard.

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Throughout this paper, the term certified Passivhaus is used to describe a project that has undergone formal certification. Certification provides a level of quality assurance through third-party accreditation, which is why this remains the recommendation of the Passivhaus Trust[2]. The PHI established a process to certify buildings meeting the Passivhaus standard for good reason and publishes quality assurance criteria accordingly. Employing the five building principles (insulation, airtightness, ventilation, high-performance windows, and minimised thermal bridging) selectively and blindly, without appropriate modelling and quality assurance, introduces considerable risks. Skipping or avoiding the more compliance-focused requirements risks undermining energy performance, as well as summer and winter comfort and affordability, as highlighted in this paper and the associated case studies documented in Appendix 2.

1 Building Regulations in Wales were devolved to the Welsh Assembly (now Senedd) in 2012 so, although they are largely identical in terms of intent and compliance regimes, some differences do exist within the detailed standards.

2 According to the PHI, a building can be described as a Passivhaus without being certified. However, whether certified or not, the building must meet the exact same requirements and be modelled in the Passivhaus Planning Package (PHPP) to legitimately use the term Passivhaus. While it is reasonable to claim that such a building is a non-certified "self-declared Passivhaus", this is more open to misuse. Caution is advised when clients set this as a target, as the lack of formal certification increases the risk of the project not meeting the expected performance standards, including energy efficiency, comfort, and quality. Certification ensures third-party verification, providing greater assurance that the building meets the rigorous Passivhaus criteria.

PRINCIPLES, STANDARDS AND CERTIFICATION

Passivhaus is seen as the 'Gold Standard' of high comfort, low energy buildings. By adopting a whole building approach with clear performance criteria (see Appendix 1), focused on high-quality construction and certified through an exacting quality assurance process, it delivers high level occupant comfort using very little energy. This 'Gold Standard' perception has endured even as increasingly stringent Building Regulations now demand components such as insulation, glazing and airtight layers with levels of thermal performance ever closer to the requirements of the Passivhaus Standard.

The performance gap between design and in-use energy performance in the UK is well documented[3] and, conservatively, is found to result in a 60% increase in space heating demand in residential dwellings and often considerably more in non-residential buildings. Passivhaus buildings, by contrast, are reliably found to perform as designed on average.[4] The fully integrated approach incorporating the detailed performance and comfort criteria, the accuracy of modelling in PHPP and the stringent quality assurance process of Passivhaus certification are contributing factors towards these consistently successful outcomes. Where a building project omits accurate modelling, or the principle of quality assurance, it cannot be described as a Passivhaus and is not likely to perform as intended.

More detail on what it means to claim the Passivhaus standard is available in *Claiming Passivhaus* (PHT, 2025), available online at https://pht.guide/ClaimingPassivhaus, and more on the certification process and its benefits in *How to Build a Passivhaus: Good Practice Guide* (PHT, 2023) available online at https://pht.guide/HowTo. Furthermore, a body of best practice guidance is available for reference which enables designers to incorporate additional mitigation of factors such as overheating risk into a PHPP model.

Published evidence indicates that although certified Passivhaus projects can incur additional costs of around 4-8%, they offer numerous benefits over the building's lifespan. By achieving the highest levels of building performance, Passivhaus buildings deliver across many domains: responding to the climate emergency; supporting health and wellbeing; enabling better people performance; delivering social return; and offering financial benefits[5]. There are also instances where using the Passivhaus approach to optimise aspects such as form factor and fenestration has even lowered costs. It is hard to argue against the case that all new buildings should be designed with such an approach foremost from the outset.

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pht.guide/Benefits

However, sometimes projects have set out to target "Passivhaus principles", in the belief that most of the benefits can be gained without incurring the costs of the rigorous approach required to deliver a certified Passivhaus. This is to misunderstand the fundamental principles of Passivhaus, which include detailed performance and comfort criteria, accurate modelling, and robust quality assurance. In such cases, the phrase "Passivhaus principles" is being used without a clear definition or understanding, and usually only some, but not all, of the principles are applied. Such ill-defined approaches, as described below, increase project risks significantly.

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3 See, for example, David Johnston et al., 'Quantifying the domestic building fabric "performance gap"', Building Services Engineering Research & Technology (2015). Available online: https://doi.org/10.1177/0143624415570344

4 See, for example, Rachel Mitchell and Sukumar Natarajan, 'UK Passivhaus and the energy performance gap', Energy and Buildings (2020). Available online: https://doi.org/10.1016/j.enbuild.2020.110240; and D. Johnston et al., 'Are the energy savings of the Passive House standard reliable? A review of the as-built thermal and space heating performance of Passive House dwellings from 1990 to 2018', Energy Efficiency, Springer (2020). Available online: https://doi.org/10.1007/s12053-020-09855-7

5 See *Passivhaus Benefits* (PHT, 2021). Available online at: https://pht.guide/benefits

WHAT ARE THE "PASSIVHAUS PRINCIPLES"?

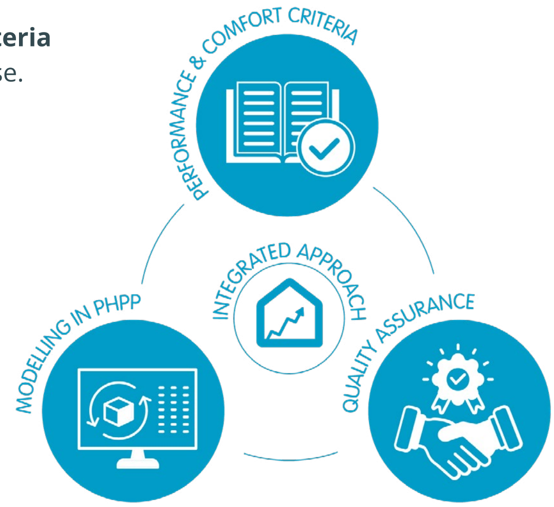
Passivhaus buildings are based on fundamental principles that together reliably deliver exceptional energy efficiency, comfort, and durability. As awareness of the Passivhaus standard has grown, so has appreciation of the underlying principles of building fabric: insulation, airtightness, ventilation, high-performance windows, and minimised thermal bridging. This must be seen as a positive. But these alone are not sufficient to reliably realise the high performance and the wide-ranging benefits of Passivhaus buildings. The three core principles of approach – detailed performance and comfort criteria, accurate modelling in PHPP, and rigorous quality assurance – are essential to successful delivery of a Passivhaus project.

It is the integration of all eight principles that enables a project to achieve the Passivhaus standard. Neglecting one risks undermining all.

PRINCIPLES OF APPROACH

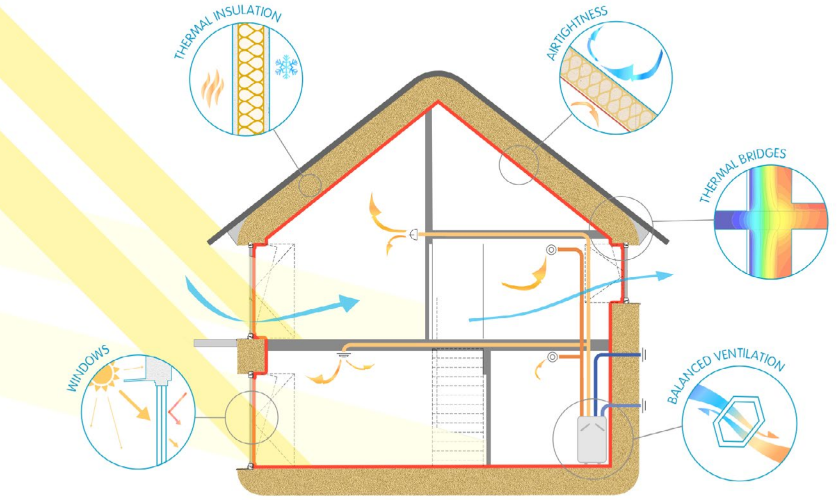
The three core principles of approach are detailed performance and comfort criteria, accurate performance modelling in PHPP, and rigorous quality assurance across design, construction, and commissioning. Together, these principles enable Passivhaus buildings to not only meet theoretical energy standards but also deliver on their real-world performance, comfort, and durability.

- Clearly defined and detailed **performance and comfort criteria** which are underpinned by a strong and proven evidence base.
- Every Passivhaus project must be modelled using the **Passivhaus Planning Package (PHPP)** for precise energy balance calculations and comfort assessments. It's both an invaluable design aid and a powerful tool for value engineering.
- **Quality assurance** is delivered through careful verification at every stage, so that the building delivers on its performance targets. Passivhaus Certification is independent and impartial, with the Certifier representing the best interests of the building and building owners, now and in the future.



BUILDING PRINCIPLES

By following these principles of approach, each Passivhaus building will have a project-specific solution which optimises the five key building principles:



- High performance **insulation** which is optimised for comfort, energy demand and the climate zone.
- Continuous, high performance **airtight** layer to minimise heat loss, eliminate draughts and maximise fabric longevity.
- **Thermal bridges** minimised to prevent cold spots and mould.
- High performance **window** specification & shading to provide optimum comfort and efficiency in summer and winter.
- Quiet and efficient mechanical **ventilation** with heat recovery (MVHR) delivering high indoor air quality.

PASSIVHAUS PLANNING PACKAGE (PHPP)

Far from being a mere compliance tool, required only for certification purposes, PHPP is an invaluable powerful design tool aid which can help to mitigate risks of poor energy performance, resident discomfort and excessive bills. Furthermore, it is ideal for value engineering, ensuring that the implications of any design choices are fully understood and that value for money is maximised. Even where budget is not the primary concern, PHPP can help highlight where design choices work against energy efficiency. As shown later in this paper, small issues that can easily be solved during design are clearly identified within PHPP, thus enabling the avoidance of expensive remediation measures or even permanent underperformance.

A basic PHPP model should be prepared at Concept stage by a competent individual, then developed throughout the design process through to completion. The decision of whether to pursue certification to one of the range of Passivhaus standards (PHI LEB; Passivhaus Classic; Passivhaus Plus; Passivhaus Premium) can even be informed by the PHPP model, and taken around the end of RIBA Stage 2 or even 3 once the implications are fully understood.

What are the benefits of an accurate design and compliance tool like PHPP?

The Passivhaus standard criteria (see Appendix 1) require a level of knowledge of building physics to understand and incorporate into design. Building physics is often not sufficiently covered by architectural training courses in the UK, or found in the skill sets of most clients. An ill-informed assumption to make is that, by incorporating some of the design principles above, the result will be a more energy efficient building as a matter of course. The thinking follows that if compliance with the certification criteria is not required, then a PHPP model is not required. However, it is critical to understand that PHPP was designed specifically for very low energy buildings – unlike other tools, it is not just a compliance tool, it is an invaluable design tool.

PHPP shows the designer how the elements such as insulation, form, glazing and orientation interact – it is this interaction that determines the year-round efficiency and comfort of the building – or the opposite. It is possible to have too much of a good thing. For example, heat loss and solar gain need to be balanced by considering proportions and orientation of glazing. Seasonal fluctuations also need to be understood to gain free heat in winter while mitigating summer overheating risks. If the interactions of the variety of factors which affect building energy performance – climate, solar radiation, form factor, insulation, glazing performance, air infiltration, ventilation etc. – are not considered and calculated, then the risks of unintended consequences rise significantly. PHPP allows a designer to consider design choices holistically. Without it, the risk of selecting unsuitable strategies rises.

Building context and climate is also considered within PHPP. In comparison to SAP, which effectively assumes that all buildings are in the same location, far more local information is available within the menu of climate files in PHPP. The altitude and exposure of a site, which has a considerable effect on building performance, is also entered as standard.

In modern industry parlance the term 'value engineering' (VE)' is usually used as cover for indiscriminate cost cutting. Wherever possible cheaper alternatives, whether in terms of materials or labour implications, are substituted and perspective of the bigger picture is lost. Correctly used, VE is an approach to a project which considers the cost of every component, yet only within the context of its function. That way, optimal value is achieved rather than lowest cost. This is an approach which fits very well with Passivhaus while PHPP is a very powerful VE tool. For example, PHPP encourages good building form factor – maximising the valuable floor area enclosed within the thermal envelope, which is where much of the cost is to be found. Similarly, careful consideration of the proportion of glazed areas on each elevation – through carefully balancing the inherently increased heat loss with the freely available solar gain – optimises the capital spend on an expensive component while minimising running costs and risks of overheating.

DETAILED PERFORMANCE AND COMFORT CRITERIA

At the heart of the Passivhaus standard is a whole-building energy balance — a rigorous calculation that ensures the overall performance of the building meets demanding but achievable limits. Unlike other standards that rely on fixed elemental targets (such as U-values for walls, roofs or floors), Passivhaus sets clear performance criteria for total space heating or peak heating load, overall energy demand, and — where relevant — on-site energy generation. Alongside these are comfort criteria that cover managing summer temperatures, airtightness, ventilation, and acoustic performance[6]. Together, these criteria provide a flexible yet robust framework: the energy balance approach allows for design freedom and the opportunity for value engineering, without compromising performance or comfort. Crucially, the criteria are based on well-established building physics and have been proven through thousands of successful projects worldwide. Their clarity helps reduce ambiguity and manage risk — supporting confident decision-making for clients, and offering consultants and contractors a clearly defined brief that can be priced, delivered, and insured with greater certainty.

QUALITY ASSURANCE

The ability to effectively eliminate the performance gap can only be delivered through rigorous quality assurance processes. Passivhaus Certification is independent and impartial, with the Certifier representing the best interests of the building and building owners, now and in the future. It involves a third party Passivhaus Certifier reviewing both the technical design and PHPP calculation as well as detailed construction information at key stages during the project. The Passivhaus Certifier may also help the designer navigate more technical or unusual aspects of modelling, and share experience of common issues from across a wide range of projects to help the design team prioritise design development.

Certification requires that overall design and construction is carried out with a calculated energy assessment within PHPP, with robust evidence including drawing information and supporting documentation on components and services. The attention to detail and quality checking principles help ensure that the planned building will actually perform as designed for energy efficiency and comfort.

The importance of appropriate operation of a building should not be overlooked. There is a clear role for activities such as:

- effective handover processes and occupant education regarding features, functions and use of the building;
- Post-Occupancy Evaluation (POE);
- appropriate maintenance regimes; and
- monitoring of building performance in terms of health, comfort and energy consumption.

The certification process effectively stops at the point of practical completion and occupation. However, certification does provide a solid basis for all such activities. Robust details, quality checked during construction, and photographic records provided accurate 'as-built' information while a PHPP model, verified by the Passivhaus Certifier and PHI, contains a precise model against which actual performance can be compared. The latest iteration of PHPP includes a monitoring tab into which performance data can be added for this purpose.

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pht.guide/Certification

6 The headline criteria are given in Appendix 1 below – for the full criteria, see *Criteria for Buildings - Passive House – EnerPHit – PHI Low Energy Building* (PHI, 2023), available online at https://passiv.de/downloads/03_building_criteria_en.pdf

CASE STUDY EVIDENCE

Two case studies have been included which are broadly similar in tenure and client intention. Both are social housing schemes in Wales, one of 13 and one of 16 dwellings, with house types varying from 1-bedroom flats up to 4-bedroom detached homes. Both were ambitious in their intention to provide lower energy bills for residents together with lower operational carbon emissions. In both cases, these ambitions have not been achieved and residents have been disappointed by comfort issues and high energy costs.

Case Study A illustrates how a project team can't just pick and choose elements of Passivhaus design or certification requirements, apply those that are easily achieved and then expect somewhere near Passivhaus performance. It shows how early design stage modelling in PHPP is critical to prevent unintended consequences. Modest investment at early design stages can potentially save more money and significant embarrassment after completion, when promised benefits to residents have not only failed to materialise, but actually led to higher energy bills.

Case study B cautions against merely specifying a variety of high technology components for a building and expecting a good result. Passivhaus might cost a bit more than a standard building, but high technology components will cost even more, have high maintenance implications and comparatively short lifespans, with no guarantee of benefits actually being delivered in terms of reduced energy bills and carbon emissions, or increased comfort.

CASE STUDY A

The first case study appended below (refer to Appendix 2) sets out the risks of unclear client requirements. Initial design briefs to the consultant team and, subsequently, Employers Requirements for the Design and Build Contract documents referred to “Passivhaus principles” and “design inspired by Passivhaus”. It was made clear that Passivhaus Certification was not required but there was mention of meeting “Passivhaus standards” without any definition of what was meant by this. Such terms are unenforceable in contractual terms and no requirements for binding contract documents were inserted into the contract. As a result, no PHPP models were prepared during the design process and no Passivhaus Certified Designer/Consultant was engaged at that stage. Clear and unambiguous terms stating quantifiable absolute energy targets, comfort and health requirements should be used or a requirement for Passivhaus Certification, together with clear identification of individuals responsible for meeting those requirements.

Upon completion of the scheme, residents immediately experienced comfort issues – cold temperatures during the heating season and overheating during the summer. Energy bills, which residents had been told would be far lower than typical, became unaffordable as they attempted to mitigate the comfort issues with increased use of the heating systems and portable active cooling systems.

The author was consulted and, having pointed out some fundamental design issues, recommended the retrospective preparation of ‘as-built’ PHPP models. This exercise identified several issues which could have been easily rectified at an early design stage but, instead, were carried through to construction to the detriment of both comfort and affordability post completion. Similarly, the absence of clear requirements for quality assurance during construction led to variability in airtightness results across the scheme, as well as the lack of any meaningful audit trail to demonstrate construction quality.

These errors had significant financial implications, which far outweighed any additional costs that would have been associated with achieving Passivhaus certification had it been a clear requirement. The potential solutions available post completion were severely limited, and those that were implemented had significant costs over and above the original budget. Resident bills were subsidised on an ongoing basis. Had the cost of PHPP modelling been incurred at concept design stage, rather than as a troubleshooting exercise after severe reputational damage had been caused, all the issues could have been avoided.

Summary of rectification costs (which would not have been required if the client had required a certified Passivhaus at the outset):

CASE STUDY A - RECTIFICATION COSTS

Item	Dwellings affected	Cost per dwelling	Total cost
External blinds	2	£750	£1,500
Direct electric heating	13	£4,000	£52,000
PV Panels + batteries	6	£10,000	£60,000
Tenant bill subsidies (year 1)	13	£1,000	£13,000
Total			**£126,500**

CASE STUDY B

The second case study (discussed in Appendix 3) shows how an excessive focus on high technology, in the absence of proper energy modelling of the building fabric, not only incurs excessive and unnecessary capital costs, but also risks not performing as desired. Additional costs for "low carbon technologies" were costed at an 18% uplift in capital costs, as compared to the 4-8% uplift[7] typically needed to achieve Passivhaus certification. Again, design choices were made in an uninformed manner and inadequate attention given to fabric specification and performance, and there was an overreliance on manufacturers offering innovative but unproven technological solutions, while apparently lacking technical support for their products.

The risk of proclaiming ambitious levels of energy performance without adequate energy modelling is made clear as predictions of 80% of required energy being generated on site and energy bill savings of up to 50% over residents' previous homes were not borne out. Indeed, the scheme saw social housing tenants effectively placed into fuel poverty in brand new homes that had been publicised as being low energy.

Clearly there are significant financial and reputational risks in claiming unprecedented energy performance, based on blind faith in technology, in the absence of a proper approach to energy efficient design supported by robust energy modelling.

Summary of rectification costs (which would not have been required if the client had required a certified Passivhaus at the outset):

CASE STUDY B - RECTIFICATION COSTS

Item	Dwellings affected	Cost per dwelling	Total cost
Direct electric heating	16	£4,000	£64,000
Tenant bill subsidies (year 1)	16	£1,000	£16,000
Total			**£80,000**

7 See *Passivhaus Construction Costs* (PHT, 2019). Available online: https://pht.guide/costs

GUIDANCE TO CLIENTS

Considering the above and the evidence from the appended case studies, there are clearly major risks inherent in taking a poorly understood “Passivhaus principles” approach, which selectively applies Passivhaus concepts without the rigour of full compliance or modelling. However, this does not mean that the exact certification level – whether Passivhaus Classic, Plus, Premium, or Passive House + Low Energy Building (PHI LEB) – needs to be nominated at the outset. Indeed, the use of PHPP to ensure compliance with other targets, such as the RIBA 2030 targets, the AECB CarbonLite standard and the Low Energy Transformation Initiative (LETI) guidance, is strongly recommended, as the fundamental part of their design guidance and performance criteria are aligned with PHPP. The optimal level of performance criteria and appropriate detailing will likely emerge as the following process is followed:

MODELLING IN PHPP

Require a PHPP model be prepared by a suitably qualified individual from the earliest stage

An experienced and competent Passivhaus Designer/Consultant should be engaged as soon as the possibilities for a site are being considered. This enables the impact of site-specific considerations on energy performance - such as climate, solar radiation, building orientation and overshading - to be understood and incorporated. PHPP modelling naturally encourages efficient building form to minimise heat loss areas, which in turn minimises embodied carbon.

Careful consideration of windows at this stage is particularly beneficial as they perform many functions. As well as forming part of the continuous airtightness layer, they are an integral part of the thermal envelope. The inevitably higher heat losses from glazing, typically five times greater than that of external walls, needs to be balanced with the solar gains and any overshading present incorporated into the energy model at this stage. Such consideration of glazing will naturally inform the orientation and massing of the building so is the ideal focus at this stage. To model a project in PHPP at a later stage misses opportunities to balance providing good daylight and views with solar gain and summer comfort risk.

Components and construction details can be assumed initially to provide a baseline in PHPP for benchmarking. Once established, any design changes proposed at any stage of a project can easily be amended in PHPP to understand their impact on energy performance. The *Passivhaus Overlay to the RIBA Plan of Work* (RIBA / PHT 2023) is available to help implement the design process and streamline decision making at the right time and in the correct order.

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pht.guide/PassivhausOverlayRIBA

Prepare a cost plan at an early stage

PHPP is an excellent tool for Value Engineering as the functions of each component are so accurately assessed in relation to all others. Preparing a cost plan as soon as an initial PHPP model has been created allows the two working documents to be compared and developed together. The implications of any proposed amendments on energy performance, capital cost and running costs can be very quickly understood. PHPP penalises poor form factors by virtue of the fact that U-values become more onerous, which leads to an avoidable cost penalty. Competent designers will drive efficiencies in form factor, minimising the area of external envelope where the cost implications are highest while maximising the internal space of the building which is where the value is. This has the added benefit of minimising embodied carbon. Again, windows are a fruitful area upon which to focus as they perform so many functions and are such a high capital cost and embodied carbon item.

As a design is developed towards the Planning Application stage, where many considerations become fixed, the PHPP file and associated cost plan provide a level of reassurance that the proposed spend will represent maximum value and, furthermore, provide robust justification for those decisions.

DETAILED PERFORMANCE AND COMFORT CRITERIA

Select an appropriate level of certification commensurate with best value

There is a strong case that, rather than set out with a level of energy performance in mind, it is preferable to consider targeting a certified standard once the design and budget have been optimised using PHPP. First and foremost the aim is to make a building that works and makes sense. A range of Passivhaus certified standards is available - see box right.

A PHPP plugin developed by DeltaQ enables project teams to swiftly and easily check alignment with other targets/ standards, such as RIBA 2030 targets and LETI guidance. By drawing calculations from an active PHPP, the plugin displays essential metrics, including Energy Use Intensity (EUI), both regulated and unregulated energy, and even operational energy costs.

PASSIVHAUS CLASSIC

Space heating demand ≤15 kWh/m².a, or peak heat load ≤10 W/m², and airtightness ≤0.6 ACH.
See Appendix 1 for detailed criteria.

PASSIVHAUS PLUS

Criteria as Classic but with renewable generation >60 kWh/m².a and lower primary energy demand (PER).

PASSIVHAUS PREMIUM

Criteria as Classic but with renewable generation >120 kWh/m².a and lower primary energy demand (PER).

PHI LEB
(PASSIVE HOUSE INSTITUTE LOW ENERGY BUILDING)

Criteria as Classic but with space heating demand ≤30 kWh/m².a and a relaxation of other metrics.

QUALITY ASSURANCE

Implement the appropriate quality assurance processes during construction

The PHPP model remains a working document throughout the construction phase, enabling the assessment of any variations and their impacts. In addition, further robust processes required for certification must be followed, including pressure testing for airtightness, commissioning MVHR systems, and photographic documentation of all critical details. This site documentation goes beyond merely recording photos at certain points in the build; it embodies a comprehensive way of working on-site.

Quality assurance processes should be active daily, with appropriate personnel overseeing them. This includes ensuring all team members are trained in Passivhaus standards, benchmarking standards to work against, and managing output in detail. These processes are similar to quality assurance practices that should be followed on all modern building projects. However, they are fundamentally different from the current management practices on most UK sites, requiring new knowledge, skills, and training.

For example, air testing is now a requirement for all buildings. However, it is more a matter of mindset and approach to testing and documentation throughout the process, rather than merely demonstrating compliance with minimum standards upon completion. Where practical, in-construction air testing of Passivhaus buildings is recommended while the relevant layer remains exposed. This allows any remedial measures to be taken before it is covered by plasterboard and finishes. A quality approach should be encouraged from the outset, encompassing work that will not be visible when the building is completed. This runs somewhat contrary to standard practice, where an interest in quality often only emerges as finishes are installed.

GUIDANCE TO CONSULTANTS AND CONTRACTORS

In light of the above, there is also a clear role for consultants and contractors in challenging a poorly resolved brief, and recommending clarification in terms of achieving the Passivhaus standard.

To accept ill-defined "Passivhaus principles" or similar within a contract is to accept a high level of ambiguity and, therefore, risk. Clearly defined criteria enables a deliverable project for which Professional Indemnity Insurance can provide adequate cover. Acceptance of vague aspirations within a brief leaves ample space for interpretation, conjecture and heightened risk throughout.

CONCLUSION

As explained above, the fundamentals of a Passivhaus building can be misunderstood as a collection of physical properties that, if assembled on paper, will translate in to a building "as good as a Passivhaus". However, this is to miss the point. To perform as a Passivhaus, these physical "ingredients" need to be assembled with a holistic understanding of how they interact with each other, and how the construction processes on site, in a particular time and place, interact with the design intent. The fundamental building physics behind Passivhaus design are sound and, indeed, essential to achieving high levels of energy performance and comfort.

It is possible to make errors such as overglazing, overall or on particular elevations, if design choices are not modelled through PHPP and if the design team have no training or experience in Passivhaus design. There is a strong argument that PHPP should be used regardless of whether a certified Passivhaus or other low energy standard is sought. It is a powerful design, value management and risk mitigation tool. It is not just a compliance requirement for use when Passivhaus certification is a clear contractual requirement. Building Regulations Parts F (Ventilation), L (Fuel and Energy) and O (Overheating) increasingly require modelling for compliance purposes. PHPP provides this and there is a strong case that a PHPP model should be deemed to satisfy Building Regulations without separate use of SAP or SBEM software. Overall, following the Passivhaus methodology under the guidance of a suitably competent individual provides excellent value when looking to achieve high levels of energy performance, regardless of whether a certified Passivhaus or other low energy standard is sought.

The PHPP modelling software is an extremely effective tool available for visualising the interactions that make up the whole. The Passivhaus quality assurance process, mandatory in Passivhaus certification, is an extremely effective method of bringing that whole into reality on site, to perform as intended.

This process allows risks to be minimised and costs to be optimised. Far from being an onerous academic exercise, the use of PHPP is a crucial tool in designing and building successfully. However, PHPP is only one part of the Passivhaus methodology. Quality assurance processes during construction, including rigorous design and installation practices, are central pillars in achieving desired energy performance outcomes.

Attention to Passivhaus construction details, such as airtightness and insulation, ensures thermal efficiency and comfort. Furthermore, the design of building services, such as using certified MVHR units, can enhance heat recovery efficiency and overall system performance. These comprehensive measures collectively contribute to the effectiveness and success of Passivhaus projects, demonstrating that Passivhaus is about an integrated approach to sustainable and high-performance building.

However, formal Passivhaus certification gives added levels of assurance due to the input of a Passivhaus Certifier and the meticulous documenting of construction products and processes. Some other approaches that seek to guarantee the performance of very low energy buildings do also exist, particularly the Association for Environment Conscious Building (AECB) Carbonlite standard. However, although this standard is nominally different, and includes slightly different performance targets, it is based on the same fundamental approach as Passivhaus, so does not suffer from the same risks as projects which refer loosely to Passivhaus without following all eight Passivhaus principles[8]. Crucially the AECB also require buildings to be modelled in PHPP which, as shown above, is critical to the effective management of risk and cost throughout the design and construction of robust, genuinely low energy buildings.

Significant funding has been injected into the social housing sector in recent years. It is imperative that lessons are now learned so that Net Zero construction and resident comfort can be pushed into the mainstream at the necessary pace. That schemes proceed under the banner of innovation does not excuse avoidable errors . The proven knowledge exists to design and construct new buildings to very good levels of energy performance but the appended case studies prove that this knowledge needs to be further instilled across the industry. They demonstrate that vague energy performance aspirations that do not utilise robust energy modelling in PHPP or require the appointment of suitably experienced and competent consultants, risk serious underperformance, while the adoption of robust Certification standards provides an extra layer of quality assurance to the extent that the 'performance gap' can be eliminated. To do otherwise risks vast amounts of public money in the case of grant-aided social housing. Furthermore, we risk providing another generation of substandard housing, which neither contributes towards Net Zero nor enhances the well-being of future generations.

How we build is under review throughout the UK for implementation in the coming years, with the proposals for a 'Scottish equivalent' of the Passivhaus Standard[9] being followed by the Future Homes Standard[10] in England and a review of Parts L and F of the Building Regulations in Wales. These case studies demonstrate the risks of leaving enough room for error within the new requirements when the tools and knowledge exist to build better every time.

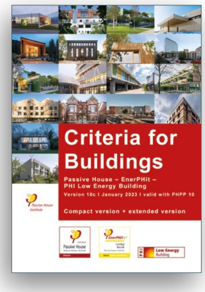
8 For guidance on when and how to use the word Passivhaus, see *Claiming Passivhaus* (PHT, 2025). Available online at https://pht.guide/ClaimingPassivhaus.

9 Updates can be found online at: Energy Standards Review – Scottish Passivhaus Equivalent: Working Group - https://www.gov.scot/groups/energy-standards-review-scottish-passivhaus-equivalent-working-group/

10 The most recent consultation can be viewed at: The Future Homes and Buildings Standards: 2023 consultation https://www.gov.uk/government/consultations/the-future-homes-and-buildings-standards-2023-consultation

APPENDIX 1

Key criteria for Passivhaus in a UK climate



To achieve Passivhaus standards, a building design must demonstrate, through use of the Passivhaus Planning Package (PHPP), airtightness testing, services commissioning, and construction evidence, that the criteria are met.

The table below shows the key headline criteria. In addition, there are detailed criteria relating to optimal thermal comfort, user satisfaction, and low risk of damage from moisture accumulation.

For the full criteria, refer to https://passiv.de/downloads/03_building_criteria_en.pdf.

Passivhaus criteria	LEB	EnerPHit [1]	Classic		Plus	Premium
Airtightness n_{50} [2]	**≤ 1** ACH @ 50 Pa	**≤ 1** ACH @ 50 Pa	**≤ 0.6** ACH @ 50 Pa			
Space Heating Demand (SHD)[3]	**≤ 30** kWh/m².a	**≤ 25** kWh/m².a	**≤ 15** kWh/m².a	–		
Heating load[3]	–	–	–	**≤ 10** W/m²		
Primary Energy Renewable (PER)[4]	**≤ 75** kWh/m².a	**≤ 60** kWh/m².a	**≤ 60** kWh/m².a		**≤ 45** kWh/m².a	**≤ 30** kWh/m².a
Renewable energy generation	–				**≥ 60** kWh/m².a	**≥ 120** kWh/m².a
Summer overheating[5]	**≤ 10%** exceeding 25°C (best practice: **≤ 2%** exceeding 25°C)					
Surface temperature[6]	–	Typically **≥ 17°C**				
Ventilation[7]	Typically **≥ 30** m³/hr.person					

VIEW FULL CRITERIA

1 This table gives the criteria for EnerPHit certification using the space heating demand method. Certification is also possible using the component method, in which each individual building element must meet defined criteria, but the overall space heating demand can vary. In both cases, variants and exemptions may apply.

2 For larger buildings ie. ≥1500m³ an additional measurement of air leakage in reference to envelope area (q_{E50}) is also required.

3 There are two alternative metrics used to limit space heating: annual demand and peak load, only one of which needs to be met. While annual space heating demand is often the headline figure, designing to limit peak heat load can offer advantages, including greater opportunities for standardised construction.

4 The majority of projects will certify using the standard PER limits. As some energy uses are driven by occupancy, PHPP 10 has in-built calculations to set a project-specific PER limit for residential and office buildings. For some atypical building uses, the limit may be varied by agreement with the PHI - see Bespoke PER. In retrofit, PER varies to allow 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.

5 The Passivhaus Trust and the UK Certifiers Circle recommend a target of ≤5% for UK projects, plus an overheating stress test, which is included in PHPP 10 onwards. Best practice is ≤ 2%. Additionally, Passivhaus certification requires written documentation of the strategy for thermal comfort in summer - see https://pht.guide/SummerComfortStatement

6 The precise criterion is ≤4.2 K below the operative indoor temperature (windows, radiant temp. at 500mm in front of pane), which typically works out at ≥17°C.

7 In the UK it is recommended to supply air at 30 m³/h.person. The 20 m³/h.person basic criterion set by the PHI is a minimum, but it is not expected to be sufficient for UK homes because of our mild and damp climate.

APPENDIX 2

Case study A: “Claiming Passivhaus principles“

Executive summary

This case study illustrates how the absence of an experienced Passivhaus Consultant capable of utilising the Passivhaus Planning Package (PHPP) modelling, along with the lack of third-party verification through certification, contributed to significant discrepancies in thermal comfort and energy efficiency. It also highlights the willingness of the team involved to revisit the project and learn from the mistakes made. This reflective approach is a strength of the Passivhaus community, emphasising continuous improvement and deepening understanding of what truly ensures high performance.

The project's reliance on partial adherence to Passivhaus principles resulted in design inconsistencies and suboptimal building features, causing undue stress and financial strain for the client. Residents experienced discomfort and high energy bills, while the project incurred additional costs for remedial measures to address performance shortcomings. This underscored the importance of thorough planning, prioritising PHPP modelling with experienced and competent consultants and proper adherence to Passivhaus standards to mitigate risks, maximise value and ensure successful project outcomes for clients and residents alike.

Client brief

Procured through a Design and Build contract, the Local Authority client’s requirements were for a semi-rural development of 13 homes, combining General Needs and Over-55’s social housing:

- 4 one bed walk-up flats (in a block similar in appearance to neighbouring houses);
- 4 two bed semi-detached houses;
- a row of 3 bungalows (2 one bed and 1 two bed);
- and 2 four bed detached houses.

As a learning exercise, two different performance specifications were prepared, with some homes nominated as variously “to Passivhaus standards” or “inspired by the stringent Passivhaus design concept” while the others were described as “Net Zero Carbon”. The specifications at the time of the Planning Application differed as follows:

3.1 Building Fabric Properties

Table 1: Building Fabric Properties

Building Fabric Properties			
	Passivhaus	Net Zero Carbon	
Opaque Elements	0.10	0.15	$W/m^2.K$
Windows and Doors	0.80	1.00	$W/m^2.K$
G Value	0.63	0.63	-
Air Permeability	0.60	1.00	$m^3/h.m^2@50Pa$

3.2 Building Services

Table 2: Building Services

Building Services		
	Passivhaus	Net Zero Carbon
Heating	Electric heating coil within ventilation system	Underfloor heating served by ground source heat pump
Ventilation	Mechanical ventilation with heat recovery	Mechanical ventilation with heat recovery
Domestic Hot Water	Domestic hot water cylinder with dedicated air source heat pump	Domestic hot water cylinder served by ground source heat pump

3.3 Low to Zero Carbon Technologies

Table 3: Low to Zero Carbon Technologies

Low to Zero Carbon Technologies		
	Passivhaus	**Net Zero Carbon**
Photovoltaic Panels (PV)	n/a	3-5 kWp per dwelling
Other	n/a	Transpired Solar Collector/Photovoltaic Thermal system/Duel Skin Roof **(Optional additions, dependant on costing exercise)**.

Extract from Energy Statement prepared by the Client's M&E Consultants

Although the same architect's details were applied to both, it is notable that the supply air was to be used for heating distribution in the nominally "Passivhaus" homes but not the "Net Zero Carbon".

The document confirms that the scheme was modelled for Building Regulations Part L1A compliance using Stroma FSAP2012. The Net Zero Carbon homes were all certified on completion as EPC A. The nominally "Passivhaus" homes were EPC B - not uncommon for Passivhaus Classic schemes despite their demonstrably better performance levels without a discernible performance gap. The 'as-built' drawings showed positions where photovoltaic panels could be mounted if achieving EPC A were to become a retrospective requirement.

Six months subsequently a Technical Design Note was prepared by the same Consultants referring to "design to Passivhaus standards" but stating "Formal Passivhaus certification is not within the scope of this project, however, the design should still be constructed to certification standards".

Reported issues

To varying degrees, all residents had issues with thermal comfort. Despite the high fabric specification, several were very cold in winter and resorted to using portable electric radiators. Electricity bills were much higher than expected, with many residents unable to pay and officially in fuel poverty. In more specific instances, overheating was experienced in Summer.

Construction quality

Overall construction quality was comparable to that seen on most new-build residential sites and the reduced performance gap usually seen on certified Passivhaus schemes was not evident.

Absence of PH Designer/Consultant and PHPP file

The aforementioned Technical Design Note included the wording "As part of the initial design phase, PHPP calculation verifications were undertaken to ensure the scheme is able to comply with the Passivhaus criteria, the contractor is to engage a certified Passivhaus Consultant to carry out the formal PHPP calculations and manage the process going forward. The contractor shall be responsible for ensuring compliance is achieved with these standards". Despite requests to do so as part of this investigation, no evidence of any initial "PHPP calculation verifications" was disclosed by the M&E Consultants. A certified Passivhaus Designer was approached by the Contractor as construction neared completion. Following some basic PHPP modelling they reported that the Passivhaus criteria would not be achievable. Despite requests to the Contractor to share this report, it was not disclosed.

Retrospective PHPP exercise

The author recommended that PHPP models should be prepared for 3 homes to give broad insight to the issues across the whole scheme. This proved of sufficient value that PHPP models were subsequently prepared for all the homes. This showed that, although there was a clear intent to adhere to some of the "principles" outlined above, the application of them had only been followed in a haphazard and inconsistent manner throughout design and build. All the findings were in accordance with anecdotal evidence of poor performance from the residents. The building envelope specification, in terms of insulated foundations, wall and roof build-ups and window specifications, was good enough to achieve Passivhaus Certification had other factors been appropriate. However, in relation to the key principles outlined above:

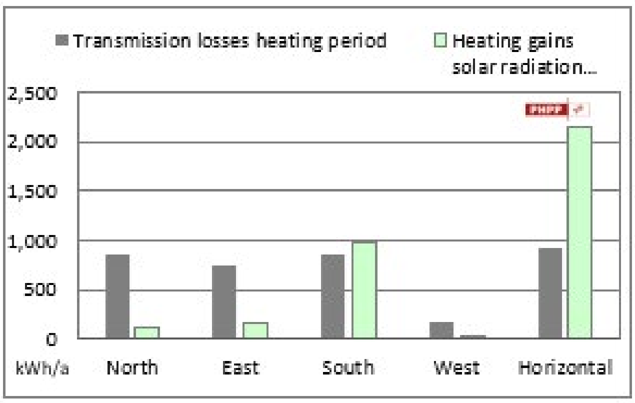
a. **Building form factors** were suboptimal, particularly for the bungalows, where high vaulted ceilings provided a pleasant, airy feel but led to increased heating cost due to the high form factors (heat loss areas divided by total floor area) between 3.84 and 4.05, far higher than the recommended maximum ratio of 3.0. For this reason, it is extremely unlikely that the bungalows could ever have achieved Passivhaus standards with the massing designed, even if other factors could have been amended. Building orientations were also suboptimal, with an excess of north-facing sliding patio doors leading to high heat losses.

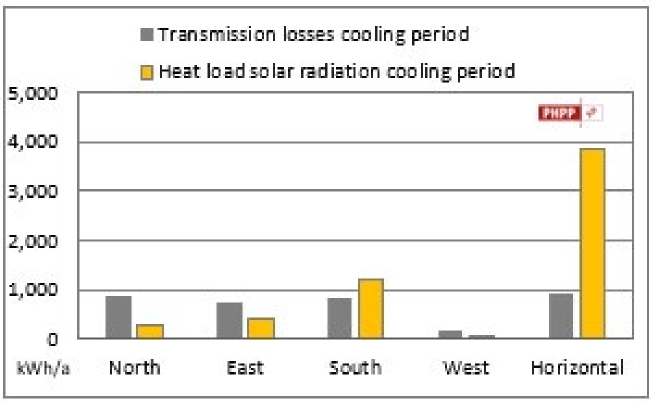
c. The airtightness level specified was 0.6 1/h, as required to meet the Passivhaus standard. However, **none of the homes achieved the airtightness target**, with test results varying from 1.09 1/h to 4.17 1/h. The two worst results were achieved in the first-floor flats, possibly due to the 6 Velux windows in each not being sufficiently airtight. Limited photographic evidence showed that appropriate membranes and tapes had been installed, so the materials costs incurred meant the Passivhaus standard should have been achievable. No evidence of any interim testing and leakage diagnostics, before the airtightness layer was covered, was provided.

d. Although most of the architect's detailing was thermal bridge-free, one area which did not appear to have received sufficient attention was the external door thresholds, where **no thermal bridge-free detail** was issued.

e. **Consideration of solar gains and shading** was also shown to have been inadequate. The PHPP models suggested that many of the window sizes could have been amended to improve the balance between heat gains and losses. Overheating issues in the first-floor flats were shown, somewhat counterintuitively, to be caused by an excess of north-east facing rooflights subject to diffuse solar gains all day in addition to early morning solar gains in mid-Summer. All the homes, except the upstairs flats, incorporated two sets of sliding patio doors, totalling between 2.7m and 6.2m wide. In some cases these faced north and contributed to high heat losses, while in others they faced south and contributed to high solar gains.

Plots 1, 1a, 2, 2a - window heat gains vs losses – as-built:
Graphs from PHPP, below, illustrate the window heat losses and gains during the heating period (winter) in green and the cooling period (summer) in yellow. The losses and gains are grouped by façade orientation, providing a clear overview of how each building face performs. The final pair of bars in each graph represents the rooflights, giving insight into their impact on the building's thermal balance, particularly summer overheating.





In addition, tables from PHPP below present the same data in numerical form, allowing for a more detailed analysis of the heat losses and gains across various orientations and during both the heating and cooling periods.

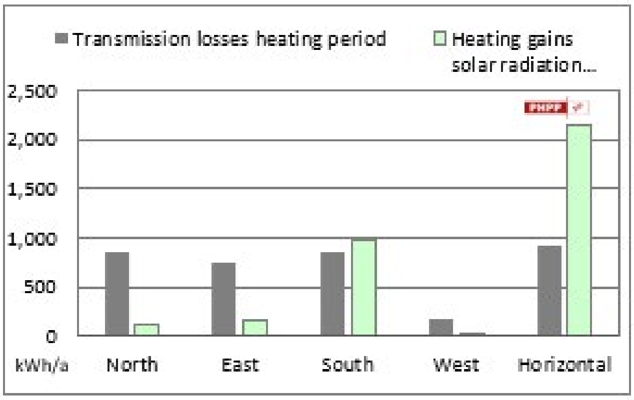
	Transmission losses heating period kWh/a	Heating gains solar radiation heating period kWh/a
North	868	124
East	755	171
South	849	981
West	178	12
Horizontal	915	2136
Total	**3565**	**3423**

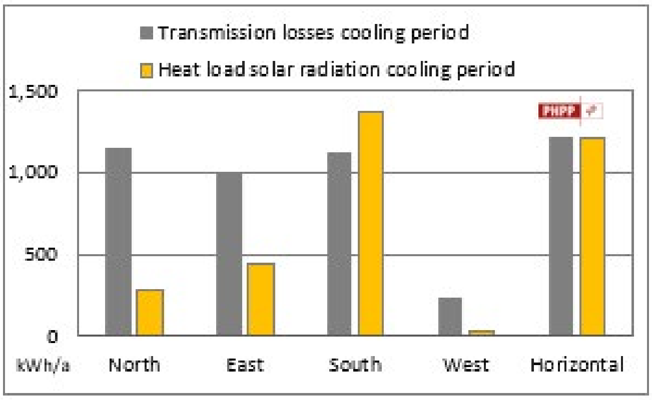
Heating degree hours [kKh/a]: 80

	Transmission losses cooling period kWh/a	Heat load solar radiation cooling period kWh/a
North	864	271
East	752	397
South	845	1200
West	177	28
Horizontal	911	3866
Total	**3549**	**5761**

Cooling degree hours [kKh/a]: 80

Window heat gains v losses: With added external heat shades to Velux windows





	Transmission losses heating period kWh/a	Heating gains solar radiation heating period kWh/a
North	867	124
East	755	171
South	848	981
West	178	12
Horizontal	914	2136
Total	**3561**	**3423**

Heating degree hours [kKh/a]: 80

	Transmission losses cooling period kWh/a	Heat load solar radiation cooling period kWh/a
North	1150	285
East	1001	439
South	1125	1364
West	236	30
Horizontal	1212	1214
Total	**4723**	**3332**

Cooling degree hours [kKh/a]: 106

Note: the rooflights are marked as Horizontal and are oriented to the North East. Shades can block 78% of solar gains.

f. Most tellingly of all, the Heating Load tab of PHPP demonstrated that the choice to use **heater batteries in the supply ductwork would never have been suitable**. Examination of the as-built information showed that the airflows had been increased to as much as three times the whole house rates required by Part F of the Building Regulations to provide sufficient heat carrying capacity. This reduced the efficiency of the heat recovery units as the air was forced through at higher speeds while detectable draughts from the supply valves further compromised comfort. To provide a source of heat, supply valves were designed and installed in the wet rooms, contrary to the principles of how any whole house ventilation system should work.

Remedial measures and costs

The overheating caused by the rooflights was able to be remediated by the installation of proprietary external blinds, available from the manufacturer specifically for the purpose. Manual blinds were chosen over automatic ones for ease of installation and lower cost. Ongoing tenant liaison will be needed to ensure that residents understand the need to close the blinds before going to bed in mid-Summer as the excess solar gains begin at dawn if the sky is clear. The blinds can be closed with the windows open to allow night cooling while ensuring that the sun will not hit the glass in the early morning. These works were costed at £1,500 (ex VAT) across the two affected dwellings. Various alternative heating strategies were suggested and examined by the author, together with the Main Contractor and the M&E subcontractor. Had the unsuitability of the heater battery strategy been understood prior to construction, the most suitable alternative would have been to alter the specification of the air source heat pumps to provide space heating rather than merely domestic hot water. However, the retrospective installation of a wet system was thought too disruptive and costly so the installation of direct electric panel radiators was proposed and costed at £24,206 (ex VAT) for the six nominally “Passivhaus” homes. Even with Passivhaus certified fabric performance levels, this strategy is only usually viable for apartment blocks where external heat loss areas are relatively small. Particularly for the bungalows, but also for the detached and semi-detached houses, the running costs of direct electric heating will be very high on an ongoing basis. The addition of photovoltaic panels and battery storage would be possible to mitigate these high costs (and also mitigate a reduction in EPC ratings) at a capital cost in the region of £60,000 (ex VAT) across the six homes.

The removal of supply ducts where not required as part of a whole house ventilation strategy (i.e. the wet areas) was also considered. The author would have preferred their complete removal to enable the performance of the system as modelled. However, the additional disruption and expense this would have entailed led to the compromise solution of recommissioning the systems with minimal flow rates to those valves.

Fees for the retrospective input of a certified Passivhaus Designer/Consultant to create PHPP models and advise on remediation were in the region of £1,500 per home. Had this input been sought from the outset, the cost would have been similar. In addition to the costs of remediation, the wasted capital costs on excessive glazing and unsuitable heater battery strategy would not have been incurred and the tenant bills would have been far lower both before and after the remedial measures.

Summary costs

- Installation of proprietary external blinds to reduce overheating — **£750 per dwelling**
- Installation of direct electric panel heaters to mitigate cold temperatures — **£4,000 per dwelling**
- Addition of photovoltaic panels and battery storage to mitigate the high costs of running electric storage heaters — **£10,000 per dwelling**
- PHPP modelling — **£1,500 per home type**

Lessons

1. The Client could certainly learn about the importance of a clear brief. A demonstrable energy performance target in kWh/m2/year or W/m2 and insistence on the use of PHPP as a design tool from the outset would have guided decisions appropriately. The wording around concepts such as "Passivhaus principles" is open to misinterpretation, particularly around the role of PHPP as a design tool rather than just a compliance document where certification is required. Had a PHPP model been developed from the outset and updated throughout the design process, concerns raised by the design team could have been assessed correctly, together with proper value management/engineering to ensure capital expenditure was well informed and achieved desired outcomes.

2. The Architect could certainly learn of the positive impact and risk mitigation that the proper consideration of form factor, orientation and glazing proportions can have for a scheme. The use of floor, wall and roof build-ups and airtightness specifications from previous schemes, even Passivhaus certified ones, will not provide the same performance levels alone . Buildings must be modelled through PHPP to ensure that all factors have been considered holistically.

3. The MEP Consultants should learn of the proper use of PHPP, ensuring that modelling is undertaken only by suitably qualified individuals.

4. The Main Contractor, who had successfully delivered a much larger Passivhaus certified scheme of 38 homes previously, should have insisted on the production of PHPP files as contractual documents at the point of signing the Design & Build contract. They should have ensured that they had been modelled by a suitably qualified individual and engaged that person or someone similarly competent to update the PHPP models throughout post-contract design to assess the impact of any changes. Undertaking airtightness testing as a diagnostic tool at appropriate stages during construction should have been costed from the outset and implemented rigorously to enable the targets to be met.

5. The M&E Subcontractor should have been firmer when raising concerns around the suitability of using the MVHR systems to attempt to supply space heating. They should certainly not have increased air flow rates to levels where air velocity compromised both heat recovery performance and occupant perception of supply air flow as draughts.

6. Product manufacturers, particularly of the MVHR systems, should have been more proactive in providing design advice and been more resistant to the use of heater batteries in their supply ductwork. Similarly, they should have advised against the installation of two separate MVHR systems within one detached house.

APPENDIX 3

Case study B: Active Homes

Executive summary

While this project was not targeting Passivhaus or claiming to follow Passivhaus principles, it has been included as a case study to highlight the risks of a technology-driven approach without a strong fabric-first methodology. This is particularly pertinent at a time when building regulations and standards around the UK are being revised and consulted on. While there is cross-industry support for a fabric-first approach, some are still lobbying for 'business as usual' with technology bolted on, which introduces significant risks—not just to individual projects, but to the nation's ability to reach net zero and to deliver healthy, comfortable, and affordable homes.

The Active Homes project in Neath, South Wales, aimed to deliver 16 social rent homes with innovative low carbon technologies. Despite the project's intention to provide energy-efficient homes with reduced energy bills, residents faced challenges due to design inconsistencies and performance discrepancies. Initial reluctance and discomfort among residents were exacerbated by delays and issues with low carbon technology, leading to higher-than-anticipated energy bills and concerns about heating and hot water.

Starting with high fabric performance levels and adopting Passivhaus from the outset would have provided a proven route to creating energy-efficient and sustainable homes, ensuring better outcomes for residents and clients alike. This case study demonstrates why prioritising Passivhaus Planning Package (PHPP) modelling and Passivhaus levels of Quality Assurance throughout construction are key tools. Without these measures, unintended consequences can occur, resulting in unforeseen remediation costs and reputational damage.

Client brief

A collaboration between Neath Port Talbot Council, Pobl Housing Association and the SPECIFIC Innovation and Knowledge Centre (led by Swansea University) the Active Homes project in Neath, South Wales, provided 16 homes, a mixture of houses and flats, for social rent. Intended as a pilot for the Homes as Power Stations (HAPS) initiative within the Swansea Bay City Region[11], further grant funding for innovative elements was provided from the Welsh Government Innovative Housing Programme (IHP)[12]. The homes were intended to generate around 80% of the energy they consume, enabling tenants to benefit from significantly reduced energy bills with savings estimated to be at least 50%, equating to savings of up to £600 annually[13].

Nominally 'low carbon' features included: photovoltaic (PV) panels with battery storage; mechanical ventilation with heat recovery (MVHR); domestic hot water from individual Air Source Heat Pumps (ASHPs) preheated by Transpired Solar Collectors (TSCs) integrated into the building envelope. 18% of the project costs were attributed to additional sums for design, supply and install of low carbon technologies.

The project was reviewed in detail, alongside four others, as part of the Building for 2050 research project launched by the Department for Business, Energy and Industrial Strategy (BEIS) in March 2019 to attempt to identify best practice in low carbon construction. A full report was published in November 2022[14].

11 Homes as Power Stations | Swansea Bay City Deal https://www.swanseabaycitydeal.wales/projects/homes-as-power-stations

12 Innovative housing programme | GOV.WALES https://www.gov.wales/innovative-housing-programme

13 Building for 2050 innovative housing - UK Construction Online https://www.ukconstructionmedia.co.uk/news/building-for-2050-innovative-housing/

14 See previous footnote.

Reported issues

In general, the sustainable nature of the homes was not given as a primary driver for residents opting to move into the new homes. There was some concern over novel technologies and some expressed preferences for a more traditional home with familiar systems such as gas central heating and cooking. Initial resident reluctance was exacerbated by delays to occupancy due to the issues with the low carbon technology. Some design issues had already become apparent before completion causing late contractual variations as the heating strategy was altered.

Anticipated lower energy bills did not materialise post-occupancy. Some residents had significant concerns about how high they were with the key cause apparently the late change of heating strategy with heater batteries in the supply ductwork being disconnected and direct electric radiators installed. The measured space heating energy use for the houses is on average around three times higher than the developers SAP estimate with the flats consuming approximately double.

Some residents reported insufficient hot water. A key reason is the heat pump recharges the cylinder more slowly than a gas boiler would. Energy use for domestic hot water (DHW) was lower than predicted; this may reflect adapting to lower-than-expected availability of hot water and the contribution of renewable heat from TSCs (not included in SAP predictions).

Monitoring continued beyond the Building for 2050 research in line with the requirements of the grant funding. A small number of homes had even higher energy use, believed to be due to problems with the batteries and/or PV systems.

Construction quality

Construction quality was comparable to that seen on most new-build residential sites. However, the reduced performance gap inherent on certified Passivhaus schemes was not evident, which is perhaps unsurprising given the lack of priority fabric performance was given from the outset.

Some failure to follow specific construction details correctly was evident, particularly at the eaves where the effectiveness of good thermal performance of the Off-site manufactured (OSM) wall panels was reduced by thermal bypass between the walls and more conventional roof construction. The eaves detail was arguably not easily buildable but had certainly had not been correctly installed, possibly because responsibility fell between the separately subcontracted packages for walls and roof.

Overall, few performance issues could be blamed entirely on construction defects and attempting to do so would neglect the detriment caused by design flaws.

Absence of PH Designer/Consultant and PHPP model

Energy modelling was limited to SAP calculations required for Part L compliance. However, given the project's use of typical Passivhaus features—such as high levels of insulation and MVHR systems—engaging a competent Passivhaus Consultant and utilising the Passivhaus Planning Package (PHPP) would have been highly beneficial. A Passivhaus Consultant would have highlighted the risks of installing MVHR units and ductwork in unheated loft spaces, while PHPP would have determined whether the heating load was low enough to make using supply air for space heating viable.

The local M&E Consultant selected for the project clearly lacked knowledge and experience regarding low energy buildings. This is perhaps indicative of the fact that M&E designers have not traditionally been required for small residential schemes, only really becoming involved in larger blocks of flats with communal access, heating systems, lifts and the like while mostly being engaged on commercial buildings. For most residential buildings, the self-certification and robust regulations governing the ubiquitous electrical and gas installations has meant that installers were able to undertake standard design functions such as sizing of boilers and radiators. Until recently Part F has required little in the way of ventilation specification so nothing above electrical safety was of concern. With the inclusion of MVHR and novel approaches to space heating, together with PV and battery, the necessary level of emphasis on correct design and specification has increased. There is frequent discussion about skills gaps and workmanship in the construction industry, often focused on trades (although gas and electrical safety are not in doubt). However, there is a clear need for design and specification skills to be improved.

In particular, a holistic approach needs to be encouraged. The days of poor performing building fabric going unquestioned by Building Services Engineers able to design adequate heating systems because of the availability of gas are numbered. The impact of seemingly small changes to building fabric on overall energy demand need to be understood and considered by the whole design team. On the Active Buildings project, the architect had little apparent involvement after submission of the planning application which potentially led to a disconnect with the M&E Consultants. This also brings into question the role of Design and Build contracts as an original design team is often not novated from the client to the contractor. Without a clear standard to be achieved, Employer's Requirements can easily be misinterpreted or become watered down.

Retrospective PHPP exercise

Retrospective PHPP modelling of the homes has not been carried out. It is possible that most if not all the design flaws causing poor performance, resident discomfort and additional running costs could be identified and quantified by such an exercise, with the most cost-effective remedies then able to be explored. However, even more beneficial would have been to model the project in PHPP from the outset.

Remedial measures and costs

The flawed strategy of attempting to use electric heater coils installed in the supply ductwork was identified around the time of project completion but before the homes were occupied. This led to disconnection from their electrical supplies, though not physical removal from the ductwork, together with the installation of direct electric radiators. This alone should have raised concerns about residents' potentially high energy bills prior to occupation. The late addition of lagging to all the ductwork in the loft spaces would have also added cost. Had the MVHR units and all ductwork been installed within the thermal envelope, only the short (<2m according to standard practice) intake and exhaust ducts between the unit and the external air would have required insulation. In terms of energy performance, installing the MVHR system in cold loft spaces increased heat loss and resulted in cooler supply air. Multiple penetrations of the ductwork through the insulation layer increased heat losses. Cool draughts from ventilation system were cited by residents as a challenge of living in their new home.

Overall, for a social landlord subsidising tenant energy costs and sustaining reputational damage, the costs of remediation were probably not the greatest concern. More worrying would be the limited ability to implement changes that would markedly improve the situation. Flawed design has left the homes with inefficient forms of electrical heating, while more efficient heat pumps are only used for the provision of hot water, which will typically give a worse Coefficient of Performance than when also used for a space heating system with low flow temperature. The opportunity to install such a system, using underfloor heating or adequately sized radiators cost effectively during construction was missed.

Lessons

Despite being the largest initiative under the Swansea Bay City Deal regional funding, with £505 million initially allocated, the HAPS concept has struggled to gain traction and fallen well short of all targets[15]. The concept is fundamentally flawed from the outset as it neglects the key element in overall energy efficiency and carbon emissions reduction: the lowering of energy demand. To attempt to use energy generation and storage technology to plug the gap still being created by inadequate fabric and ventilation is to attempt to ignore reality. To brand homes as "power stations" belies the meagre number of kWh that can be delivered from onsite generation and the high costs of doing so. Far higher value is achieved by focus on reducing the kWh required by a building in the first place.

That some of the design flaws were identified close to project completion, prior to occupation but too late to specify optimal systems, shows these errors were in plain sight and should have been understood. Adoption of proven Passivhaus standards and the use of PHPP from the outset would have led to the identification of flawed strategies early, enabling appropriate designs to be proposed and avoiding sub-optimal results.

Passivhaus levels of Quality Assurance throughout design and construction, utilising PHPP modelling, are essential. Without these, unintended consequences can easily materialise, causing unforeseen remediation costs and significant reputational damage. The old carpenter's adage of "measure twice, cut once" has never been more apt as we look to create the next generation of buildings with better energy performance. On-site energy generation and storage is not a quick fix, bolt-on alternative to building quality. It should only be the icing on the cake of a well designed and constructed building with high quality insulation, airtightness and heat recovery ventilation.

If an 'active house' is defined as a home that can generate over 80% of its energy requirements from on-site generation capacity, the only way to get anywhere close is to have very low energy demand, particularly space heating demand. Without very high fabric performance levels, which in turn require MVHR, there will rarely be anywhere near enough roof space to provide meaningful PV capacity. In short, an effective and proven way to build an active house is to start with a Passivhaus.

15 £505m Welsh 'homes as power stations' project has only created six jobs to date (nation.cymru) https://nation.cymru/news/505m-welsh-homes-as-power-stations-project-has-only-created-six-jobs-to-date/

The Passivhaus Trust is an independent, non-profit organisation that provides leadership in the UK for the adoption of the Passivhaus standard and methodology.

Passivhaus is the leading international low energy design standard, backed with over 30 years of building performance evidence. It is a tried & tested solution that enables a meaningful transition to net-zero now. Over 65,000 buildings have been certified to this standard worldwide. The Trust promotes Passivhaus as a robust way of providing high standards of occupant comfort and health AND slashing energy use and carbon emissions from buildings in the UK.

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