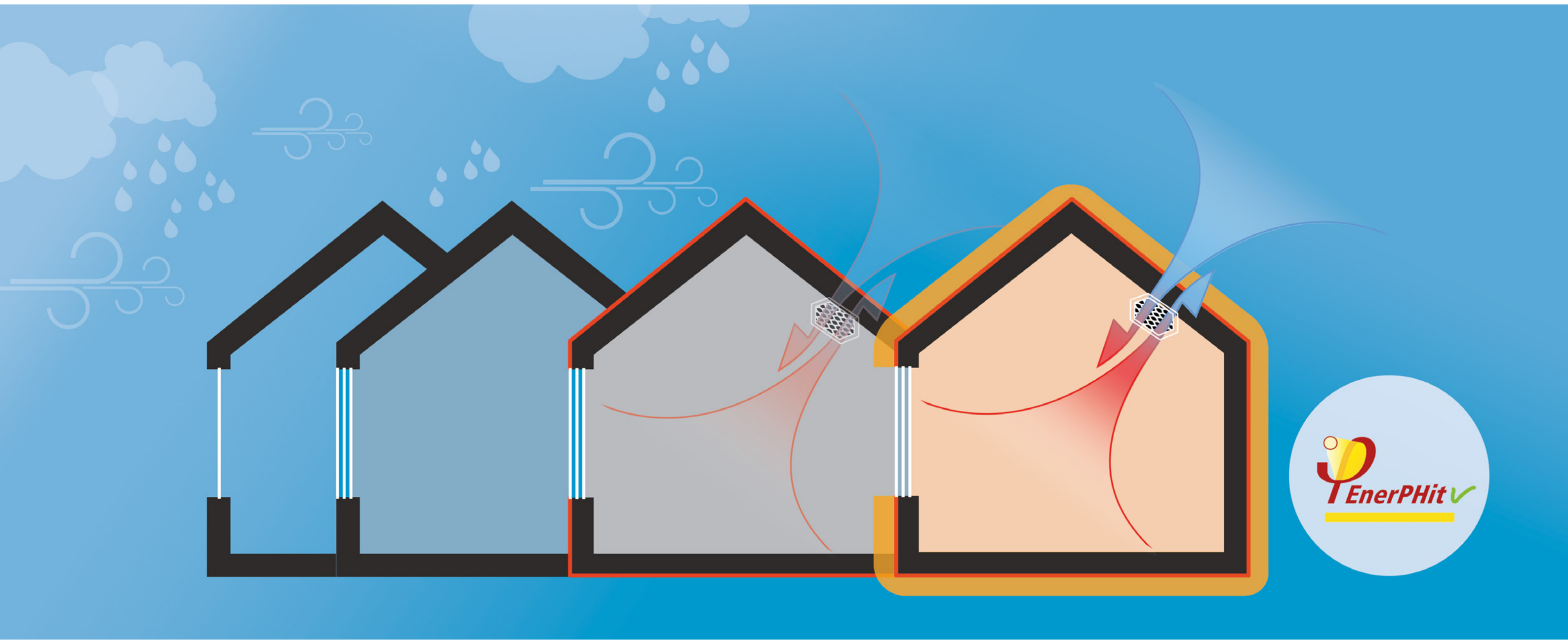
Passivhaus retrofit in the UK



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Executive summary

There are clear imperatives to reduce carbon emissions resulting from the built environment. While it is important to ensure our new buildings are as efficient as possible, our existing buildings are by far the biggest part of the problem.

Looking at our existing UK building stock, we see:

- It currently produces 27% of our carbon emissions with 18% alone coming from our homes
- It is not fit for purpose with 3.3 million households living in fuel poverty
- It consists of millions of poor-quality buildings, which have a detrimental impact on our health[1]
- It is not optimised for a decarbonised grid

By contrast, high quality deep retrofits deliver:

- Reduced fuel bills, addressing fuel poverty
- Improved health and wellbeing outcomes
- Buildings optimised for a decarbonised grid (with energy consumption issues addressed 'at source', i.e. at point of building, therefore reducing impact on wider utilities infrastructure)
- Reduced carbon emissions
- Reduced demand for renewable energy
- Reduced peak load

1 See PHT Benefits Guide, forthcoming 2021, for more detail on this topic.

While the imperative for retrofit is significant, individual buildings will come with their own unique set of challenges and budget limitations. We must recognise that it is unlikely that any retrofit programme will be able to reach all the UK's 28 million homes and all the non-residential buildings by 2050. There will therefore remain a cohort of buildings with poor fabric performance which will need to be compensated for by those buildings that are able to reduce their demand further, for example to EnerPHit levels. There will also then be a significant number of buildings somewhere in-between which may be more suitable for slightly lower than EnerPHit levels of performance, as covered in this paper. These middle buildings need to avoid the complexity for later decades, however, of the 'carbon lock-in effect' or 'stranded assets' as buildings utilise a decarbonised grid.

However, irrespective of the targets being set, to gain the maximum benefit from retrofit work it is important that a holistic whole building approach is taken, and strategies are put in place to control quality and eliminate the energy performance gap and, as far as possible, any unintended consequences.

Taking all these factors into consideration, the Passivhaus Trust recommends an EnerPHit-informed Retrofit Plan (EiRP) is created for all retrofit projects. This will create a whole building retrofit plan that allows all retrofits to benefit from the distinct advantages of the EnerPHit methodology. This includes modelling the existing building in the Passivhaus Planning Package (PHPP) to provide detailed calculations of the existing fabric performance of the building, which provides a base from which various upgrade options, including a range of energy performance targets, can be tested as part of an options evaluation process. Where projects adopt the EnerPHit standard they will also benefit from the performance assurance provided by the EnerPHit certification process. Any approach which does not include EnerPHit certification should be augmented by an additional and appropriate quality assurance mechanism.

Importantly, all approaches to retrofit, including EnerPHit, require some augmentation to deliver robust solutions addressing all aspects of the retrofit performance gap and unintended consequences.

The Passivhaus Trust recommends an EnerPHit-informed Retrofit Plan (EiRP) is created for all retrofit projects.

EiRP is defined as:

The existing building has been modelled in the Passivhaus Planning Package (PHPP) to understand the existing energy demands and this model has been used to test various levels of retrofit, up to and including the full EnerPHit standard. If the full EnerPHit standard is not considered feasible as a single stage project initially, designers have then referred to the PHT Retrofit Flow Chart, figure 8, to determine next steps.

Introduction

The UK has now set targets to reduce emissions by 78% from 1990 levels by 2035 and to net zero by 2050[2]. We will not be able to achieve this without decarbonising our existing buildings. A 2021 report from the Committee on Climate Change noted that there has been minimal progress on improving insulation or switching to low-carbon heating in our buildings in recent years[3].

The International Energy Agency (IEA) set out the rapid transition to low-carbon options for buildings in its *Net Zero by 2050: A Roadmap for the Global Energy Sector*, stating the need for widespread retrofitting of existing buildings. The IEA's 2020 figures put global retrofit rates below 1% with the Road Map setting out a requirement for 50% of existing buildings to be retrofitted to zero-carbon ready levels by 2040, increasing to 85% by 2050. The IEA estimate that all the technologies required to achieve deep reductions in global emissions exist today, with real-world examples of policies to drive their adoption. The IEA also highlight the co-benefits of widespread retrofit, including benefits to global GDP and global retrofit sector jobs[4].

To optimise on these co-benefits and make a meaningful step forward in our journey to Net Zero, our retrofit strategies in the UK must be ambitious and inclusive, covering both domestic and non-domestic building stock. Home-working is likely to affect energy demand in homes and workplaces. Increases in emissions from residential buildings (7% increase observed in 2020) could exceed savings in non-residential buildings (4% fall observed in 2020)[5], reinforcing the importance of upgrading the 28 million existing homes in the UK.

This paper looks at why retrofit must form an essential part of our national Zero Carbon ambitions and debunks the idea that we can wait for the grid to decarbonise, or for technology to provide solutions.

Setting a target

In establishing a target for our existing buildings, the Trust carried out an analysis of the following existing and emerging Retrofit standards:

- Passivhaus EnerPHit
- AECB Retrofit
- LETI Retrofit Guidance (due later in 2021)

- as well as looking at how PAS2035 can work in tandem with these standards.

This paper examines the validity of meeting these standards for our existing stock and the outcomes delivered by these varying standards, and then goes on to suggest how the EnerPHit process might be used as part of the UK national retrofit strategy.

2 https://www.gov.uk/government/news/uk-enshrines-new-target-in-law-to-slash-emissions-by-78-by-2035
3 Progress in reducing emissions: 2021 Report to Parliament, Committee on Climate Change, June 2021, Page 60
4 International Energy Agency (2021) Net Zero by 2050: A Roadmap for the Global Energy Sector https://www.iea.org/reports/net-zero-by-2050
5 BEIS (2021) Provisional UK greenhouse gas emissions national statistics 2020

Why retrofit is important

The built environment contributes around 40% of the UK's total carbon footprint.

The UK's buildings currently produce 27% of our carbon emissions with 18% alone coming from our homes. Decarbonising this sector is therefore critical to achieving net zero.

While it is important to ensure our new buildings are as efficient as possible, our existing buildings are by far the biggest part of the problem. The UK has some of the oldest and least energy-efficient housing stock in Europe and 80% of the buildings that will be around in 2050 have already been built – with the majority of those built before 1990. Retrofitting some 28 million buildings is a huge challenge and we therefore need to be realistic about what should and could be achieved.

Considering retrofit within a global context, a 20% reduction in demand for new buildings by using existing structures better could save up to 12% of global emissions in the building and infrastructure sector[6].

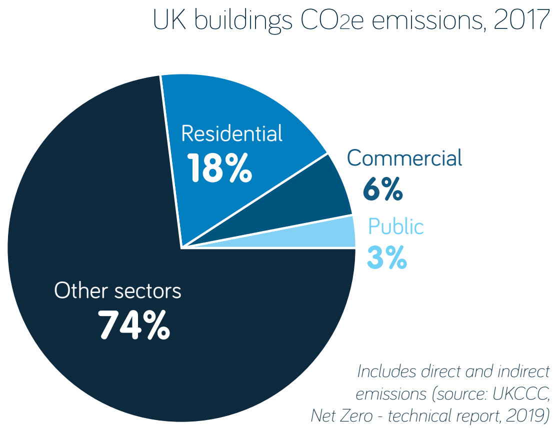

Figure 1 *- Contribution of buildings to UK carbon emissions*

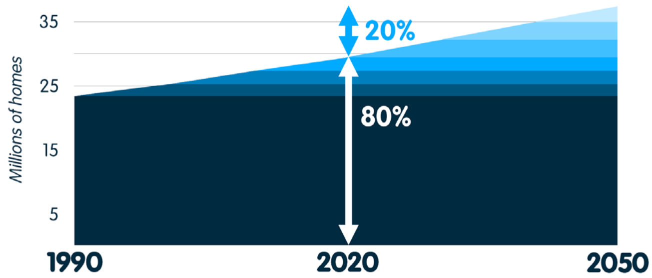

Figure 2 *- UK housing stock projections to 2050*

However, while reducing emissions is of critical importance, it is not the only reason to retrofit. A good retrofit will result in lower energy bills and thus less fuel poverty. It is also highly likely to result in better health with cold homes, summer comfort and indoor air quality all benefitting from improvement. In fact, the OECD and IEA estimate that 75% of the benefits of retrofit come in the form of improved health outcomes[7]. In turn, these effects offer broader benefits to society with improved wellbeing making people happier, healthier and more productive[8].

Retrofit plans can be integrated into existing asset management plans providing future added value for large public sector clients. This future value may be through occupant health, capital value increase and wider social value. The appraisal of social value, also known as public value, is based on the principles and ideas of welfare economics and concerns overall social welfare efficiency, not simply economic market efficiency[9]. RIBA's 2021 *Built for the Environment* report[10] highlighted the importance of this approach of moving away from decisions dominated by capital cost, and instead understanding and adopting whole-life costing models.

Adopting these approaches can improve quality of life, deliver more homes, and retain cultural heritage and community ties as well as avoid carbon-intensive and costly demolition and rebuild processes.

6 C40 Cities, Arup & the University of Leeds. Buildings and Infrastructure Consumption Emissions. [Online] 2019. https://www.arup.com/perspectives/publications/research/ section/buildings-and-infrastructure-consumptionemissions

7 OECD/IEA, 2014 Capturing the Multiple Benefits of Energy Efficiency Executive Summary: "Energy efficiency retrofits in buildings"

8 See PHT Benefits Guide, forthcoming 2021 for more detail on this topic

9 The Green Book Central Government Guidance on Appraisal and Evaluation, crown copyright 2018

10 https://www.architecture.com/-/media/GatherContent/Future-Architects-Resources/Additional-Documents/Built-for-the-Environment-reportpdf.pdf

What depth of retrofit is needed?[11]

Retrofit can often be difficult and expensive. Existing buildings come in a wide range of shapes, sizes and ages, many of which are difficult to bring up to exemplar standards of energy efficiency. So, in determining what depth of retrofit is required, we must be pragmatic about what can be achieved and balance that against what is necessary.

Why not just rely on a decarbonising grid?

If our primary objective is to reduce carbon emissions, then it is clear that we need to move to low (or zero) carbon sources of energy. With hydrogen for domestic heating looking unlikely anytime soon, this leads us to the conclusion that electricity, coupled with heat pumps, is the most effective solution. Once a heat pump is providing heating and hot water for a building, as the grid decarbonises its carbon emissions will reduce accordingly. Ultimately, a low or zero carbon grid will also mean very low emissions from that property without significant energy efficient improvements. This logic suggests that an extensive retrofit which significantly improves the building fabric (often called a 'deep retrofit') is actually not a prerequisite for net zero. However, this could be a dangerous assumption without considering the bigger picture ...

The grid does have limits ...

Although the energy offered by wind, solar and tide exceeds our energy needs, our capacity to harvest that energy is not infinite - there is a financial and carbon cost for all renewable technology. Hence there is a limit to how much renewable energy we will have in the future. Also, crucially, as renewable energy comes from naturally variable sources, there is a limit to how much power we can use at any one time, and there will also be a limit on how much storage we are able to provide. We also need to remember that all sectors (particularly transport) will be transitioning to draw their energy from the grid, and so our renewable energy sources will need to cater for all their demands as well.

There are limits to the peak heating load that can be met...

The total amount of renewable energy we can generate over the course of each year is not the only limiting factor. Perhaps more of an issue is the peak load that the national grid is able to deliver now and in the future (see figure 3). It is estimated that the peak thermal load currently demanded by our homes and delivered by gas is 170GW. The current electric grid capacity is around 60GW and even by 2050 is projected to only be 100GW.

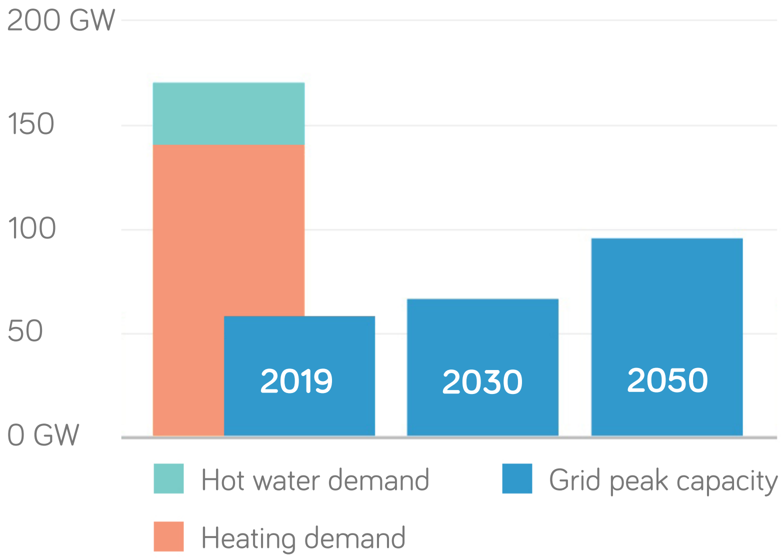

Figure 3 *- Grid capacity and heating peak load (GW)*

11 Note that the text from this section has been drawn from the LETI Climate Emergency Retrofit Guide, produced in conjunction with the Passivhaus Trust (and others).

The graph on the right shows two future peak load scenarios:

Scenario **A**

Existing homes are switched from gas to electricity without demand reduction through energy improvement works, resulting in an additional heating peak load of 15kW per home, to now be delivered by the national grid at peak times.

Scenario **B**

Existing homes undergo deep energy retrofit works, reducing their demand at peak times, resulting in an additional heating peak load of only 5kW per home.

This clearly demonstrates that demand reduction is an essential requirement to enable us to achieve a net zero balance.

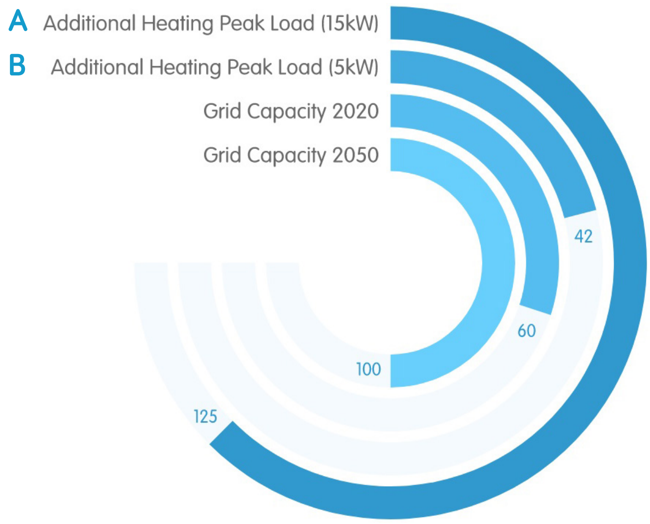

Figure 4 *- Grid capacity and heating peak load current and future scenarios(GW)*

Heat pumps are great, but ...

Retrofitting a heat pump into an existing building is by no means straightforward. Heating systems designed to operate with gas boilers work at high flow temperatures while heat pumps work most effectively at lower temperatures. Making a building suitable for a heat pump is therefore likely to involve some level of demand reduction – i.e. reducing heat loss – combined with measures such as increasing radiator sizes to enable greater heat distribution. The greater the reduction in demand, the more efficient the heat pump will become. If we don't reduce demand, then we could end up with cold homes which cost more to heat than they did with a gas boiler. Higher costs to achieve lower carbon emissions might be acceptable for some people, but for most, a retrofit would be expected to result in lower fuel bills.

Retrofit should reduce our fuel bills ... shouldn't it?

Some 11% of UK households, that's 3.3 million homes, are in fuel poverty[12], and this is likely to increase because of the continuing gas market volatility. Our efforts to achieve net zero shouldn't make this worse. Electricity is currently around four times more expensive than gas. While switching to an electrical-only building will eliminate the gas standing charge, this still means that a Seasonal Coefficient of Performance (SCOP) of around 3 will need to be achieved from a heat pump to ensure running costs remain the same as for a gas boiler. This level of SCOP is typically only achieved using low flow temperatures which, again, implies lower heat demand. Furthermore, a lower heat demand also reduces fuel bills. Getting this wrong would not only push more people into fuel poverty, but would discourage any large-scale take up of heat pumps from the public in general.

12 Data for the 4 nations drawn from:
England: assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/882159/fuel-poverty-factsheet-2020-2018-data.pdf
NI: www.communities-ni.gov.uk/topics/housing/ fuel-poverty
Scotland: www.eas.org.uk/en/ fuel-poverty-overview_50439/
Wales: https://gov.wales/ fuel-poverty-estimates-wales-2018

But maybe health and wellbeing is the most important factor ...

Poor quality homes can have a detrimental impact on our health[13]. Many of our existing dwellings are too cold in winter, too hot in summer and suffer from poor indoor air quality. These issues impact our health and wellbeing, affecting in particular the very young, the elderly and those with respiratory conditions or compromised immune systems. The BRE have estimated that poor housing costs the NHS £1.4 billion every year. But perhaps the more significant figure is that for every £100 saved in direct healthcare costs, there is another £1200 of indirect savings and benefits to society[14].

Achieving warm homes, improving summer comfort, eliminating mould and improving indoor air quality is unlikely to be achieved by a small number of minor retrofit measures designed to simply enable a heat pump to be fitted. In fact, a poorly executed retrofit can result in moisture and condensation issues which actually exacerbate health risks.

So, how far should retrofit go?

Overall, these arguments would suggest that achieving net zero, enabling heat pumps, improving health and realising broader societal benefits are most likely to be achieved by a deep level of retrofit which results in significant energy demand reduction. Shallow retrofit puts building owners at risk of possessing stranded assets as a result of carbon lock in.

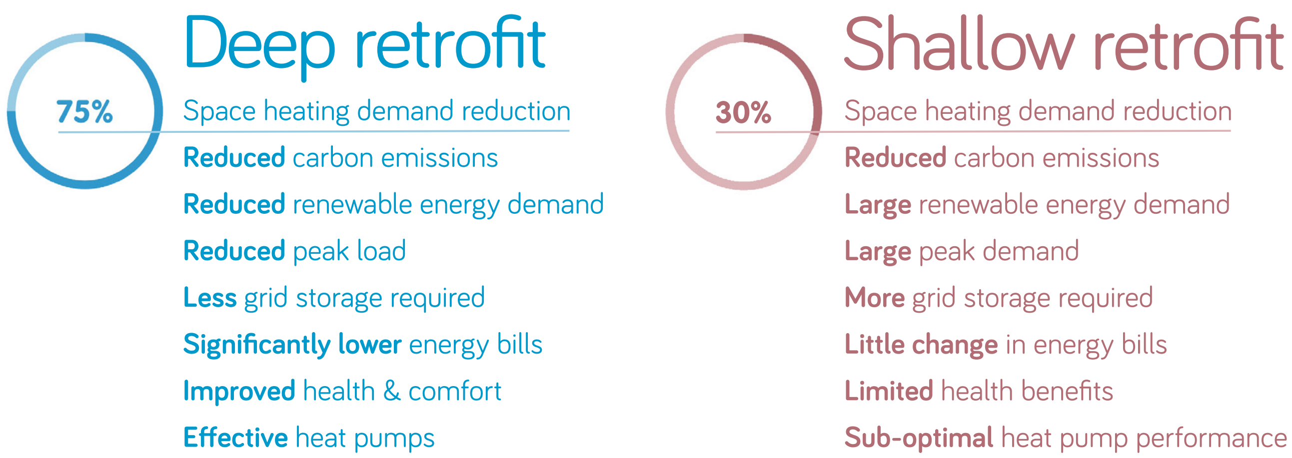

***Figure 5** - Comparison of energy demand reductions and associated co-benefits from shallow and deep retrofits*

13 See PHT Benefits Guide, forthcoming 2021 for more detail on this topic.
14 BRE report "The full cost of poor housing" 2016

What does EnerPHit deliver?

EnerPHit is the Passivhaus retrofit standard. It uses the same set of criteria as for Passivhaus Classic new build, but with a small relaxation for certain criteria. The principal criteria are shown below.

Criteria	Passivhaus classic new build	EnerPHit
Space Heating Demand	≤ **15** kWh/m^2.a	≤ **20** / ≤ **25** / ≤ **30** kWh/m^2.a *
Primary Energy Demand	≤ **135** kWh/m^2.a	≤ **135** +(QH – 15) **
Primary Energy Renewable[15]	≤ **60**	≤ **71** (Cool temperate) / ≤ **65.5** (Warm temperate)
Airtightness n50	≤ **0.6** ach @ 50Pa	≤ **1** ach @ 50Pa
Summer overheating	Max 10% at > 25°C	Max 10% at > 25°C
Surface temperature	> 17°C	> 17°C
Ventilation	30 m^3/hr.person	30 m^3/hr.person

**Depending on climate zone*

*** Where QH is the achieved space heating demand*

***Table 1** - EnerPHit and Passivhaus new build criteria*

The EnerPHit space heating criterion target depends on the climate zone. The UK spans three climate zones (see below), but the majority of the country is classed as cool temperate and thus EnerPHit will typically deliver a space heating demand of 25 kWh/m^2.year.

Climate zone	EnerPHit space heating demand limit
Cold	30 kWh/m^2.year
Cool temperate	25 kWh/m^2.year
Warm temperate	20 kWh/m^2.year*

** The UK Passivhaus Trust does not recommend that the Warm Temperate zone is applied within the UK. If a project falls within this zone we recommend the Cool Temperate Zone is applied.*

***Table 2** - EnerPHit space heating demand by climate zone (subject to altitude)*

The majority of the other criteria are the same as for Passivhaus Classic with the exception of airtightness which is relaxed from 0.6 ACH@50Pa to 1.0 ACH@50Pa.

Thus, if we consider EnerPHit in the context of the UK stock, it will result in a retrofitted building which has a space heating demand 80% lower than the national average.

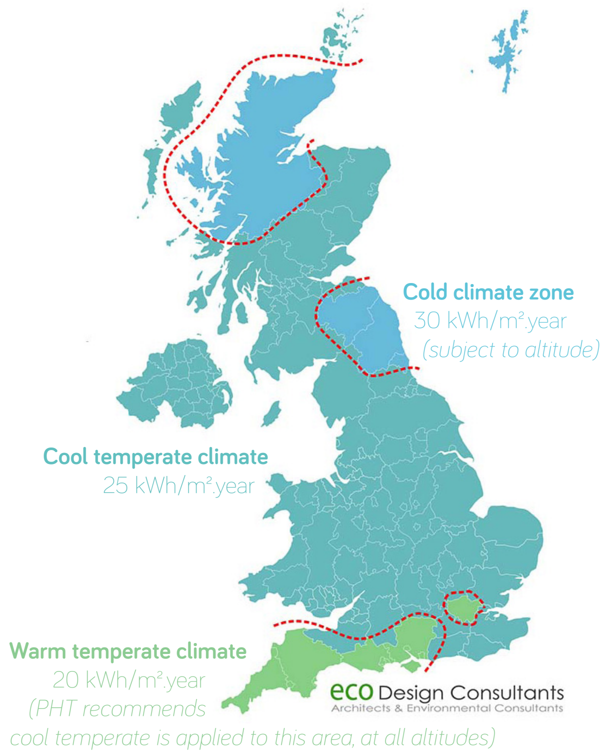

***Figure 6** - UK climate zones (subject to altitude)*

15 The PER demand for EnerPHit is calculated using the following formula: 60 + (QH - QH,PH) • fØPER,H where QH is the retrofitted building's space heating demand, QH,PH is 15 and fØPER,H is the primary energy factor of the building's heating system. The figures shown above assume an Air Source Heat Pump which has a PER factor of 1.1.

The EnerPHit component approach

The EnerPHit standard can also be achieved via the component approach. This doesn't refer to certified Passivhaus components, but rather to the component parts that make up the building – i.e. walls, roofs, floors, windows and doors. Rather than set a specific space heating demand target, this alternative approach sets limits for the thermal performance of the building elements alongside the same targets for airtightness, ventilation and surface temperatures. The reason for this option is to cater for buildings where the orientation, form factor and glazing preclude achieving the required space heating demand, even when the fabric has been upgraded to levels commensurate with Passivhaus performance.

The component approach limiting values for EnerPHit in the UK are summarised below.

	Maximum fabric U-values (W/m²K)			Maximum whole window U-values (Wm²K)			Ventilation performance	
Climate zone (see map)	Ground floor (ground cassette only)	External walls and roofs (with exterior insulation)	External walls and roofs (with internal insulation)	Windows in walls	Windows in pitched roofs	Windows in flat roofs	Minimum heat recovery efficiency (%)	Maximum airtightness (ACH@50Pa)
Cold	0.12	0.12	0.30	0.65	0.70	0.80	80%	1.0
Cool Temperate	0.15	0.15	0.35	0.85	1.00	1.10	75%	1.0
Warm Temperate*	0.30	0.30	0.50	1.05	1.20	1.20	75%	1.0

**The UK Passivhaus Trust does not recommend that the Warm Temperate zone is applied within the UK. If a project falls within this zone we recommend the Cool Temperate Zone is applied.*

***Table 3** - EnerPHit component approach limiting values*

Although there is obviously no specific space heating demand associated with the component approach, experience in the UK indicates that it typically results in a space heating demand of between 30 and 40 kWh/m².year. This increases to an upper value of around 60kWh/m².year in northern parts of the UK.

The range of approaches to EnerPHit certification mean that the standard is widely applicable to UK retrofit projects.

Retrofit approaches

This section focuses on a number of standards being used in the UK. This is not all encompassing – other UK retrofit standards exist and are emerging.

The AECB and LETI have both recently produced retrofit specifications. Both have been derived from the views of experienced practitioners who have been undertaking deep retrofit in the UK for some time. Their targets are chosen to deliver a good depth of retrofit which is both feasible and affordable for most UK homes and could also be achieved at scale. The AECB offer a retrofit standard which can be certified against, whereas LETI are simply offering guidance to support a good level of retrofit. For this reason LETI strongly recommends that a recognised retrofit standard and quality assurance process is used alongside the LETI guidance. EnerPHit retrofits achieve reductions aligned with LETI's exemplar targets in terms of retrofit ambition.

PAS 2035 *Retrofitting dwellings for improved energy efficiency – Specification and guidance* is a framework and guidance document for delivering retrofit projects, published by the British Standards Institute (BSI). It promotes a fabric-first, whole house approach. It focuses on proper retrofit planning and quality assurance and requires the appointment of accredited professionals - including a Retrofit Coordinator - to oversee the retrofit project. PAS 2035 does not set energy efficiency targets or define how 'deep' one should go, so is not included in the tables below.

Its aim is to avoid the unintended consequences, defects and performance gap of poor retrofit. All retrofit projects receiving central government funding are required to be PAS 2035 compliant. PAS 2035 works in tandem with the PAS 2030 standard for the installation of energy efficiency measures in existing buildings. Taken together, PAS 2030 and PAS 2035 lay down the steps domestic retrofit projects can follow to gain compliance and ensure consumer satisfaction in accordance with the recommendations of the *Each Home Counts* review. PAS 2035 can be used in tandem with the retrofit standards listed below. An EnerPHit-informed Retrofit Plan (EiRP) can be used to form the PAS 2035 improvement options evaluation, and also form the basis of a PAS 2035 Retrofit Plan.

Criteria	Passivhaus Classic new build	EnerPHit	AECB Retrofit	LETI Retrofit (Guidance)*
Space heating demand	≤ **15** kWh/m².year	≤ **20**, **25** or **30** kWh/m².year *or circa 20-60 for component approach*	≤ **50** kWh/m².year *with exemption up to 100*	≤ **50** kWh/m².year *exemption up to 60 with an exemplar target of* ***≤ 25***
Primary energy renewable (PER) / energy use intensity (EUI)	PER: ≤ **60** kWh/m².year	PER: ≤ **71** kWh/m².year *(Cool Temperate)* PER: ≤ **65.5** kWh/m².year *(Warm Temperate)*	*Not specified – fabric only*	EUI: ≤ **50** kWh/m².year *exemption up to 60 with an exemplar target of* ***≤ 40****. With grid storage losses included these become ≤ 65 with exemption up to 70***
Primary energy demand	≤ **135** kWh/m².year	≤ **135** kWh/m².year + (QH – 15) * 1.2	*Not specified, but direct electric & new gas boilers are only allowed by exception*	*Not specified*
Airtightness n50	≤ **0.6** ach @ 50Pa	≤ **1.0** ach @ 50Pa	≤ **2.0** ach @ 50Pa	≤ **2.0** ach @ 50Pa *exemption up to 3 with an exemplar target of* ***≤ 1.0*** *ach @50pa*
Summer overheating	Max **10%** > 25°C	Max **10%** > 25°C	Max **10%** > 25°C	*Not specified*
Surface temperature (inc. windows)	**> 17°C**	**> 17°C**	**> 17°C**	*Not specified*
Surface temperature coefficient	Cool-temperate: **0.7** fRsi*** Cold: **0.75** fRsi Warm: **0.65** fRsi	Cool-temperate: **0.7** fRsi Cold: **0.75** fRsi Warm: **0.65** fRsi	**>0.75** fRsi	*Not specified*
Ventilation	**30** m³/hr.person	**30** m³/hr.person	**30** m³/hr.person	*MVHR specified, rate m³/hr.person not specified*
How is this standard demonstrated?	**PHPP**	**PHPP**	**PHPP**	**PHPP** or simplified elemental approach

**The LETI guidance is due for publication October 2021. Values subject to change until published.*

*** The LETI EUI target does not include an allowance for electricity grid storage losses – however, this is included in the Passivhaus new-build and EnerPHit PER limits. So to make this comparable to the Passivhaus metric, the LETI figures shown above including electricity gird storage losses assume an Air Source Heat Pump with PER factors of 1.1 for heating and 1.21 for hot water and an average Seasonal Coefficient of Performance (SCOP) of 2 for both heating and hot water.*

****The fRsi factor is a dimensionless number, ranging from 1 to 0. fRsi = 1: the internal surface temperature at the thermal bridge is exactly the same as in the rest of the house. It is the best result you could ever get, and it is physically impossible to obtain; fRsi = 0: the temperature at the thermal bridge is identical to the outside one, with a terrible outcome in terms of comfort. This result is also physically impossible.*

Table 4 *- Comparison of retrofit approaches*

The LETI specification also includes guidance for a component approach where, similar to the EnerPHit component approach, elemental u-values are specified. However, unlike EnerPHit, the aim of this alternative is to provide practical guidance for retrofits where detailed PHPP modelling will not be undertaken.

There are parts of the AECB Retrofit Standard, such as the approach to moisture risk, that the Passivhaus Trust recommend is applied to all retrofit projects. The AECB run a Carbonlite Retrofit Course, developed specifically for the UK, that gives construction professionals an understanding of retrofit that can be applied to all the approaches discussed in this document, and provides valuable tools to avoid or manage unintended consequences. This course is recognised by the International Passivhaus Institute. The AECB Retrofit Standard is also complemented by the AECB water, daylighting and lifetime carbon standards.

The retrofit performance gap

Energy performance gap

The performance gap in new-build homes is well documented and a conservative estimate of its size is 60% additional space heating demand. However, the presence and size of the equivalent energy performance gap in retrofitted homes is not well understood. The root causes of the new-build performance gap all apply to retrofit. But there is less regulation in the retrofit sector and the contractors completing this work will tend to be smaller with fewer specialist skills. If anything, the retrofit performance gap is therefore likely to be even more significant than in the new-build sector.

As has been demonstrated in several studies, the Passivhaus approach effectively closes the energy performance gap using a combination of rigorous design, demanding criteria and an independent certification process.

Unintended consequences

However, the performance gap in retrofit is far wider than energy. It also encompasses unintended consequences, many of which are related to moisture. A good retrofit is one that avoids all unintended consequences. Many of the principles of Passivhaus can help us achieve this, including quality control, airtightness and continuous insulation. To ensure good moisture design it is recommended that all retrofit projects incorporate a moisture risk assessment, and similarly, to maximise summer comfort, a summer overheating stress test should be incorporated into the design process, as set out in table 6.

Comparing retrofit approaches

Having now set out the various retrofit approaches, it is possible to compare the level of energy reduction each one is targeting, together with how they try and ensure other outcomes such as low overall energy use, as well as health and comfort improvements.

	Standards		Guidance
	EnerPHit	**AECB Retrofit**	**LETI Retrofit**
Improved fabric performance	Space heating demand limit	Space heating demand limit	Space heating demand limit
Overall limit on energy demand and emissions	Primary Energy or Primary Energy Renewable limit (equivalent to EUI limit plus storage losses allowance)	No limit for overall energy demand but direct elec. and new gas boilers are not accepted (unless by exception)	• Hot Water demand limit • Overall Energy Use Intensity (EUI) limit
Comfort and health outcomes	• Surface temperature limit • Summer overheating limit • Ventilation rate minimum • Airtightness limit	• Surface temperature limit • Summer overheating limit • Ventilation rate minimum • Airtightness limit • Moisture & mould reduced • Radon evaluated	Airtightness limit*
Closure of energy performance gap	• PHPP modelling, avoidance of thermal bridges and airtightness • Independent QA process	• PHPP modelling, avoidance of thermal bridges and airtightness • Verification by a suitably qualified person	Not addressed*

** LETI strongly recommends that a recognised retrofit standard and quality assurance process is used alongside the LETI guidance*

Table 5 *- Comparison of retrofit approaches in achieving desired outcomes*

It is also important to recognise the limitations of these approaches and provide recommendations for how they can be augmented to avoid unintended consequences, as set out in table 6 below.

	Standards		Guidance
Unintended consequences	**EnerPHit**	**AECB Retrofit**	**LETI Retrofit****
Energy performance gap	Included	Partially included within the standard, augment with: • Independent QA process • EUI Limit	Augment with independent QA process
Moisture damage	Partially included within the standard, augment with moisture risk assessment*	Included	Augment with moisture risk assessment*
Summer overheating	Partially covered in both EnerPHit and AECB, but recommendation to augment with Summer overheating stress test		Augment with Summer overheating stress test
Comfort & health not optimised	Included	Included	Augment with EnerPHit comfort/ health criteria

** Moisture risk assessments should follow the AECB Retrofit Standard Guidance Document*
***LETI are simply offering guidance to support a good level of retrofit. For this reason LETI strongly recommends that a recognised retrofit standard and quality assurance process is used alongside the LETI guidance.*

Table 6 *- Augmentation recommendations for retrofit approaches to address unintended consequences*

This demonstrates that while all approaches have criteria aimed at improving fabric performance, the supporting criteria to drive overall energy reductions, comfort and health outcomes, and closure of the performance gap are less consistent.

This also shows that all approaches require some augmentation to deliver robust solutions addressing all aspects of the retrofit performance gap and unintended consequences. Common to all approaches is a requirement to augment with additional summer overheating stress testing, which should be undertaken for all retrofit projects in the UK.

The AECB standard is a holistic standard, covering a range of retrofit specific challenges in addition to those listed above. This includes, flood, fire and heritage risk evaluation. The AECB Carbonlite Retrofit Course also covers constraints for existing buildings in retrofit design, set within the context of the UK building stock.

Where are we starting from?

Where we might end up with a retrofit depends to a certain extent on where we are starting from. Understanding where this might be is by no means straightforward as the UK's regulatory instrument (the EPC) does not provide us with detailed information about the actual energy performance of buildings.

Space heating demand is a key Passivhaus criterion and is a good proxy for a building's fabric performance. The Passivhaus Trust have worked with LETI to build a stock model of the UK's existing domestic buildings, which has been used to model the space heating demand profile of the UK's homes, broken down by building form.

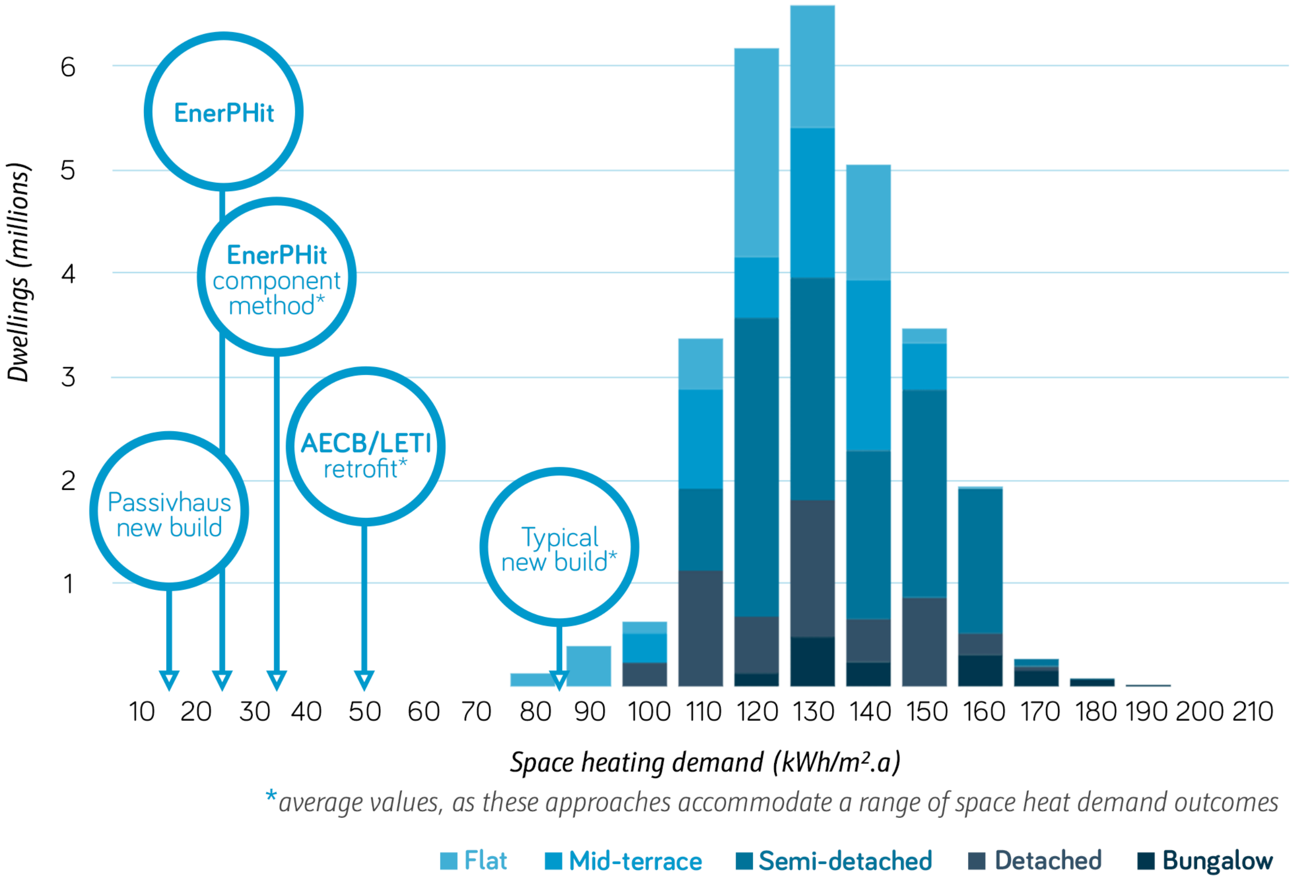

Figure 7 *- UK housing stock breakdown by space heating demand and building form*

This modelling reveals that the average UK space heating demand is around 120-130 kWh/m².year with a spread from 80 to 190 kWh/m².year. In comparison, a typical UK new build (Building Regulations 2020) has a space heating demand of 85 kWh/m².year. The spread of retrofit targets discussed above shows the space heating demand criterion for each.

This shows that for an average home to reach EnerPHit levels, an 80% reduction is required. For the component approach, this averages 72% and for the AECB/LETI criterion, it averages 60%.

Analysis of the UK existing non-domestic building stock will be considered in more detail in a future publication as more data becomes available.

Innovation

Across Europe there are many innovative solutions being used to deliver EnerPHit projects. While a detailed analysis of these is beyond the scope of this paper, it is important to reference both the International Passivhaus Institute's EuroPHit Project and OutPHit study. These initiatives show how both the step-by-step approach and single stage projects can be built into successful financial modelling and delivery mechanisms, with the potential to deliver the energy demand reduction we require, at the scale necessary, to meet our Net Zero targets.

When to use what

This paper has set out the various approaches to retrofit in the UK and compared both their specific criteria and their approach to ensuring that all the potential benefits of retrofit are realised.

While the imperative for retrofit is significant, every project will have a limited budget, and mandating an exemplar level of retrofit for all homes in the UK is likely to be prohibitively expense and thus doomed to failure. However, some buildings may lend themselves to achieving the highest levels of reductions. For example, multi-residential buildings with compact forms where economies of scale can be realised are likely to be able to achieve EnerPHit levels of space heating demand with very little extra-over costs compared to a minimal refurbishment. Non-domestic buildings, particularly those within public sector ownership, as well as existing social housing, provide an excellent opportunity to appraise retrofit projects based on social value and adopt innovate funding approaches to deliver these to the full EnerPHit standard. It is important that decision making is not based solely on capital cost. Where EnerPHit can be delivered at an estate-wide level we have an opportunity to create transformative change for our communities.

We must also recognise that it is unlikely that any retrofit programme will be able to reach all the UK's 28 million buildings by 2050. There will therefore remain a cohort of buildings with poor fabric performance which will need to be compensated for by those buildings that are able to reduce their demand to EnerPHit levels. There will also then be a significant number of buildings somewhere in-between which may be more suitable for the AECB/LETI levels of performance.

Furthermore, as has been seen with Passivhaus new-build, exemplar projects demonstrate what can be achieved, and serve as test-beds to develop new technologies and skills which then filter out into the mainstream.

Achieving the full range of desired outcomes and their associated benefits is essential – anything less is a missed opportunity.

Taking all these factors into consideration, the Passivhaus Trust recommends an EnerPHit-informed Retrofit Plan (EiRP)[16] is created for all retrofit projects. This will create a whole building retrofit plan that allows all retrofits to benefit from the distinct advantages of the EnerPHit methodology. This includes modelling the existing building in the Passivhaus Planning Package (PHPP) to provide detailed calculations of the existing fabric performance of the building, which provides a base from which various upgrade options, including a range of energy performance targets, can be tested as part of an options evaluation process. Where projects adopt the EnerPHit standard they will also benefit from the performance assurance provided by the EnerPHit certification process. Any approach which does not include EnerPHit certification should be augmented by an additional and appropriate quality assurance mechanism.

Importantly, all approaches to retrofit, including EnerPHit, require some augmentation to deliver robust solutions addressing all aspects of the retrofit performance gap and unintended consequences (refer to table 5).

16 EiRP is defined as: The existing building has been modelled in the Passivhaus Planning Package (PHPP) to understand the existing energy demands and this model has been used to test various levels of retrofit, up to and including the full EnerPHit standard. If the full EnerPHit standard is not considered feasible as a single stage project initially, designers have then referred to the PHT Retrofit Flow Chart, figure 8, to determine next steps.

Taking all these factors into consideration, the Passivhaus Trust recommends the following approach to retrofit (which can work in tandem with PAS 2035 for government funded projects utilising the PAS 2035 framework):

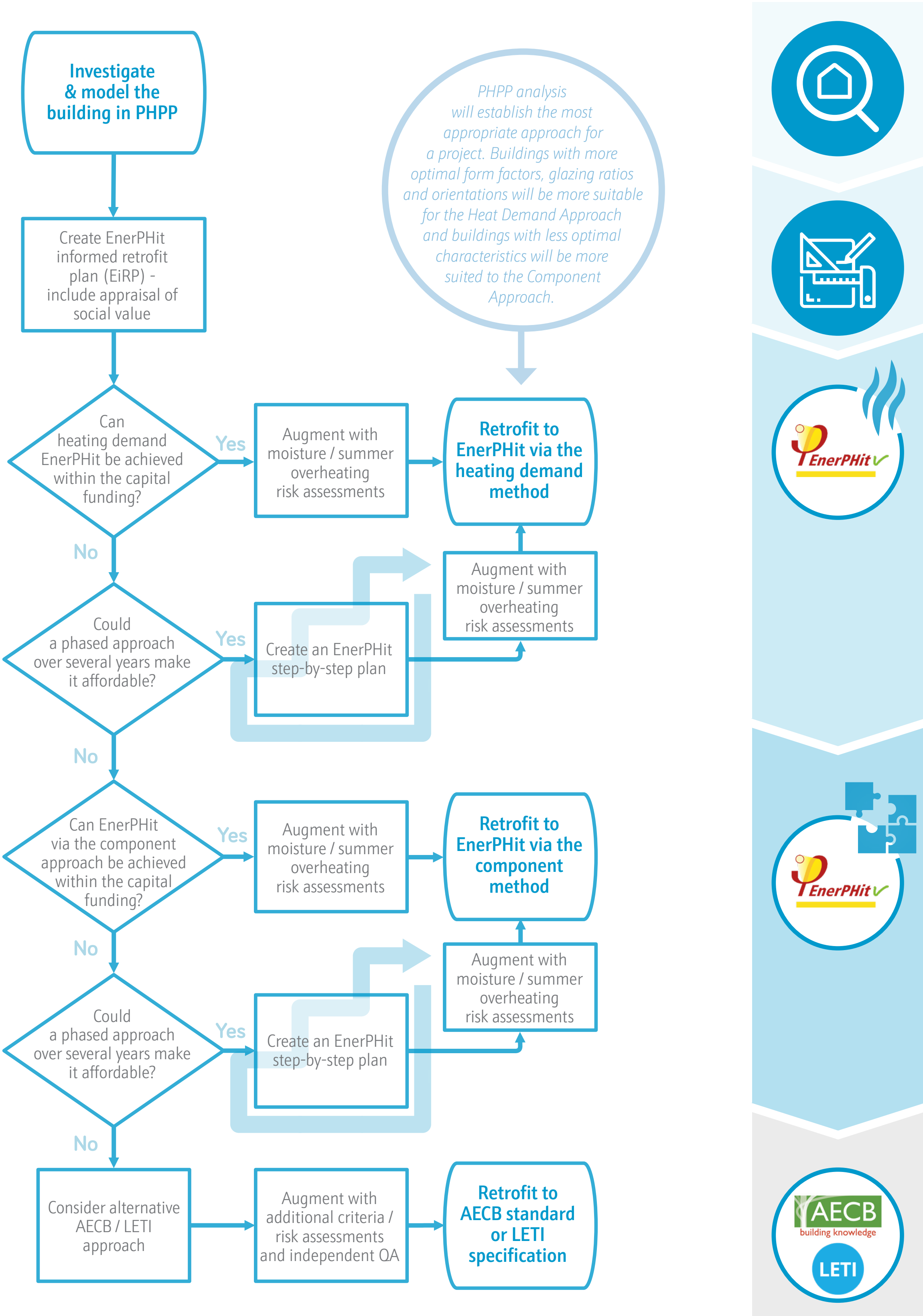

Figure 8 *- Passivhaus Trust recommended approach to retrofit*