

RESEARCH PAPER

EnerPHit Component Step-by-Step

Theoretical Case Study Retrofits

May 2026

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Executive summary

This research paper explores the application of the EnerPHit component method as a staged retrofit pathway for typical UK dwellings. Four virtual archetypes – two pre-1919 semi-detached houses, one post-1919 mid-terrace house, and one top floor flat – were modelled using a Variants PHPP to assess the impact of successive retrofit steps on space heating demand (SHD), energy use intensity (EUI), carbon emissions and energy bills.

The staged approach reflects the way retrofit is typically delivered in the UK: incrementally, often aligned with funding availability, component end-of-life replacement, and household budget constraints. A total of five retrofit steps were defined, consistent with the EnerPHit Component Method, beginning with loft insulation and then MVHR, wall insulation, window replacement, floor insulation, and heat pump installation.

Key findings include:

- The first retrofit step must be carefully defined to achieve the 20% reduction in either heating demand or PER that is required for staged certification. In many cases, loft insulation alone may not achieve this threshold unless combined with airtightness improvements or MVHR.
- Extensions built to EnerPHit component standards (e.g. a room-in-roof conversion or rear single-story extension and is often included in the first retrofit step) improve relative performance intensity metrics (kWh/m².a) but increase total heated floor area. EnerPHit is an effective way of offsetting the carbon impact of building an extension.
- The EnerPHit component method can, in some archetypes, achieve Space Heating Demand (SHD) values below 25 kWh/m².a, which is the limit set by the EnerPHit space heating demand method in most parts of the UK. However, this is not guaranteed across all dwelling types and climates. The top floor flat model remained above this threshold despite compliant components, highlighting the influence of form factor and exposure.
- The timing of heat pump installation influences carbon outcomes. Early system change delivers immediate CO₂ reductions but raises running costs, while later installation can lower running costs following fabric improvements.
- EnerPHit can be an effective way of offsetting the additional operational costs of electrification of heating and hot water in flats where direct electric is used.

The study also examines the use of PHPP for modelling existing homes. While PHPP is conservative and optimised for certification, designers can use tools such as periodic heating, adjusted occupancy profiles and updated UK carbon factors to produce more realistic retrofit options assessments — provided certification and advisory models are clearly separated.

Overall, EnerPHit via the component method provides a robust and flexible framework for delivering high-performance retrofit in the UK. When supported by a comprehensive EnerPHit Retrofit Plan (ERP) and careful PHPP modelling, it enables staged delivery without compromising long-term performance ambition. More information about EnerPHit standards within the UK policy context alongside other retrofit compliance standards and targets is available in *Passivhaus Retrofit in the UK* (Passivhaus Trust, 2026)¹.

¹ Available online at <https://pht.guide/Retrofit>

Introduction

The EnerPHit component method offers a staged pathway to high-performance retrofit that reflects how energy improvements are typically delivered in the UK. Rather than requiring a deep, whole-house intervention in a single phase, the component method allows Passivhaus-level specifications to be applied element-by-element, over time. This aligns with the realities of household budgets, disruption tolerance, and the structure of UK retrofit funding, which is often measure-based and subject to change.

“All models are wrong. But some are useful” George E.P. Box

In practice, many UK retrofit projects proceed incrementally. Roofs are replaced at end of life, windows are upgraded during refurbishment, and heating systems are changed when they fail. Without a whole-house strategy, these moments can lock in underperformance for decades. The EnerPHit Retrofit Plan addresses this risk by defining a coherent long-term pathway, even if implementation is phased over many years. By preparing a fully designed retrofit plan and tender information in advance, project teams can respond quickly to funding opportunities as they arise, while maintaining alignment with long-term deep retrofit ambition.

Passivhaus retrofit in the UK is often associated with deep, single-phase projects targeting EnerPHit via the space heating demand method. In contrast, there are relatively few UK case studies demonstrating the staged component method. This paper therefore models four common UK dwelling archetypes and applies the EnerPHit component method step-by-step to explore how space heating demand, energy use intensity (EUI), carbon emissions and energy bills evolve across successive retrofit stages.

All modelling relies on assumptions. As George Box famously noted, “All models are wrong, but some are useful.” By clearly defining and maintaining consistent assumptions, we can use PHPP and the Variants tool to identify meaningful trends and compare the relative impact of retrofit measures.

The final section of this paper also reflects on the use of PHPP for modelling existing homes, and suggests how designers can use it effectively to communicate retrofit strategies and performance outcomes to clients.

The UK archetypes

A UK housing stock archetype model prepared for LETI² (extrapolated from the English Housing Survey data) informed the selection of the archetypes used in this study and the development of their specifications. This was combined with our knowledge of the existing UK housing stock and those homes that have typically been improved with deep retrofit. We have aimed to represent mainstream fabric types across the four archetypes and tried to avoid excessive diversification as it could hinder meaningful comparison.

On this basis, our four archetypes are two semi-detached houses, one mid-terrace house, and one flat.

Archetypes 1 & 2: Semi-detached house with loft space

Semi-detached houses are the most represented dwelling in the housing survey stock model and are widely recognised as a typical UK house form. For this reason, two pre-1919 semi-detached archetypes have been modelled. Both have the same baseline specification, but they will undertake separate retrofit pathways. One will extend into the roof and the other will keep the same thermal envelope.

Fabric specification:

- suspended timber floor
- solid uninsulated walls
- minimal loft insulation

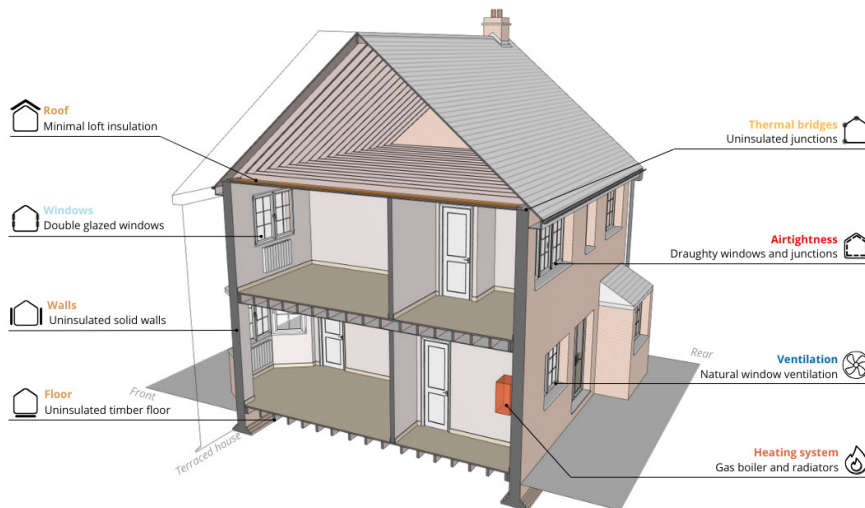


Fig. 1: Archetypes 1 & 2: Baseline 3D model

2 For details of the LETI modelling, see *Climate Emergency Retrofit Guide* (LETI, 2021), available online at <https://www.leti.uk/retrofit>

Archetype 3: Mid-terrace house

This archetype represents a typical post-1919 middle dwelling in a row of houses, with only two sides exposed to the exterior.

Fabric specification:

- solid uninsulated floor
- cavity uninsulated walls
- minimal loft insulation

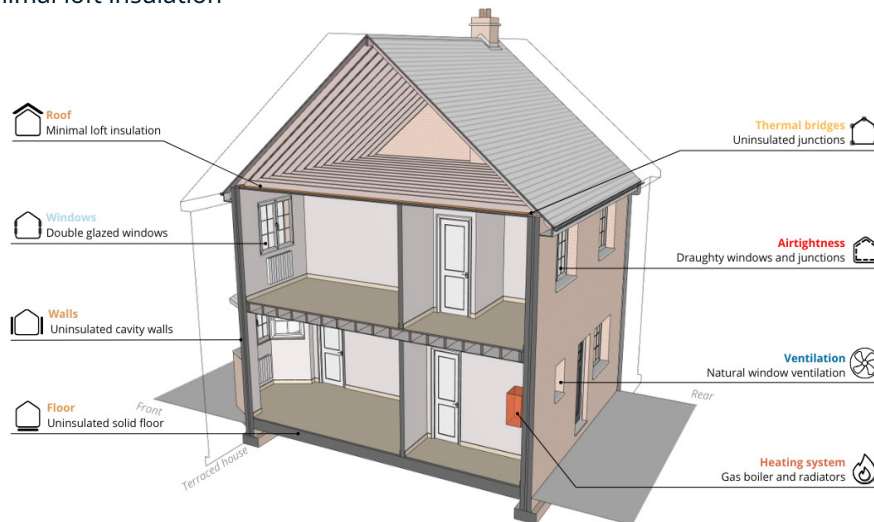


Fig. 2: Archetype 3: Baseline 3D model

Archetype 4: Top floor flat in a multi-residential building

Flats in multi-residential buildings are another common dwelling type. This archetype represents a top floor flat, which typically has the greatest fabric exposure and, consequently, the highest heating demand.

Fabric specification:

- cavity insulated walls
- moderate loft insulation

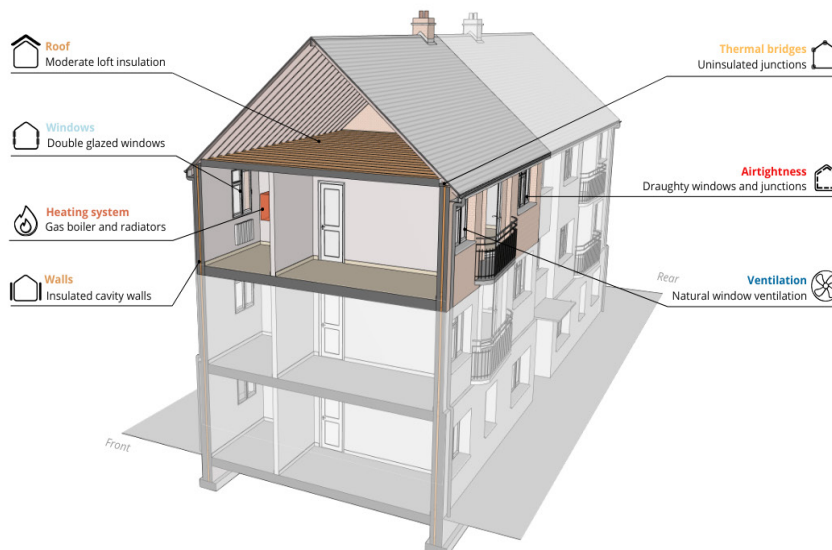


Fig. 3: Archetype 4: Baseline 3D model

Archetypes comparison summary

Archetype	Floor	Walls	Roof
Archetype 1: semi	Suspended timber	Solid uninsulated	Minimal loft insulation
Archetype 2: semi	Suspended timber	Solid uninsulated	Minimal loft insulation
Archetype 3: mid-terrace	Solid uninsulated	Cavity uninsulated	Minimal loft insulation
Archetype 4: flat	-	Cavity insulated	Moderate loft insulation

Table 1: Archetypes comparison summary

Baseline specification

The baseline PHPP models use the following general and building fabric specifications. These take the LETI archetype models as a starting point while providing further detail and refinement for certain fabric U-values. Solid uninsulated and cavity walls U-values are taken from the BRE consultation paper on U-values in existing buildings.³

Fabric group	Building element	U-value W/m ² K
Floors	Solid uninsulated floor	2.47
	Suspended timber floor	1.64
Walls	Solid uninsulated wall	1.69
	Solid insulated (RiR)	0.25
	Cavity uninsulated	1.52
	Cavity insulated	0.67
	Timber frame (dormer)	0.35
Roofs	Minimal loft insulation	1.18
	Moderate loft insulation	0.36
Windows and doors	Double-glazed	2.2*
	Solid doors	3.0* ¹
Element	Type	Specification
Ventilation	Natural – window opening	No heat recovery
Heating and hot water	Gas boiler with radiators	Modern condensing

* Average window U-value installed

*¹Door U-value installed

Table 2: Baseline specification

³ Review of default U-values for existing buildings in SAP, BRE, 2016, https://bregroup.com/documents/d/bre-group/cons-16-wall-u-values-for-existing-dwellings-v1_0-pdf

Modelling approach and baseline assumptions

In general, the inputs from the LETI stock modelling have been maintained to preserve consistency with other industry guidance, where relevant to this project, and other reference data. Other inputs have been modified as necessary to improve accuracy or to incorporate more specific information where available. Where reference data was unavailable or could not be determined, conservative assumptions have been applied.

The following list itemises key PHPP inputs and identifies the references used to inform the decision-making for each.

- The Climate Zone chosen is Cool-temperate (specifically Zone 07- Midlands), as the most common PHPP modelling climate in the UK.
- Building altitude set to 68m as per LETI archetypes modelling input. A quick search shows most built towns in the UK are at around 70-75m from sea level, so the input used has been considered relevant to be kept.
- Floors, external walls, roofs and windows areas in LETI archetypes modelling have been used. The floor perimeter has been adjusted to account for any adjacent building element.
- A thermal bridge allowance has been made, using an estimated Psi-value multiplied by the perimeter length where a difference in insulation level exists between building elements.
- Solid wall U-values as per 'Review of default U-values for existing buildings in SAP' BRE Consultation Paper. All other building element as per PHPP U-value calculations. Baseline windows overall U-values as per UK RdSAP tables.
- Windows are all double-glazed as this seems to be the most common case in existing UK houses (English Housing Survey 2023 to 2024 estimates that 89% of all homes have double glazing around the entire home).
- It is assumed all ventilation is provided through natural window ventilation and intermittent extract fans.
- No window or night summer ventilation has been modelled as there is no overheating in the baseline archetypes.
- Conservative space heating distribution and DHW pipe lengths have been inputted based on PHPPs for real residential buildings.

Regional distribution and variations

While the archetype definitions are derived from the English Housing Survey, the selected dwelling forms and construction types are broadly representative of the wider UK housing stock. Evidence from the Scottish House Condition Survey, Welsh Housing Conditions Survey, and Northern Ireland House Condition Survey indicates comparable distributions of pre-1919 solid wall dwellings, post-war cavity wall construction, and common dwelling typologies such as terraces, semi-detached houses, and flats.

Regional variations do exist—particularly in the proportion of flats (higher in Scotland), rural detached housing (more prevalent in Wales), and specific construction traditions—but these do not materially alter the relevance of the selected archetypes for comparative analysis at UK scale.

Retrofit steps

A series of five EnerPHit retrofit steps have been defined, taking into consideration performance improvement, cost, level of disruption, and any impact that the implementation of one step may have on subsequent steps. A consistent set of steps is applied across all archetypes, with adaptations made to specifications as required to reflect the characteristics of each case, and to test the impact of early installation of a heat pump. Details are shown in the 'Outline specification' table below.

The timing of the steps is flexible. The first two steps may be combined into a single initial step, and similarly the final two steps may be combined, depending on the end of life of the element, the homeowner's ambitions and financial capacity. This flexibility allows the retrofit to be implemented in three, four, or five steps, according to what is most suitable for the individual case.

The steps comprise an EnerPHit Retrofit Plan (ERP) for each archetype, with the outline specification complying with the EnerPHit component method criteria. After completion of all five steps, each archetype will meet the criteria for full EnerPHit certification.

After completion of the first step, the retrofit can be pre-certified by a Passivhaus Certifier, provided that a significant energy reduction is achieved, as shown by:

- at least 20% reduction of the PER, or
- at least 20% reduction in the heating demand, or
- a new extension is built to Passivhaus specifications⁴.

The archetypes modelled in this report have been assumed to achieve this at the first step through installation of Passivhaus levels of loft insulation or RiR extension insulation together with an airtightness improvement from 11.5 ACH to 9 ACH. In practice, whether a 20% saving is achieved by these measures is going to depend on what insulation was present in the loft in the existing home. The archetypes modelled here have minimal levels (50mm insulation); a house with more insulation may not achieve the 20% saving simply by insulating the loft. In such cases, the first step may need to be combined with another energy efficiency measure such as MVHR.

The rationale behind the step definitions and their expected performance impacts are explained below. Ideally, the end of life of a building element should drive its replacement, and this can be planned out in the EnerPHit Retrofit Plan.

Step 1.1: Loft insulation

Loft insulation is identified as an initial retrofit step due to its significant impact on building performance, delivering reductions in energy bills and improvements in thermal comfort. It is also relatively straightforward to implement and minimally disruptive, all of which makes it cost-effective. The resulting reduction in space heating demand, when combined with an associated improvement in airtightness achieved through roof airtightness works, can deliver the minimum 20% reduction required for EnerPHit pre-certification, although this will depend on existing roof insulation levels.

⁴ There is also a fourth option, relevant only for a retrofit of multiple dwellings: "at least one housing unit has been almost entirely modernised in accordance with the ERP in a building with several owners". For full details, see "Pre-certification for staged retrofits" in *Criteria for Buildings, Passive House - EnerPHit - PHI Low Energy Building (PHI)* available online: <https://pht.guide/Criteria>

Archetype 2 will undergo a room-in-the-roof conversion, with insulation of the pitched roof, and introduction of a larger dormer to the rear. This will obviously be an expensive step, but the benefit of the additional space is often a big draw for home improvers, and it is an excellent opportunity to improve the loft to the EnerPHit component specification.

Step 1.2: Mechanical ventilation with heat recovery (MVHR)

Ventilation in existing homes in the UK is often inadequate⁵ and inconsistent from day-to-day, and from room-to-room. We shouldn't rely on leaky fabric to provide adequate indoor air quality. In retrofit, where we are making the home increasingly airtight, the mantra 'no insulation without ventilation' drives us to include MVHR early on in the retrofit steps. MVHR systems, as demonstrated in *The Case for MVHR* (PHT, 2020)⁶ do not work any less efficiently in leaky homes (where only a part of the thermal envelope has been upgraded) and so provide a good choice for this retrofit stage. The installation of an MVHR can also improve comfort and health whenever it takes place in the retrofit stages⁷.

This measure may be implemented in conjunction with the loft insulation works to reduce cost, by avoiding the need to remove loft insulation later to install the ductwork. Or alternatively, this could be a subsequent step when it becomes economically feasible for the homeowner. Where implemented as a separate measure, the routing of ductwork through the roof should be considered and planned in advance.

Step 2: Windows replacement and wall insulation

Wall insulation and window replacement are among the most disruptive and costly retrofit measures. However, they have the greatest impact on space heating demand. They should ideally be undertaken together as this makes it easier to achieve robust window to wall detailing, airtightness continuity and effective mitigation of thermal bridging. It is of course possible to separate them into two stages, but for the purposes of this study we have chosen that they be installed together.

Step 3.1: Floor insulation

Floor insulation has a comparatively lower impact on overall building performance than roof or wall insulation and is therefore scheduled as one of the later retrofit steps. When combined with appropriate airtightness measures, floor insulation contributes to achieving a fully continuous airtight envelope, enabling the dwelling to reach very low airtightness levels in line with EnerPHit criteria.

Step 3.2: Heat pump

After the building fabric has been fully upgraded, a new low-carbon heating system can be correctly sized and installed. For this reason, the heat pump is implemented as the final retrofit step in archetypes 1 and 2, and direct electric in archetype 4. This step may be combined with Step 3.1 (floor insulation) if this is economically feasible for the homeowner. A different step sequence has been adopted for Archetype 3, mid-terrace, to test and encourage the early installation of heat pumps, given the associated CO₂ emissions savings.

⁵ *Ventilation and Indoor Air Quality in New Homes*, MHCLG (2019)

⁶ *The Case for MVHR*, PHT (2020) - <https://pht.guide/CaseforMVHR>

⁷ *Health, Wellbeing and People Performance*, PHT (2023) - <https://pht.guide/HealthandWellbeing>

Retrofit steps for Archetype 1

Semi-detached with cold roof, pre-1919

Retrofit is modelled as a staged sequence of loft insulation, MVHR, external wall insulation with triple-glazed windows, suspended timber floor insulation, and finally an air source heat pump. This follows a fabric-first route, with the heating system replaced once demand has been reduced.

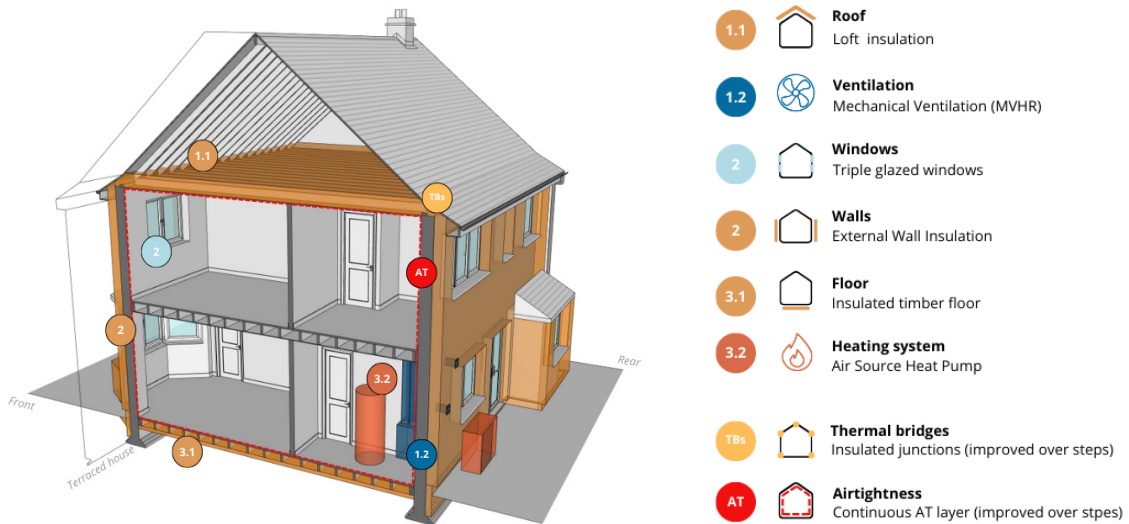


Fig. 4: 3D model showing retrofit steps for Archetype 1

Retrofit steps for Archetype 2

Semi-detached with roof conversion, pre-1919

This follows the same staged sequence as Archetype 1, but with the first step delivered as a room-in-the-roof conversion insulated to EnerPHit component standard rather than loft insulation at ceiling level. The later steps are MVHR, external wall insulation with triple-glazed windows, suspended timber floor insulation, and an air source heat pump.

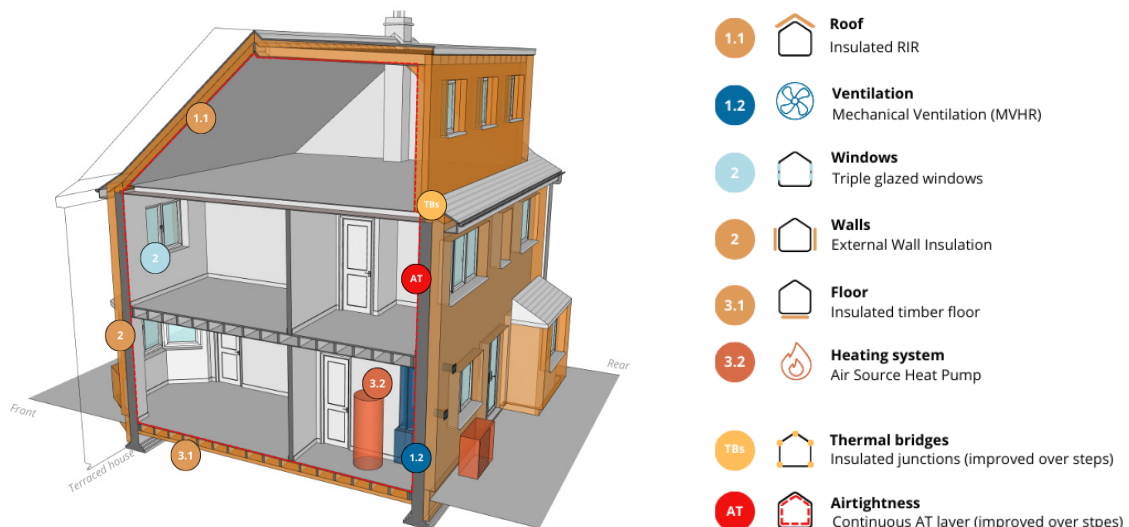


Fig. 5: 3D model showing retrofit steps for Archetype 2

Retrofit steps for Archetype 3

Mid-terrace, post-1919

For this archetype, the sequence is adjusted to test earlier electrification: loft insulation is followed by early installation of a heat pump, then MVHR, external wall insulation with triple-glazed windows, and floor insulation. This allows the modelling to compare earlier carbon savings from system change with later fabric improvements.

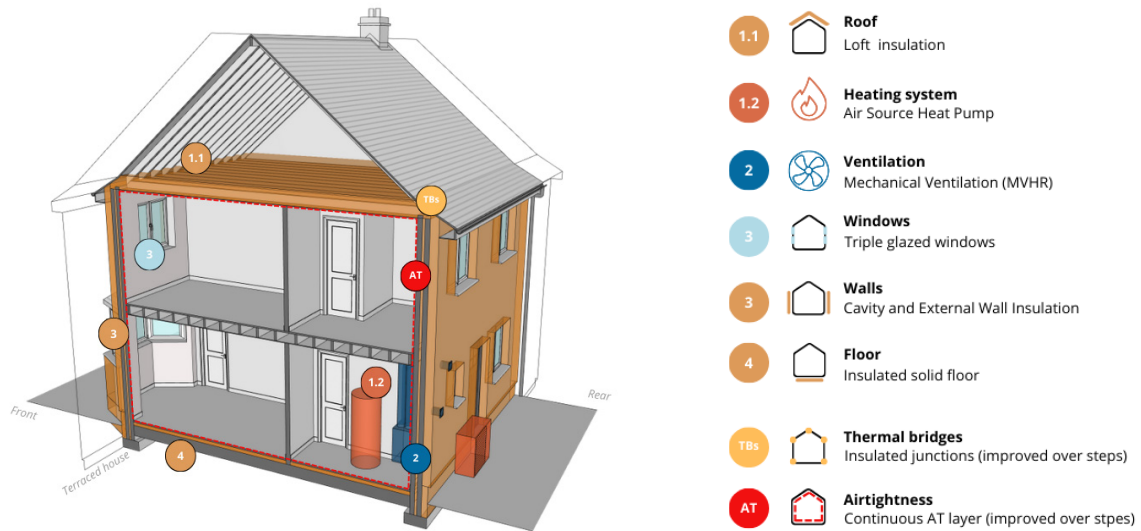


Fig. 6: 3D model showing retrofit steps for Archetype 2

Retrofit steps for Archetype 4

Top floor flat

The top floor flat is retrofitted in stages through roof insulation, MVHR, triple-glazed windows with internal wall insulation, and finally direct electric heating. Because this is a flat, the fabric strategy differs from the houses, with internal rather than external wall insulation and no floor insulation step.

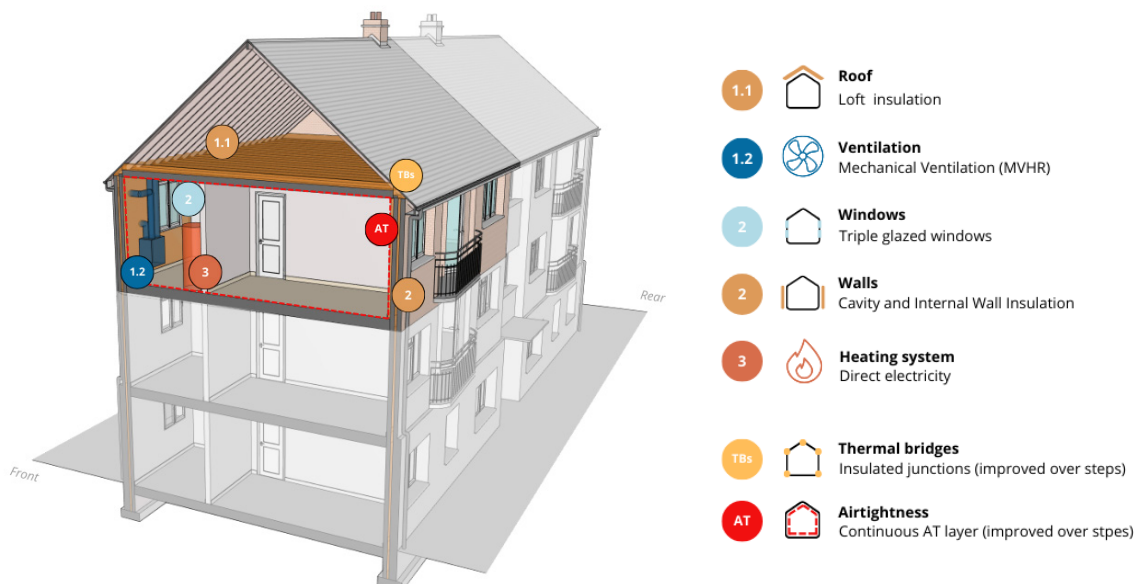


Fig. 7: 3D model showing retrofit steps for Archetype 2

Elemental specification

		Archetype 1 Semi, loft	Archetype 2 Semi, RiR	Archetype 3 Mid-terrace	Archetype 4 Top floor flat
Fabric Group	Building Element	U-value (W/m ² K)			
Floors	Solid floor	-	-	0.25	-
	Suspended timber floor	0.18	0.18	-	-
Walls	Solid wall (EWI)	0.15	0.15	-	-
	Solid insulated (RiR)	-	0.11	-	-
	Cavity uninsulated (EWI)	-	-	0.15	-
	Cavity insulated (IWI)	-	-	-	0.34
	Timber frame (dormer)	-	0.15	-	-
Roofs	Loft insulation	0.15	-	0.15	0.15
	Insulated sloped roof	-	0.15	-	-
Windows and doors	Triple-glazed	0.93*	0.93*	1.09*	1.12*
	Solid doors	0.85**	0.85**	0.85**	0.85**
Element	Type	Efficiency (%)			
Ventilation	MVHR	75	75	75	75
Heating and DHW	ASHP (heating)	400	400	400	
	ASHP (DHW)	350	350	350	
	Direct electric panels				100

* Average window U-value installed

**Door U-value installed

Table 3: Elemental specification

Modelling assumptions for retrofit steps

Thermal bridges

As for the baseline case, thermal bridge allowances have been made, with conservative but not overly pessimistic Psi-values assumed where one building element is insulated and the adjacent is not. This reflects junctions that would be only temporarily addressed in order to avoid moisture issues, until subsequent steps allow insulation continuity to be fully achieved. This means that the thermal bridge allowance is different for every step.

Airtightness

The expected improvement in airtightness from insulation and airtightness measures at each step has been estimated, with progressive reductions applied to achieve the final target of 1 ACH required by the EnerPHit component method.

Ventilation unit

A representative ventilation unit with a modest heat recovery efficiency has been selected to meet the EnerPHit Component criteria of 75% effective heat recovery (installed), although in practice, most market available MVHR units offer higher efficiencies.

Summer ventilation

Window and/ or night summer ventilation has been included in the modelling from Step 3 onward, where overheating levels begin to rise and mitigation measures are required.

Heat generator

A standard air/water heat pump (ASHP) has been selected, with a user-defined efficiency of 4.0 for heating and 3.5 for domestic hot water.

Heat pump performance depends on the unit selected, system design, installation quality and operation in use, and can therefore vary significantly, as discussed in *The Right Time for Heat Pumps* (Passivhaus Trust, 2024)⁸. The efficiencies assumed for this modelling are intended to represent best practice design as expected in an EnerPHit project.

8 *The Right Time for Heat Pumps: Decarbonising Home Heating in a Staged Retrofit*, Passivhaus Trust (2024) <https://pht.guide/HeatPumpsRetrofit>

Insulation materials

The insulation materials used to achieve the required U-values are described below, including thickness and corresponding thermal conductivity. This is illustrative only, to demonstrate how the target U-values could be achieved in practice. Alternative materials would also be acceptable, provided they meet the required U-value criteria. Materials should be chosen by a retrofit designer based on their compatibility with the existing construction, especially in consideration of moisture risk and properties, and the quality of installation that is likely to be achieved. Other considerations include embodied carbon, off-gassing of VOCs, performance, fire regulations, cost, and availability.

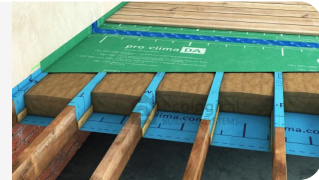


Solid floor

80mm rigid insulation ($\lambda = 0.022$ W/mK)
U-value = 0.25 W/m²K

Suspended timber floor

100mm insulation between rafters ($\lambda = 0.036$ W/mK)
+ 80mm rigid insulation below ($\lambda = 0.038$ W/mK)
U-value = 0.18 W/m²K

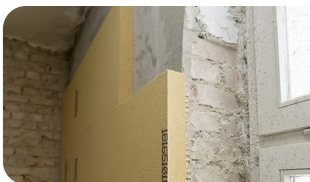


External wall insulation

220mm insulation batts ($\lambda = 0.036$ W/mK)
U-value = 0.15 W/m²K

Cavity + EWI

50mm blown insulation ($\lambda = 0.034$ W/mK)
+ 170mm insulation batts ($\lambda = 0.036$ W/mK)
U-value = 0.15 W/m²K



Internal wall insulation

80mm wood fibre insulation ($\lambda = 0.038$ W/mK)
U-value = 0.34 W/m²K

Dormer timber frame and sloping roof (RiR)

100mm insulation between joists ($\lambda = 0.036$ W/mK)
+ 140mm insulation above or below ($\lambda = 0.036$ W/mK)
U-value = 0.15 W/m²K



Loft insulation

300mm loft insulation ($\lambda = 0.044$ W/mK)
U-value = 0.15 W/m²K

Modelling results

Component vs space heating demand method

As discussed in *Passivhaus Retrofit in the UK* (PHT, 2026)⁹, the component method allows us to apply EnerPHit specification to an existing property even where form factor, orientation and openings are particularly unfavourable. The archetypes modelled in this paper are typical of the UK housing stock and are modelled in the Midlands climate (Zone 7 - Sutton Bonington). It is interesting to note that the component method also achieves the space heating demand method limit (< 25 kWh/m².a) for the semi-detached property and the mid-terrace. However, the flat only achieves a space heating demand of 39 kWh/m².a.

Final energy and space heating demand

Final energy is impacted by both the space heating demand (SHD)¹⁰ of the building and also the efficiency of the heating and hot water system. We can see this in the final energy and space heating demand graphs shown below. In archetypes 1 and 2 the SHD (in light blue) does not change when installing a heat pump at the final step, but the final energy drops quite dramatically because a heat pump is far more efficient than a gas boiler. The same happens with archetype 3, when the final energy drops far lower than the SHD after installation of an ASHP. The SHD catches up in subsequent steps as the MVHR is installed and the remainder of the fabric is retrofitted.

Modelling assumptions for results graphs

Carbon factors are the latest from DESNZ (Greenhouse gas reporting: conversion factors 2025)¹¹. Energy costs are from the Ofgem price cap 1st Jan to 1st March 2026.

9 *Passivhaus Retrofit in the UK*, Passivhaus Trust (2026) <https://pht.guide/Retrofit>

10 Both space heating demand (SHD) and final energy (i.e., the energy delivered to the building at the meter) are generally expressed relative to the floor area of the building. Passivhaus calculates floor area in a slightly different way to the most common UK method: Treated Floor Area (TFA) in PHPP counts only useful area, excluding areas like staircases, and is generally about 90% of Gross Internal Area (GIA). The Energy Use Intensity (EUI) metric used in UK-specific guidance and standards such as the UK NZCBS, by contrast, is based on GIA. SHD in the UK NZCBS is also based on GIA, so will be lower than SHD as reported by PHPP. Confusingly, all of these metrics report the same unit, kWh/m².a, so it's always important to be clear about which square metres are being counted. In the results graphs in this paper, we have been consistent in using TFA, in order to make the relationship between space heating demand and final energy clearer. EUI and SHD based on GIA can both be easily reported from PHPP using the free Delta Q UK Design Alignment plugin available from the Passivhaus Trust - <https://pht.guide/UKDesignAlignment>. It should be noted that energy modelling in SAP is different again - it only considers regulated energy (heating, hot water, lighting and fans), and excludes unregulated energy (appliances and plug loads), unlike the EUI metric and final energy in PHPP.

11 Available online: <https://www.gov.uk/government/publications/greenhouse-gas-reporting-conversion-factors-2025>

Archetypes 1 & 2 results

Semi-detached, pre-1919 cold loft and room-in-roof conversion

Comparing the final energy and space heating demand bar graphs for archetypes 1 and 2, on first reading it appears that insulating at pitched roof level and introducing a RiR conversion reduces the heating demand and final energy more than insulating at loft level (see fig. 9 and fig. 10). Clearly, increasing the volume and area of the thermal envelope is going to increase the total heating load of the house. However, both of these metrics divide everything by the useful space inside the building – that is, they are relative measures not absolute measures. The metrics don't care how big the house is, just how efficient the form factor is. Here, the RiR has increased the TFA, while the external thermal envelope hasn't increased as much proportionally, which means the form factor is now more favourable.

A more revealing story is evident in the energy bills and carbon emissions line graph (see fig. 8 below), where we can see that insulating at loft level reduces total carbon emissions and energy bills further than the RiR conversion. Despite the increase in heated space, the RiR conversion to EnerPHit component levels of insulation is still a slight improvement on the existing home with minimal, compressed loft insulation. It also achieved the 20% energy reduction required for the EnerPHit component pre-certification stage.

This shows that choosing an EnerPHit specification for extensions to existing homes can be an effective way of offsetting the extra heated space and its associated impact on energy bills and carbon emissions.

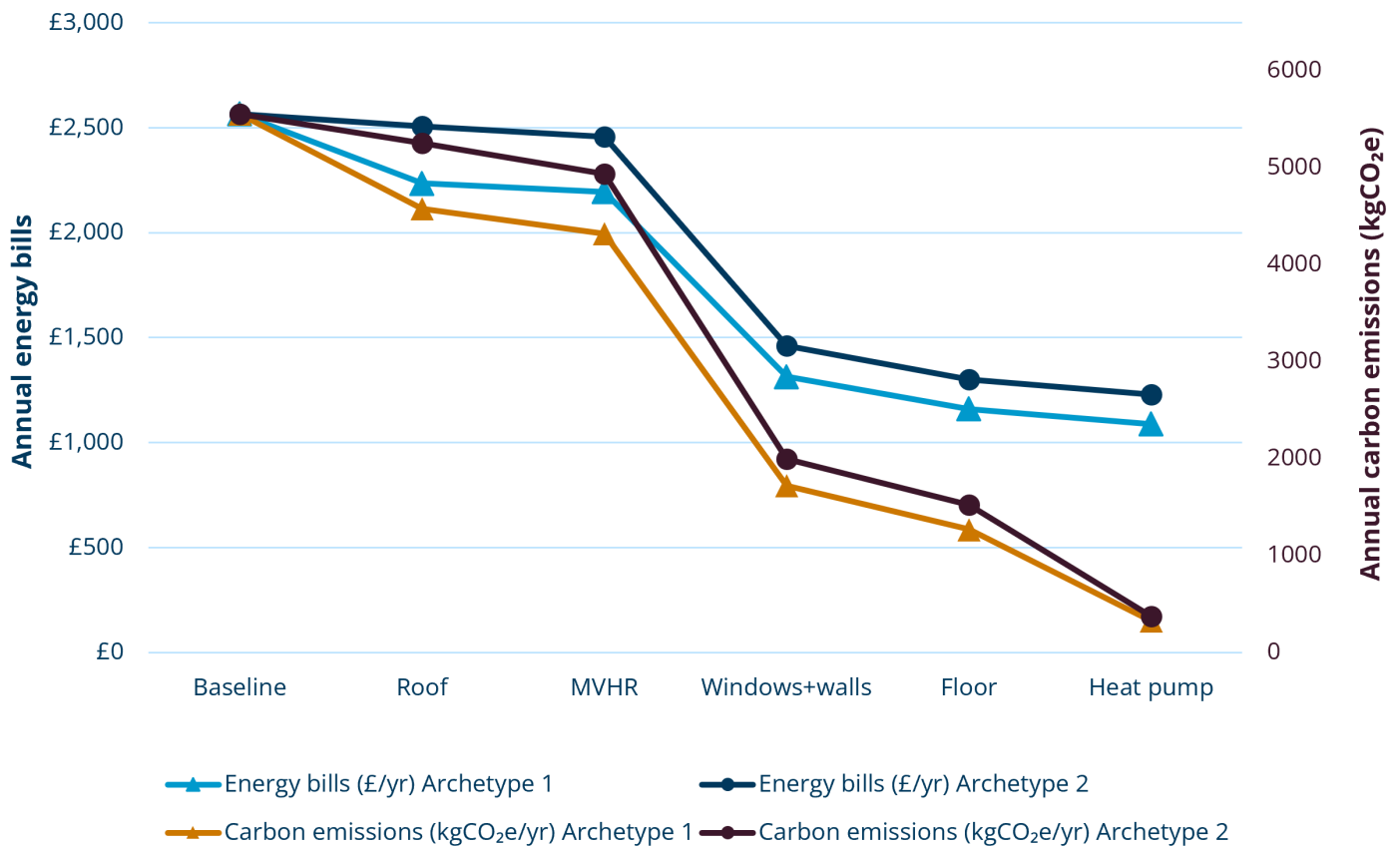


Fig. 8: Line chart comparing annual energy bills and carbon emissions through the retrofit steps for Archetypes 1 and 2 (with loft insulation and RiR respectively)

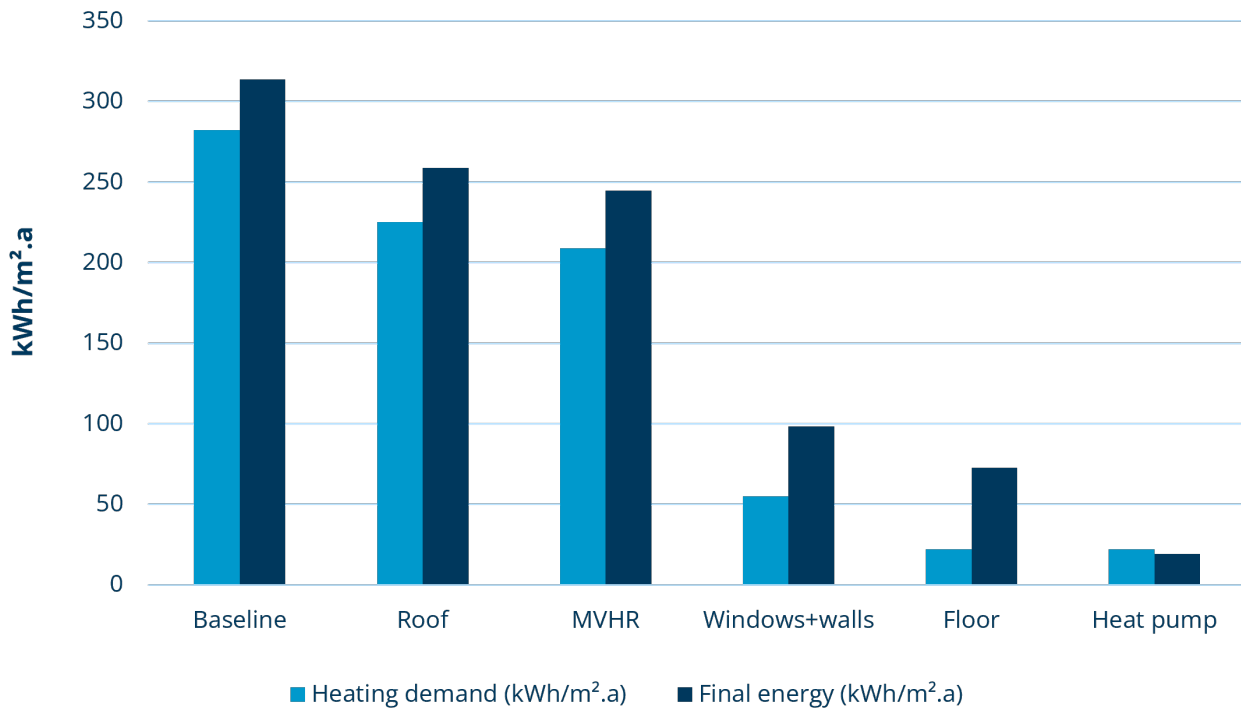


Fig. 9: Bar chart comparing modelled heating demand and final energy through the retrofit steps for Archetype 1 (with loft insulation)

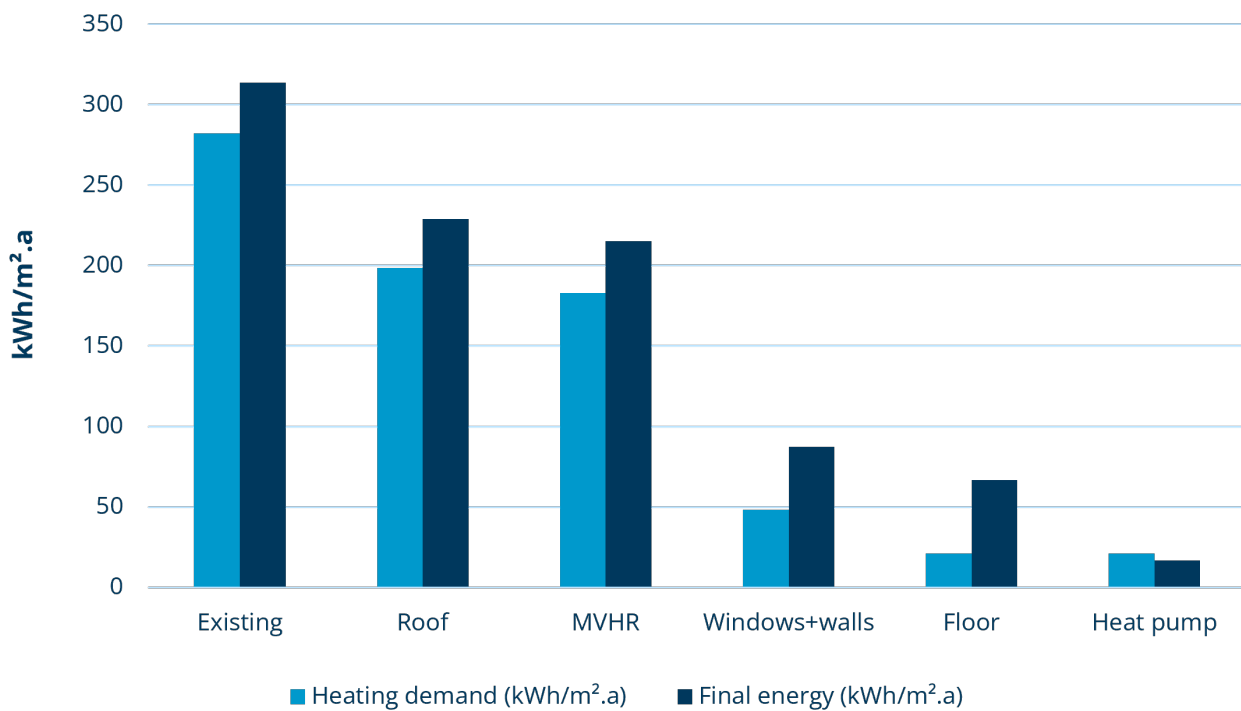


Fig. 10: Bar chart comparing modelled heating demand and final energy through the retrofit steps for Archetype 2 (with RiR conversion)

Archetype 3 results

Mid-terrace, post-1919, early heat pump installation

The impact of early heat pump adoption is clear. There is a significant drop in final energy at this step because heat pumps are over 3x more efficient than gas boilers in converting energy into heat. For the same reason, the carbon emissions also dropped to about a third compared with the existing building. However, in this model energy bills actually increase slightly from Step 2 to Step 3, when the heat pump is installed. It's important to note that this is dependent on the efficiency that can be obtained at this stage in the retrofit¹² and the available smart tariffs – energy pricing is the most volatile factor at play here.

If radiators are replaced alongside the heat pump, then the heat pump should be operating at lower flow temperatures by the time final EnerPHit certification is achieved, which could improve the efficiency. However, in these modelling case studies the same heat pump efficiency has been assumed throughout all retrofit stages.

Energy efficiency measures appear to have a smaller impact on the reduction of carbon emissions than was the case in Archetypes 1, 2 and 4. This is simply because of the order that measures are installed. The wall insulation and windows step, for example, reduces the carbon emissions by the same proportion from the previous step, but because the emissions have already been lowered by the heat pump, the absolute carbon savings here are smaller. This is the rule of diminishing returns: the cost per tonne of carbon saved tends to increase as the retrofit progresses.

This is why it is important to understand motivations for retrofit: targeting carbon may lead to a different sequence of measures than targeting energy bills, final energy, or qualitative outcomes such as comfort and health.

¹² *The right time for heat pumps: Decarbonising home heating in a staged retrofit*, Passivhaus Trust, April 2024 <https://pht.guide/HeatPumpsRetrofit>

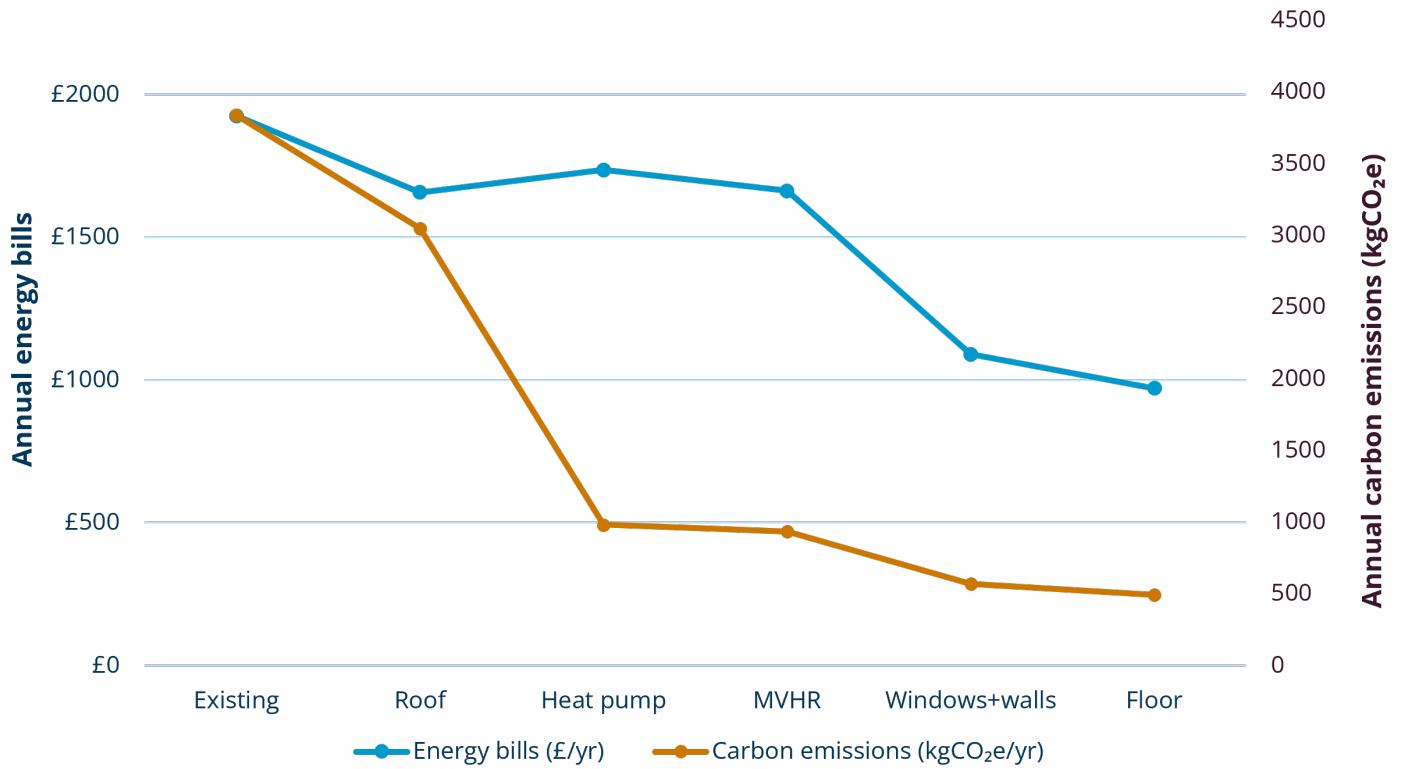


Fig. 11: Line chart comparing annual energy bills and carbon emissions through the retrofit steps for Archetype 3

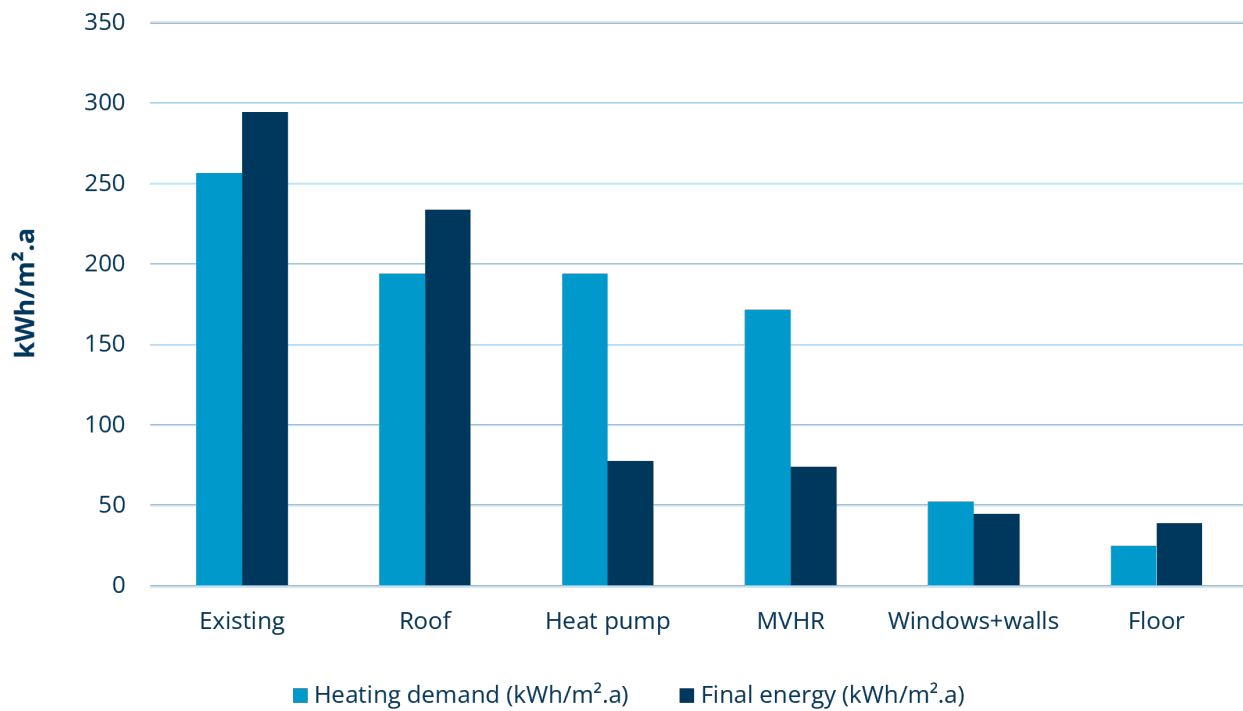


Fig. 12: Bar chart comparing modelled heating demand and final energy through the retrofit steps for Archetype 3

Archetype 4 results

Top floor flat, electric heating

Archetype 4 is notable because it is the only archetype to use internal wall insulation. Where internal insulation is applied, the EnerPHit component criterion for wall U-values is less stringent than for external insulation, because of the greater risk of interstitial condensation. As a result, the improvement in space heating demand and other metrics is smaller than in archetypes 1, 2 and 3, which use external wall insulation.

Moving to direct electric space heating and hot water is a straightforward electrification option for flats, where no community heat pump system is available. It is not the only option: compact units, for example, are increasingly being specified for flats and will result in lower running costs than direct electric heating, while also providing ventilation and hot water in an integrated system. Other heat pump solutions are also available. Direct electric does, however, have certain practical advantages: it is space-saving and simple to install, and may be attractive where lower upfront cost is the priority.

There are limited efficiency savings in moving from a gas boiler to direct electric space heating and hot water, and while electricity costs between 4 and 5 times more than gas, as is currently the case, direct electric is likely to be much more expensive unless significant energy efficiency measures are installed. As the results of this case study show, even at EnerPHit⁺ levels of insulation, direct electric is still likely to result in higher energy bills than in the existing flat.

Without equivalent improvements in energy efficiency, the operational cost of switching to direct electric would likely be prohibitive.

EnerPHit can therefore help make electrification of heating and hot water in flats more affordable in use.

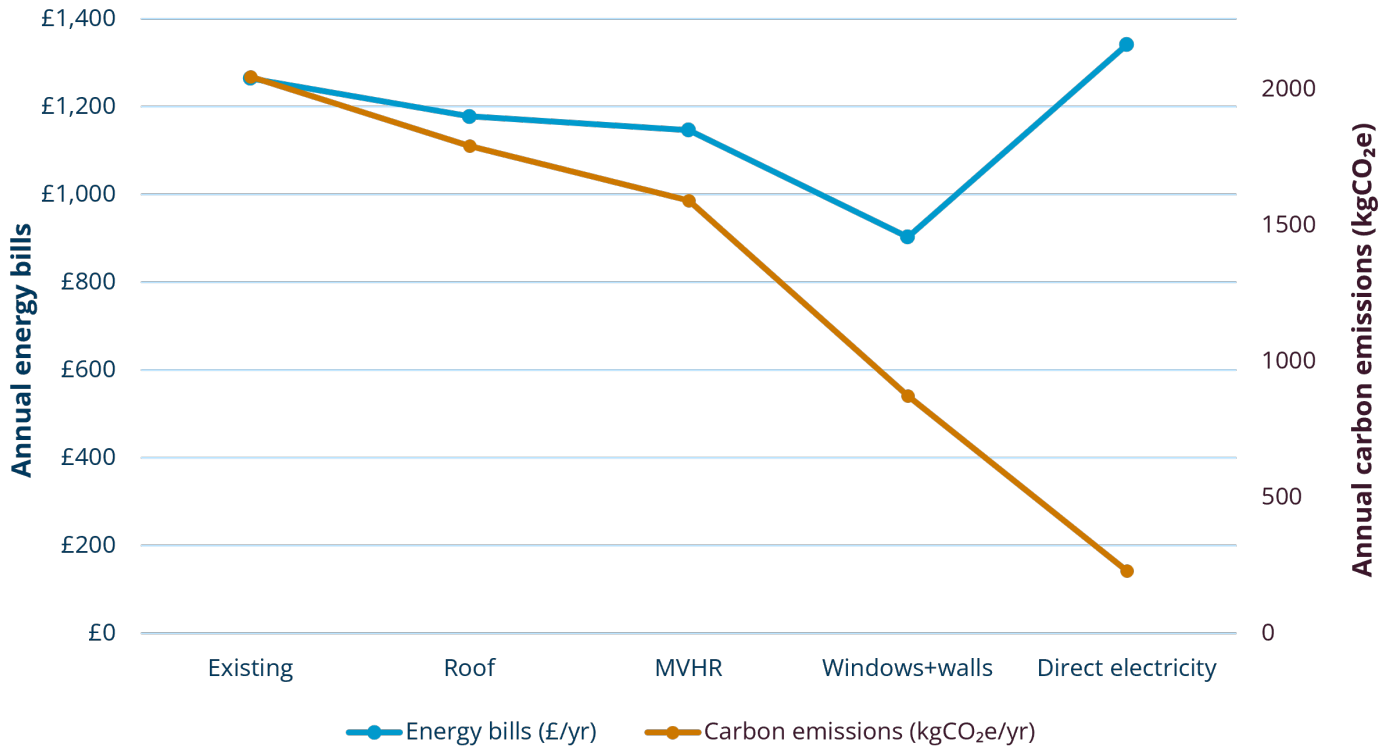


Fig. 13: Line chart comparing annual energy bills and carbon emissions through the retrofit steps for Archetype 4

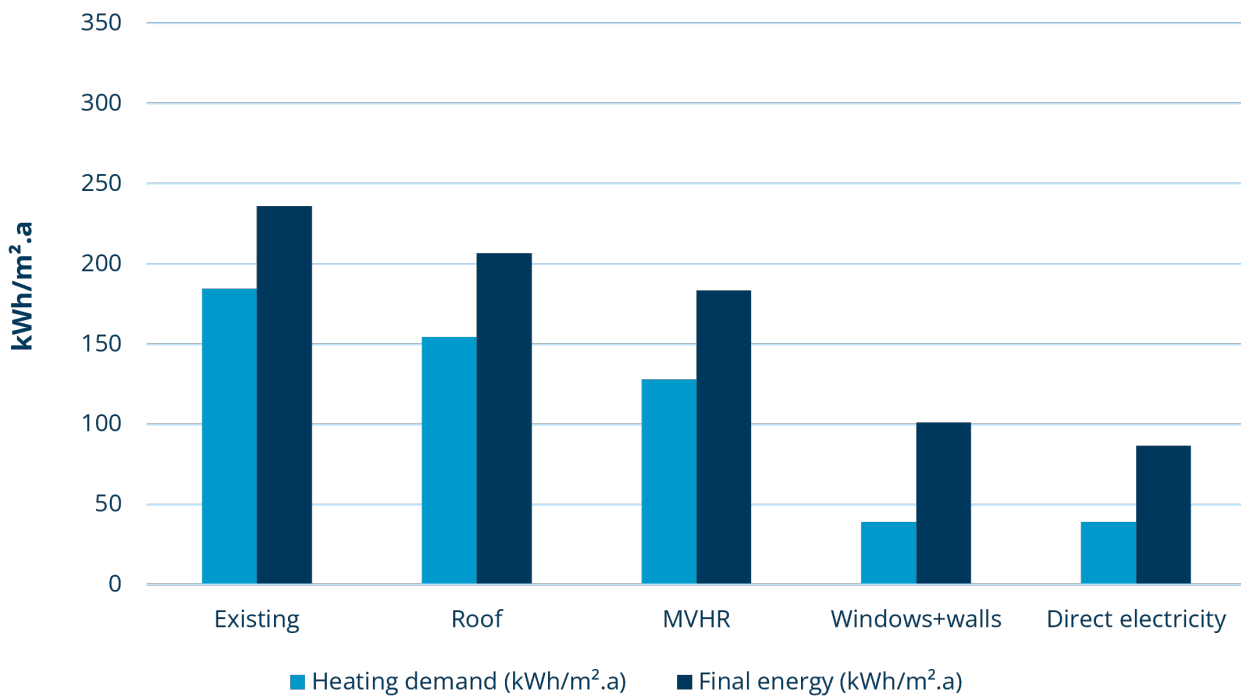


Fig. 14: Bar chart comparing modelled heating demand and final energy through the retrofit steps for Archetype 4

Retrofit Options Assessment – modelling with PHPP

Modelling energy-intensive homes in PHPP

PHPP is a steady-state energy model developed to simulate Passivhaus buildings and optimised accordingly. For existing buildings, we find that it tends to overestimate energy use for UK homes. Where the aim is to produce a retrofit options assessment that gives clients more realistic estimates of energy bills and carbon savings, we recommend making the following adjustments to the PHPP. Note that these changes are not acceptable for EnerPHit certification; for certification, the PHPP manual and the criteria must be followed.

Periodic heating

PHPP assumes that homes are heated to 20°C all the time, but in the UK we typically heat intermittently, or on a heating schedule. We're so used to intermittently heating our homes in the UK that we don't see it as a comfort gap, but if energy was a lot cheaper, or if our homes were a lot easier to heat, then we probably would keep them at 20°C all the time. To model existing homes more accurately we can use the Periodic Heating plugin for PHPP and the occupants' actual heating profile. This approach can also be applied to PHPP Variants, although the average internal temperature as calculated by the Periodic Heating tool must be manually added in the Variants tab as a user input.

Actual occupancy

Using actual occupancy can also improve the accuracy of the estimate of internal heat gains and electricity use.

Infiltration rate

It may also be prudent to increase the wind protection of the building from "2. Moderate" to "3. High" in the Ventilation sheet to more accurately reflect infiltration in leaky buildings. This is based on a paper presented by Leeds Beckett University at the International Retrofit Conference 2025¹³, which found that the PHPP modelled infiltration for non-airtight buildings was much higher than measured, and even higher than estimated in our UK energy models (SAP), although more research is required in this area.

Energy costs and CO₂ emissions

Use UK energy costs and the latest greenhouse gas (GHG) emissions factors for electricity and gas when calculating running costs and CO₂ emissions. These will be different from the values used in the EnerPHit Retrofit Plan.

13 <https://energyhouselabs.salford.ac.uk/conference/international-retrofit-conference/>

Comparing retrofit measures

Sometimes it is important to understand the impact of individual measures on the reduction in space heating demand, carbon or other metrics. The results in this report are cumulative, so the decrease or increase in that metric from one retrofit step to the next is always relative to the previous step. For example, applying floor insulation to an almost completed EnerPHit retrofit is going to show much smaller drops in space heating demand, energy use intensity, energy bills and carbon emissions than if applying floor insulation to an uninsulated house.

To compare measures effectively, they should be modelled and presented individually as well as cumulatively, as shown in the graph below. That way, the savings in energy bills or carbon for each measure can be fairly compared to the original building.

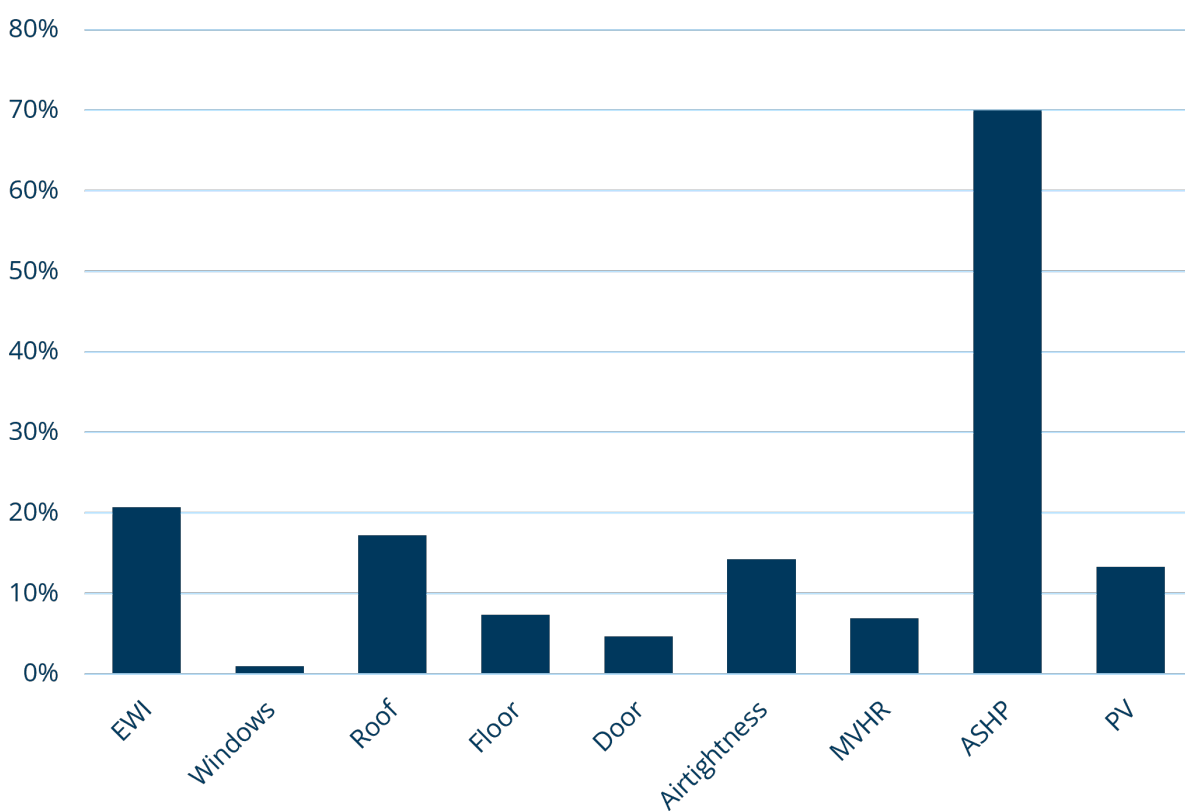


Fig. 15: Example of a retrofit options assessment that compares the impact of individual measures as well as a package of measures (Note that not all elements of this retrofit achieve the EnerPHit criteria)

The Passivhaus Trust is at the forefront of a transformative shift in the built environment, revolutionising how buildings are designed, constructed, retrofitted, and occupied. As the official UK arm of a global movement, we champion the international Passivhaus standard - proven to create healthy, resilient buildings that deliver immediate climate action.

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