Herefordshire Council

Net Zero Retrofit Guide

Contents

Foreword and commitment 3

Introduction 4

This Environmental Building Standards Retrofit Guide 6
Core principles of Net Zero carbon buildings 7
Introduction to energy targets and Key Performance Indicators (KPIs) 8
The electricity revolution: a greener grid and the future of heat 9
The cost of Net Zero homes 10

Retrofit 11

Why? Key reasons and benefits of a low carbon retrofit 12
Energy targets and Key Performance Indicators (KPIs) for retrofit 13
The 'whole house' approach and PAS 2035 14
Changing a home's carbon dioxide pathway 15
Mapping to journey towards Net Zero 16
A long term whole house renovation plan for a phased retrofit 17
Key retrofit risks and how to mitigate them 18
Heritage buildings and conservation areas 19
An extension should trigger the improvement of the home 20
Low carbon heating options 21
Heat pump options 22
Why windows should be upgraded 23
Insulating walls 24
Insulating floors and roofs 25
Introduction to thermal bridges 26
Junctions 27
Airtightness for retrofit 28
Retrofitting a ventilation system 29
Water efficiency and domestic hot water 30
Retrofitting solar PVs 31
Smart controls and demand response 32
Indicative costs of retrofit 33
Embodied carbon 34
How it comes together -Retrofit of a typical terrace house 35
How it comes together - Retrofit of a terrace house in a conservation area 36
Retrofit considerations 37
Case studies for retrofit 38
Case studies for retrofit 39

Products 40

Windows 41
Doors 42
Insulation materials 43
Airtightness products 44
Ventilation units 45
Waste Water Heat Recovery Systems 46
Heat pumps 47
Air source heat pumps (ASHPs) 48
Ground source heat pumps (GSHPs) 49
Domestic appliances 50
Solar photovoltaic (PV) panels 51

How to Specify 52

Approach to deliver Net Zero carbon buildings 53
Finding competent contractors 54
Specifying airtightness requirements 55
Commissioning of heat pumps and MVHR systems 56
Building performance delivery schemes 57
Building regulations and planning approval 58
Communicating this to customers and clients 59
The importance of maintenance – Keep operating at Net Zero carbon 60
Links to guidance 61

On 8 March 2019 Herefordshire Council declared a Climate Emergency following unanimous support for a climate emergency resolution at full council. This declaration was updated on 11 December 2020 when Herefordshire Council declared a Climate and Ecological Emergency (CEE) following support for a climate and ecological emergency resolution at Full Council. Therefore further guidance is required for new and retrofit schemes.

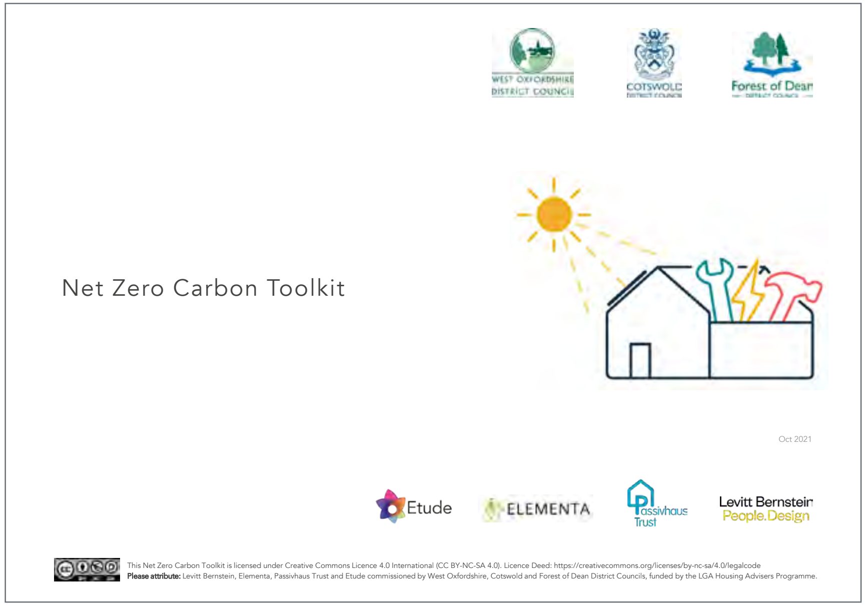
Supplementary Planning Guidance has recently been produced for new build development, guidance is set out in the Environmental Building Standards Supplementary Planning Document. However further guidance is required for existing buildings for retrofit schemes

As a local planning authority, we are dedicated to supporting individuals, businesses and communities on this pathway to Net Zero. Herefordshire has reviewed and utilised (with permission) the excellent guidance provided by The Forest of Dean, Cotswold and West Oxfordshire District Councils to produce this retrofit guide. The purpose of this guide is to enable those wishing to improve the energy efficiency and reduce carbon in their building schemes.

Achieving the UK's legally binding target of Net Zero is no small task, nor is it one that any single person or organisation can achieve alone. It requires everyone to come together, to work collectively, to share in their experiences and to build on their successes along the way.

Whether you are a small or medium medium-size house builder, an architect, a self-builder or a consultant advising clients, this Toolkit will help you. With local planning policy expected to strengthen requirements for Net Zero in development terms, this guidance explains how this can be delivered through construction.

We hope you find technical value, as well as inspiration and motivation, to achieve the best housing design possible.



Thank you to Forest of Dean, Cotswold and West Oxfordshire District Councils and technical experts Etude, the Passivhaus Trust, Levitt Bernstein and Elementa Consulting for sharing the guidance with us and permitting us to use this under a creative commons licence.

Introduction

This chapter sets out why this toolkit has been produced and how it can be used.

It also defines Net Zero carbon buildings and puts them in the context of the wider electricity revolution.

In 2018, the Intergovernmental Panel on Climate Change (IPCC) showed the world there would be only 12 years to prevent irreversible catastrophic damage from a changing climate.

Any temperature increase above 1.5°C would trigger far worse effects than previously thought, in terms of drought, flood, poverty for many people, and catastrophic biodiversity loss.

Herefordshire Council, along with other local planning authorities across the country, declared a climate and ecological emergency to deliver local action in response to a global issue.

Herefordshire Council has taken the retrofit aspect of the net zero carbon toolkit[1] and will help assist in the planning, design and construction of a retrofit housing or building project.

It provides a technical, go-to guide on what to consider to achieve fabric energy efficiency; what systems to include; where to go for expert advice; and what to consider once you have finished your housing project and you are handing over to occupants.

[1] https://www.fdean.gov.uk/media/nzdh0poj/net-zero-carbon-toolkit.pdf

(Source: IPCC)

This Environmental Building Standards Retrofit Guide

Who is it for?

This toolkit has been created to make Net Zero carbon retrofit more accessible. It has been created for building professionals (developers, contractors, architects and engineers) and is also relevant to self-builders, planning officers and other housing professionals. Although it can be used by homeowners, it is aimed at those who already have some knowledge or experience of construction.

Guidance for new buildings is set out in the Environmental Building Standards SPD[2].

Retrofit

The toolkit sets out guidance for retrofit of existing homes in separate chapters. So whatever your project, you will find relevant information here.

Small to medium scale housing

The primary focus is on small to medium scale housing projects, but the principles are generally applicable to projects of any scale.

Understanding the complete picture

The toolkit aims to build the awareness and confidence of people implementing low or zero carbon projects and generally seeks to answer the following questions:

- Why?
- What to do and how to bring it all together?
- What does “good” look like?
- What to specify and how to choose products?

[2] Supplementary Planning Documents – Herefordshire Council

Core principles of Net Zero carbon buildings

Net Zero carbon buildings in operation are supported by three core principles: energy efficiency, low carbon heat and renewable energy.

Energy efficiency

Buildings use energy for heating, hot water, ventilation, lighting, cooking and appliances. The efficient use of energy reduces running costs and carbon emissions. It also reduces a building's impact on the wider energy supply network, which is also an important consideration.

There are different metrics we use to measure the efficiency of a building, including Space Heating Demand and Energy Use Intensity (both measured in kWh/m^2/yr). These are described on the next page.

Low carbon heating

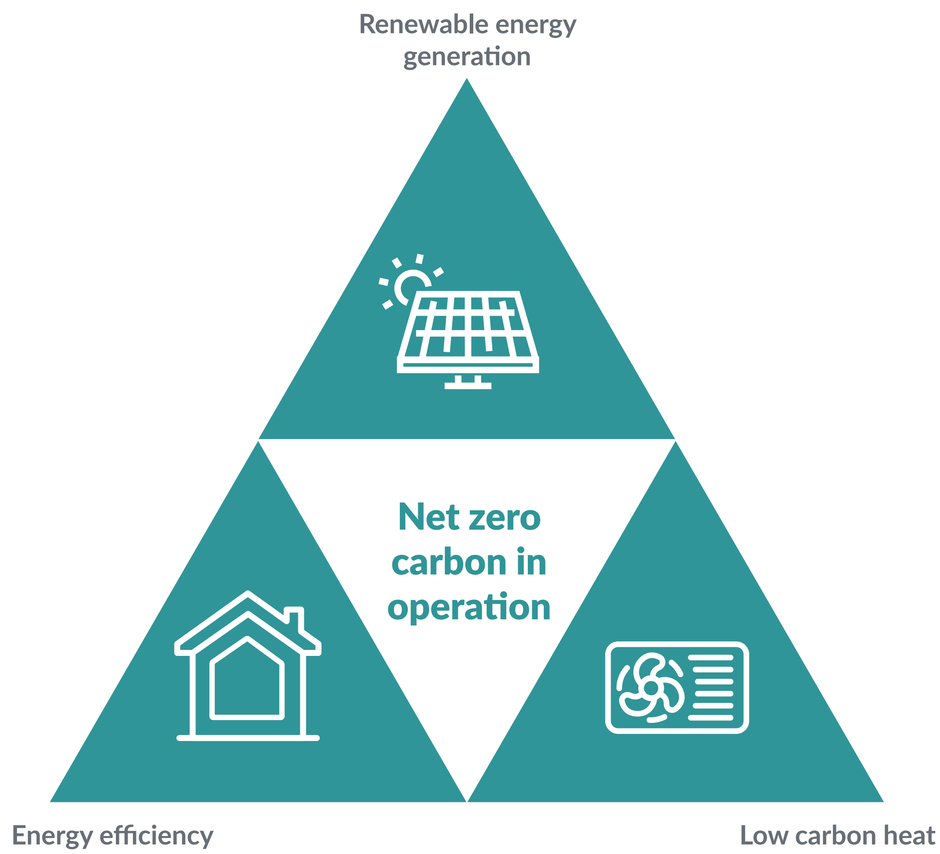
Low carbon sources of heat are an essential feature of Net Zero carbon buildings. All new buildings should be built with a low carbon heating system and must not connect to the gas network. Existing buildings need to transition away from gas and oil now.

Renewable energy generation

In new buildings, renewable energy generation should be at least equal to the energy use of the building on an annual basis for it to qualify as Net Zero carbon in operation. This is straightforward to achieve on site for most new homes through the use of solar photovoltaic (PV) panels. The roofs of existing homes should also be utilised for PV panels, to support the increased demand for renewable energy.

Embodied carbon

Operational carbon is only part of the story. Net Zero buildings should also minimise embodied carbon in materials.



The three pillars of a Net Zero carbon building in operation

Introduction to energy targets and Key Performance Indicators (KPIs)

What energy targets should I aim for?

We recommend the operational targets for retrofit housing set out on this page, which are consistent with the LETI Climate Emergency Design Guide. Energy use targets are more transparent and robust than carbon reductions targets and are the best way to ensure zero carbon is delivered in practice.

What is an ultra low energy home?

An ultra low energy home is one which has a very low space heating demand. This requires a fabric efficiency and airtightness equivalent to that of a new Passivhaus home.

What is the most efficient form of heating system?

Heat pumps are considered the most efficient low carbon heat source keeping energy use to a minimum, while not using fossil fuels on site. Gas or oil boilers must not be used anymore.

Why set a renewable energy target?

Net Zero carbon in operation can only be achieved by increasing renewable electricity generation. Solar PVs represent a mature and easy to use technology.

Reducing the embodied carbon of a building

Limit the embodied carbon or emissions associated with the manufacture, transport, construction, repair, maintenance, replacement and deconstruction of building elements. This can be achieved by making informed design decisions based on quantified carbon reductions.

The constituent method can be used where detailed energy modelling is not possible or financially feasible on a small project. Page 13.
https://ecda.co.uk/wp-content/uploads/2021/11/LETI-Retrofit-Guide.pdf

Retrofit housing

KPIs

Ultra low energy homes

Space heating demand

50kWh/m²/yr*

*on average (range of 20-120 kWh/m²/yr)

Energy use and efficient heating

Energy use Intensity

50kWh/m²/yr*

*on average

Renewable energy

Electric generation intensity

120kWh/m^2_{fp}/yr

m^2_{fp}: m² building footprint

Towards a decarbonised and smarter electricity system

The carbon content of electricity has fallen over the last few years. It is now three times less than ten years ago and already lower than natural gas on a per kWh basis. It is forecasted to continue to reduce even further over the next 20-30 years. This explains the current energy revolution and why the electrification of transport and heat is the best strategy to move away from fossil fuels. It is also considered unlikely that hydrogen will play a significant role in heating our homes.

In order for this electricity revolution to be successful and as cost effective as possible it is very important to reduce energy use so that energy demand is not more than renewable and nuclear energy generation by 2050. If electricity demand is more flexible, it can also be matched to times of high renewable energy generation. Electric vehicle charging from homes will also create additional demand for electricity*.

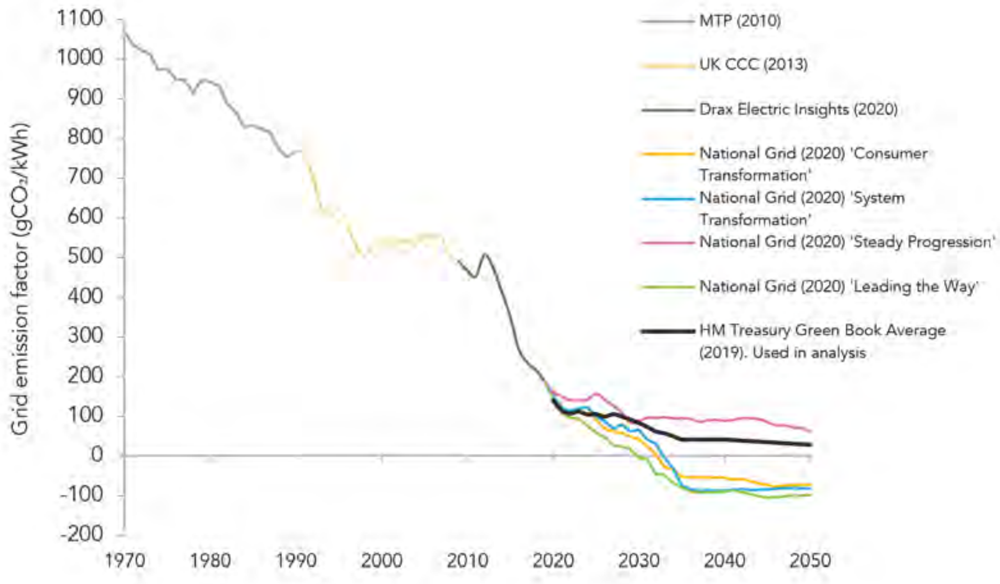
The impact on buildings

The electrification of heat (e.g. the replacement of gas boilers by heat pumps) is widely considered as one of the main priorities of decarbonisation. New gas or oil boilers should not be installed in buildings anymore, in new or existing homes.

Energy storage (e.g. hot water tank) and management (e.g. smart controls) as well as smart meters for Time of Use (ToU) variable electricity tariffs are all likely to become increasingly important.

In summary, electrification and digitalisation provide the backbone of decarbonisation for buildings.

* Electric vehicle charging is not currently covered by the Net Zero carbon home definition. It is captured in the assessment of transport emissions.



***Long-term variations in emission factor of grid electricity show the rapid historical reduction in emission factors** © Etude based on data from Market Transformation Programme, UK Committee on Climate Change, Drax, National Grid and HM Treasury.*

Note: *The National Grid Future Emissions Scenarios (FES) show that if the power sector removes CO_2 from the atmosphere by the growth of biomass and captures it when it is used in power stations, it could be carbon negative. This would rely on the use of Bioenergy with Carbon Capture and Storage (BECCS). Carbon Capture and Storage is a process in different steps: CO_2 produced is captured, transported away and isolated from the atmosphere in long long-term storage in geological formations or for use in industrial processes). When more carbon is removed from the atmosphere and stored by a process than is emitted into the atmosphere, emissions are negative. BECCS features prominently in three of the four scenarios modelled in FES.*

There is a (small) cost premium

Achieving Net Zero as a society will have a cost. For some sectors it will require investments in Research and Development (R&D) as technological innovation is required. For others Net Zero compliant solutions exist but currently have a very high cost premium which needs to be reduced to be acceptable at scale.

New buildings are comparatively less challenging: technologies, techniques and processes required to deliver Net Zero carbon buildings in operation are already available and will only lead to a small cost premium compared with a Part L 2021 compliant house or block of flats, i.e. 2-6% additional capital cost.

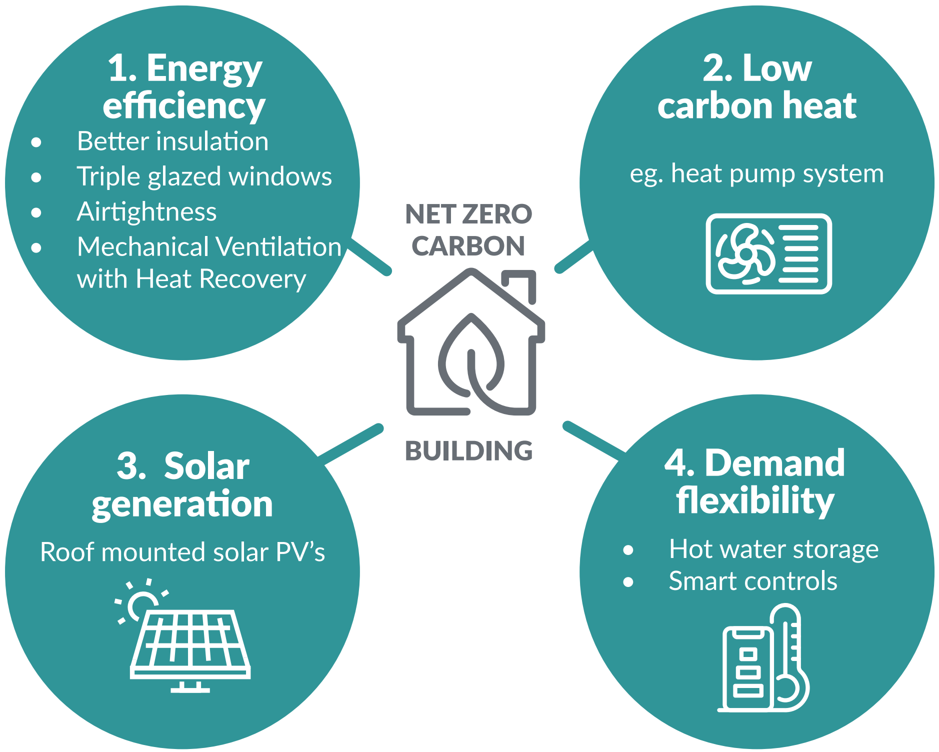
Lowering the embodied carbon of existing buildings will be more challenging and requires both material and procurement innovations. However, this does not have to lead to a significant cost premium either.

Avoided costs for society as a whole

All new buildings built to poor levels of energy efficiency and fitted with gas boilers will have to be retrofitted in the next 20-30 years in order to achieve Net Zero. The cost of future retrofit is significantly higher than the cost of ‘getting it right now’. There are also wider off off-site benefits in terms of reduced infrastructure costs as less renewable energy generation will be required.

A good deal for residents

Net Zero carbon homes are not only good for the planet: they will also be much cheaper to run than a standard new build house. This is due to the combined effects of a lower energy demand alongside greater flexibility of energy use during the day and of solar electricity generation and self consumption.



Additional costs of Net Zero carbon buildings in operation can be split up into four key categories

Retrofit

Putting our existing homes on track towards Net Zero is a challenge but it can be done. This section explains how.

Existing buildings are the real challenge

England currently has some 25 million homes. All of those will have to have some form of retrofit by 2050 while, in that time, we will have only built another six million homes. This means that 80% of the homes that will be present in 2050 have already been built. If we are to successfully decarbonise housing, retrofitting is where the real challenge lies: we need to increase their energy efficiency, change their gas or oil heating system for a low carbon heat system (e.g. heat pump) and generate more renewable energy on their roofs.

Reducing fuel bills alongside carbon emissions

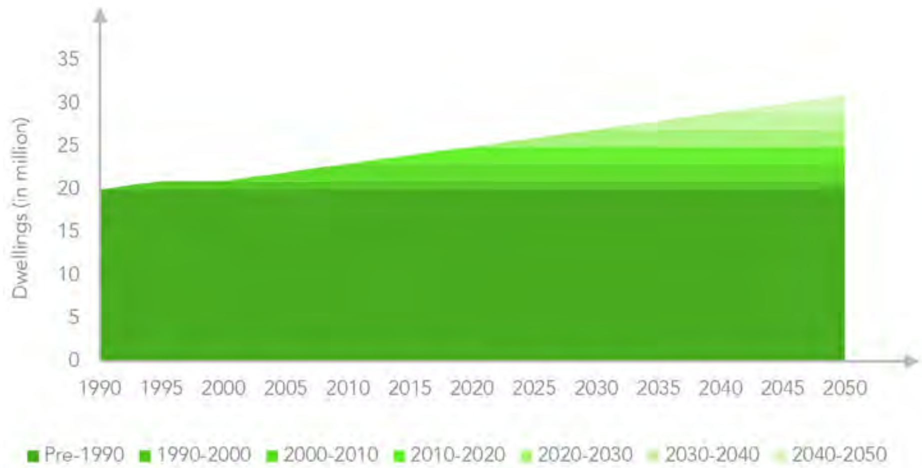
Whilst decarbonising homes is important to mitigate climate change, it is not the only reason to retrofit. In 2020, one in eight households in England were considered to be in fuel poverty and 1 in 6 in Herefordshire. There is, unsurprisingly, a strong correlation between inefficient homes and fuel poverty with 88% of all fuel poor households living in properties with a Band D EPC or below. We can deliver lower bills as well as lower carbon emissions emissions[1].

Health and wellbeing

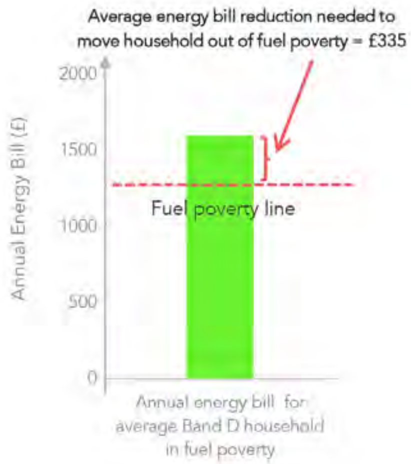
Improving the energy efficiency of a home is also likely to increase thermal comfort (both in summer and in winter) and improve indoor air quality through better ventilation. This will have a positive impact on everybody, but especially small children, the elderly and those with respiratory conditions. The International Energy Agency (IEA) and the OECD suggest health improvements might account for 75% of the overall value of improving the energy efficiency of buildings[2].

[1]The average Band D annual energy bill is £1600 and the average reduction needed to bring these households out of fuel poverty is £335

[2]Separately, the BRE have estimated that poor quality housing costs the NHS £1.4 billion in avoidable treatments.



England Housing Stock – 1990 to 2050 (Millions of dwellings)



*Fuel poverty, health and wellbeing are all positive benefits of retrofit (**Source:** BRE)*

Energy targets and Key Performance Indicators (KPIs) for retrofit

Setting the right brief and targets is key

To achieve the most energy efficient outcome it is important that the brief and targets reflect this ambition from the start. A strong brief provides tangible guidance on how targets can be achieved. Best practice KPIs for retrofit housing are listed in the adjacent table and all KPIs must be met for a home to be Net Zero carbon.

Getting the right team

The success of the retrofit approach relies on the coordination of a shared vision. Therefore getting the right team on board at the right time is critical. The early appointment of an energy consultant with specialism in ultra low energy design and retrofit is recommended. Workshops at briefing stage can be used to establish the long term retrofit plan and ensure the wider consultant team are clear on the targets and objectives.

Consider energy modelling

Analysis of the design through energy modelling will ensure that the KPIs are met in practice. This involves the early appointment of an energy or retrofit consultant to steer the design from concept stage and carry out modelling using accurate tools such as the Passivhaus Planning Package (PHPP).

Without energy modelling

Using energy modelling is always the recommended route to ensure accuracy, however it is possible to target best practice by setting the right specification and design requirements as part of the project brief. Refer to 'How it all comes together' for retrofit of a terrace house (including the case of a terrace house in a conservation area). The LETI Retrofit Guide can also be used for further guidance (www.leti.london).

	Retrofit housing (KPIs)
Ultra low energy homes	**Space heating demand** **50kWh/m²/yr*** **on average (range of 20-120 kWh/m²/yr)*
Energy use and efficient heating	**Energy use Intensity** **50kWh/m²/yr*** **on average*
Renewable energy	**Electric generation intensity** **120kWh/m²$_{fp}$/yr** *m²$_{fp}$: m² building footprint*

The importance of a ‘whole house’ approach

Successful retrofit relies on a structured process including adequate assessment, design, installation and monitoring to feed back into future work. These principles as well as the idea of whole house thinking and the role of retrofit coordinators have fed into the creation of PAS (Publicly Available Specification) 2035 the UK’s first retrofit standard. This helps to deliver quality and manage risks associated with retrofit. It aims to ensure clients and homeowners get value for their investment. PAS 2035 follows two core principles:

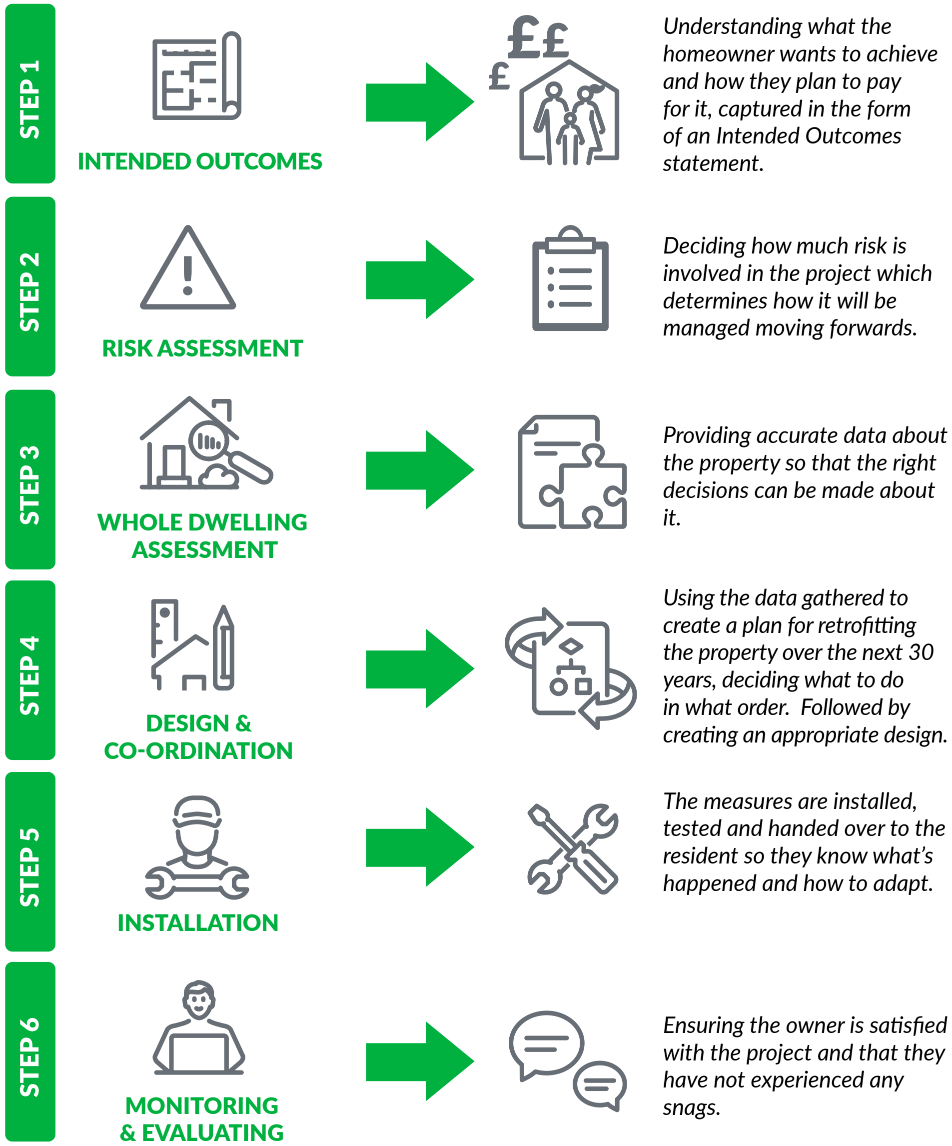
1. A ‘**fabric first**’ approach to reduce the heat demand of a building as much as possible and to ensure newly airtight homes are well ventilated and avoid issues with damp and humidity.

2. A ‘**whole house approach to retrofit**’ to ensure retrofit plans for homes consider improvements to the fabric, services and renewable energy generation in a coherent way to minimise both risks and carbon emissions.

Who is a Retrofit Coordinator?

PAS 2035 requires an accredited Retrofit Coordinator to be appointed who will take responsibility for demonstrating compliance with the PAS 2035 standard. This is a relatively new role and different projects require input from different retrofit specialist depending on the risk category. The Retrofit Coordinator identifies whether the project falls into a low, medium or high-risk category and advises on appropriate steps to minimise risk. For more information, please refer here[3].

[3] https://retrofitacademy.org/



PAS 2035 recommends 6 steps to follow on a quality assured retrofit project

How does a home produce carbon?

The vast majority (85%) of homes in the UK get their heating and hot water from a gas boiler and many other homes use other fossil fuels (e.g. oil). All the other energy uses in the home are drawn from the electricity grid. The emissions from the gas boiler are emitted on-site whilst the emissions associated with electricity use are emitted in a power station. Ten years ago, electricity was about 2.5 times more carbon intensive than gas, but things have changed a lot since then.

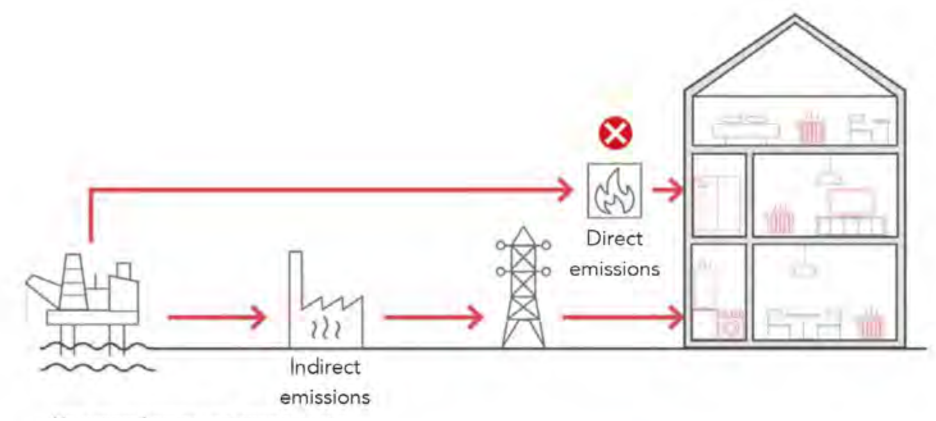
What has changed?

Over the past ten years, coal-fired power stations have been retired and the amount of renewable energy that feeds into our electricity grid has increased significantly. This means that the carbon intensity of our electricity has now dropped and is now about 30% lower than gas. As we add more renewables to our grid in the coming years, this will continue to drop until we approach a zero carbon grid.

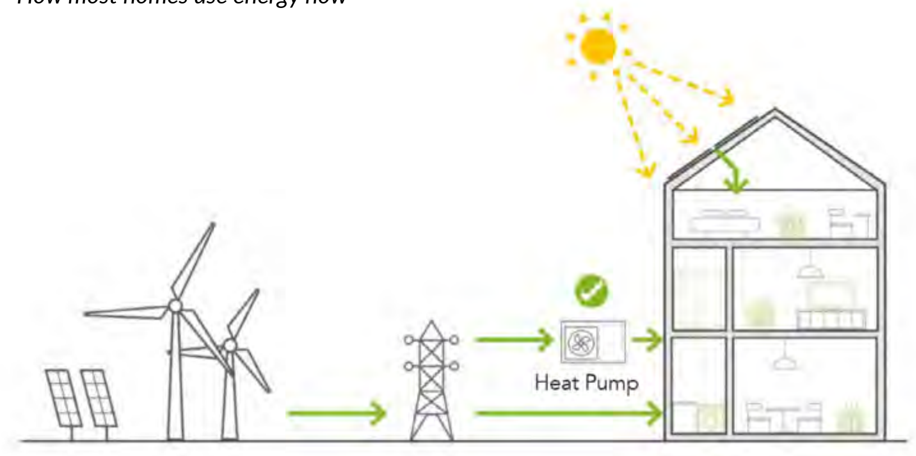
In contrast, a gas boiler installed today, will continue to emit carbon at the same rate until it is decommissioned – which could be another 25 years. This means that it has become a priority to move our homes away from gas to an electric-based system for heating and hot water.

Where do heat pumps fit?

Heat pumps will be discussed in more detail later, but they offer an excellent way of transitioning to electricity whilst reducing the load on the grid as they extract additional energy from the surrounding air or ground. Both the Government and the UK Climate Change Committee agree that they will form a major part of our future heating systems.



How most homes use energy now



How most homes should use energy now and in the future

Each house or flat is different. They will have different starting and final positions on the adjacent 'Retrofit Map' but ultimately, by 2050 (or earlier) all homes must be moved to one of the green squares.

The adjacent **Retrofit Map** could also be used to identify the buildings which should be most urgently retrofitted (in **red**) as they will be consuming most of the carbon budgets. Other factors (e.g. maintenance schedules, replacement opportunities, resident's appetite) may also influence the prioritisation.

Use of fossil fuels
Not compatible with Net Zero.
The heating system must be changed.

Low carbon heat but risk of high energy costs
A change of heating system may not be required but fabric, ventilation and system should be improved

Low carbon heat and sufficient level of energy efficiency
Compatible with Net Zero

[1]A heat network would qualify as 'low carbon heat network' for the purpose of this Retrofit Map only if it would have a lower carbon content of heat (per kWh delivered) than direct electric heating. Any system using fossil fuels and/or with high distribution losses is unlikely to qualify.

[2]Could be an individual or building level heat pump with low distribution losses.

A long term whole house renovation plan for a phased retrofit

An ambitious objective

The objective of a retrofit project should be to achieve Net Zero carbon by 2050 (or earlier). This means that:

- The home's energy efficiency is improved
- A low carbon heating system is installed
- Renewable energy is installed on on-site
- The home is made smart ready

A whole house renovation plan is a useful tool to prepare and provides a pragmatic and coherent way to deliver this ambition.

Phasing improvements as part of coherent whole house plan

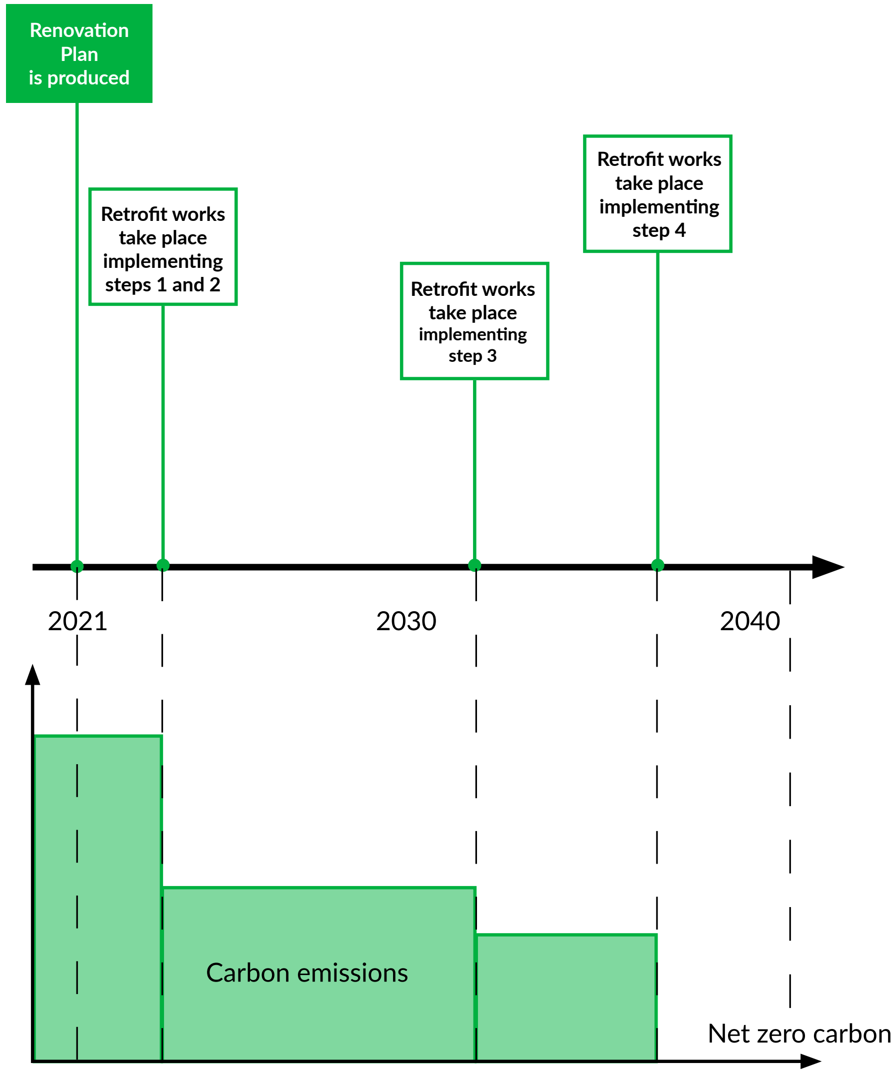
It may not be possible to implement all retrofit measures at once, but it is important to plan ahead so that packages of work are coherent and complementary. The preparation of a whole house plan is recommended to help in that planning.

This page shows how the measures can form part of a strategy for improvements. It would help landlord and residents to progressively save carbon and energy costs and avoid undertaking measures that conflict with planned future improvements.

A digital logbook

Alongside the whole house renovation plan, a building digital logbook can be developed to gather and retain all relevant information about the building.

Together, they form the **Building Renovation Passport**.



Note: the expected decarbonisation of the grid is not represented for simplicity but will also contribute to the reduction of carbon emissions over time.

It's all about moisture ...

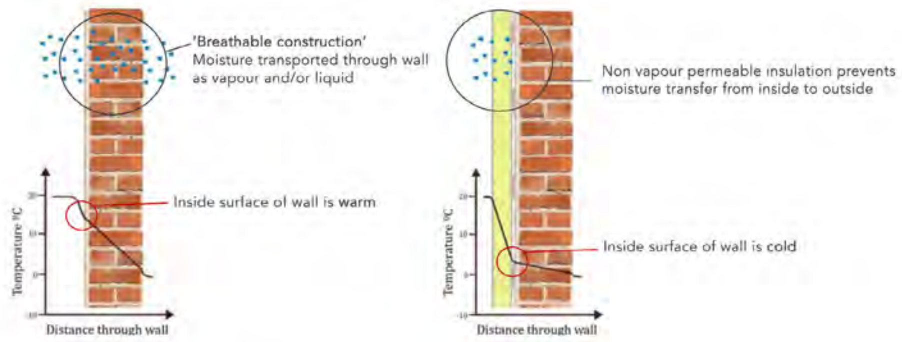
Our homes need to remain structurally sound, free from damp, mould and rot. Regrettably, many existing homes already suffer from excessive cold, damp, mould and condensation. A poorly planned and executed retrofit could actually make this worse. It is very important to understand this risk to mitigate and avoid it.

It may not be obvious, but our homes are constantly dealing with moisture. They are keeping out the rain and stopping the damp rising up from the ground. They are also dealing with the significant amounts of moisture that we generate inside the home from cooking, washing and breathing. Finally, if the building fabric does somehow get wet, they are designed to ensure that it will dry out without long-term damage. Interfere with any of these mechanisms, and we could end up doing damage to the health of both the building and its occupants.

Clear principles can address this risk

The risks of retrofit are well understood and can be overcome with sensible design and well-executed construction. Some key rules are:

- No insulation without ventilation . As you add insulation you are also likely to increase airtightness. This means less air moving through the building. You can counter this with opening windows and extract fans, but ideally by fitting a whole-house ventilation system like Mechanical Ventilation with Heat Recovery (MVHR). It is important that any mechanical equipment installed is user friendly, with simple controls with clear instructions.
- External insulation is best. Internal insulation means your external walls become cold and there is therefore a risk of condensation if the warm internal air reaches a cold surface. So, external insulation is preferred, but if internal insulation cannot be avoided, vapour open insulation (such as wood fibre) should be used. It is chemically fixed to the inside surface thus reducing the risk of condensation.



The risk of condensation with internal insulation

Installation of wood fibre insulation boards internally
*(**Sources:** Back to Earth & ASBP)*

Low carbon retrofit of heritage and traditional construction buildings in conservation areas is necessary and possible. There are a growing number of examples which show it can be done, and the PAS retrofit framework provides a suitable methodology.

Environmental and heritage conservation can go hand in hand

Heritage conservation is often given as an excuse to not improve energy efficiency and reduce carbon emissions. Proposals for those measures are sometimes refused by Local Planning Authorities particularly where they are not well thought through and do not form part of a whole building approach and therefore could cause damage to the structure of the building.

However, in addition to offering significant potential for carbon reductions, well-planned retrofit programmes can also contribute to conservation by incorporating maintenance and repair, and offering a new lease of life to buildings. They limit the risk of under-heating by occupants worried about energy bills, and associated risks of fabric degradation. By being more comfortable, buildings are also more likely to remain valuable and well looked after in the future.

Identifying relevant solutions for the context

Upgrading existing windows, and/or installing replacement double/triple glazed windows (subject to planning officer's support) can reduce heat loss by up to 40%. Recent advances in windows technology such as evacuated glazing offer the possibility of recreating traditional windows forms but with only a fraction of the heat loss. This technique can in some cases be applied to listed buildings.

Emerging products such as insulating plasters also offer the opportunity to insulate walls in a sensitive manner.

There is a growing library of resources for responsible retrofit of traditional and historic buildings, including the above Sustainable Traditional Buildings Alliance (STBA) and Historic England guidance

Recent examples of exemplar retrofits with heritage considerations:
*Grade I listed Trinity Student Halls in Cambridge (left, **source:** Max Fordham),*
*and Grade II early Victorian home in Clapham, London (right, **source:** Arboreal).*
Both include the application of internal insulation, with attention to moisture movement and monitoring of interstitial moisture level.

An extension should trigger the improvement of the home (especially low carbon heat)

Grasping the opportunity

When considering the lifetime of a house, there are not many times when major improvements can be made. An extension is a fantastic opportunity to make a significant step towards Net Zero carbon and not locking in poor/high carbon decisions.

What to consider

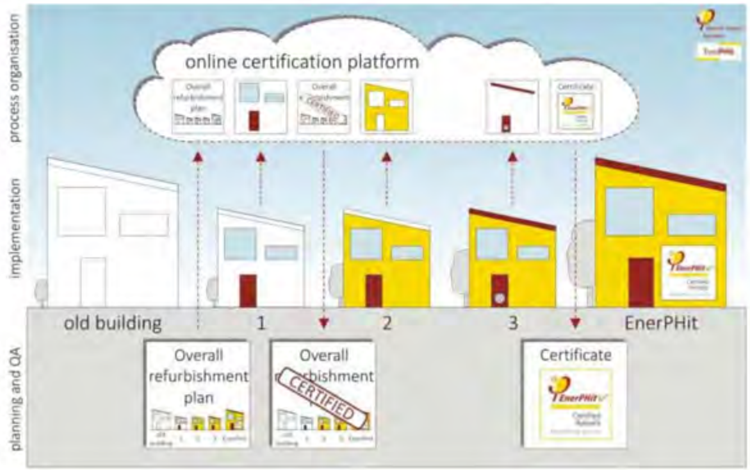
When considering the scope and costs of extending a home, the following opportunities should be considered:

1. Upgrading the heating system, and replacing the gas boiler with a heat pump.
2. Replacing existing windows with double or triple glazed windows
3. Upgrading the existing external fabric of the existing building (including both insulation and airtightness).
4. Installing Mechanical Ventilation with Heat Recovery (MVHR)
5. Installing solar PV panels to generate electricity

Staged retrofit – piece by piece

It is possible to undertake a staged retrofit when extending a home. A very useful resource and robust methodology is the EnerPHit Retrofit Plan. This scheme helps create a plan for taking a staged retrofit process, where the measures to improve the building fabric are put to a timeline. This allows the extension to be built and improvements to be made over time, and not just in a single phase. This can be an attractive and practical approach as often the capital costs of undertaking an extension and undertaking a major refurbishment all at once may not be affordable.

*EnerPHit retrofit project with extension (**Source:** Passivhaus Plus)*



*EnerPHit staged retrofit improvement plan process (**Source:** PHI)*

Heat pumps are the best option

The electricity grid has decarbonised and will continue to decarbonise, thus most likely low carbon heat source is using electricity. This is done most efficiently, and has lower running costs when using heat pumps. There are various types of systems available including, air-to-air and air-to-water heat pumps, ground source heat pumps, exhaust air heat pumps, heat pumps integrated into a domestic hot water store, and shoebox water-to-water heat pumps connected to an ambient loop. Hot water storage is required when using heat pumps.

What other options are available?

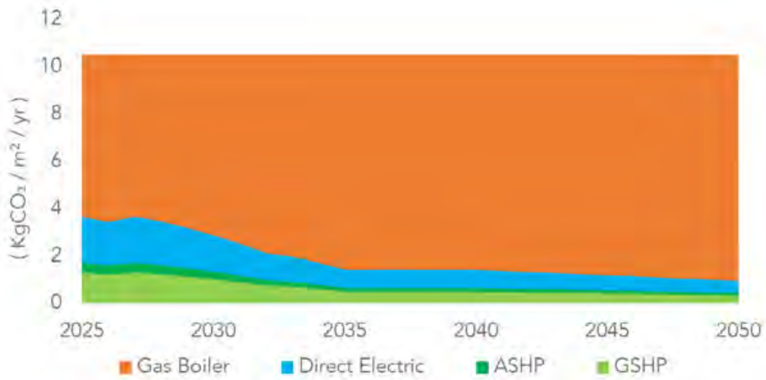
Direct electric heating, for example through panel radiators will become low carbon in the future, as the grid continues to decarbonise. However direct electric heating can lead to very high heating bills.

Hydrogen is very unlikely to be a solution for the majority of homes. ‘Green’ hydrogen from renewable power electrolysis is truly zero emissions. However, the UK gas supply industry advocates ‘Blue’ hydrogen manufactured from methane with carbon capture of its high emissions using yet to be proven at scale carbon capture and storage technology. Thus it is yet to be proven that hydrogen at scale is in fact low carbon and of an acceptable price.

Using woodburning stoves causes problems with air quality and involves burning raw materials, which should be avoided.

Is your home ready for low carbon heat?

If your home does not have a reasonable level of energy efficiency, particularly if it is a large house, using a heat pump can be quite expensive. In those cases, it is recommended to improve the fabric and airtightness, potentially over time.



This graph compares carbon emission associated with various heating systems over for a typical home. Emissions from a gas boiler stay constant, whereas emissions from direct electric systems and heat pumps reduce over time due to grid decarbonisation. Heat pumps have lower emissions than direct electric systems purely because they are more efficient.

	System	Carbon Emission Reduction	Running Cost	Capital Cost	Air Quality Neutral	Ease of Use & Maintenance
Best	Ground Source Heat Pump	✓✓	✓✓	✗	✓	✓
	Air Source Heat Pump	✓	✓	~	✓	✓
	Direct electricity	~	~	~	✓	
	Biomass/ wood burning stove	~	~	~	✗	✗
Worst	Hydrogen	✗	?	?	✓	✓

Key ✓✓ Very good; ✓ Good; ~ Neutral/ dependant; ? Unknown; ✗ Bad

The table compares various low carbon heating options across different criteria

Heat pump options

There are various types of heat pump options available for retrofitted homes. This page outlines which heat pumps are available and which to choose.

Most homes with a heat demand below 100kWh/m².year will be suitable for a heat pump, unless there is not sufficient space. At the higher end of this criteria larger radiator sizes or underfloor heating may be required.

1 Which heat pumps are the best for new homes?

- Monoblock or split (air source) heat pump, generating heating and hot water
- A ground source heating pump system, generating heating and hot water
- Individual heat pump connected to an ambient loop

Reasons why these heat pumps might not be suitable

- **Available space:** These heat pumps require space for indoor and/or outdoor units
- **Ground conditions:** Some ground conditions are not suitable for ground source heat pumps
- **Size of development:** an ambient loop is only really suitable when there are more than 30 homes

If these systems do not work

2 Is the space heating demand <100kWh/m².yr?

No

It is recommended to retrofit the home such that the heat demand is as low as possible, as this reduces carbon emissions and fuel bills.

If the home cannot be retrofitted to below 100 kWh/m².yr heat demand then it is still recommended to install a heat pump, but assess the impact on energy costs.

Yes

3 Which are next best for new homes with a low space heating demand?

- A heat pump integrated into a hot water store.(ie. hot water heat pump) Heating is delivered through direct electric panel radiators
- An exhaust air heat pump with direct electric panel radiators are needed for peaks*

Reasons why these heat pumps might not be suitable

- **Available space:** These heat pumps require space for a hot water store
- **Ducting:** A heat pump integrated into a hot water store required ducting to the outside, in some homes there might not be space for this
- **Ventilation:** an exhaust air heat pump requires integration into an MVHR unit, MVHRs are highly recommended

If these systems do not work

4 Is the space heating demand <40kWh/m².yr?

No

It is recommended to retrofit the home such that the heat demand is as low as possible, as this reduces carbon emissions and fuel bills.

If there is not sufficient space to install a heat pump, then consider direct electric heating and hot water.

Yes

5 Consider direct electric heating and hot water

**An exhaust air heat pump (compact unit) combined a heat pump and a MVHR. Some products can only meet the heat demand in smaller dwellings and/or this with a space heating <15kWh/m².year,*

Why windows should be upgraded

Windows can lose more than ten times more heat compared to a well insulated external wall. Unless the current windows have been installed recently, it is very important to ensure that windows are replaced with high performing triple glazed windows (with a whole unit U-value calculated ($U_w$value) of less than 1.0 W/m^{2}K).

Detailing the window replacement

Where possible, the window should be replaced in line with the insulation layer of the external wall to continue the thermal line of the dwelling.
The connection of the window to the external wall needs to be carefully considered as this is a weak spot thermally. It needs to be designed so that the risk of condensation between the external wall and window is reduced. A specialist consultant who can undertake thermal bridge modelling may need to be consulted for project specific guidance. The use of low conductivity cavity closers and products like compacfoam can be a good way to reduce thermal bridging, and reduce the risk of condensation.

Airtightness

When installing the windows, care should be given to the junction between the window frame and the airtightness layer of the external wall. High performance airtightness tape should be used to limit infiltration as the connection between windows and external walls can be leaky if not properly installed.

Exceptions

Replacement windows may not always be appropriate in the context of a listed building, or some older buildings in conservation areas, and other methods of improving the energy efficiency of the existing windows may need to be considered as part of a more holistic ‘whole house approach’ (e.g. draught proofing or secondary glazing).

*Photo of triple glazed aluclad timber window (**Source:** Internorm)*

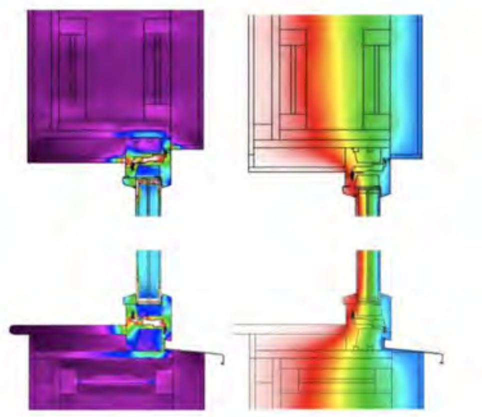


*Photo of thermal bridge calculation of window install (**Source:** Warm)*

*Replacement triple glazed windows (**Source:** Internorm)*

*Photo of window install in Enerphit retrofit (**Source:** Passive House Plus)*

Insulating externally or internally?

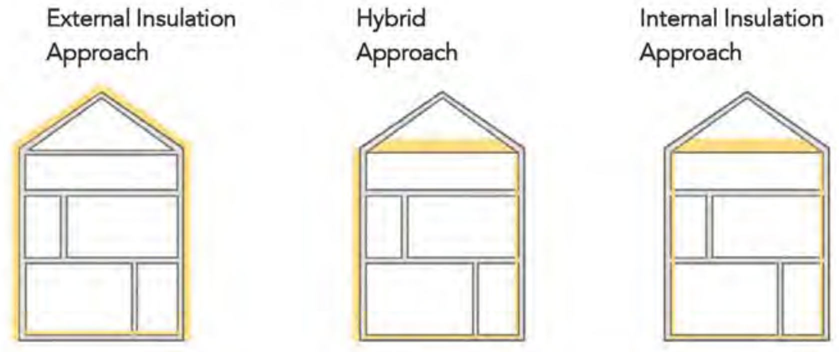
From a heat loss perspective, it is better to externally insulate as this allows the insulation to wrap around the building continuously and avoids the need to address weak points and junctions e.g. around floor joists. However, it will mostly come down to what is practical on the specific site: how much space there is available; the aesthetics preferences; whether the building has conservation or planning constraints that prevent external insulation; the level of disruption the installation will have to occupants; and the relative installation cost.

External insulation

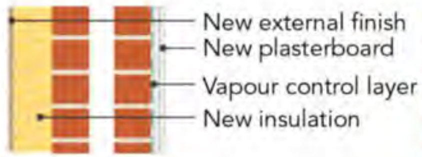
External wall insulation is a good solution. It is very effective thermally, does not reduce internal space and generally enables residents to stay in the property when insulation is being fitted. The external appearance of a building will be affected, and roof eaves may require extending. Insulation can be easily covered in render but brick slips, pebbledash and cladding are also possible.

Internal insulation

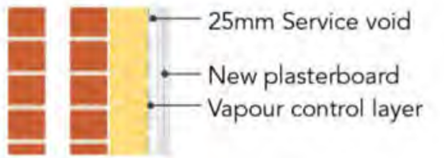
Use breathable materials internally e.g. wood fibre insulation, hemp lime insulation. Avoid using non-breathable materials internally e.g. rigid insulation. Even though this can achieve a good thermal performance and is often cheaper, it can increase the condensation risk and make detailing around junctions more complicated. Consider the combustibility of insulation, natural products are likely to be combustible but can be used safely in the right application. Where space is limited internally consider using thin products such as aerogel insulation. Consider installing service voids for electrics to run outside of the insulation line.



In some circumstances, it may be beneficial to consider a hybrid approach e.g. internal insulation at the front to retain the architectural features of the front façade and external insulation at the rear. This maximises the insulation gains of using external insulation where it has less of a visual impact.

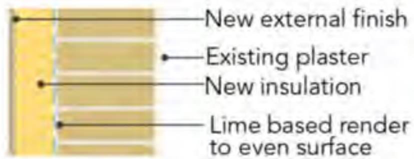


Externally insulated Brick Cavity

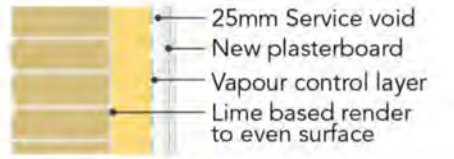


Internally insulated Brick Cavity

N.B. If considering cavity fill insulation ensures measures have been made to prevent condensation



Externally insulated stone wall



Internally insulated stone wall

Consider floor-to-ceiling heights

When insulating floors or ceilings be sure to check the floor to ceiling height. Insulating floors may require raising the floor level, so ensure you have considered the impacts e.g. steps at the entrances, door heights and consistent staircases levels.

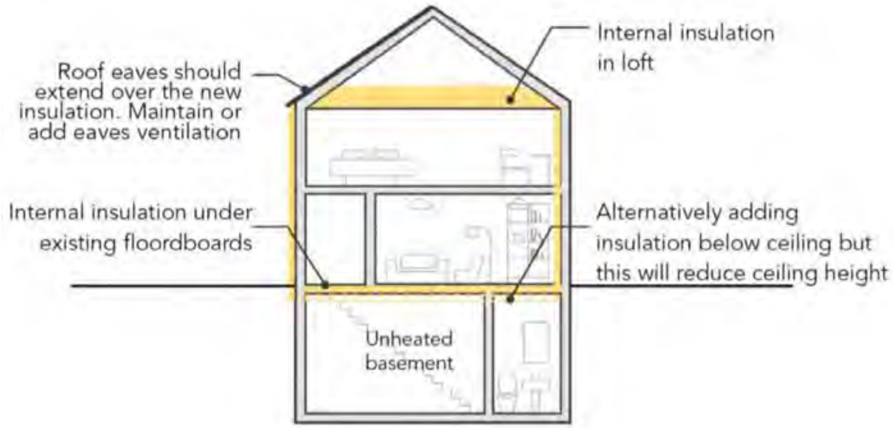
Extending eaves over external wall insulation

Where external wall insulation meets the roof consider extending eaves to cover the additional wall thickness. Also be sure to maintain or add ventilation at the eaves.

Insulating roofs

If you have an unheated attic space the simplest approach is to insulate the floor in the loft. Ideally relocate existing water services and tanks in the roof void or insulate them if not possible. If you require a heated and habitable loft, add insulation between rafters and apply insulated sheathing board over the rafters as shown in rafter detail below. Plasterboard can be fixed to the underside of the insulation. Consider fabric improvements in conjunction with any loft extension works.

Rafter insulation detail



Thermal bridges

A thermal bridge, or cold bridge, is a piece of material through which heat flows easily, relative to adjacent materials. For example, a concrete lintel that interrupts the wall insulation layer would be considered a thermal bridge. Thermal bridges should be avoided as they increase heat loss, and can cause cold spots that lead to condensation and decrease comfort for home occupants.

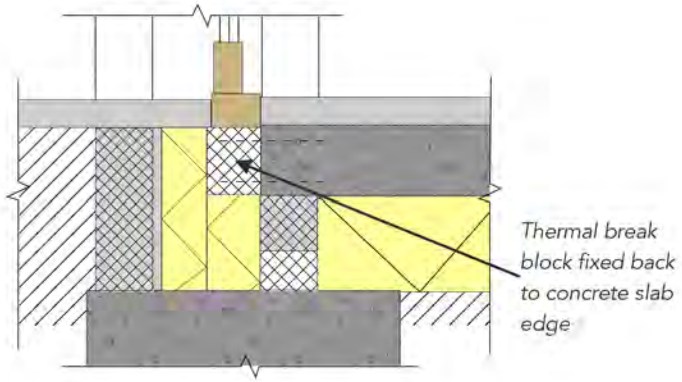
Identifying thermal bridges

A good approach to retrofit is to sketch out a cross section drawing of the building. Clearly identify materials that keep heat in, such as insulation, doors, and windows. Ideally, these should all connect together without insulation depth reducing by more than a third. Different materials should be butt jointed, or overlap, ideally for a distance equivalent to the thickness of the insulating element.

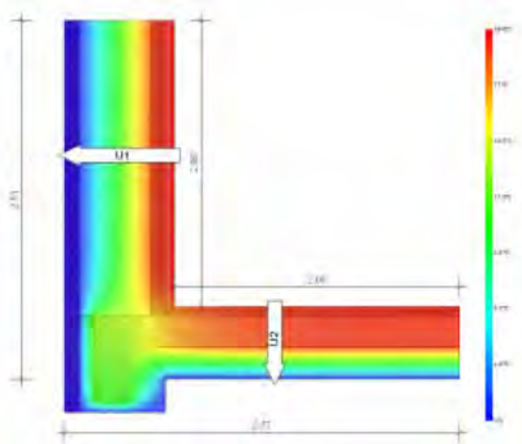
Tackling thermal bridges

There are many off-the shelf products available to avoid thermal bridging. Learn about these and use them where possible. Examples include thermally broken lintels, foam glass blocks, high density EPS foam, and specialist structural thermal breaks that can be cast into concrete, or used to fasten steelwork together.

In retrofit, there will be thermal bridges that cannot be avoided. In these cases, aim to increase the distance that heat must flow to escape the structure. For example, an insulation downstand or skirt could be applied around the external wall to ground floor junction of a building to reduce heat flow. Consider using thin pieces of higher performing insulation such as phenolic board or aerogel where depth is constrained.



Sketch out key junctions and ensure there is a continuous line of insulation that runs around the building. Try to ensure the insulation depth does not reduce by more than a third around any junction, and ensure window and door frames are in line with insulation.



Consider commissioning thermal bridge modelling for particularly challenging junctions to inform your strategy. Small changes to the position and type of material used in construction can have a big affect on the heat flow, a model will help to show this.

Consider junctions carefully

Junctions which pose a weak point for heat loss, i.e. a thermal bridge, should be considered on a case by case basis. Key examples of such junctions are outlined below. Special care should taken to reduce the condensation risk posed at each junction. We strongly recommend engaging an architect or consultant who is able to produce a risk assessment and help design out condensation risk.

1 Roof eaves with external wall insulation

The space between the external wall insulation and roof insulation is a weak point for heat loss. This can be compensated by providing a strip of internal insulation at ceiling level.

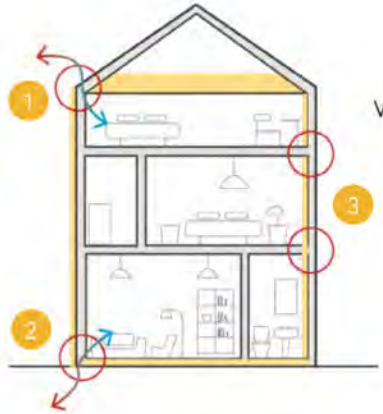
2 Foot of the façade with external wall insulation

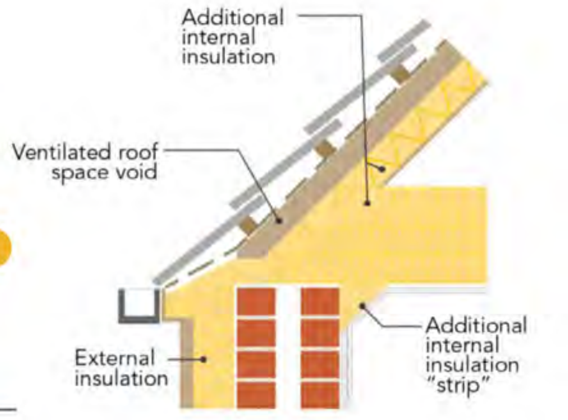
Avoid creating weak points for heat loss at the foot of the façade between external insulation and ground floor. Insulating externally down the wall below ground level as far as possible and provide some internal wall insulation up to counter top level.

3 Joist ends with internal wall insulation

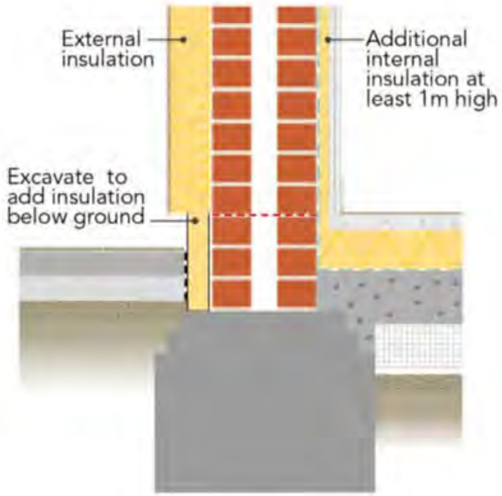
When applying internal insulation it is important to protect joist ends against thermal bridging and condensation risk:

- The most effective approach is to cut and rehang joists away from the external wall e.g. support them on hangers or by a beam between party walls. This allows for a narrow cavity of insulation to be inserted between the façade and end of joist.
- When insulating behind the joists is not possible, consider hanging the joists or wrapping the breather membrane around the end of the joist to prevent the build up of condensation.

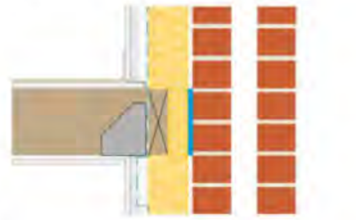




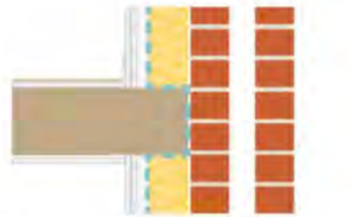
Detail for roof eaves and 'internal strip of insulation'



Measures to avoid thermal bridge at the foot of the façade



To avoid thermal bridge + condensation cut and rehang joist away from wall



To avoid condensation risk wrap joist (or add hanger)

The importance of airtightness

The airtightness of existing homes varies hugely, however it is recommended that retrofit work targets a value of between 0.5 and $3m^3/h/m^2$, depending on the depth of retrofit and project

Start with a plan, investigate, then update the plan

Building airtight starts with a well thought through airtightness and ventilation strategy. Existing buildings conceal many secrets however, so expect to update the plan once you start stripping out the building. A key consideration in retrofit is managing moisture risk and minimising risk of warm humid indoor air coming into contact with cold surfaces.

Use the right products

Retrofits will use similar products to new build projects. Consider ordering a range of tapes, primers, membranes and parge coats in advance to test on parts of the building. It may be necessary to combine traditional building practices with modern airtightness products. Consider this carefully and contact manufacturers for advice if necessary.

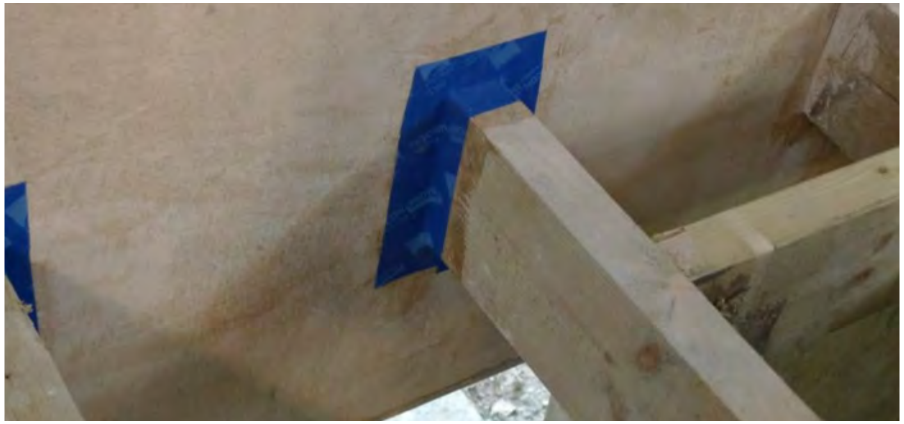
Stick to the plan on site

Retrofit can be a bit chaotic, so ensuring the airtightness strategy is implemented properly is even more important than for new build. Expect setbacks and be ready to adapt your approach as necessary.

Test, then test again

Plan for at least two air tests. The first test should be completed as soon as the building is weathertight and while joints between different components in the airtight layer are still accessible so leaks can be repaired if necessary.

Achieving airtightness is possible in retrofit, but it is often necessary to strip back to the basic structure and perform basic repair work before methodically applying airtightness products and principles. Always consider risk of moisture and condensation.
*(**Source:** Eightpans)*



*Applying airtightness tape to joist ends is a common measure required to achieve good airtightness in existing buildings. Large gaps may need filling with mortar first, and remember to apply a suitable primer. (**Source:** Ecomerchant)*

Why is it important?

Existing buildings in the UK are generally leaky and naturally ventilated, leading to discomfort and large energy demands. Insulation, airtightness and new windows are often considered important but they generally should not be done without the retrofit of a controlled ventilation system. A mechanical ventilation and heat recovery (MVHR) system is often the best solution.

Mechanical Ventilation with Heat Recovery

The most efficient way to provide ventilation, is through a MVHR system. The equipment circulates air in a dwelling using a small fan, whilst recovering the heat from inside so it is not lost.

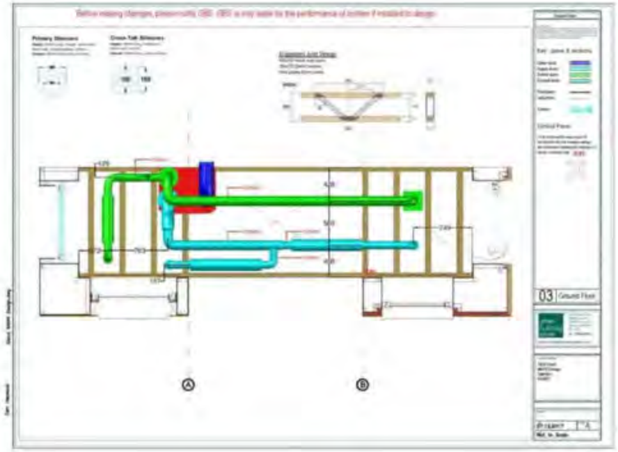
Designing and selecting the correct MVHR system

You will need a building services engineer and/or experienced subcontractor and/or a MVHR manufacturer/supplier to calculate the fresh air required, and design the MVHR system for your dwelling.

The MVHR unit should be sized and the system designed according to some specific requirements of the home and to achieve acoustic requirements. It is important to plan the space required for the MVHR unit and the associated ductwork and silencers. Rigid, insulated ductwork should be adopted where necessary. The MVHR unit should preferably be a Passivhaus Certified Unit.

Installing and commissioning the system

Historically the installation and commissioning of MVHR systems has been poor. To ensure the system works as planned, the system must be properly tested to ensure it is balanced, delivers the designed fresh air required and does not generate noise beyond what is expected.



*MVHR system design for an existing dwelling (**Source:** Green building store)*

*Image of Zehnder MVHR unit being retrofitted into an existing house (**Source:** Bow Tie Construction)*

*Flow rate measurement: image of MVHR system being commissioned (**Source:**Fourwalls)*

Reduce overall water consumption

Water efficiency is about reducing our use of mains water and the effect our homes have on water resources.

Reduce hot water to reduce energy use

In very low energy buildings, the energy required for hot water can exceed the amount of energy required for space heating. Therefore optimisation of hot water systems is essential to ensure energy use remains low.

What can you do?

Reduce flow rates

- The AECB water standards (opposite) provide clear guidance on sensible flow rates for showers and taps in low energy buildings.

Reduce distribution losses

- All pipework must be insulated.

Insulate to minimise losses from hot water tanks

- The standby losses of hot water tanks are highly variable, and can have a significant impact on overall energy use. Target a hot water tank heat loss of less than 1 kWh/day equivalent to 0.75 W/K.

Install waste water heat recovery systems in shower drains

- A simple technology that recovers heat from hot water as it is drained. Vertical systems can recover up to 60% of heat more than common horizontal ones recovering 25-40%.

Consider water recycling

- This is the process of treating waste water and reusing it, it can be used for large portions of potable water use.

Appliance/Fitting	AECB Good Practice Fittings Standard
Showers	6 to 8 l/min measured at installation. Mixer to have separate control of flow and temperature although this can be achieved with a single lever with 2 degrees of freedom (lift to increase flow, rotate to alter temperature). All mixers to have clear indication of hot and cold, and with hot tap or lever position to the left where relevant.
Basin taps	4 to 6 l/min measured at installation (per pillar tap or per mixer outlet). All mixers to have clear indication of hot and cold with hot tap or lever position to the left.
Kitchen sink taps	6 to 8 l/min measured at installation. All mixers to have clear indication of hot and cold with hot tap or lever position to the left.
WCs	≤ 6 l full flush when flushed with the water supply connected. All domestic installations to be dual flush. All valve valve-flush (as opposed to siphon mechanism). WCs to be fitted with an easily accessible, quarter turn isolating valve with a hand hand-operated lever. Where a valve valve-flush WC is installed, the Home User Guide must include information on testing for leaks and subsequent repair.
Baths	≤ 180 litres measured to the centre line of overflow without allowing for the displacement of a person. Note that some product catalogues subtract the volume of an average bather. A shower must also be available. If this is over the bath then it must be suitable for stand stand-up showering with a suitable screen or curtain.

Refer to the full AECB document for more information.

Where to start

Contacting a local MCS certified solar installer is a great first step to retrofitting a solar Photovoltaic (PV) system. They can assess your property, provide information on solar panels and inverters, and provide a quotation indicating how much energy the system will generate. Quotations typically also include financial analysis such as annual savings and simple payback period. Prices can vary substantially between installers though, so obtain several quotes.

Planning work

Unless you live in a bungalow, scaffold will typically need to be erected to install solar panels. Consider whether this could provide opportunities to carry out other retrofit work such as wall insulation, replacing windows, or tackling a thermal bridge between your wall and roof insulation. Standard solar scaffolds may not include working decks on intermediate floors, so if you do plan to do other work discuss it with your installer.

Getting up and running

Once your system is installed, you will need to get registered for the Smart Export Guarantee to receive payments for exported solar energy. Check Solar Energy UK's league table to find an energy supplier offering a competitive rate. Most schemes require an MCS certificate from the solar PV installer and a smart meter or export meter that can record the amount of energy you are supplying to the electricity grid.

*Over a million homes in the UK already have solar panels, many of which have been retrofitted. Notify your building's insurance provider if you are having solar panels fitted to ensure they are covered and your policy remains valid. (**Source:** Alamy Stock Photo)*

*Products and processes have been specifically developed to securely fit panels to existing roofs. Example shows a stainless steel roof hook being mounted to a slate roof. (**Source:** Schletter installation video)*

Intuitive and flexible energy use

Demand response or energy flexibility refers to the ability of a system to reduce or increase energy consumption for a period of time in response to an external driver (e.g. energy price change, grid signal). Energy storage allows these systems to consume, retain and release energy as required in response to specific energy demands. Smart controls respond to these external drivers and demands to manage our systems.

Maximise renewables and stabilise the grid

These measures can help maximise the utilisation of on-site renewables and help stabilise demand on the grid. Moreover it will help to decarbonise the grid: when renewable electricity generation is low, demand response measures reduce the load on the grid, reducing the amount of peak gas plant that must be switched on to meet the grid demand.

Smart controls and demand response measures in the home (Source: SMA Solar UK)

What can you do?

Peak reduction

- Use passive measures and efficient systems to reduce heating, cooling and hot water peaks

Active demand response measures

- These measures reduce the electricity consumption for a certain period.
- Install heating and cooling set point control with increased comfort bands, controlled with smart thermostats or home energy management systems.
- Integrate thermal storage of heat into communal or individuals system within a building.
- Reduce lighting ventilation and small power energy consumption

Electricity generation and storage

- Use products that can generate electricity and feed into the grid, or power the building.
- Consider solar PV to water heat storage or battery storage.

Electric Vehicle (EV) charging

- It is generally accepted that there will be a large increase in electric vehicles, so it is essential to implement demand response to ensure grid stability.
- Charge EVs only when needed and allow the supplier to cut the charging short during peak times
- Install 'Vehicle to Grid' technology which allows the EV battery to be used to supply the building during grid peak periods.

Behaviour change

- Raise awareness of how people use electricity and the impacts.
- Consider incentives to reduce peak demand.
- Encourage responsible occupancy.

Microgrids

- Consider being part of a small semi-isolated energy network, separate from the national grid.

How much does it cost to retrofit and what are the results?

Retrofit costs depend hugely on the baseline building's characteristics and condition. A rough guide for an average semi-detached home is £5-15k for a shallow retrofit which, if starting with a poor baseline, could save around 30% in carbon emissions, through to £45-55k for a deep retrofit which would include significantly improving the building fabric, changing the heating system to a heat pump and fitting roof mounted solar PVs. This level of retrofit could achieve an 80-90% reduction in carbon emissions – particularly in the future as the heat pump makes use of a lower carbon grid.

Seeing retrofit as an additional cost to maintenance?

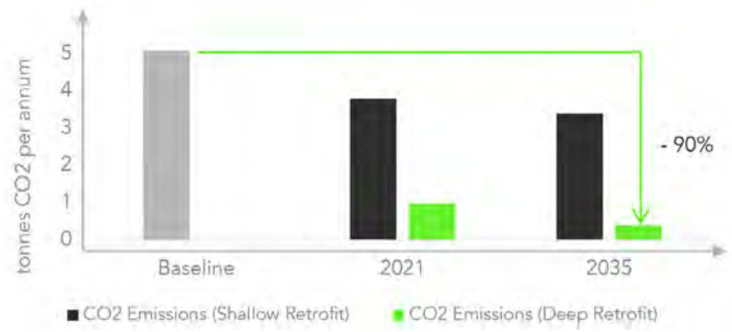
It is important to consider whether a measure is best undertaken as part of a planned or required maintenance activity. For example, re-rendering a wall would be an ideal time to apply external insulation and would mean the actual extra costs are just the insulation material and labour to secure the insulation to the wall.

And don't forget the co-benefits

Improved comfort, health and lower fuel bills are all valuable and important outcomes of retrofit. Prioritising measures using these different criteria is likely to produce a different order of priority for retrofit. For example, health and wellbeing is probably most improved by a Mechanical Ventilation with Heat Recovery (MVHR) system as this will dramatically improve indoor air quality and comfort. On the other hand, in most solid-walled dwellings, external wall insulation will offer the greatest net energy savings, and so the most significant reduction in fuel bills, despite being relatively expensive.

Measure	Shallow	Deep
Fit 100% low energy lighting	£20	£20
Increase hot water tank insulation by 50mm	£50	£50
Loft insulation - add 400mm	£500	£500
Fit new time and temperature control on heating system	£150	£150
Improved draught proofing	£150	
100% draught proofing - improve airtightness		£2,000
Cavity wall insulation - 50mm	£600	£600
Floor insulation- between & below suspended timber		£1,500
Insulate all heating and hot water pipework		£500
Fit mechanical ventilation and heat recovery (MVHR)		£7,000
Main heating - High efficiency condensing gas boiler	£3,800	
Main heating - Air source heat pump and new HW tank		£9,000
Half glazed doors - double glazed (16mm argon)	£1,500	
Half glazed doors - triple glazed, high performance		£2,000
External wall insulation - 160mm Expanded Polystyrene		£11,000
Double glazing (16mm argon filled, Low E)	£7,000	
Triple glazing (16mm argon filled, Low E)		£8,400
Photovoltaic Panels, 3kWp array (21m² area)		£6,500
Miscellaneous and enabling works	£1,000	£5,000

Indicative retrofit costs for an unrenovated 90m² semi-detached dwelling



CO_2 reductions for an unrenovated 90m² semi-detached dwelling

Embodied carbon is the carbon emissions associated with the extraction and processing of materials, energy use in the factories and transport associated with the products used in the retrofit. It includes emissions associated with disassembly and disposal of these products at end of life as well as the construction of the building and repair, replacement and maintenance. It also includes the demolition and disassembly of the building at the end of its life. Low embodied carbon design is not inherently more expensive or more complex, it just requires awareness and good design.

What can you do?

1. **Use re-used or reclaimed materials**
   Prioritise materials that are reused or reclaimed and that are durable. If not available use materials with a high recycled content.
2. **Use natural materials**
   Use natural materials where possible. Insulation choice is a good opportunity to reduce embodied carbon.
3. **Lean design**
   Finishes: Use self-finishing internal surfaces.
   Building Services: Target passive measures such as improved fabric to reduce the amount of services needed. Reduce the need for long duct runs, specify low Global Warming Potential (GWP) refrigerant (max. 150) and ensure low leakage rate.
4. **Encourage EPDs**
   Ask manufacturers for Environmental Product Declarations (EPD) and compare the impacts between products in accordance with BS EN 15804 (2019)
5. **Easy maintenance and use**
   Consider maintenance and access requirements, maintained equipment will last longer.
6. **Design for disassembly**
   Consider disassembly to allow for reuse at the end of life of the building, this is key to creating a circular economy. Create material passports for elements of the building to improve the ability of disassembled elements to be reused.

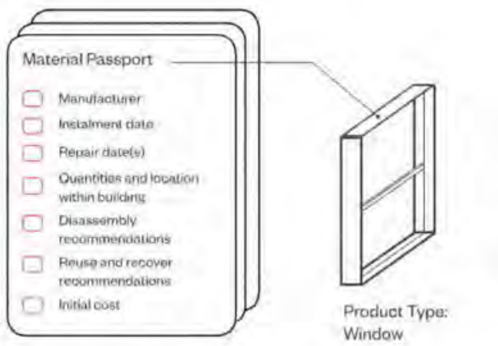
Sheep wool insulation
*(**Source:** Thermafleece)*

Cellulose-made from recycled paper
*(**Source:** Eco Spray Insulation)*

Cork insulation
*(**Source:** Corkribas)*

Hemp insulation
*(**Source:** Unyte Hemp)*

Some insulating materials like straw bale, hempcrete, and wool store (sequester) carbon and have negative emissions



Create material passports for products: A material passport provides identification of materials, components and technical characteristics with guidance for deconstruction and applicability of re-use. In this way the building becomes a material bank for future use.

Design checklist

Heating System

Replacing the heating system e.g. adding a heat pump can significantly improve efficiency

Mechanical Ventilation

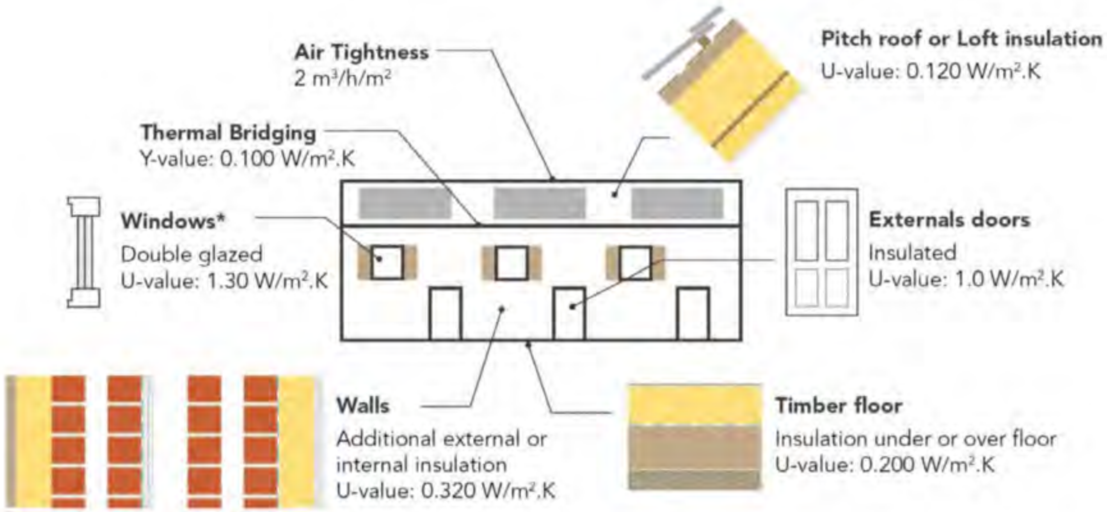
MVHR 90% efficiency ≤2m duct length from unit to external wall

Airtightness

An extremely airtight building fabric of 2 $m^3/h/m^2$ at 50 Pa.

Improve fabric efficiency

Add insulation externally or internally to improve fabric efficiency

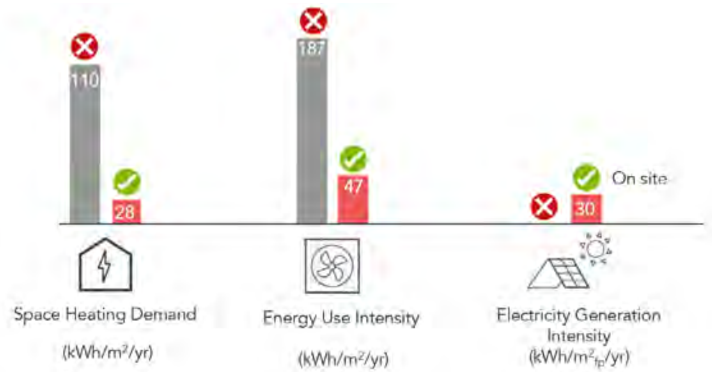


Performance

As the Energy Use Intensity (EUI) is the same as the electricity generated on site that means that the building is net zero carbon.

Typical terrace house built to building regulations

New zero carbon terrace house



Working with constraints

A retrofit of building within a conservation area or with other heritage constraints can be challenging. It is therefore important to weigh up the options and "do the most where you can". It should be noted that these constraints do not apply to the majority of the houses in the U.K. and only a select few. It is advisable to bring on board a heritage consultant early to understand the constraint and work together to find appropriate solutions.

Consider a hybrid approach

Consideration to the placement of additional insulation to work with the building's aesthetics using a combination of internal and external insulation. For example, if a building has a decorative frontage which contributes to character of the street, it may be better to use internal insulation on this façade. Whereas the rear of the property may be seen as less significant and therefore external insulation could be applied here.

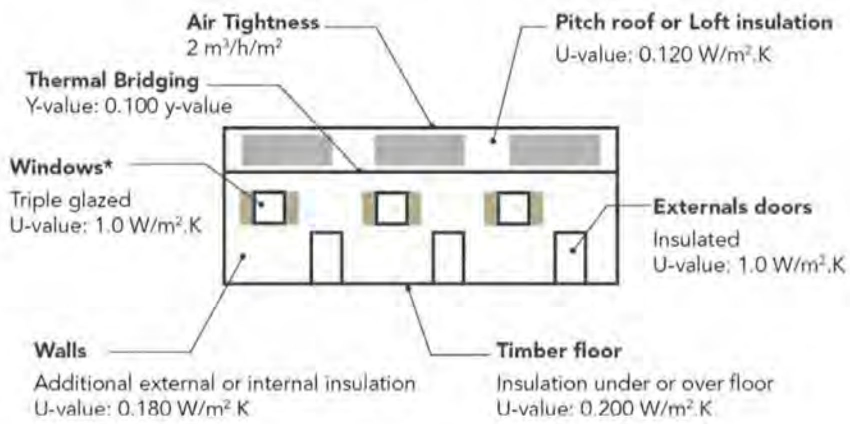
Breathable materials

In older stone wall construction that are more prone to damp, consider natural breathable materials (hydrophobic insulation) such as hempcrete which will not trap moisture.

Finding opportunities for renewables

Consider placement of solar panels on non prominent roofs that do not impact any constrained aesthetics. Also consider the orientation of solar panels to ensure they working efficiently i.e. avoid placing on shaded and north facing roofs.

Diagram illustrating a hybrid retrofit approach with internal and external insulation.



Recommended U-values to target net zero carbon for a constrained property.

The intention of this toolkit is to provide clear guidance on what you should consider when retrofitting a building to be Net Zero carbon.

Things to consider in Retrofit Schemes

When looking to build sustainable and low energy buildings, there are plenty of distractions. Many products, systems and technologies are suggested to be silver bullets in helping achieve Net Zero carbon buildings. Unfortunately, when put under scrutiny, many products or strategies do not achieve the desired outcome.

Additionally environmental schemes for existing homes may not all by themselves help the building achieve Net Zero carbon. To achieve Net Zero will be a collective effort of how we develop as well as how we travel and lifestyle choices.

Consider alternative materials and heating and ventilation systems

There is an emerging consensus in the construction industry on how to achieve Net Zero operational carbon. For example, there are several key energy efficiency, heating and ventilation principles which need to be adopted which have been discussed in earlier sections. Taking a business as usual approach to construction is not sufficient because many traditional ways of heating and ventilating homes are not aligned with a Net Zero objective. The images opposite illustrate materials and systems to consider when retrofitting schemes.

Consider the risks of moisture and condensation

One of the major risks associated with low energy and Net Zero carbon retrofit is creating areas where moisture condenses leading to mould growth. This typically happens when applying wall insulation, or where thermal bridges (e.g. around windows) are not treated to reduce the risk of condensation. It is extremely important to not forget about moisture as part of the retrofit process, and specialist advise should be sought to advise in order to mitigate this risk. Breathable insulation is also important to consider in terms of vapour permeability, Hygroscopicity and capillarity action. More information on breathable insulation can be found on the following link https://ukcmb.org/

Consider installing heat pumps instead of replacing gas boilers.

Consider blocking up open fire places

Consider MVHR over extract only ventilation systems.

Consider which renewables are most appropriate for your property

Do not rely on trickle vents to provide ventilation- additional measures, such as MVHR may be required.

Consider triple glazing instead of double glazing.

There are many examples

A lot of examples of successful retrofits are now available. The adjacent images illustrate different typologies and examples, but there are many more.

Key lessons learnt

Successful retrofit relies on a structured process including adequate assessment, design, installation and monitoring as set out within the Publicly Available Specification (PAS) 2035. It is underpinned by the idea of a retrofit coordinator who will help lead the process from start to finish.

Opinion has varied on how far to go over the last 30 years. Schemes like the Green Deal did not set an end goal or a metric but used ‘pay back rules’ which tended to undermine whole house thinking and quality. Consensus is now emerging that whole house plans are an appropriate way to take into account the specific characteristics of a house while providing a flexible path to the end goal for homeowners and landlords. For example this would enable them to coordinate retrofit with their ongoing maintenance/extension and other life plans.

It can be done: the Technology Strategy Board “Retrofit for the Future” programme, undertaken over 10 years ago, delivered 80% carbon reductions on 37 pilot homes.

This included 11 pre-1919 homes which demonstrated that heritage sensitive retrofit measures can deliver the scale of carbon reduction we need to see happening more.

(© Marion Baeli, Paul Davis and Partners)

***Shepard's Barn**, County Durham*
*(**Source:** LEAP Architects)*

***Passmore Street**, London*
*(**Source:** Grosvenor Britain & Ireland)*

Ernley Close, Manchester
(Source: 2e Architects)

Wilmcote House, Plymouth
(Source: ECD Architects)

Grove Road, London
(Source: Bere Architects)

Akerman Road, London
(Source: 15-40 Architecture)

Case study examples of different retrofit in Herefordshire

Domestic retrofit in Herefordshire EnerPHit, Herefordshire
- Harold Street, Hereford, by SimmondsMills
- Reform Cottage EnerPHit, Kingsthorne, Herefordshire

Educational retrofit in Herefordshire
- Steiner Academy, Much Dewchurch, Herefordshire

Domestic apartment retrofit in Herefordshire
- Cornish style properties, Hunderton Road, Hereford, Herefordshire

Domestic retrofit case studies on a small scale
- Cosy Homes, Oxfordshire

Wholehouse retrofit, Cambridgeshire
- Whole House Retrofit

- Other domestic cases studies can be found on Ecofurb:
  Some of the EcoFurb case studies

Reform Cottage, Kingsthorne, Herefordshire
Source: Andy Simmonds Architect

The Steiner Academy,
Much Dewchurch, Herefordshire
Source: Jon Renshaw Architects

Cornish style properties,
Hunderton Road, Hereford
Source: Connexus

Cosy Homes, Oxfordshire
Source: Cosy Homes

Wholehouse retrofit, Cambridgeshire
Source: Green building store

Products

Achieving Net Zero on new and existing homes also relies on good quality products.

This section explains the level of performance to require from products which will help to reduce energy use and generate renewable energy.

Window types

Window performance will vary greatly and is not always immediately apparent from their external appearance – or even price.

Key selection criteria

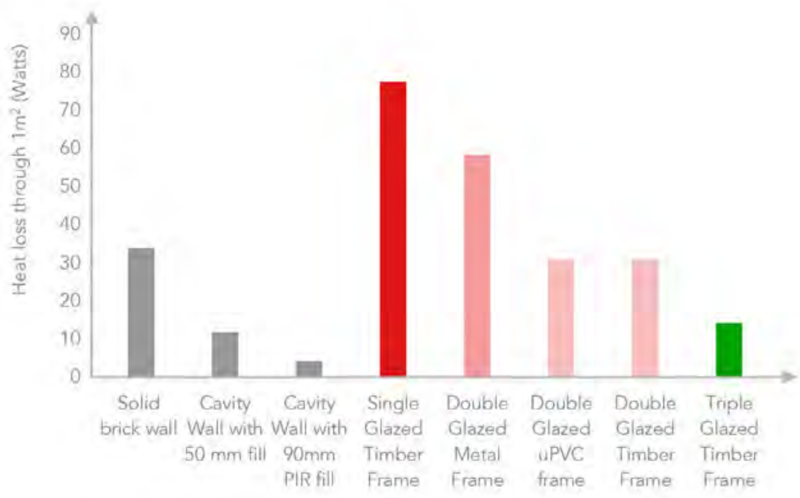
Glazing U-value
This is an indication of the ability of the glazing itself to retain heat. For double glazing, this should be 1.3 W/m²K or lower. For triple glazing you should expect 0.6 W/m²K or lower.

Frame type
The frame is an important part of the window's thermal performance. Generally, it is best to avoid metal frames unless they have a dedicated thermal break. Timber frames offer good levels of performance and are a good option in most cases and can be clad in aluminium if required. If you can find out the frame U-value, it should be ideally less than 1.6 W/m²K.

Whole window U value
Sometimes, manufacturers do not provide a separate glazing and frame U-value and will only provide a U-value for the whole window. If this is the case, aim for <1.4 W/m²K for double glazed and <0.85 W/m²K for triple glazed.

Window design
For most types of frame, the frame performance will be worse than the glazing performance. This means that we should try and minimise the amount of frame – including mullions and transoms – to make the window as efficient as possible. This will also improve the amount of daylight entering the building.

Airtightness
The way in which the window's closing mechanism works, combined with the design of the opening sash sections will influence how good the window will be at keeping out draughts. Look for a multi -point mechanism with two separate seals – this will help with security as well as airtightness. Ask if the window has an air-permeability test rating – if it does, it should be Class 4.



Heat loss through 1m² of various wall and window types (with 0°C external temperature)

*Triple glazed opening sash – timber frame with aluminium cladding and two seals (**Source:** Internorm)*

*Multi-point locking mechanism (**Source:** Sashed)*

This page summarises some of the key selection criteria when reviewing which doors to purchase.

Key selection criteria

U-value
This describes the thermal performance of the door product. Consideration should be made to the U-value of the whole door unit. A U-value of 1.0 W/m^2K should be used as a guideline.

Glazed doors
If the door is glazed, then the glazing properties need to be considered. The g-value as well as the U-value needs to be considered as these impact energy performance and solar gains.

Airtightness rating
The airtightness rating of the doorset systems should be reviewed, and high performance systems specified.

Embodied carbon
The amount of carbon dioxide equivalent emissions generated in the production and manufacture of the door unit material should be considered.

Security
Consideration should be made to the security ratings when selecting the doors.

Performance ULTRA insulated timber door (Source: Green building store)

Triple glazed timber doors (Source: Green building store)

Triple glazed balcony door (Source: Internorm)

Garage Door (Source: Hormann LPU67 Thermo M)

Find High Performance Door Products
The Passive House Institute Component database *is a fantastic way of searching for high performing door products.*

Insulation materials

There are many types of insulation products which are appropriate based on their application. Insulation, and the systems used to support them are key to achieving low U-values. The following considerations should be made when selecting Insulation:

Key selection criteria

Area for use
Where will the insulation be used (e.g. external wall, roof, floor).

Thermal conductivity
How much heat the material conducts. The lower the conductivity, the better performing the product.

Moisture and air permeability
Some insulation products allow water vapor and/or air to pass through them, and some don't. It is important to understand their hygroscopic properties, particularly when retrofitting a pre-1919 building.

Thickness
The thickness should be considered to ensure it achieves the required U-value and aligns with building setting out. For external walls, it is important to ensure that the products used to support insulation are available in the length required.

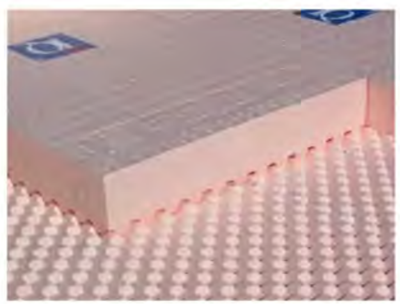
Physical properties
Insulation can be rigid or not, and there are advantages to both. Consideration should be made for insulation installation on site and methods of construction.

Fire rating
The building regulations associated with fire rating and insulation should be consulted to ensure safe and compliant products are used in the correct areas.

Compressive strength
Some insulation may require a degree of compressive strength, and this should be considered (usually floors).

Embodied carbon
The amount of carbon dioxide equivalent emissions generated when producing the insulation material should be considered.

*Dritherm mineral wool insulation (**Source:** Knauf)*



*Insulating foundations (**Source:** Isoquick)*

*Structural insulating material (**Source:** Foamglas Perinsul)*

Finding High Performance Insulation Products

The Passive House Institute Component database *is a fantastic way of searching for high performing insulation products.*

Main building elements

The main building elements that form the airtight layer are the floors, walls, roof, windows/rooflights and doors.

Concrete surfaces such as a floor or roof slab can usually be considered airtight. Masonry walls built from blockwork are not airtight, but can be made so with a suitable parge coat and wet plaster. Timber framed structures such as walls and roofs can use airtight OSB boards or specialized airtight membranes to create an airtight building element.

Connections

Most connections between airtight elements of the building are made airtight through the use of specialist airtight tapes. These are designed and manufactured to last for many decades and should never be substituted for other construction tapes. Many different versions are available for different applications, for example fleece backed tapes that can be plastered over, double sided tapes for window frames, tapes for below ground use. Certain surfaces require application of a primer before taping, so make sure you know where these are on your project. Some sealants are also available for situations where tapes are not suitable.

Services

Building services such as cables, pipes and ducts can be sealed with airtightness tapes, or specialised grommets that come in a range of sizes and styles. While grommets are more expensive, they can reduce the amount of labour required to achieve airtight service entries.

*Large airtight surfaces within buildings are typically created from airtight OSB, parge coat and wet plaster applied over blockwork, concrete castings, or specialised airtight membranes. Do not use cheap polythene membranes, as these are fragile and lack the rigidity to tape without creases that cause leaks. (**Source:** Pro Clima)*

Components of the airtight layer are primarily connected together with tapes. Appropriate primers should be applied to certain surfaces before taping to ensure adhesion. Airtightness grommets and specialised long-life sealants are also available to assist with more specialist junctions in construction. (Sources: Pro Clima, Siga)

Mechanical Ventilation with Heat Recovery (MVHR)

There are many MVHR units available on the market. In practice, a building services engineer or professional will often be involved in helping you to select an appropriate unit. Key selection criteria to consider are:

Air volume flow rate (litres per second)
This must be high enough to meet requirements in Part F of the building regulations, and to mitigate overheating risk.

Pressure drop (pascals)
This is how much pressure the MVHR can overcome and will influence your ductwork design.

Noise rating (dB)
This needs to be low enough at the design duty not to cause a nuisance. In a utility space NR35-40 may be appropriate, however if it is near living space or sleep accommodation NR25 or lower should be targeted.

Size
MVHR units come in varying sizes and shapes, some are more suited to cupboard installation and some are longer and flatter suited to a ceiling void. A key consideration for size is selecting a unit to suit the space available that allows for the filter to be easily changed.

Specific Fan Power (Watts per litre per second)
This is critical to the energy efficiency of the ventilation system. A value of 0.9 or lower is recommended.

Heat recovery efficiency (%)
This defines how much heat can be recovered from the exhaust air. For best practice a minimum of 90% efficient should be targeted.

Summer bypass
This automatically bypasses the heat exchanger so heat is not recovered when using the ventilation unit for cooling.

Certification
Choose an MVHR unit that is Passivhaus certified to ensure quality and performance

*A range of Passivhaus certified MVHR units are available in both wall and ceiling mounted designs. The performance of Passivhaus certified units has been independently verified, which can be a good indication that a manufacturer is motivated to demonstrate the energy performance of their product. (**Sources:** Paul Heat Recovery, Zehnder, Brink)*

*Pre-insulated MVHR ducting is available from a range of manufacturers in both rectangular and round format. These systems can simplify duct installation between the MVHR unit and outdoor air terminals, improving energy efficiency. Combined intake/exhaust terminals are also available, which often help to minimise duct length, also increasing efficiency. (**Sources**: Domus Ventilation, Paul Heat recovery)*

Waste water heat recovery systems recoup heat

Waste water heat recovery (WWHR) systems recover heat from shower or bath water as it is drained, this is used to warm the incoming mains water. The systems are very simple, and typically come in two forms, vertical or horizontal.

WWHR systems can be included in retrofit

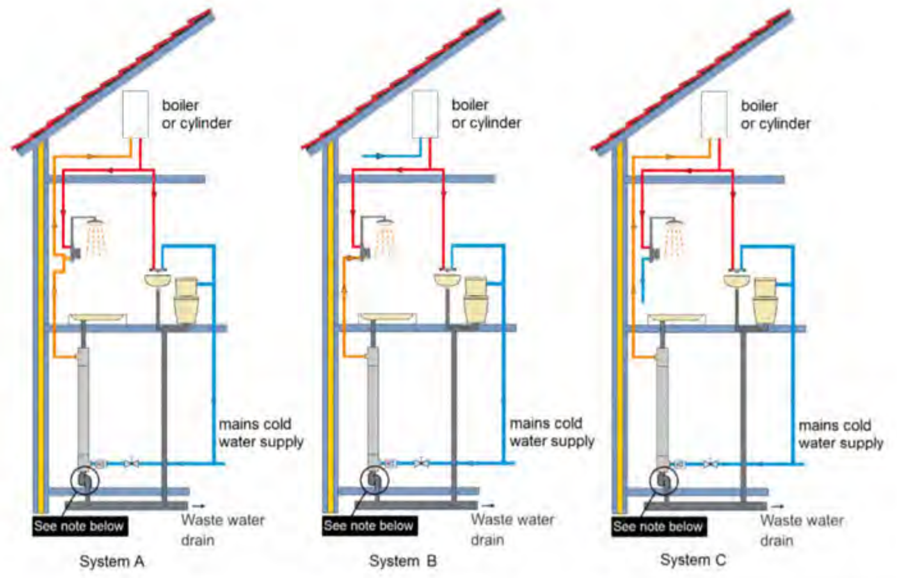
Although WWHR units are far easier to install for new housing, this does not mean they cannot be installed as part of retrofit. As long as there is access to the pipework serving the shower and suitable pipework lengths, a unit can be installed.

Key selection criteria

Efficiency of recovery unit (%)
This represents the percentage of heat recovered by the MVHR system compared to actual heat required for the shower. The efficiency is greater for showers with lower flow rates.

For vertical units, target greater than 55% and for horizontal units, target greater than 25%.

Other key considerations during selection and installation
include shower flow rates, pipework connection sizes for the mains water and waste water, and water pressure. Manufacturer guides will provide acceptable ranges and details for their products.



System A	- WWHRS outlet connects to water heater inlet AND shower cold inlet
System B	- WWHRS outlet connects to shower cold inlet ONLY
System C	- WWHRS oulet connects to water heater ONLY

*A diagram of installation configurations for waste water heat recovery. (**Source:** HeatraeSadia)*

Selecting the right heat pump

Sizing a heat pump is never simple. There is no one-size-fits-all as the heating demands of every property and family is unique. To get air source and ground source heat pump size right, the following things should be considered.

- Type/size of property
- Level of insulation/heat loss
- Size of radiators/underfloor heating
- Desired indoor temperature
- Seasonal outdoor/ground temperatures in your area

Key selection criteria

Maximum heating capacity (kW)
Heat pumps are given output ratings in kilowatts (kW) which represent how powerful a heat pump is. For heat pumps, bigger is not always better though: they should be sized according to the peak heating demand. Max heating capacity tends to range from 4 kW and 16 kW.

Minimum heating capacity (kW)
The minimum capacity of the system selected is as important as the maximum. A good heat pump has adequate turn-down to perform well during low-load conditions as well as peak conditions

Coefficient of Performance, CoP
The efficiency of a heat pump is expressed as ratio of the heat energy produced to input electrical energy. For example, if a heat pump produces 4 kWh of usable heat for a home and requires 1 kWh of electricity to do so, it has a COP of 4.

Seasonal Coefficient of Performance, SCoP
This is an average coefficient of performance taken across the entire heating system, and the main metric used to define the performance of a heat pump.

Maximising heat pump efficiency

The efficiency of heat pumps increase as the temperature difference between the heat source and system temperatures. To increase efficiency consider:

Lower system temperatures
Whereas radiators typically require a minimum water flow temperature of 45-55˚C, underfloor heating can operate as low as 25-35˚C. Lower system temperatures also mean lower losses in conversion, storage and distribution of heat.

Heat source
The temperature of the ground is roughly 10–13˚C all year round, so a ground source heat pump remains consistently efficient, unaffected by seasonal changes. An air source heat pump on the other hand is subject to fluctuating air temperatures. In the colder months, when there is the greatest demand for heating, they are at their least efficient.

Maintenance and warranty

When correctly installed, heat pumps should require little maintenance and last for at least 20-30 years. If something does go wrong, it can lose efficiency fast, but this underperformance should be noticeable. Most heat pumps come with a 5-10 year warranty on parts and labour.

	Heat pump type	Standard CoP	Best Practice CoP
Heat Pump - Space Heating	ASHP	2.50	3.50
	Closed GSHP		4.50
	Open GSHP		5.50
Heat Pump - Domestic Hot Water	ASHP	2.0	2.50
	Closed GSHP		2.50
	Open GSHP		3.00

Efficient and fossil fuel free

Air source heat pumps (ASHPs) absorb heat from the outside air, from temperatures as low as -15 °C, to provide space heating and hot water. They run on electricity but are far more efficient at generating heat than conventional systems and therefore require less energy. Unlike gas and oil boilers, heat pumps tend to deliver heat at lower temperatures over much longer periods.

The two main types

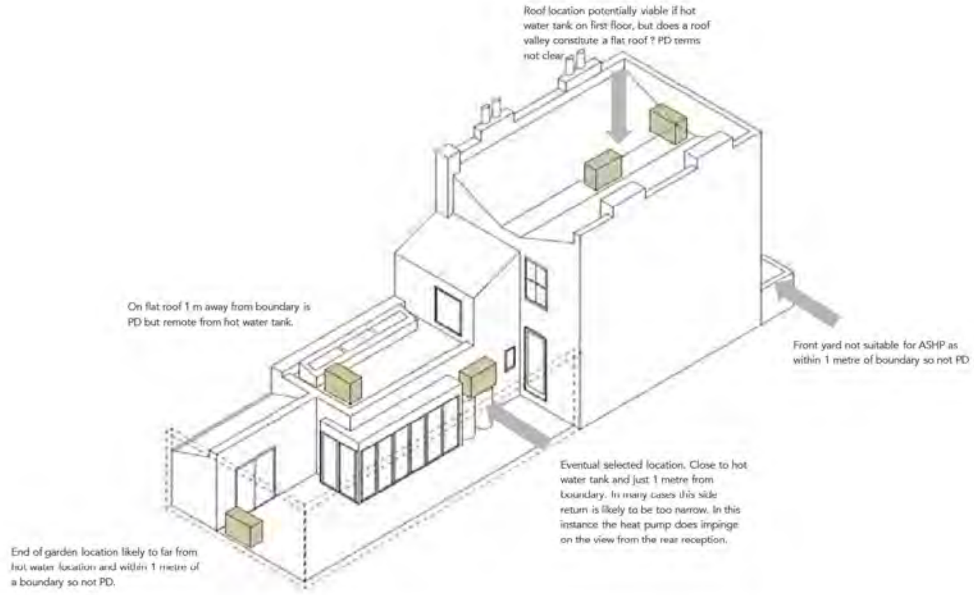
Air-to-water heat pumps are the most common and can be used with a wet central heating system. Because of the lower temperatures they work well with underfloor heating or larger radiators. Air-to-air heat pumps provide warm air directly to a room. They will not provide you with hot water as well.

Heat pumps need a home, and you may need planning permission

You will need a place outside the home where the external unit can be fitted to a wall or placed on the ground, with plenty of space around it for air flow. The external unit is often connected to an internal unit containing circulation pumps and hot water, which is usually larger than the average boiler. Although they might not take up much space, heat pumps may be visible. If permitted development rights cannot be used, a planning application may be required with a noise report.

Potential fuel bill savings

Installing a typical system costs around £5,000 to £11,000. It will most likely reduce fuel bills if replacing a conventional electric heating system, but you are unlikely to save much on your heating bills if you are switching from mains gas, unless other energy efficiency and fabric improvements are made.



Potential locations identified by the architect for a terrace house
*(**Source:** Prewett Bizley Architects)*

Benefits

1 It could lower fuel bills if replacing conventional electric heating

2 It could provide an income through the UK government's Renewable Heat Incentive (only applies to air-to-water heat pumps)

3 Fossil fuel free and highly efficient therefore will reduce carbon emissions

4 It can provide hot water as well as space heating

5 It can be easier to install than a ground source heat pump

Ground source heat pumps (GSHPs)

Efficient and fossil fuel free

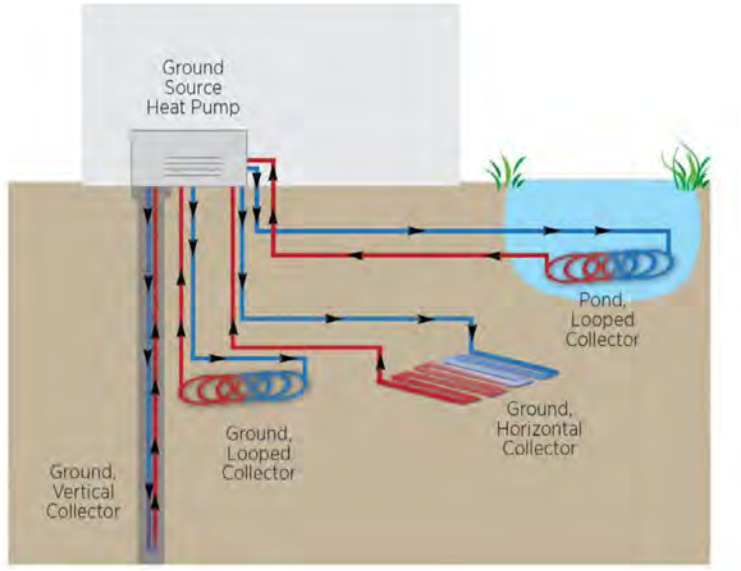
Ground source heat pumps (GSHPs) use a buried ground loop to extract heat from the ground which is then passed through a heat exchanger into the heat pump. This heat can be used to serve radiators, underfloor heating, warm air systems and hot water. Heat pumps run on electricity, but the heat they extract from the ground is renewed naturally. They are far more efficient at generating heat than conventional systems and therefore require less energy.

Space is required for the ground loop

The length of the ground loop required depends on the amount of heat needed. If there is enough space, the loop can be laid horizontally in a trench. Where there is not room to do this, you can drill vertical boreholes, typically between 90m and 160m deep, but this requires specialist machinery and may increase the cost of installation.

A potential source of income

Installing a typical system costs around £14,000 to £19,000. It will most likely reduce fuel bills if replacing a conventional electric heating system, but you are unlikely to save much on your heating bills if you are switching from mains gas, unless other energy efficiency improvements are made. If the system is part of a new development, combining the installation with other building work can reduce the cost of installing the system.



*Different types of ground loop can serve the heat pump depending on the space available. (**Source:** Kete-RVS)*

Benefits

1 It could lower fuel bills if replacing conventional electric heating

2 Fossil fuel free and highly efficient will reduce carbon emissions

3 It can provide hot water as well as space heating

4 Minimal maintenance required

White goods

The main energy consuming appliances to consider are dishwashers, clothes washers, clothes dryers, refrigerators, freezers and cookers. When purchasing from new, energy labels should be available. Compare these to best practice performance on the Top Ten UK site below, and choose the most efficient appliance that meets your needs.

If purchasing second hand appliances, energy labels can often be found by searching the model number of the appliance.

Consumer electronics

The energy consumption of consumer electronic devices is usually quite low. Possible exceptions include devices that produce heat, such as coffee makers with keep hot functions.

Audio visual

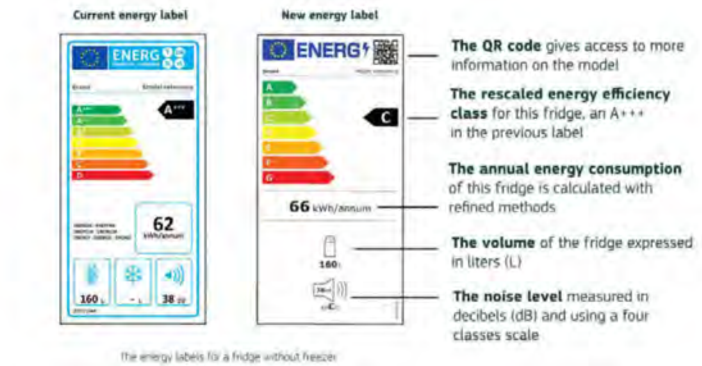
Most new televisions and stereos are relatively energy efficient, however energy labels are available, so follow the same advice as for selecting white goods. Games consoles have powerful processors that can use reasonable amounts of energy, so should be turned off when not in use.

Standby consumption

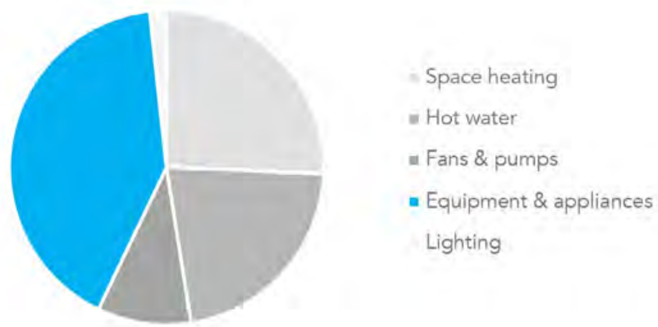
While electricity use in standby mode (also known as vampire load, or phantom consumption) used to be a significant concern, a series of increasingly stringent EU regulations over the past decade have effectively reduced it to negligible levels.

Resources

The Energy Saving Trust's 'Top Ten' is an excellent resource that lists the most efficient appliances currently available on the market.



Most appliances for sale in the UK will continue to carry EU energy labels. These were rescaled in Spring 2021 to adopt the original A to G system, ending the use of A or higher ratings. Under the new scale, there are few A-rated appliances currently on the market – this is intentional, to allow room for future improvements to efficiency.*



Electricity used by equipment and appliances is likely to be the largest end use of electricity in many net zero energy homes, so it is important to choose the most energy efficient appliances you can. Data based on energy modelling for a net zero energy new build home.

Solar photovoltaic (PV) panels

Solar PV panels

Modern solar PV panels are a simple, mature and reliable technology. Most solar PV panels currently manufactured are based on wafers of monocrystalline silicon. Outdated polycrystalline technology is still available and should be avoided. Choose a panel with a 25 or 30 year linear power output warranty.

Sizes vary, but 1,730mm x 1,040mm is typical. Expect a power output of 360 Watts per panel, though up to 400 Watts or more is possible. It does not usually cost much more to specify a higher power panel, so this is often a good option to consider, particularly if you plan on using a heat pump or electric vehicle in the future.

Solar tiles are available, however standard format solar panels dominate the market for good reason. If you decide to install solar tiles, choose a company with a track record that will be around in the future to provide spare parts and support if required.

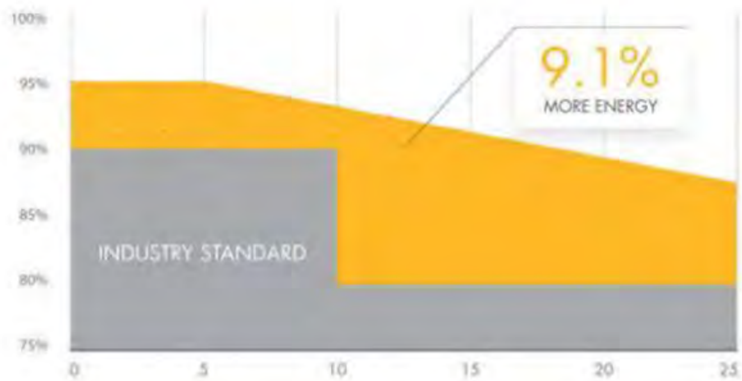
Inverters

The inverter in a solar PV system conditions the electricity generated by the solar panels so it is safe to use in your home. Traditional systems used a single large inverter, however small 'microinverters' that mount behind each panel offer numerous benefits. They cost a little more than a single larger inverter, but can increase energy output up to 15% and are very reliable, with 25 year warranties available.

Batteries

In many cases, batteries cost more to buy and operate than they will ever save you, though there are exceptions. Batteries also increase the complexity and embodied carbon of a solar PV system. Consider smart thermostats, solar hot water diverters and solar EV charging to increase self consumption of solar electricity.

*Specify monocrystalline silicon solar panels and microinverters for best long-term performance. Image shows a generic solar panel and an Enphase IQ7 microinverter. (**Source:** Enphase Energy)*



*Power output warranties lasting 25 to 30 years are standard for solar photovoltaic panels. Look for a panel with a linear (rather than stepped) performance warranty for increased lifetime energy production. (**Source:** SunPower)*

How to Specify

Delivering homes that will perform well in reality (and not just on paper) relies on a quality assured construction or retrofit process.

This section provides guidance on how to specify key elements.

Decide on your targets

From the very start of the project, you should be clear about the targets that you are aiming for. For retrofit this should be expressed in Energy Use Intensity (EUI) and Space Heating Demand and should be modeled early on to see how your project matches up. Space Heating Demand is an excellent proxy for the fabric efficiency of the building. It will tell you how far you have gone down the fabric first approach. Exemplar values for homes are 15 kWh/m_2.year for new build and 25 kWh/m_2.year for retrofit, although retrofits can be challenging and a target of 50 kWh/m_2.year would be a significant achievement in most cases.

Do whatever it takes to move to electrical heating and hot water

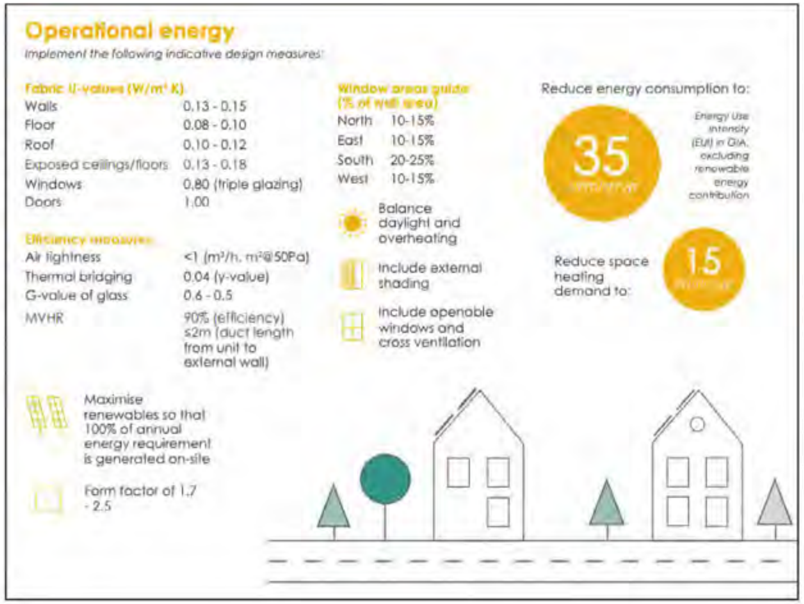
This guide has made it clear that fundamental to achieving Net Zero carbon homes is transitioning to electrical based heating and hot water to capitalise on grid decarbonisation. To avoid high running costs, this is best achieved by fitting heat pumps. Thus, make sure you design your fabric, heating and hot water strategy around the basic premise of a heat pump. For retrofit, even if you can not fit one straight away, put enabling measures in place so one can be fitted in the future.

Build your knowledge

Much of what goes in to a Net Zero homes, it not necessarily part of normal building practice. It is important to get the whole team on board from the designers, right through to the site team. Arrange regular meetings so that everyone understands the key principles that are being targeted like airtightness and eliminating thermal bridging.

Measure the results

How do you know it has worked? It is now cheap and easy to monitor energy use so put this in place as part of the project so you can see how it performs and, if necessary, make some improvements next time.



LETI Targets for new-build dwellings
*(**Source:** LETI Climate Emergency Design Guide)*

The AECB Retrofit standard sets a space heating demand target of 50kWh/m².year

There is no substitute for experience

When looking for suitable contractors, find out if they have completed any low energy or Net Zero projects. Ideally, they will have completed a project which has been quality assured or certified in some way. A Passivhaus certified project (new build or retrofit), AECB self-certification with independent verification, or a self-declared LETI Pioneer project would all be good indicators. Failing that, any project which has good post-occupancy monitoring data showing its actual performance is also a good sign.

National schemes

PAS 2035 sets out a framework for the design and management to ensure the safe and effective implementation of energy efficiency measures. PAS 2030 set out the standards that must be achieved in installing these energy efficient measures. If you are embarking on anything more than a very minor retrofit, then it would be advisable to ensure that your design team includes a qualified Retrofit Coordinator who has met the requirements of PAS 2035 and that your contractor has achieved PAS 2030 certification.

Other trade bodies

For specific retrofit elements, there are also other trade bodies which you can ask whether your provider is registered with:

- Cavity Insulation Guarantee Agency
- Solid Wall Insulation Guarantee Agency
- Microgeneration Certification Scheme (MCS) -for heat pump and Solar PV installations
- Trustmark

PAS 2035:2019
The Design Process

PAS 2030:2019
The Installation Process

PAS2030 and PAS2035

Agencies and schemes which protect consumers and require certain standards

Specifying airtightness requirements

This section summarises the requirements during construction in order to ensure that the airtightness target can be achieved.

Managing the airtightness risk

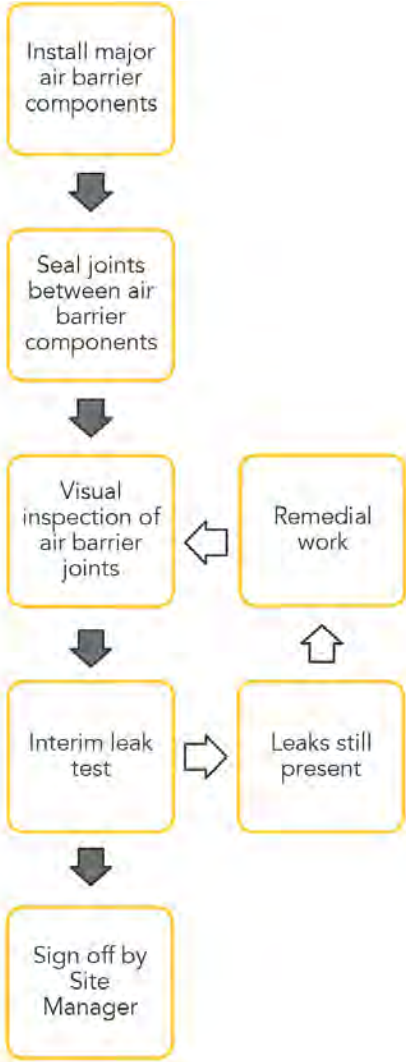
It is possible to robustly manage the risk of achieving the airtightness requirement on site. The contractor should take responsibility for delivering the airtightness and propose a robust strategy. A programme including interim leak tests, proposed materials and proposed responsibility will be required as a minimum. Early testing gives reassurance that the quality of construction is on course to meet the target, and allows any quality issues to be easily and cost effectively found and rectified. Leaving these issues to the end of the project is a far more risky and potentially costly approach and may lead to failing to meet the airtightness target.

The importance of interim leak testing

A phased leak testing strategy is recommended. Each dwelling should be tested for air leaks before the air barrier is covered or closed up.

- All air barrier parts should be installed and open to visual inspection.
- Using a blower door fan to negatively pressure areas undergoing internal investigation or positively pressurise areas for external investigation.
- Carrying out investigation on the air barrier side of the construction (internal for most of the building.)
- Using thermographic camera equipment, smoke pens, or feeling the joints to identify any air leaks.
- Remedying any leaks.
- A section should be deemed to pass the leakage test when no leaks in the external fabric can be detected with reasonable effort.

There is more information on airtightness on page 111 of the EBS SPD.



Recommended airtightness process: visual inspection, leak finding and interim air testing are all required before the final air test

Commissioning of heat pumps and MVHR systems

Heat pumps

- The commissioning of a heat pump is very similar to the commissioning of a boiler.
- Ensure the system is watertight – complete a standard test, first with pressurised air, then with water.
- Ensure the fuel source is safe – in this case check the electrical test certificate is in place.
- Ensure the unit is functioning correctly – check the flow volume and temperature (ideally at varying external air temperatures)
- Ensure the water pressure is inline with manufacturers recommendations.
- Ensure the user is trained – make sure any alarms are being generated correctly and that the user understands what protocols to follow for each alarm option.

MVHR systems

The following items should be checked on MVHR units

- Check filters are clean
- Inspect ductwork for any air leaks and seal where appropriate.
- Check that the ductwork is clean at the terminals
- Set the fan speed and balance the supply and extract flow rates
- Ensure the supply and extract rates to each grille are operating at the design air flow
- If there is a boost function make sure that this works correctly
- Ensure the user understands how to use and maintain the MVHR

Examples of Passivhaus certified MVHR units.
*(**Sources:** Paul Heat Recovery, Zehnder, Brink Climate Systems, Vallox, Airflow Developments)*

Building performance delivery schemes

This page summarises several operational energy standards which would help achieve the levels of energy efficiency and construction quality required to deliver Net Zero carbon buildings.

New build standards

Passivhaus Classic, Plus and Premium
These schemes are facilitated by a designer and third party certifier to ensure the design and construction achieve best practice levels of energy efficiency and renewable energy generation (for Plus and Premium).

PHI low energy building standard
Similar to Passivhaus, this standard has slightly reduced energy efficiency targets.

Building Energy Performance Improvement Toolkit (BEPIT)
This scheme provides a practical framework through each stage of the project in order to deliver energy efficiency measures on site.

Retrofit standards

EnerPHit
Similar to Passivhaus, this scheme helps deliver exceptional levels of energy efficiency through deep retrofit and refurbishment.

AECB Low Energy Retrofit Standard
This standard is primarily focused on improving the building fabric but low carbon heat also needs to be considered.

Energiesprong
A model for retrofitting several homes at once. The up front costs of this scheme are financed through a payback based on savings to the tenants bills and an additional 'comfort charge'.

PAS 2035
This code of practice published in 2019 seeks to provide quality assurance for retrofit. It focuses on the process, not the target(s).

New build standards

Certified Passive House
Passive House Institute

PHI Low Energy Building

BEPIT
Building Energy Performance Improvement Toolkit

Retrofit standards

EnerPHit
Certified Retrofit
Passive House Institute

energie sprong uk

AECB building knowledge

Standards summarised on this page help achieve the space heating and energy consumption levels of performance required to achieve net zero carbon buildings.

Some standards also address low carbon heat and renewable energy generation but they focus primarily on energy efficiency. Embodied carbon is not addressed by the above schemes and would require separate consideration

When you need building regulations approval

Most building work (whether refurbishment, retrofit or new build) will need building regulations approval. Building Regulations is mostly concerned with ensuring homes are safe to live in.

In most cases your builder or tradesperson will be responsible for ensuring building regulations approval is obtained. However, you should check this at the beginning and be clear who is liaising with the building control body. The ultimate responsibility lies with the building owner, and fines may be issued where approval is not obtained.

You will need to use a building control body to check and approve work before, during and after construction. This can be through a local authority building control service (LABC) or through a private approved inspector. In some cases tradespeople can self-certify, if they are registered with a competent persons scheme.

When you need planning

If you are altering the appearance or function of your building or site you may need to apply for planning permission from your local authority. This will be required if you want to:

- build a new home
- build an extension above a certain size
- change the use of an existing building for residential use.

To find out if you need planning permission, and how to apply for it, contact your local planning authority (LPA) through your local council.

Sources of information

The Planning Portal website and the Local Authority Building Control websites are both excellent sources of information on planning permission and building regulations approval.

	Building regulations approval	Planning permission
Objective	To ensure the safety and health of people in or about those buildings.	To control the impact the development will have on the general environment.
Concerned with:	• Structure • Fire safety • Electrical safety • Access • Ventilation • Energy efficiency	• Appearance • Impact on neighbouring properties • Landscaping • Highways access
Through	• A building control body (through local authority or privately). • Competent persons scheme for some small works (e.g. repairs, replacement or maintenance.	• Local Authority planning department.
Find out more	• Herefordshire Council Building Control Tel: 01432 261938 www.herefordshire.gov.uk/building-control/apply-building-regulations/2	• Herefordshire Council Planning Services www.herefordshire.gov.uk/planning-services/planning-services-1

☑ Always check with your local authority whether you need either planning permission or building regulations approval.

☑ Are your tradespeople registered with the competent persons scheme?

☑ Check “right to light” laws when building, which are not included in the planning permission process, but a legal right of neighbouring properties.

Communicating this to customers and clients

The industry is on a path to Net Zero carbon

We are in a climate emergency and it is important that we communicate this effectively to customers and clients to ensure immediate action is taken to meet our Net Zero carbon target. In 2019 the UK Government amended the Climate Change Act to adopt the recommendations of the Committee on Climate Change, and adopted a target for achieving net zero emissions by 2050. Delivering Net Zero carbon homes is an attainable target which can be achieved today and in recent years this has been clearly mapped out.

The future of housing

The Committee on Climate Change (CCC) report 'UK housing – fit for the future?' highlights the need to build new buildings with 'ultra low' levels of energy use. It makes a specific reference to space heating demand and recommends a maximum of 15-20 kWh/m^2.yr for new dwellings. Currently new domestic buildings can have a heating demand ranging anywhere from 40-120 kWh/m^2.yr. Buildings provide a significant opportunity for reducing emissions without impacting the quality of experience for those that use them. Targeting good practice design, such as Passivhaus for new homes, and well considered retrofit strategy will also ensure high construction quality and minimise defects on site.

Affordable and clean energy for residents

The transition to Net Zero carbon housing will also improve energy bills for residents, as well as local air quality. Moving away from fossil fuels and switching to low carbon heating is a necessary part of meeting Net Zero carbon.

The UK Government has committed to Net Zero emissions by 2050. Many regions and organisations are being put under pressure to improve on this.

Over 1400 local jurisdictions, including Herefordshire, have declared a climate emergency.

Extinction rebellion and School Strikes for Climate protests showing strong public support for response to the Climate Emergency and action today. Greta Thunberg and the Schools strike movement have inspired the next generation of citizens Worldwide.
*(**Sources:** Participedia, The Guardian)*

The importance of maintenance – Keep operating at Net Zero carbon

In order to for a building to operate at Net Zero it needs to be maintained properly, particularly in the following areas.

MVHR

MVHR needs to be installed in an accessible location as filters need to be cleaned/changed every 3-6 months so that it operates efficiently.

Heat Pumps

Immersion heater should only be used as a back up to heat the water in the hot water store and only manually switched on if the heat pump is not working. If the Immersion heater is an automatic back up (might be the case for Exhaust air heat pump) – use of this Immersion heater should be closely monitored to make sure that it is not turned on more than it should be.

Airtightness layer

There is a continuous airtightness barrier around the building. It is important that this barrier is not broken, otherwise the airtightness of the building will get worse. Key watchpoints;

- Drilling into the wall – know where the airtightness layer in the building avoid damaging it by drilling through/perforating it.
- New penetrations for equipment such as washing machines, should be installed with airtightness grommets so that the water pipes do not increase the air permeability.

Solar PV

Every few months it is good to check the generation meter, to make sure that the panels are generating electricity and there is no fault. It is also important to clean the Solar PV panels every year, to make sure that they are operating as efficiently as they can.

MVHR filters are easy to remove and clean, clean filters improve energy efficiency.
*(**Sources:** Vent Axia, Nuaire)*

Airtightness grommets need to be used so that service penetrations do not increase air permeability
*(**Source:** Pro Clima)*

PV panels need to be cleaned at least once per year.
*(**Sources:** EasyAcc, Amethyst Cleaning)*

Links to guidance

For further information on retrofit guidance and projects, please find links below:

- AECB - The AECB is the home of sustainable building
- Centre for Sustainable Energy - What is retrofit?
- Innovate UK - UKRI (Formally known as Technology strategy board)
- UK GBC - UK Green Building Council
- LETI London Publications
- Passivhaus Trust
- The Passivhaus Institute
- The Green Finance Institute
- Financing Energy Efficient Buildings: the path to retrofit at scale
- The Retrofit academy | Retrofit Coordinator & PAS 2035 Training
- Social housing toolkit | Social Housing Retrofit Accelerator
- The Construction Leadership Council