Birmingham City Council

Guidance Toolkit on Building Retrofit

February 2024

Contents

1. Introduction and Purpose of this Document

1.1 This guidance note has been developed using the 'Net Zero Carbon Toolkit' Which was developed through a collaboration between Cotswold District Council, West Oxfordshire District Council and Forest of Dean District Council Funded through the Local Government Association (LGA) Housing Advisers Programme, the guide has been produced by leading technical experts from Etude, the Passivhaus Trust, Levitt Bernstein and Elementa Consulting. Birmingham City Council has updated the Toolkit with technical expert Phil Beardmore

1.2 Acknowledgements: Levitt Bernstein, Elementa, Passivhaus Trust and Etude commissioned by West Oxfordshire, Cotswold and Forest of Dean District Councils, funded by the LGA Housing Advisers Programme

1.3 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.

1.4 The National Planning Policy Framework (February 2023) makes clear that the transition to a low carbon future and use of renewable and low carbon energy in a changing climate is a core planning principle of national planning policy.

1.5 The Retrofit Toolkit is designed to assist in the planning, design and construction of a new build or retrofit housing project. It provides a technical, go go-to guide on what to consider in the very early stages of design; how 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. This document does not constitute an adopted supplementary planning document, or validation requirement.

2. Who is this Guide for?

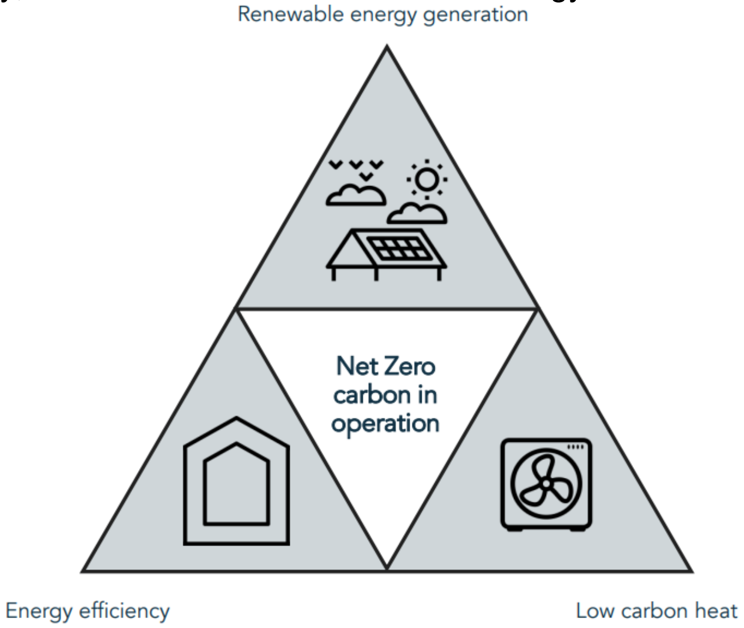
2.1 This toolkit has been created to make Net Zero carbon or low carbon retrofit more accessible. It has been created for building professionals (developers, contractors, architects and engineers) and is also relevant to planning officers and other housing professionals. Although it can be used by homeowners,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

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

3. Core Principles of Net Zero Carbon Buildings

3.1 The core principles

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



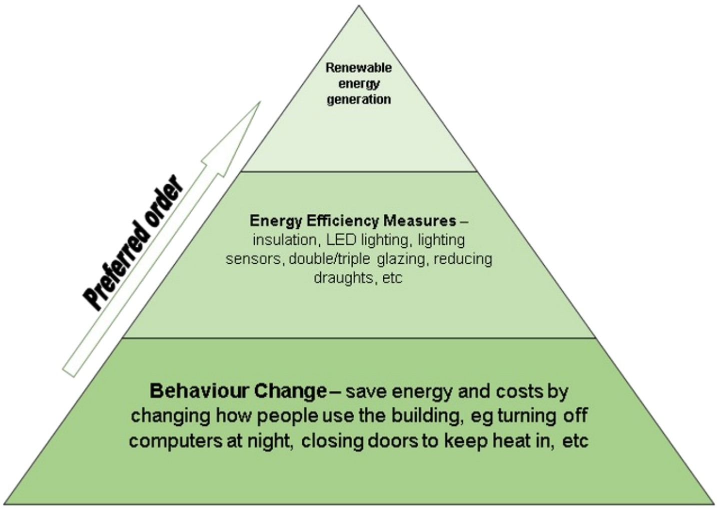
The three pillars of a Net Zero carbon building in operation

3.2 Energy efficiency

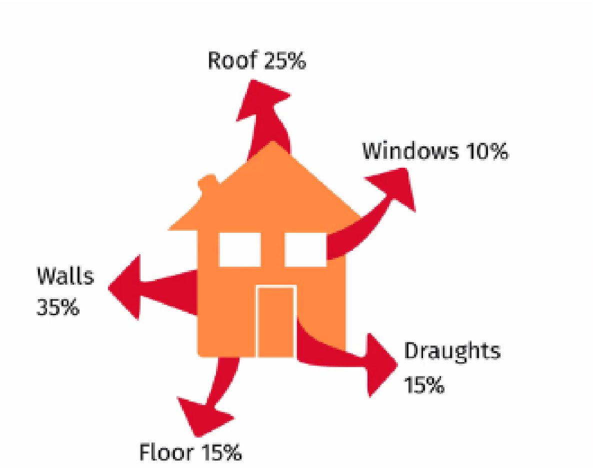
Buildings use energy for heating, hot water, ventilation, lighting, cooking and appliances. The efficient use of energy reduces running costs and carbon emissions. It also reduces a building's impact on the wider energy supply network, which is also an important consideration. There are different metrics we use to measure the efficiency of a building, including Space Heating Demand and Energy Use Intensity (both measured in kWh/m2/yr).

While energy efficiency is vital to reduce carbon emissions, it is also important to consider how a building is used and to ensure that the occupiers know how to use the low carbon technology effectively. Any retrofit work should be accompanied by easy to use guides e.g. videos, quick start cards and a training session with the occupiers. The best retrofit measures can be undermined by occupiers turning off the ventilation, overheating rooms to dry clothes or leaving doors open to remove kitchen smells.

The energy saving hierarchy is shown below:



Heat is lost from a building through all of its surfaces. This is the typical heat loss for a detached house (diagram below) and this would be lower for a flat in an apartment block with fewer external walls. The amount of heat loss can also be affected by how draughty the building is.



3.3 Low carbon heating

Low carbon sources of heat are an essential feature of Net Zero carbon buildings. Heat pumps are an energy efficient alternative and are the likely future alternative to gas boilers for most homes.. Other non-fossil fuel heating can also be considered e.g. infrared for space heating and smart technology tanks for hot water heating.

3.4 Renewable energy generation

Roofs can provide an ideal location for solar energy generation technologies such as solar photovoltaic (electricity) and solar thermal (heat) systems. Coupled with improved insulation and low carbon heating alternatives, these technologies can help further reduce carbon emissions and running costs.. Net Zero carbon in operation can only be achieved when coupled with renewable energy generation.

Solar photovoltaics and solar thermal are well established and easy to use technologies. It is important that solar arrays are appropriately sized to the energy demand of the building. Solar thermal is generally coupled with hot water storage and electricity generated by solar photovoltaics can be stored in batteries.Excess electricity can be sold back to the Grid however the greater the electricity demand that can be utilised on site, the better the return on investment.

3.5 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.

4. Key Reasons and Benefits of a Low Carbon Retrofit

4.1 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, replace gas or oil heating system for a low carbon heat system (e.g., heat pump) and decarbonise remaining energy demand via renewable energy generation.

4.2 Reducing fuel bills alongside carbon emissions

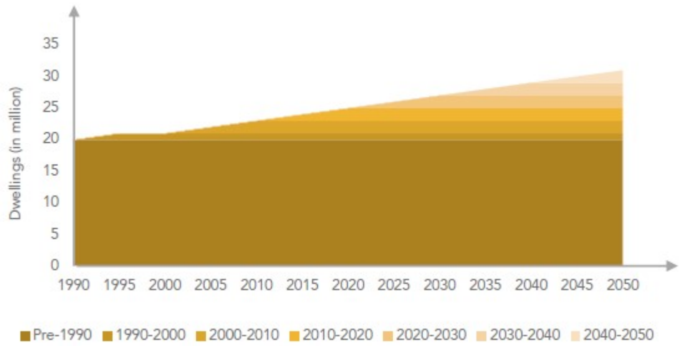
Whilst decarbonising homes is important to mitigate climate change, it is not the only reason to retrofit. In 2022, central government data showed that 21.8% of Birmingham homes were considered to be in fuel poverty. There is, unsurprisingly, a strong correlation between energy inefficient homes and fuel poverty with 88% of all fuel poor households living in properties with an Energy Performance Certificate (EPC) Band D or below. Retrofitting can deliver lower bills as well as lower carbon emissions[1].

4.3 Health and wellbeing

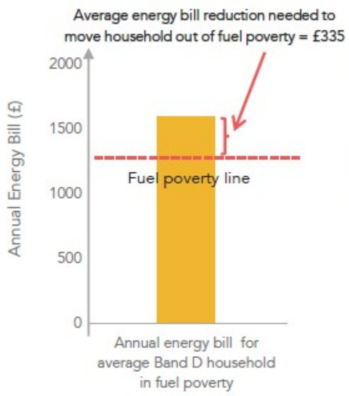
Improving the energy efficiency of a home is also likely to increase thermal comfort (both in summer and in winter) and improve indoor air quality through better ventilation. This will have a positive impact on all occupants but especially small children, the elderly and those with respiratory conditions. 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)

5. Energy Targets and Key Performance Indicators for Retrofit

5.1 Setting the right brief and targets is key

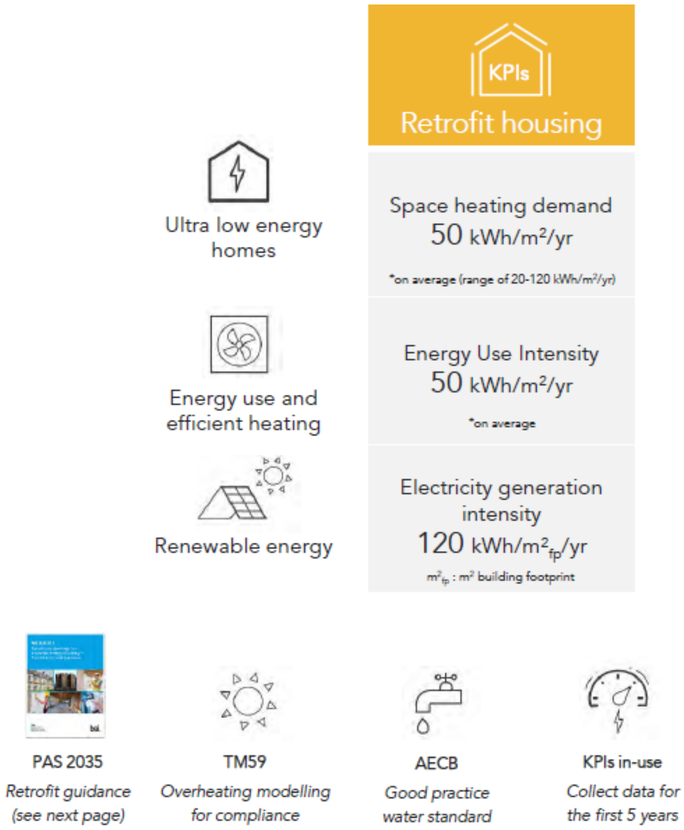
To achieve a Net Zero retrofit it is important that the retrofit brief and targets reflect this ambition from the start. A strong brief provides tangible guidance on how targets can be achieved. Best practice Key Performance Indicators (KPI's) for housing retrofit are listed in the adjacent table and all KPI's need to be met for a home to be considered Net Zero carbon.

5.2 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 Net Zero design and retrofit is recommended. Workshops at briefing stage can be used to establish the long term retrofit plan and ensure the contractor team are clear on the targets and objectives.

5.3 Consider energy modelling

Analysis of the design through energy modelling will ensure that KPI's 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).



PAS 2035 guidance should be followed on publicly funded retrofit projects.

5.4 Without energy modelling

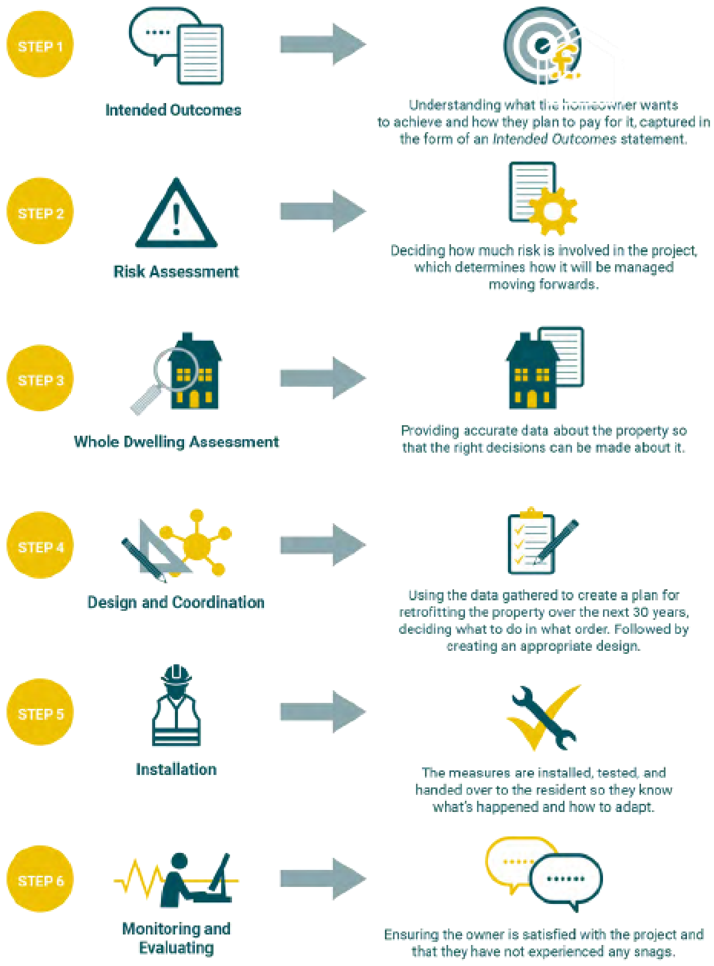
Energy modelling is recommended, however it is possible to target best practice by setting the right specification and design requirements as part of the project brief. Refer to the 'How it all comes together' for retrofit of a terrace house (including the case of a terrace house in a conservation area).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

6. The 'Whole House' Approach and PAS 2035

6.1 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 standard helps to deliver quality retrofits and manage risks associated with whole house projects. 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.



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

6.2 Who is a Retrofit Coordinator?

PAS 2035 requires the appointment of an accredited Retrofit Coordinator. The Retrofit Coordinator takes 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*.

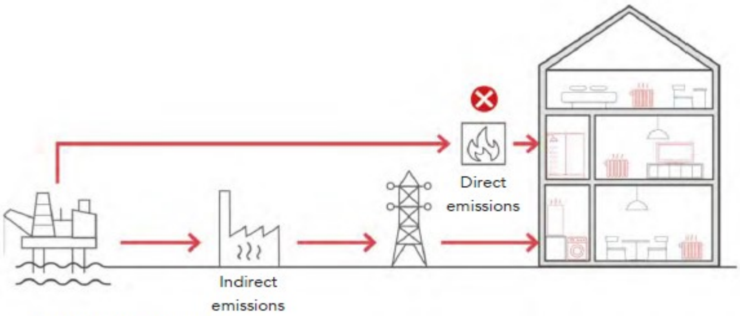
7. Lowering the Carbon Impact of Homes

7.1 How does a home produce carbon?

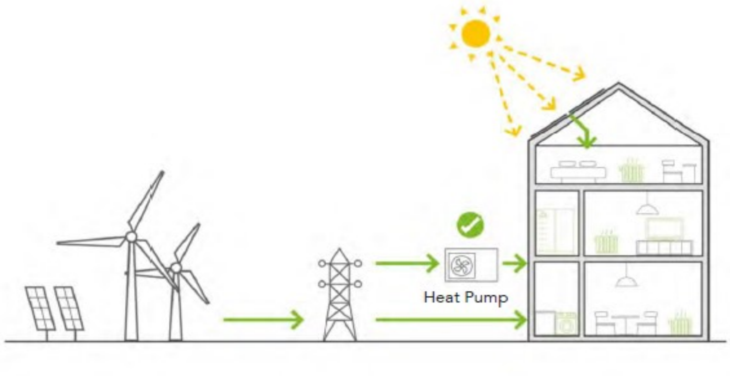
The vast majority (85%) of homes in Birmingham use a gas boiler for space heating and hot water. Electric heating is commonly used in flats and a fewer number are heated using oil.. Whilst homes connected to the gas network may still use gas for cooking, all other energy uses in the home are drawn from the electricity grid. The carbon emissions from a gas boiler are emitted on-site whilst the emissions associated with electricity use are emitted at a power station. Ten years ago, electricity was about 2.5 times more carbon intensive than gas, but with investment in renewable energy and the phase out of coal for electricity generation, gas is now greater than electricity, with electricity set to further reduce in impact over coming years.

7.2 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.



How most homes use energy now



How most homes should use energy now and in the future

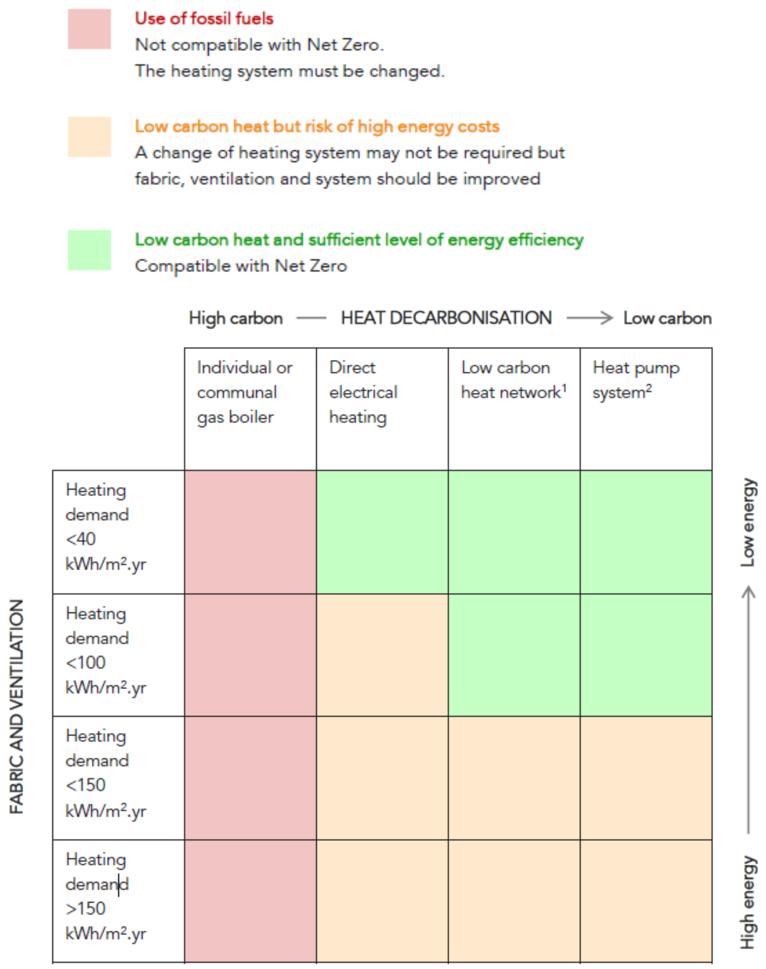
7.3 Where do heat pumps fit?

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 heat energy from the surrounding air, water sources or ground and efficiently convert into usable heat. Both the Government and the UK Climate Change Committee agree that they will form a major part of our future heating systems.

8. Mapping to Journey Towards Net Zero

8.1 Mapping the journey

8.1.1 Each house or flat is different. They will have a 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.



[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.

8.1.2 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.

8.2 A long term whole house renovation plan for a phased retrofit

8.2.1 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 used to provide heat or power; this may be installed on site or provided via a community generation scheme or national grid
- The home is made smart ready

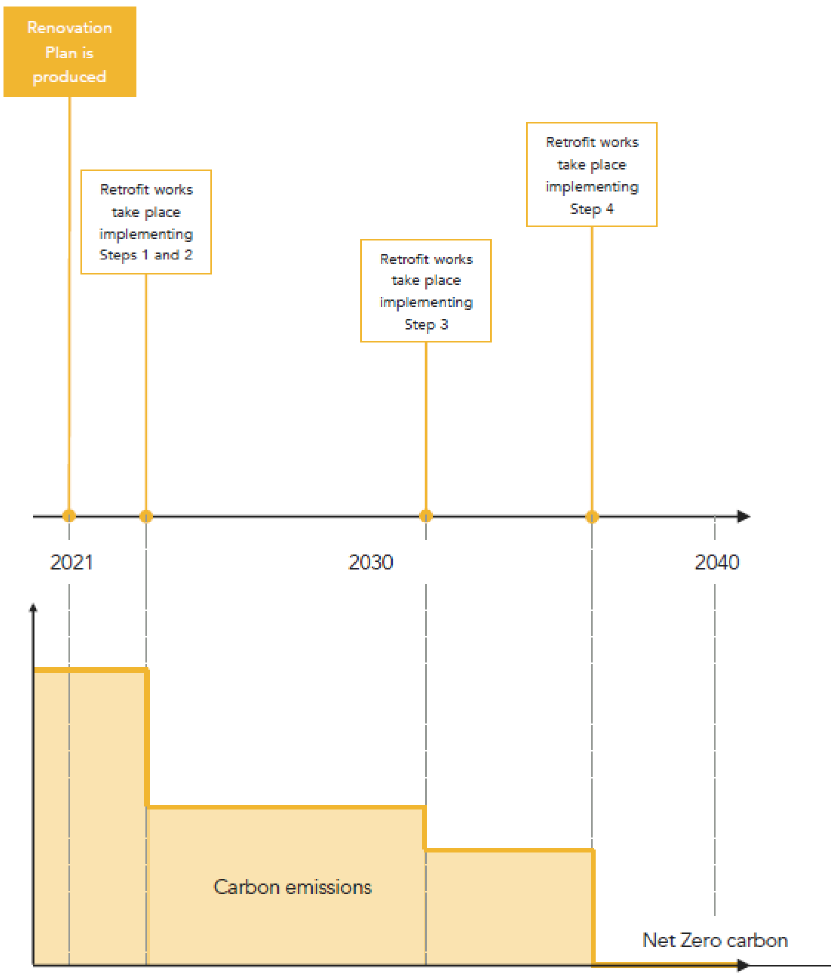
A whole house renovation plan is a useful tool to prepare and provides a pragmatic and coherent way to deliver this ambition.

8.2.2 **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. The diagram below 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.

8.2.3 **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.

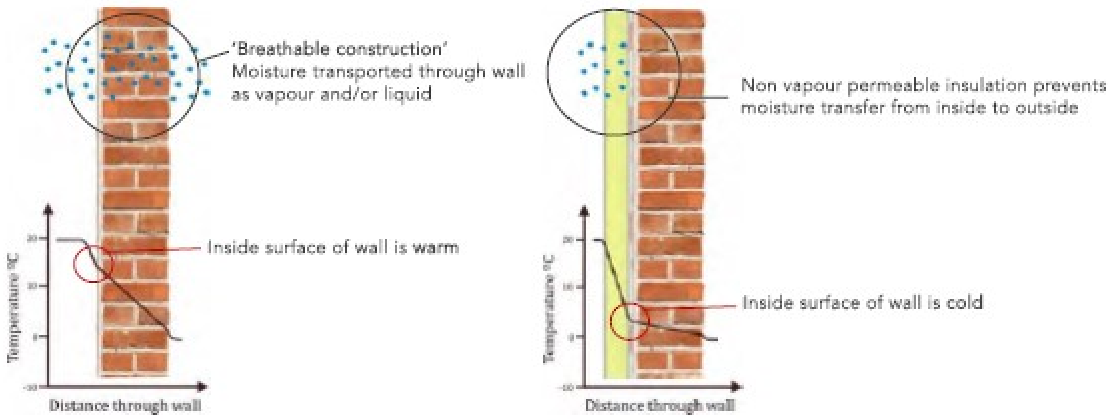


Note: the expected decarbonisation of the grid is not represented for simplicity but will also contribute to the reduction of carbon emissions over time.

9. Retrofit Risks and how to Mitigate Them

9.1 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.



The risk of condensation with internal insulation

It may not be obvious, but our homes are constantly dealing with moisture. They are keeping out the rain and preventing damp rising up from the ground permeating into the building structure. 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. Negatively impacting any of these mechanisms could end up doing damage to the health of both the building and its occupants.

9.2 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).
- **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. Care needs to be taken with loft and under floor insulation to ensure that moisture can escape. If a suspended floor is insulated it can make the crawl space colder and prevent moisture escaping

which can lead to hidden damp and mould beneath the floor. A similar situation can arise with loft insulation.

Installation of wood fibre insulation boards internally

(Sources Back to Earth & ASBP)

9.3 Do not forget about the risk 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.

9.4 Don’t be misled by technologies and environmental 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, some products or strategies do not achieve the desired outcome.

Taking a whole house approach ensures that the appropriate technologies are used, alongside other measures.

To avoid being misled, take advice from accredited installers and qualified retrofit assessors and coordinators. Trustmark has information and lists of accredited retrofit contractors on its website: https://www.trustmark.org.uk/homeowner/information-guidance/retrofit-your-home

The Government has information about energy saving products on its website and information specifically on heat pumps: https://www.gov.uk/check-heat-pump and https://helpforhouseholds.campaign.gov.uk/energy-saving-advice/

There are also a growing number of companies who offer retrofit advice, can support with whole house retrofit assessments and recommend quality assured contractors.

9. 5 Avoiding business as usual

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.

10. What about heritage buildings and conservation areas?

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. Historic England also provide a clear retrofit guide. You may wish to make a submission for preapplication advice to help identify any potential issues prior to the submission for full planning permission.

10.1 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.

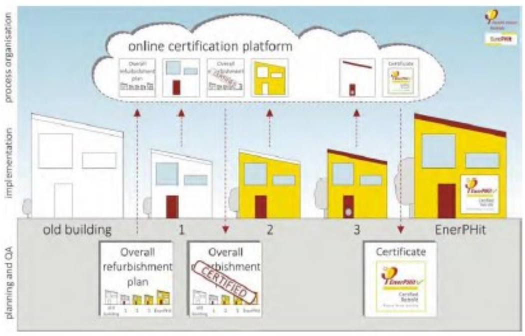
However, in addition to offering significant potential for carbon reductions, well-planned retrofit programmes can also contribute to conservation by incorporating maintenance and repair and offering a new lease of life to buildings. They limit the risk of under-heating by occupants worried about energy 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.

10.2 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.

11. An Extension Should Trigger the Improvement of the Home

EnerPHit retrofit project with extension (Source: Passivhaus Plus)



EnerPHit staged retrofit improvement plan process (Source: PHI)

11.1. 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. 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. Using a smart hot water tank
3. Replacing existing windows with double or triple glazed windows
4. Upgrading the existing external fabric of the existing building (including both insulation and airtightness).
5. Installing Mechanical Ventilation with Heat Recovery (MVHR)
6. Installing solar PV panels to generate electricity

11.2 Staged retrofit – 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.

11.3 Unfortunately, there are many home extensions which have made homes less energy efficient and harder to retrofit in the future due to poor layout, or insufficient space for external wall insulation. Careful planning is essential and a retrofit assessment which gives a plan for the whole house is useful to do this. The recommendations in the report do not all have to be completed in the same year, but having the work planned out will ensure that previous work doesn't stop new energy efficiency works going ahead.

12. What are the Low Carbon Heating Options?

12.1 Heat pumps are the best option for many homes

The electricity grid is being decarbonised with a UK Government target of net zero grid by 2035. Electrification of heat is therefore a likely trajectory for most UK homes with heat pumps playing a key role for most. There are several types of heat pump system 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 to maximise their efficiency.

12.2 Which heat pump is best for me?

There are various types of heat pump options available for retrofit - this page outlines which heat pumps are available and which to choose.

Most homes with a heat demand below 100kWh/m^2.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 retrofitted 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/m^2.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/m^2.yr heat demand then it is still recommended to install a heat pump, but assess the impact on energy costs.

Yes

3 Which are the next best heat pumps?

- A heat pump integrated into a hot water store (i.e. 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/m^2.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/m^2.year,

12.3 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 if not used appropriately. The use of pulsing infra-red heaters or high retention storage heaters can present an affordable alternative for whole house heating.

Hydrogen is unlikely to be a suitable options for many. ‘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 and storage. although this method is yet to be proven at scale and domestic trials of hydrogen heating have so far had mixed results.

The use of woodburning stoves results in the release of particulate matter, a significant contributor to poor air quality and involves burning fossil fuels, which should be avoided.

Heat networks are a UK priority to supporting building heat decarbonisation. UK Government has introduced legislation to support the expansion of heat networks and provide up to 20% of UK building heat demand, up from 3% today. Heat networks distribute heat or cooling from a central source or sources and deliver it to a variety of different customers such as public buildings, shops, offices, hospitals, universities and homes. By supplying multiple buildings from a single (or multiple interconnected) heat source, heat networks avoid the need for individual building heating systems. Whilst legislation is primarily targeted at large scale buildings or heat users, communally heated flats are suitable for heat network connection and individual homes with wet central heating systems (where hot water is distributed via pipes) may also benefit from connection. Birmingham is working to expand the availability of heat networks across the city where they provide a cost-effective alternative to individual building heating systems.

12.4 Retrofitting Solar PV

12.4.1 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.

12.4.2 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.

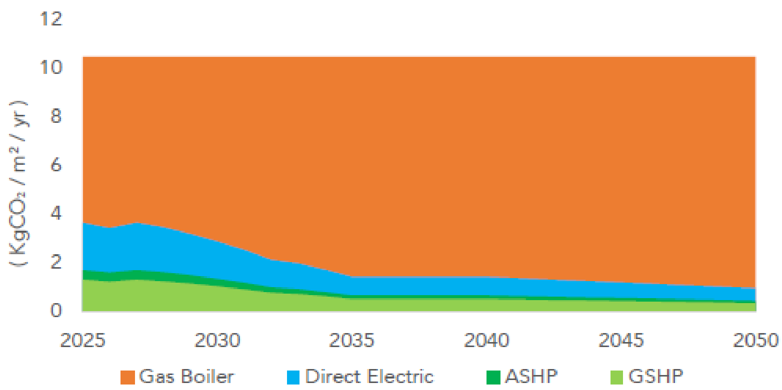
Over a million homes in the UK already have solar panels, many of which have been retrofitted. Notify your building's insurance provider if you are having solar panels fitted to ensure they are covered and your policy remains valid. (Source: Alamy Stock Photo)

12.4.3 Getting up and running

Once your system is installed, you will need to get registered for the Smart Export Guarantee (SEG) 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. Most SEG payments are low in comparison with the cost of electricity from the Grid, so be prepared to maximise consumption of electricity when it is being generated during the day, or invest in electricity storage via batteries.

12.5 Is my 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 such 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 (Best → Worst)	Carbon Emission Reduction	Running Cost	Capital Cost	Air Quality Neutral	Ease of Use & Maintenance
Ground source heat pump	✓✓	✓✓	✗	✓	✓
Air source heat pump	✓	✓	~	✓	✓
Direct electricity	~	~	~	✓	
Biomass/ wood burning stove	~	~	~	✗	✗
Hydrogen	✗	?	?	✓	✓

The table compares various low carbon heating options across different criteria

Key	✓✓	✓	~	?	✗
	Very Good	Good	Neutral / Dependant	Unknown	Bad

13. Window Upgrades

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 value) of less than 1.0 W/m^{2}K). When replacing windows it is important to note that since 2002, all replacement glazing has been controlled by building regulations and planning permission may also be required e.g. in listed buildings.

13.1 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 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.

Replacement triple glazed windows
(Source: Intemorm)

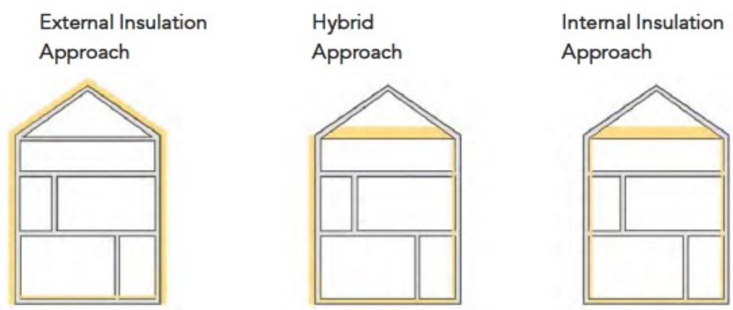
Photo of window install in Enerphit retrofit
(Source: Passive House Plus)

13.2 **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.

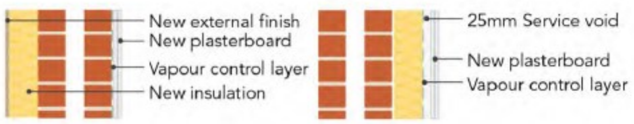
13.3 **Exceptions** - Replacement windows may not always be appropriate in the context of a listed building, or some older buildings in conservation areas, and other methods of improving the energy efficiency of the existing windows may need to be considered as part of a more holistic ‘whole house approach’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

14. Insulating Walls

14.1 **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.



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

14.2 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. It is likely that external insulation will require planning permission so you should consult with the Local Planning Authority through their pre-application service prior to financially committing to any measures.

14.3 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.

15. Insulating Floors and Roofs

15.1 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.

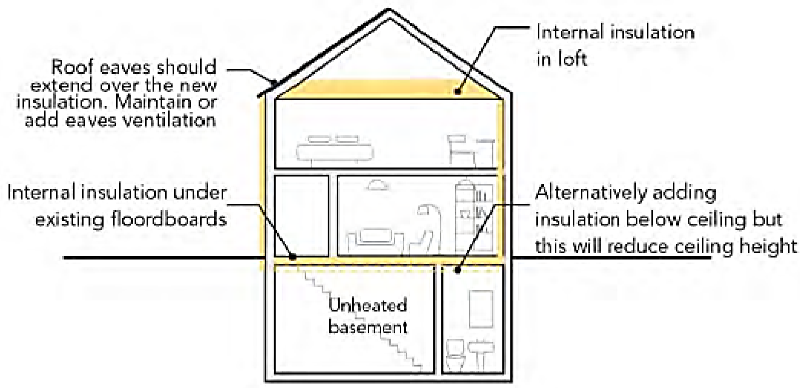
15.2 Extending eaves over external wall insulation

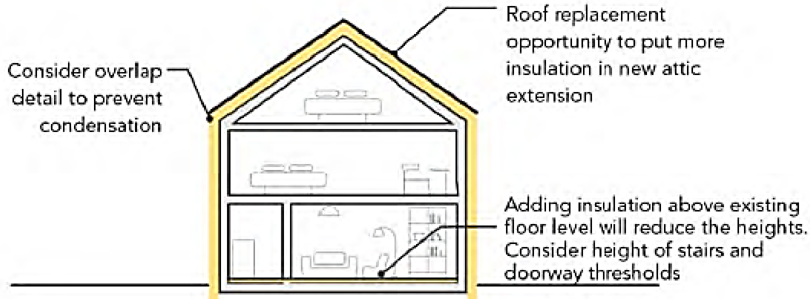
Where external wall insulation meets the roof consider extending eaves to cover the additional wall thickness. Also be sure to maintain or add ventilation at the eaves.

15.3 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.

Spray foam insulation at rafter level must be seen as a serious modification to a home as it changes a cold loft into a warm loft and this can increase damp and condensation problems. There is further guidance from the Royal Institute of Chartered Surveyors:
https://www.rics.org/news-insights/rics-release-new-spray-foam-consumer-guide

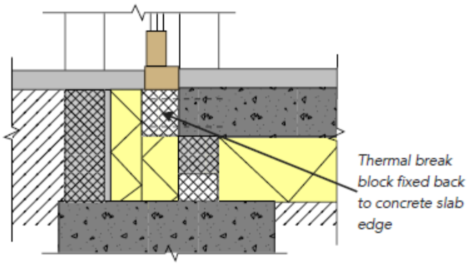




16. Thermal Bridging and Junctions

16.1 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.



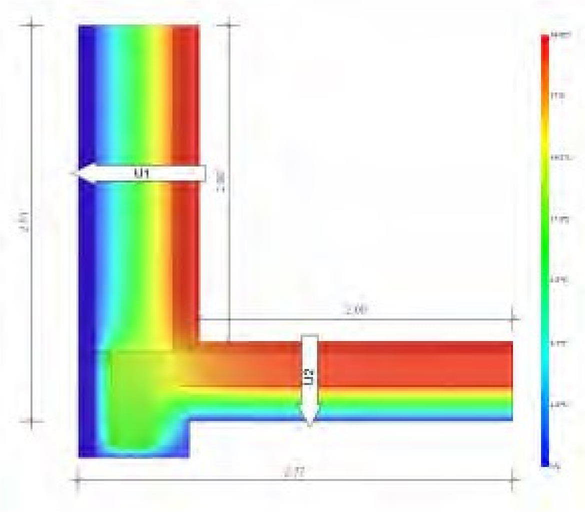
Sketch out key junctions and ensure there is a continuous line of insulation that runs around the building. Try to ensure the insulation depth does not reduce by more than a third around any junction, and ensure window and door frames are in line with insulation.

16.1.1 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.

16.1.2 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.



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.

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.

16.2 Junctions

16.2.1 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.

16.2.2 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.

16.2.3 Foot of the façade with external wall insulation

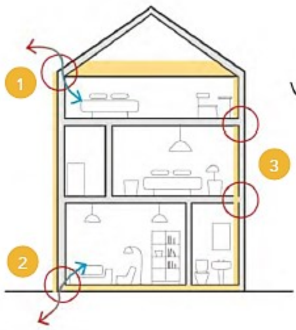
Avoid creating weak points for heat loss at the foot of the façade between external insulation and ground floor. Insulating externally down the wall below ground level as far as possible and provide some internal wall insulation up to counter top level.

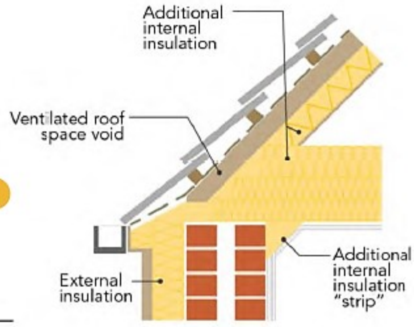
16.2.4 Joist ends with internal wall insulation

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

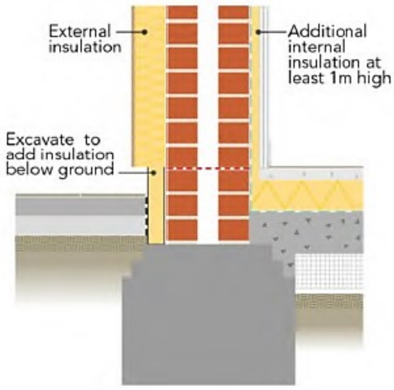
- The most effective approach is to cut and rehang joists away from the external wall e.g. support them on hangers or by a beam between party walls. This allows for a narrow cavity of insulation to be inserted between the façade and end of joist.

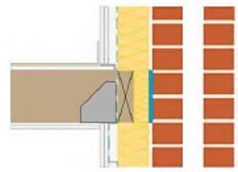
- When insulating behind the joists is not possible, consider hanging the joists or wrapping the breather membrane around the end of the joist to prevent the build up of condensation.





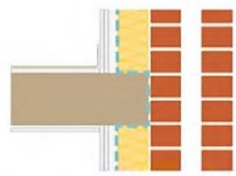
Detail for roof eaves and 'internal strip of insulation'





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

Measures to avoid thermal bridge at the foot of the façade



To avoid condensation risk wrap joist (or add hanger)

Source: Levitt Bernstein

17. Airtightness for Retrofit

17.1 The importance of airtightness

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)

17.1 .1 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 limitations. Air tightness requires more draughtproofing and needs to consider the gaps between floorboards, skirting boards, pipes to the outside and potentially even cat flaps and key holes, depending on the level or airtightness to be achieved.

17.1.2 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.

17.1.3 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.

17.1.4 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.

17.1.5 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.

17.2 Retrofitting a ventilation system

17.2.1 Why is it important?

Existing buildings in the UK, particularly those built before Building Regulations required insulation, are generally leaky and naturally ventilated. This can result in draughty homes high energy demands. Insulation, airtightness and new windows are often considered an important part of retrofit but appropriate ventilation must also be included. A mechanical ventilation and heat recovery (MVHR) system is often a preferred solution especially with a very airtight building. However, there are other ventilation options including smart air bricks, decentralised MVHR, and mechanical extract ventilation with a humidity sensor.

17.2.2 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 can be reused.

Image of Zehnder MVHR unit being retrofitted into an existing house

(Source: Bow Tie Construction)

17.2.3 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.

17.2.4 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.

18. Water Efficiency and Domestic Hot Water

Water efficiency is about reducing our use of mains water and the effect our homes have on water resources. 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 (below) provide clear guidance on sensible flow rates for showers and taps in low energy buildings.
- Reduce distribution Losses - All pipework must be insulated.
- Install a smart tank which heats just the water required by the household
- 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 with more common horizontal ones recovering 25-40%.
- Consider water recycling - This is the process of treating waste water and reusing it and it can be used for large portions of potable (not drinking) water use. There are various systems that can treat the water and store it, but often this involves adding chemicals eg chlorine and extra pipework around the building. The cost of this would need to be weighed up against possible money saved.

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-flush (as opposed to siphon mechanism). WCs to be fitted with an easily accessible, quarter turn isolating valve with a hand-operated lever. Where a 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-up showering with a suitable screen or curtain.
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.

Refer to the full AECB document for more information.

19. Smart Controls and Demand Response

19.1 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.

19.2 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.

19.3 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 battery of the EV 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.

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

Microgrids

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

20. Embodied Carbon

20.1 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.

20.2 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 number 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

5. Easy maintenance and use
   Consider maintenance & 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.

21. Indicative Costs of Retrofit

21.1 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.

21.2 Indicative retrofit costs for an unrenovated 90m² semi-detached dwelling, based on 2020 prices (Net Zero Carbon Toolkit[3]).

Material inflation has increased significantly and there are sometimes shortages of materials globally.

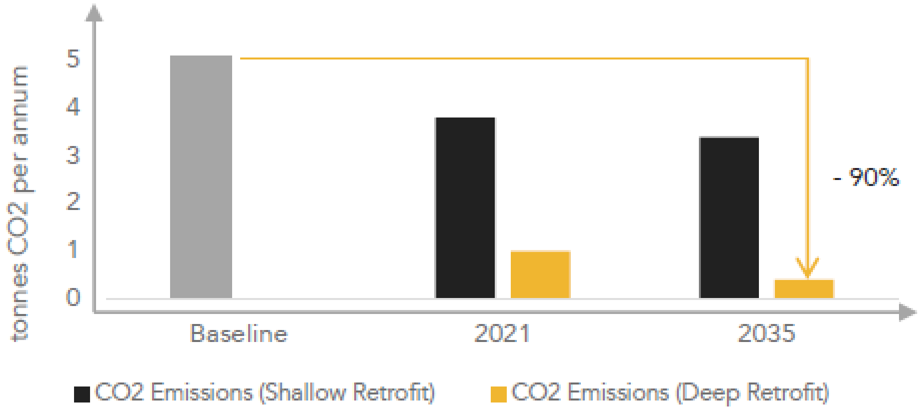
Measure	Shallow	Deep
Fit 100% low energy lighting	£20	£20
Increase hot water tank insulation by 50mm	£50	£50
Loft Insulation -add 400mm	£500	£500
Fit new time and temperature control on heating system	£150	£150
Improved draught proofing	£150	
100% draught proofing -improve airtightness		£2,000
Cavity 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		£9,000
New smart hot water tank		£2,000
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, (21m 21m² area)		£6,500
Battery for solar PV		£1,000
Miscellaneous and enabling works	£1,000	£5,000

21.3 Is retrofit 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.

[3] Net Zero Carbon Toolkit, Levitt Bernstein, Elementa, Passivhaus Trust and Etude commissioned by West Oxfordshire, Cotswold and Forest of Dean District Councils, funded by the LGA Housing Advisers Programme.

But don't forget the co-benefits!



CO_2 reductions for an unrenovated 90m² semi-detached dwelling

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.