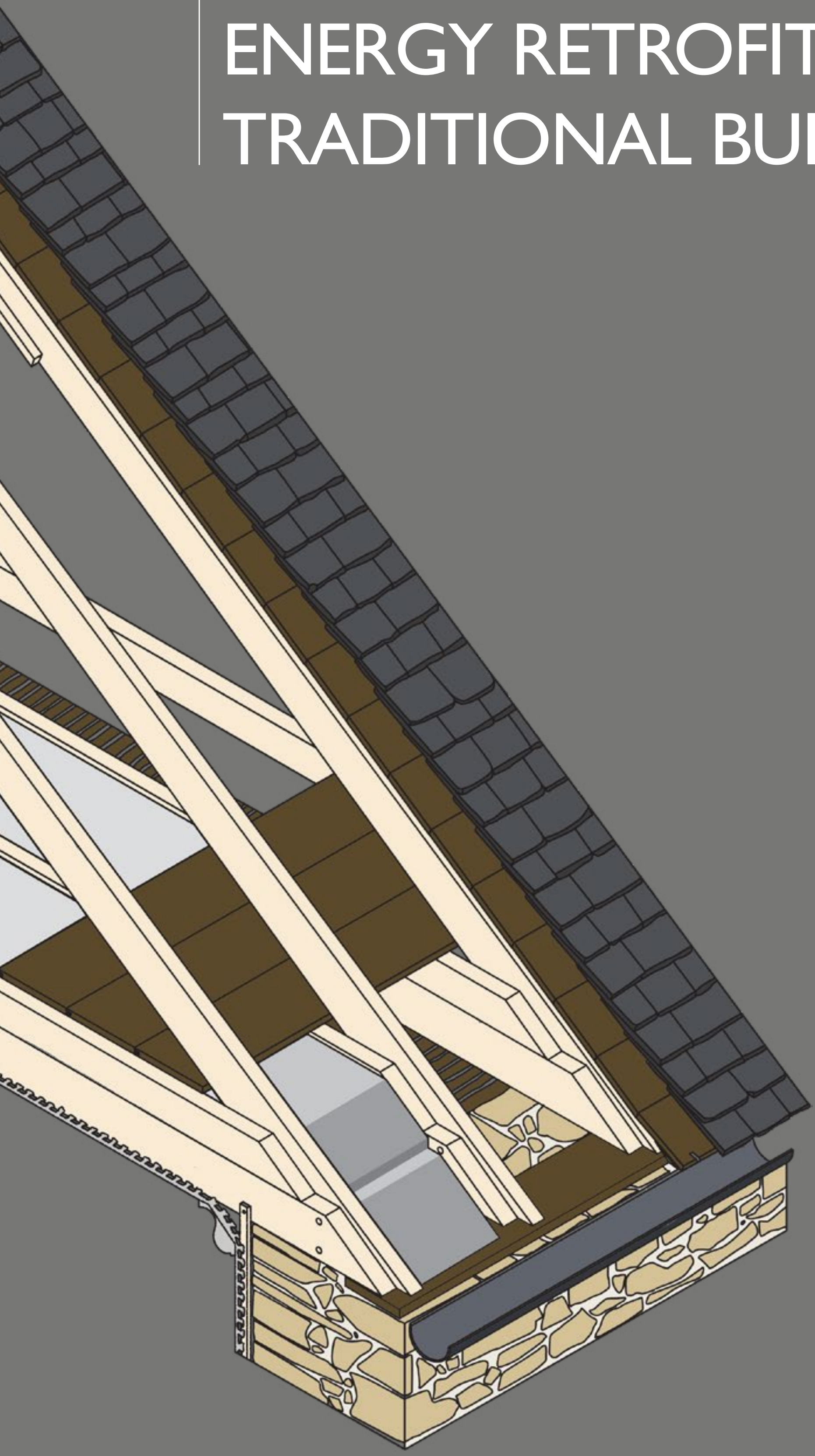
GUIDE TO ENERGY RETROFIT OF TRADITIONAL BUILDINGS



HISTORIC
ENVIRONMENT
SCOTLAND

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Principal Authors: Moses Jenkins and Roger Curtis

Editor: Lila Angelaka, with thanks to RIAS Conservation Committee for assistance and review

If you have any comments or queries about our Retrofit Guide, please get in touch by email at TechnicalResearch@hes.scot.

Any enquiries regarding this document should be sent to:

Historic Environment Scotland
Longmore House
Salisbury Place
Edinburgh
EH9 1SH
+44 (0) 131 668 8600
www.historicenvironment.scot

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1. INTRODUCTION

1.1 AIMS

Scotland is committed to some of the most ambitious carbon reduction targets in the world. The Climate Change (Emissions Reduction Targets) (Scotland) Act 2019 has set a target for net zero emissions by the year 2045. With around 40% of Scotland's total carbon emissions coming from domestic energy consumption and almost 20% of all buildings being of traditional construction, improving the energy efficiency of these buildings will be necessary to meet the national carbon reduction commitments.

With this in mind, an extensive programme of domestic retrofit is clearly needed and the existing built environment, including older or historic buildings, will need to play its part in the national refurbishment effort. While it has been common to assume that older buildings are 'hard to treat', trials over many years have shown that a good level of upgrade is achievable with a range of sympathetic interventions that allow the building to function as before.

Historic buildings enrich Scotland's landscape and they are central to our everyday lives, creating a sense of place, identity and wellbeing. They not only add cultural value, but they are adaptable and robust, with architectural features and sustainable materials that were designed to cope with the elements and allowed for a natural dispersion of moisture through fabric and passive ventilation mechanisms. Therefore, the existing range of traditional and historic buildings should be regarded as part of the resource solution, not as an energy problem in isolation.

Historic Environment Scotland (HES) is at the forefront of this effort and has been leading in the research and guidance to improve energy efficiency in traditional and historic buildings since 2008.

1.2 SCOPE OF THE GUIDE

This guide looks into the thermal retrofit of traditional buildings in Scotland. It considers the various factors in a thermal upgrade and how these might apply to designated and non-designated historic structures. This guide supersedes Historic Scotland's Short Guide 1 (published in 2013) and reflects important changes in the wider context, including new insulation measures that have been developed.

The purpose of the guide is to allow designers or contractors to consider how best to approach the refurbishment of a traditional or historic building, balancing the various requirements that each project will bring. The guide can also be used to provide guidance for local authority building control officers in their assessment of applications for building warrant approval. The measures which are described aim to maintain much of the original fabric, for historic reasonsm as well as environmental ones. They are suitable for all pre-1919 buildings with solid walls but also have relevance for later buildings, where the same principles remain valid. Other relevant factors will be introduced too, such as embodied carbon, the circular economy and wider sustainability in construction. Many of the measures described are the result of Historic Environment Scotland's (HES) work in the retrofit sector since 2008, and the case studies can be reviewed in further reading. Knowledge and understanding have also come from other sources; notably, the Sustainable Traditional Buildings Alliance (STBA) and joint work with Historic England.

For more details on the work carried out, readers are directed to the suite of HES Technical Publications. These publications have four levels on matters affecting traditional buildings: Inform Guides, with general information for homeowners; Short Guides, with more detail for trades and architects, surveyors, designers; Technical Papers, which cover a range of topics at a more academic level of detail; and Refurbishment Case Studies, which describe work on pilot projects. This project work gives the technical backbone to the issues discussed in the guide. All are available free of charge from the publications section of the HES website.

Note: Many sections of this document contain embedded links that will take the reader to more background or specific information on the project where the measure was tested.

2. REDUCING CARBON EMISSIONS IN THE BUILT ENVIRONMENT

2.1 POLICY BACKGROUND AND INITIATIVES IN SCOTLAND

The effects of climate change on traditional buildings may be considerable (Figure 1). This is part of the driving force behind the retrofit of traditional buildings in Scotland and the ambitious Scottish Government targets for carbon reduction.

The Scottish Government Heat in Buildings Strategy states that HES will work to help ‘develop more solutions to transition Scotland’s historic buildings to zero emissions heating’. This has been further enhanced in the Energy Efficient Scotland Route Map and the Climate Ready Scotland: Scottish Climate Change Adaptation Programme (the SCCAP). These two documents task HES with undertaking a number of research themes to improve the resilience of the historic environment in Scotland, with the Energy Efficient Scotland Route Map stating: ‘The research and development of new approaches for the energy efficiency of these pre 1919 buildings is overseen by Historic Environment Scotland.’ The principal areas of research are laid out in the SCCAP and include HES being tasked with undertaking research and case studies on the thermal performance of the traditional building envelope, with the intention of publishing this research to inform guidance.

This revised, expanded ‘short guide’ is an important part of HES meeting the commitments set out in the Energy Efficient Scotland Route Map and the SCCAP. It will also meet the commitment in the HES-led strategy for the historic environment, *Our Past, Our Future*, which places meeting net zero as a priority, as well as commitments in our Climate Action Plan 2020-2025.

This guide also seeks to support the current Scottish Government targets for all buildings, which can be found on the Scottish Government’s website about energy efficiency. This will see substantial investment in making buildings more energy efficient, with the goal that, by 2040, our homes and buildings will be warmer, greener and more efficient. In this guide, HES will support these ambitious targets to remove poor energy efficiency as a driver for fuel poverty by presenting methods and materials which can make traditional buildings more energy efficient.

Figure 1: The efects of climate change on traditional buildings may be significant, as shown here. Image © Paul Hendy

2.2 SUSTAINABILITY

Maintenance should always come before any refurbishment or upgrade work is considered; this is the most sustainable thing you can do with your building. It is important that any retrofit or other repair and maintenance work to traditional buildings is undertaken in a sustainable manner. To do this, it is more than just the carbon emissions from the building used in heating that need to be considered. The following sections set out brief principles of sustainability to consider when working with traditional buildings.

Refurbishment of existing buildings: Saving carbon is not all about operational energy; there is also the embodied carbon from the construction of buildings, including those already built. When existing buildings are retained and repaired, their embodied carbon, which is energy already used, is also retained, and the operational energy associated with running the building can then be reduced by appropriate measures and upgrades. However, improvement measures will also generate carbon, which can vary depending on the materials selected, where they have come from, how long they last, etc. In a recent study by Historic England (Heritage Counts 2019: There's no place like old homes) it was found that an existing traditional building, refurbished and upgraded, will save more carbon than its demolition and replacement.

The circular economy: The refurbishment of a building needs to be done sustainably and using products that are created in an environmentally responsible way with minimal use of energy. As opposed to the current linear economy (production, use, disposal), a circular economy looks to reuse or repurpose materials in such a way that nothing is wasted, thus allowing us to preserve finite resources. This approach can be applied to the refurbishment of buildings, as well as individual building elements. The repair and reuse of materials in situ is the preferred option. After this, reusing the materials in a different location is the next step. Recycling materials is not necessarily desirable, since it requires a significant input of energy. HES is working with Zero Waste Scotland to minimise waste in refurbishment as part of their ‘Designing Out Waste in Construction’ programme.

Local materials and supply chain: Society is increasingly realising the benefits of a more local economy of goods and services. Construction in the past was a very localised industry, with local materials and design characteristics. While it might be difficult to re-establish local supply chains today, the benefits of local people doing local work are real; there is more accountability, highly specific knowledge, often greater flexibility and innovation. Certainly, the use of materials which have been grown or made in Scotland will assist in jobs in many regions and reduce the carbon expended in their importation.

Carbon capture: Much as peatland will capture carbon over time with its build-up of organic matter, so will the growth of trees. When a plantation tree is harvested, that carbon remains locked in, and the use of timber for framing or insulation is another form of carbon capture. The same applies to other grown materials which can be used for insulation, such as hemp, sheep’s wool or recycled cotton waste. So, where possible, materials should seek to capture carbon; this can assist in working out the overall carbon expended in a building refurbishment and mitigate higher operational emissions, where fabric cannot be improved beyond a certain point.

3. TRADITIONAL BUILDINGS

This section introduces definitions and key points relating to older buildings (traditional, historic or listed) and outlines why they are treated differently to later construction. They should be upgraded, and this document is all about that, but that they are approached in a slightly different way, especially in regard to the materials used.

3.1 DEFINITION

Traditional buildings are generally considered to be those built before 1919, using load-bearing mass masonry walls with pitched roofs of slate, pantiles or thatch. Windows are generally single glazed with timber frames, often in the sliding sash and case pattern. The buildings often have internal timber and lime plaster finishes, other materials which permit vapour exchange and air movement, and various forms of passive ventilation systems. The term ‘traditional buildings’ covers a broad range of structures, not just those that are listed, historic or considered ‘heritage’. This definition is set down in the Building Standards, where it is made clear that when considering an energy retrofit for traditional buildings, a different approach is sometimes needed. This is considered in depth in Section 10.

Scotland has 479,000 traditional buildings, comprising 19% of the total domestic building stock, according to the 2019 Scottish House Condition Survey. They include cottages, villas, public and commercial buildings, as well as tenements and terraced houses, which are prevalent in urban environments, as seen in Figure 2.

Figure 2: Traditionally constructed houses in southwest Scotland.

3.2 HISTORIC AND LISTED BUILDINGS

Most historic and listed buildings are traditionally built, but not all. Many structures from around 1919 onwards used modern materials, which are often impermeable and behave differently to traditional ones. Buildings of the modern movement and domestic buildings from the post-war period do not perform well thermally (the thermal upgrade for this type of building will be addressed in a separate publication). It is worth noting here that a 'historic building' is a cultural definition, not a technical one, so HES will contend that measures for traditionally built structures (such as those shown in Figure 2) are technically appropriate for most historic ones.

In Scotland there are around 47,000 buildings which are listed for their special architectural or historic interest. Listed building consent may be required for some works to listed buildings, but guidance is designed to manage change sensitively rather than to prevent it. All the measures in this guide are likely to be suitable for listed buildings, depending on the context or what might make a specific element important.

4. WIDER CONSIDERATIONS

As the sustainability agenda matures and additional imperatives emerge, refurbishment needs to go beyond the basics of insulation and air leakage control. This section will consider some of the additional factors in refurbishment, such as client priorities, carbon, historic value, etc., that precede the design of any fabric works. Some of these factors will be directly linked to individual clients and their circumstances, while others relate to national-scale issues of embodied carbon, resource retention and maximisation.

4.1 CLIENT OBJECTIVES AND INTENDED OUTCOMES

Part of the goal in any refurbishment is to reduce energy demand and carbon emissions and save money. The energy efficiency work may also be part of a wider works or refurbishment. Depending on the project priorities, the focus of the works will take slightly different directions.

Carbon: Seeking to save carbon can require significant intervention and cost, but the result can be an equally significant reduction in energy use. In a refurbishment of an older building, there will be a limit on how far this can go.

Budget: If funds are limited, then the focus will be on the key works that get the greatest reduction for the money. This will be closely linked to the Energy Performance Certificate (EPC) assessment.

Historic value: If a building has original internal linings, finishes and features, then the priority will usually be to intervene without affecting them, with some limitations on the scope of the retrofit and more modest energy savings as a result. This is especially true for any building that has a particularly significant interior.

EPC improvement: The target may be a better EPC band. This will mean that the interventions may be influenced by what Reduced Data Standard Assessment Procedure (RdSAP) will account for. Section 12 on EPCs below will outline key factors in material and heating choices.

Payback times: Owners who are not planning to stay in a property for long may want to see a quick return on their investment. As considered in Section 5, in refurbishment as in many other areas of work, the law of diminishing returns applies to energy efficiency measures. The factors above will tend to give a threshold where a 50% reduction in energy use is achievable within most scenarios, but beyond that the costs start to increase. These costs may be beyond the anticipated payback times for the measures.

4.2 COSTS AND FUNDING

HES is not able to assist with funding private retrofit work. However, the Energy Saving Trust will advise on what options are available to you. For more details, see the Energy Saving Trust website.

4.3 HES CASE STUDIES

The examples given throughout this guide are based on a series of trials and pilot projects undertaken or managed by HES and published as Refurbishment Case Studies. These projects were carried out on a variety of different traditional building types including detached rural cottages, tenement flats, townhouses and public buildings dating from the 18th, 19th and early 20th centuries.

Attention is also drawn to the HES's Technical Paper series, which provides detailed information on relevant technical issues; particularly Technical Paper 24, which presents the results of a review of HES's case studies carried out by an independent firm of surveyors to show the effectiveness of the measures undertaken.

4.3.1 Measuring heat loss

Throughout this publication, the effectiveness of specific insulation measures in relation to thermal performance is indicated using U-values. A U-value is a measure for the amount of heat transfer through a material (measured in watts per square metre) at a temperature difference of 1 Kelvin. In building fabric work, the lower the U-value, the better the insulation or thermal performance of a building element. All the U-values presented in this guide are actual measurements from HES energy efficiency case studies. More details on each project can be found in the relevant Refurbishment Case Study. Further details on U-values in traditional buildings and how they are measured can be found in HES Technical Paper 1, Technical Paper 2 and Technical Paper 10.

4.4 PLANNING AND REGULATIONS

4.4.1 Listed building consent and planning permission

The measures described in this guide are likely to be relevant to most traditional buildings and some listed ones. However, where a building is listed, listed building consent may be required for certain works which go beyond like-for-like repair. (To see if your building is listed, go to pastmap.org.uk.) In some cases, works affecting the exterior of a building will require planning permission. The relevant local planning authority will make decisions about what requires listed building consent and planning permission.

4.4.2 Conservation areas

Conservation areas are places of special architectural or historic interest which are protected with the aim of preserving or enhancing their character. This generally means there are restrictions on permitted development rights; there may be specific Council guidance on certain types of windows, wall finishes and doors, and permission may be required for even minor works. Conservation areas are managed solely by the relevant local planning authority (except where demolition is proposed and HES should be consulted on the conservation area consent) and they should be contacted for any advice on works in a Conservation area.

4.4.3 Energy Performance Certificates

The standard of thermal performance which traditional buildings are required to achieve has increased. The Scottish Government has set a target that by 2033 all Scottish homes should achieve an EPC band C where technically feasible and cost effective. Meeting these standards is of increasing importance and for most people it will affect the choice and level of measures installed; this is discussed further in Section 12 of this guide.

4.4.4 The Scottish Building Standards

In some situations, traditional buildings may also be required to meet specific standards when being converted in order to comply with the Scottish Building Standards. In such cases, it is important that care is taken to ensure the measures used to meet these standards do not lead to the decay of building fabric in the long term. The measures presented in this guide will show methods and materials which satisfy Building Standards and are also technically feasible for use with the fabric of traditionally constructed buildings. More specific information on how the Building Standards apply in an energy retrofit can be found in Section 10.

4.4.5 Building regulations and warrants

In all projects where a building warrant is required and compliance with Section 6 of the Scottish Government Building Regulations is necessary, a certifier of design can be used to provide assurance of compliance. Achieving the rates set out in the functional standards may not be possible in existing buildings. In this case, a client or project team may wish to access specialist expertise and appoint an approved certifier of design to develop a solution that achieves compliance. Six schemes are run in Scotland which suit the circumstances of traditional and historic buildings. More about this can be found in Section 10 of this guide.

4.4.6 PAS 2035 and PAS 2038

PAS 2035:2023 is a document which aims to support standards in the retrofit of domestic buildings. It was produced by the British Standards Institution and is sponsored by the UK Government's Department for Business, Energy and Industrial Strategy (BEIS). It covers topics such as how to access dwellings for retrofit, identify improvement options, design and specify Energy Efficiency Measures (EEM) and monitor retrofit projects. It is important to recognise that not everything covered in PAS 2035 will be applicable to traditionally constructed buildings, and careful design and application of retrofit measures in such buildings will be required over and above any requirements in the PAS. A forthcoming standard, PAS 2038, will cover non-domestic buildings.

4.5 DESIGN MATTERS

4.5.1 Heating options

It is easy in the energy efficiency discussion to focus entirely on the measures required to increase insulation and reduce air infiltration. While these considerations are valid, it is worth remembering that the objective is to achieve a building that is healthy and comfortable for the occupants. That means understanding human physiology and what makes us comfortable. Our evolution also means that people are more comfortable with radiant heat. The ability to control one's immediate environment is also important, so access to ventilation is necessary. These factors are discussed in HES Technical Paper 14: Keeping Warm in a Cooler House.

It is worth noting that as the gas and electricity grid become progressively more decarbonised, there will be greater emphasis on the efficiency and fuel source of heating plant and equipment.

4.5.2 Climate change adaptation

The climate in Scotland is changing and, although the details of exactly what this means are still emerging, it generally shows an increase in precipitation and extreme weather events, with milder but wetter winters and hotter summers. This may change the focus in refurbishment, which won't be limited to improving the thermal performance of a building but will also be required to address the increased wetting of the building fabric and how rainwater is managed. Various such measures for climate change adaptation are considered in HES Short Guide 11: Climate Change Adaptation for Traditional Buildings.

In addition, with climate change leading to increased temperatures in the summer, buildings will need to be able to cope with overheating as much as keeping occupants warm. Traditional measures such as roller blinds, vented cupola rooflights and ventilation pathways will be necessary to address the need for fresh air and keeping cool in a house without overloading the grid. Further information on ventilation can be found in the HES Inform Guide: Ventilation in Traditional Houses.

4.5.3 Use of micro-renewables

In some older buildings, in order to achieve national energy efficiency targets for domestic buildings and given the practical and economic limits on the extent of refurbishment, it might be necessary to consider the use of renewable energy equipment. This might be a solar PV or solar thermal array, renewable heating such as an air source heat pump, or a wind turbine. For example, Holyrood Park Lodge reached Band C at the end of the fabric works but could reach a Band B with the use of an air-source heat pump or solar PV panels (see Section 12).

Depending on the situation, the property may already have access to renewables. This will affect the nature of the space and domestic water heating arrangements, changing the balance of options described above. Further options and advice for renewables in older properties is given in HES Short Guide 8 'Micro-Renewables in the Historic Environment'.

4.6 ACCESSING ENERGY EFFICIENCY ADVICE

This document aims to complement the impartial advice provided by the Energy Saving Trust on how to reduce domestic energy and carbon dioxide emissions in the domestic energy sector. The Trust should be the first point of contact when seeking advice on thermal improvements and upgrade work. They also provide advice on sustainable transport and renewable technology, as well as access to funding schemes. This advice is delivered through the Energy Saving Scotland advice centre network, managed by the Energy Saving Trust and funded by the Scottish Government and Transport Scotland. They have a staff of advisors who are trained in improvement measures for older buildings and will be able to build on the advice given in this guide. (What we do at Energy Saving Trust)

4.7 TRAINING AND QUALIFICATIONS

When planning a programme of work, the design and delivery of the measures must be carried out by a team or individual who understands traditional construction and the measures that are appropriate. This guide seeks to aid those who are required to have knowledge regarding energy efficiency measures for such buildings and has been formulated to meet the requirements of the National Occupational Standards, both for insulation and building treatments and for the retrofit pathway for construction site managers. The guide, therefore, helps those who need to meet the relevant knowledge requirements of these National Occupational Standards, both at operative and management level.

In addition, a qualification has been developed by HES for designers and installers and is advised under the Scottish Government Retrofit Skills Matrix for work on traditionally built and listed structures. This training has been available from the HES training facility since Spring 2022. Further details about this and other relevant training can be found on the Engine Shed website (www.engineshed.scot).

Training provision will be at the core of the successful delivery of the energy efficient targets of Scotland programme and other schemes, and HES is taking the lead in Scotland in addressing the retrofit skills challenge with training facilities and equipment for this national priority (Figure 3).


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Figure 3: Traditional building training with one of the rigs at the Engine Shed facility in Stirling.

5. PRINCIPLES IN REFURBISHMENT

HES has developed some principles to balance the requirements of energy efficiency with other considerations in refurbishment work on traditional buildings, such as building aesthetics, cost, duration of the measures, amount of waste, compatibility of measures with the building fabric and indoor air quality. These considerations echo commitments made by others in the sector regarding resource retention, reuse and approach to materials and are also supported by research from various organisations that work with older buildings.

These refurbishment principles have been successfully demonstrated through a number of HES research projects and can be summarised as follows:

Maintenance: Prior to any refurbishment work, the building has to be in good condition and free from penetrating damp or other sources of water ingress. In addition, climate change in Scotland means that there is more rain and extreme weather events are becoming more common. This, together with any backlog of repair and maintenance, can further accelerate building decay. Therefore, energy efficiency work has to come after external repairs and maintenance are addressed.

Compatibility: Measures that allow the building fabric to perform as intended. The materials used should be appropriate for the building. In most cases, this will mean they are water vapour permeable and capillary active.

Indoor air quality: Adequate ventilation should be maintained to ensure the health of the building and its occupants. This might mean using existing chimney flues and other traditional features to reintroduce natural ventilation routes.

Waste minimisation: Minimise waste by upgrading existing elements. This means adding to the parts of the fabric rather than replacing them, such as fitting new glass panes in existing window frames or insulation fastened onto doors. The waste stream from conventional refurbishment is excessive; skips full of linings and many perfectly serviceable building components, such as doors and windows or non-compostable waste from offcuts of new insulation materials, all contribute to further resource depletion and more landfill. Zero Waste Scotland publishes guidance on waste and other matters concerning sustainability and the circular economy. See: www.zerowastescotland.org.uk.

Proportionality: There needs to be a balance between increased thermal performance, cost to the client and impact on the traditional or historic fabric. The approach of ‘what can the building reasonably take' should drive the planning of interventions, not a specific U-value or target. There is evidence from the STBA that, beyond a certain point, the thickness of insulation ceases to yield benefit.[i]

Building design: Buildings generally work best as originally designed. This means that modern interventions can often affect the performance of a historic building, and removing these can improve the light, airflow and overall amenity. Examples might be removing a lowered ceiling or later partitions and subdivisions, reopening blocked fireplaces, reinstating lightwells, removing over cladding or inappropriate finishes, or opening up previously blocked ventilation routes such as underfloor ventilation grilles.

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[i] https://stbauk.org/stba-research/, May, Neil, 2012: A Short Paper on Internal Wall Insulation

6. BUILDING MAINTENANCE

Proper and regular maintenance is a prerequisite to undertaking energy efficiency improvements in a traditional building. If a building is not watertight, there is little point in making energy efficiency upgrades. If dampness or excess moisture is already present, such upgrades may cause further issues and damage. An example of defective fabric is shown in Figure 4 below, where a blocked downpipe is saturating the wall, allowing plant growth. Insulation here would be rendered ineffectual. The blocked downpipe must be repaired, and the wall dried out prior to any such work. Furthermore, heat loss through a damp masonry wall is higher than from a dry wall. Details of appropriate maintenance measures in traditional buildings are given in a number of HES publications, including Short Guide 9: Maintaining Your Home, and Short Guide 11: Climate Change Adaptation in Traditional Buildings.


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Figure 4: All buildings should be well maintained and any defects should be repaired before retrofit work is undertaken. This downpipe has been blocked for some time and the masonry behind appears to be saturated; the defect should be addressed first, before any insulation work.

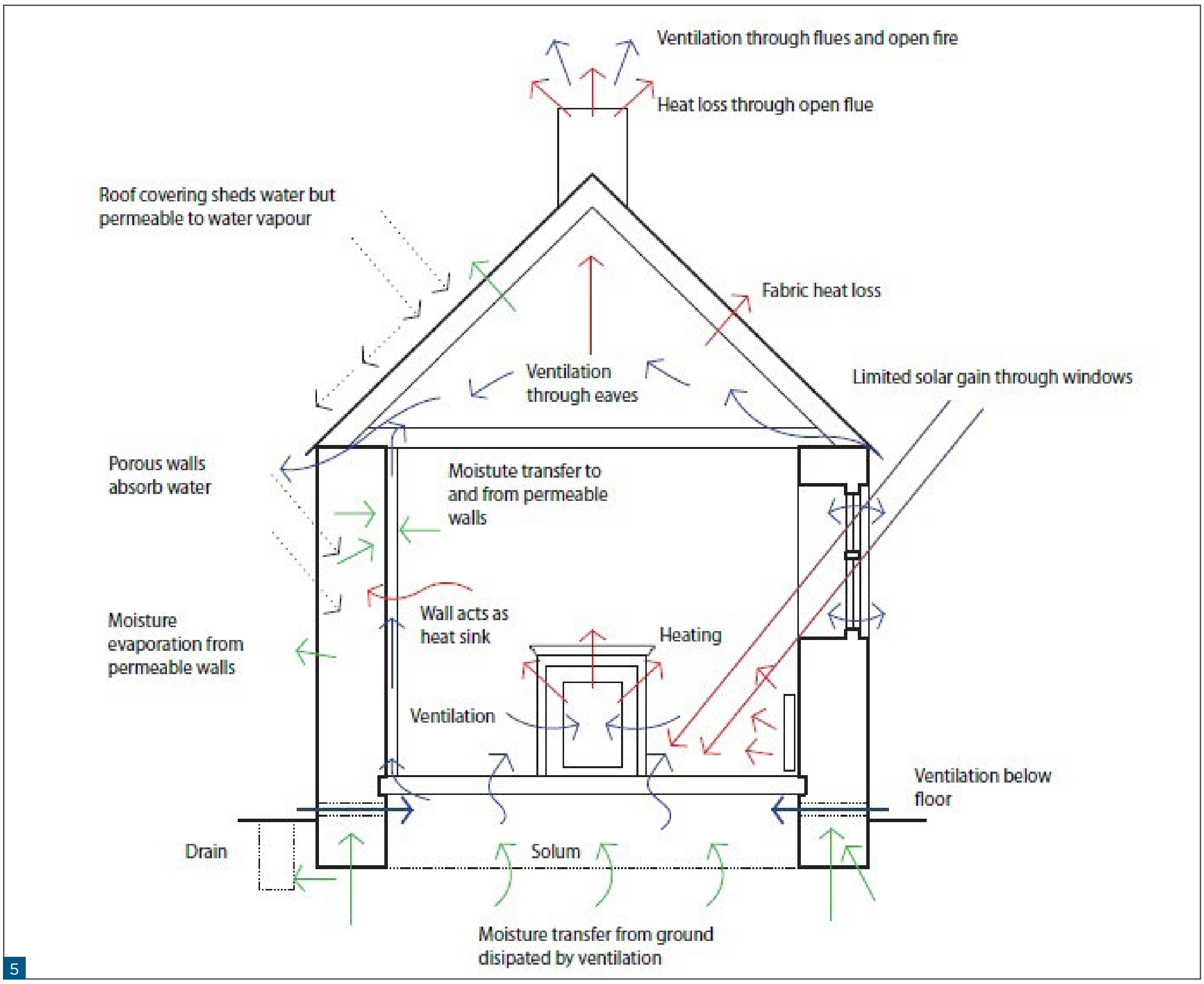
7. VENTILATION

7.1 AIR MOVEMENT

Traditional building fabric is generally vapour open and construction materials, such as stone, mortar, plasters of earth or lime and timber, allow a degree of water vapour movement as discussed above. In addition to the water vapour movement through materials, bulk movement of air is also required in a building to aid the vapour dispersal from the fabric and to ensure, along with other factors, the health and wellbeing of the occupants. In the past, buildings were constructed in a way that allowed modest air movement through vents, windows, doors and chimneys (Figure 5). It is understood that much of this air movement was deliberate, as open fires needed incoming air to draw properly.

More modest background ventilation was provided separate to the flues, with air coming in through the solum vents, rising behind the plaster linings, and dispersing through the gaps and small openings in the roof space. Such ventilation should never be fully eliminated but reduced to acceptable levels, as considered later in this guide.

Figure 5: Air movement in a simplified traditional building, showing air entering and leaving the structure through gaps, etc., as well as water vapour passing through materials.



7.2 AIRTIGHTNESS

Consideration of moisture movement and ventilation is important when dealing with traditional buildings and energy efficiency. Provided these factors are considered, it is entirely possible to successfully improve thermal performance and reduce energy use in a traditional building without damaging either its character or the building fabric. In seeking to better manage airtightness in older buildings, a recent HES case study achieved an air leakage reduction from 18 to 8 air changes per hour, using the measures described in this guide. This degree of airtightness challenges the assumption that old buildings have to be draughty. The critical point her, however, is that ventilation was still maintained; the intention was not to make a traditional building perform like a modern building. A balance needs to be struck between improving the airtightness of a building, and reducing airflow to a point at which poor internal conditions result.

7.3 NATURAL OR PASSIVE VENTILATION

Older buildings were mostly ventilated by passive means, normally through modest air infiltration through windows, doors and up and out via the chimney flues. The design of older buildings allowed what is called 'cross ventilation', where air was admitted on one side and released on the other. Many public buildings, such as halls and theatres, had sophisticated passive ventilation systems using roof-level vents and draught-free air entry. In recent years, these have sometimes been removed or blocked and, as a result, overheating and discomfort often occurs. In a recent project, HES supported the reinstatement of roof-level ventilators on a former school in Oban as part of the restoration of a passive vent system (Figure 6) to investigate traditional ways of ensuring good indoor air quality.

Figure 6: Reinstated ridge level vents at a former school in Oban. Image © Rockfield Centre

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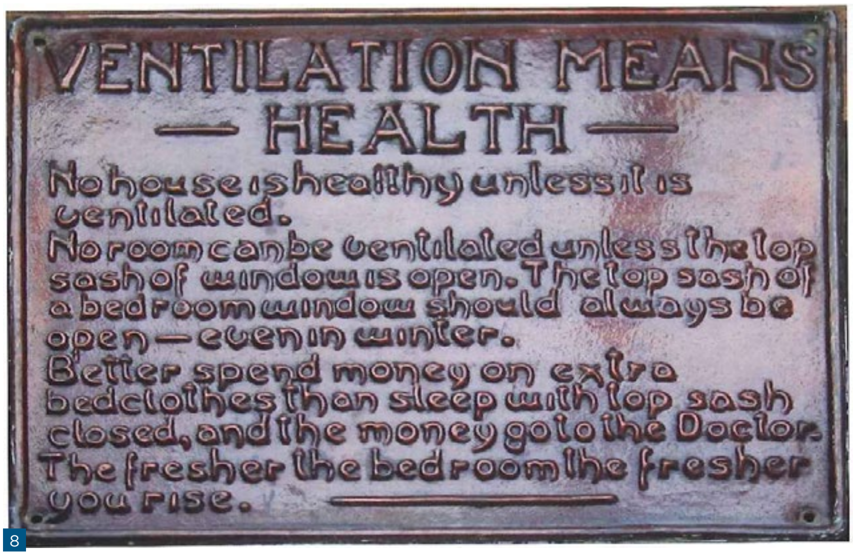
The use of open fires in the past ensured an ongoing exchange of air in buildings. Also, occupants used to ventilate their buildings to a greater degree than is typical today. A way of ensuring modest background ventilation is to allow warm, damp air to escape out of the building at high points, such as stairwell cupolas in tenements or stairwell rooflights in cottages. Clues to excessively high humidity levels can be beads of condensation on the underside of a rooflight, often resulting in water running down the plaster. The key to this is control – opening when needed and keeping closed at other times to retain heat. At Holyrood Park Lodge, a small window in the hallway was made to be openable by a worm gear (Figure 7) to demonstrate how passive ventilation and cooling could be adapted into buildings as summers become hotter and the need for cooling increases. In addition, the recent Covid-19 pandemic has led to a greater focus on ventilation and conditions inside homes, over and above the issue of simply retaining heat.

Figure 7: This quarter light has been made to open to allow managed ventilation.

7.4 INDOOR AIR QUALITY

In the early 20th century, there was an emphasis on ventilation for health. This was partly a method of infection control, and partly about the need for ventilation due to gas and paraffin lighting. Some housing providers in the early 20th century even attached instructions in the kitchen of each property for the guidance of tenants (Figure 8).



VENTILATION MEANS
— HEALTH —
No house is healthy unless it is ventilated.
No room can be ventilated unless the top sash of window is open. The top sash of a bedroom window should always be open — even in winter.
Better spend money on extra bedclothes than sleep with top sash closed, and the money go to the Doctor.
The fresher the bedroom the fresher you rise.

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Figure 8: Traditional buildings were constructed with a good understanding of passive ventilation. Image © The Gannochy Trust

The object of ventilation is to ensure both the occupants and the building fabric remain healthy. Insufficient ventilation will result in the build-up of water vapour, certain gases, aerosols and particulates, as well as VOCs and chemical loads. Indoor air quality (IAQ) is used to refer to the levels of these compounds in the air. High humidity and carbon dioxide levels are indicators of poor air quality. Outside air in a clean environment has around 400ppm of CO2, and air in a room with levels of carbon dioxide above 1,000 parts per million starts to feel stuffy. Relative humidity above 80% is likewise uncomfortable. Therefore, appropriate ventilation needs to be considered at all stages of the retrofit. For more details on this aspect, see the HES Technical Paper 12: Indoor Environmental Quality in Refurbishment.

While having high levels of airtightness is not a direct objective in a HES retrofit, reducing air leakage in and out of the building is clearly necessary. This can be achieved by the combined effects of various measures – floor insulation, window and door draught-stripping, wall insulation and the temporary closing of hearths (such as with chimney balloons). Such an approach was taken at Holyrood Park Lodge, and airtightness testing (Figure 9) showed that an improvement of 30% was achieved after the works.

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Figure 9: An air pressure test taking place at Holyrood Park Lodge before the interventions.

While mainly passive ventilation is the desired approach in traditional building refurbishment, building regulations oblige a degree of mechanical ventilation to bathrooms and kitchens. Also, some older buildings, particularly small ones, will not have sufficient cross ventilation or internal volumes to allow the full dispersal of water vapour. Other buildings may also have been poorly converted in the past, with internal kitchens or bathrooms added without proper thought for their ventilation. In such cases, some additional capacity may be needed. In one case study, a humidity-controlled extractor fan was installed at the top of a stairwell to manage the removal of warm, wet air coming up from around the property (Figure 10). In the past, the openable stairwell skylight allowed this to be done manually, but in this case an automatic feature was preferred by the client.

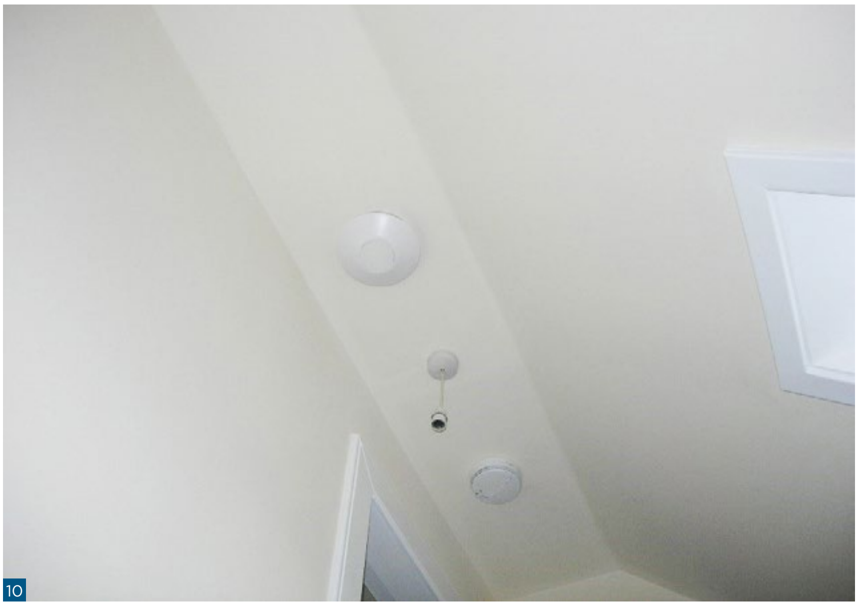

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Figure 10: Humidity-controlled extract ventilation used in a HES case study to manage excess moisture.

8. MOISTURE IN BUILDINGS

The internal moisture load within domestic buildings can be significant. Drying clothes, breathing, bathing/showering and cooking, amongst many other activities, can introduce significant amounts of moisture vapour into the internal environment of a building. Where moisture vapour comes into contact with a cold surface, it will condense, forming surface condensation. There is also the possibility of this moisture vapour coming into contact with a cold surface between two parts of a building envelope; for example, where insulation abuts a masonry wall. Where condensation forms between two parts of a building envelope or, indeed, within part of a building envelope, such as in the centre of a mass masonry wall, what is termed 'interstitial condensation' will occur. Moisture condensing on the surface of or within the building fabric is inevitable within a traditionally constructed building; this is how the building is designed to work, as summarised in Figure 11. What is important to the long-term condition of building fabric is that the condensation moisture can diffuse out of the building fabric. If any of the routes shown in Figure 11 are inhibited, then vapour will concentrate and condense, causing dampness. Similarly, if materials are used which inhibit that diffusion of moisture, it may well become trapped within the building fabric. When this occurs, that moisture can lead to decay mechanisms, especially in timber.

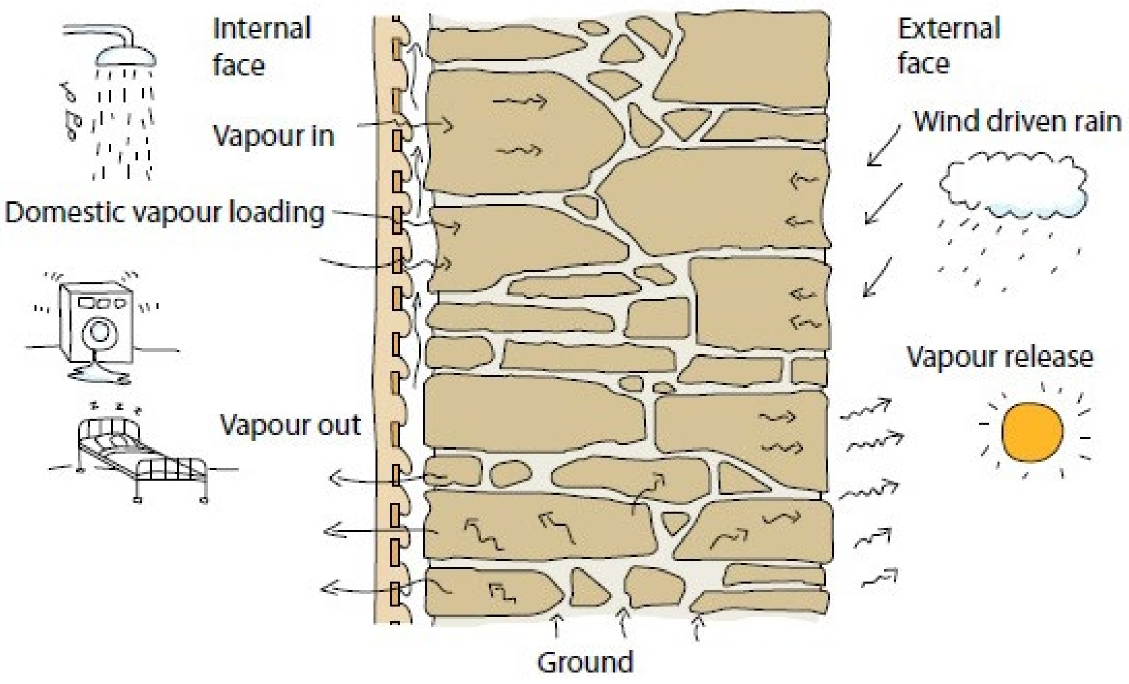

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Figure 11: A simplified version of water vapour movement in a mass masonry wall.

8.1 A 'BREATHABLE' CONSTRUCTION

Traditional buildings are often referred to as having 'breathable construction'. This acknowledges the fact that the materials used for their construction have the ability to absorb and release moisture. Moisture movement within building materials is a complex area of consideration. There are many individual dynamics within what is termed 'breathable construction': **moisture vapour permeability**, for example, refers to the ability of a material to allow water vapour to diffuse through it; **hygroscopicity** is the ability of a building material to absorb, retain and release moisture; **capillarity** refers to the absorption, desorption and movement of water as a liquid. These different dynamics rely on various material properties, such as pore structure, within stone and brick.

Whilst this cannot be covered in detail in this guide, other sources of more detailed information are included in the 'further reading' section. These material properties are of benefit when seeking to buffer the peaks of humidity created through the daily tasks of occupation. Exactly how much water vapour is moved through component materials of a traditional building, and at what rate, will depend on the type of stone or brick from which the wall is made, the voids in the wall, and the external condition of the masonry. In retrofit work, using materials and construction methods that are appropriate for traditional buildings will ensure that energy efficiency improvements are technically compatible with the building fabric and will therefore reduce the risk of damage from inappropriate interventions. Furthermore, such compatibility will ensure that the upgrades are durable and long lasting.

HES refurbishment case studies have supported the use of vapour and capillary active materials to control internal humidity and prevent moisture build-up. This is shown through the monitoring of moisture levels in a number of projects. In one of these projects, at Holyrood Park Lodge, relative humidity values varied significantly before the interventions, mainly due to the building being underheated. However, monitoring has shown that, post-refurbishment, the west wall behaves much as traditional walls behave in heated buildings, with a much lower relative humidity level. These relative humidity levels are an improvement to both the internal environment and the wall conditions, showing that the insulation had indeed a positive impact. A representative graph of humidity through the wall section, including within the insulation, is shown in Figure 12.

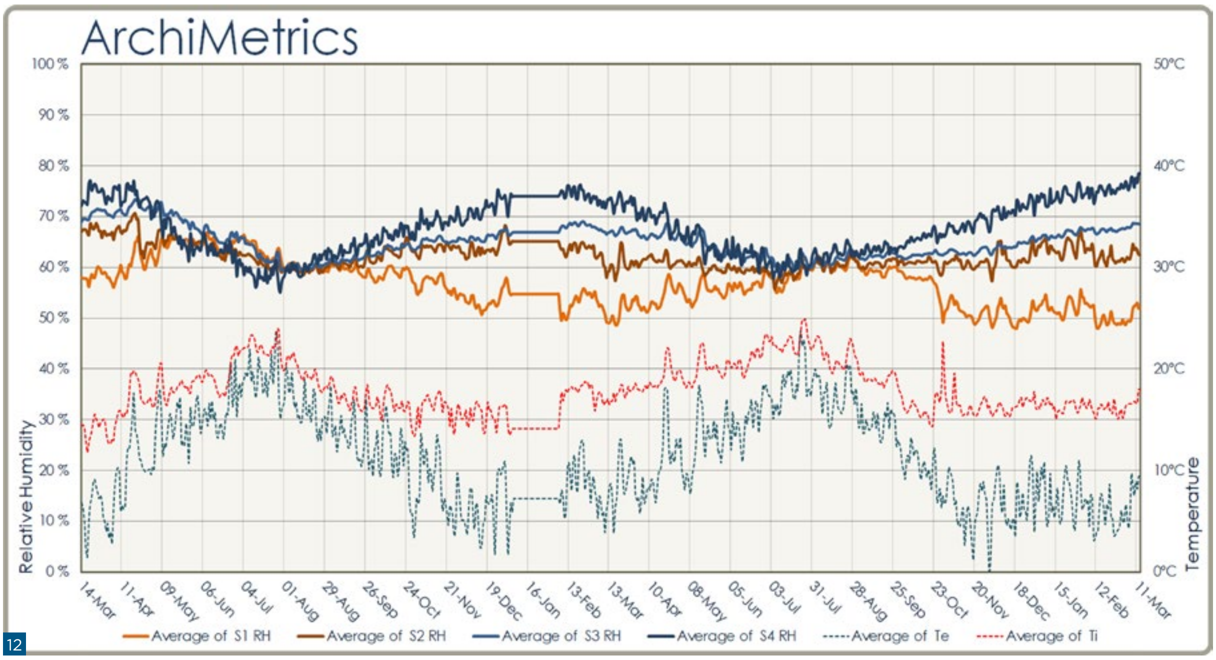

Figure 12: Extensive moisture monitoring from the Holyrood Park Lodge case study has demonstrated the successful use of vapour permeable insulation in traditional buildings. Four combined temperature and RH sensors were placed at various depths of the wall, with S1 being in the insulating cellulose fibre layer and S4 closer to the external wall face. Image © ArchiMetrics

The wrong materials and inadequate ventilation can lead to condensation and mould growth, as seen in Figure 13. Energy efficiency improvements that utilise materials which are impermeable to moisture are less able to buffer humidity and can result in moisture being unable to dissipate from building fabric. If this is combined with the blocking of ventilation pathways, the potential for long-term decay of building fabric is considerably increased.

Figure 13: Vapour impermeable materials and a lack of ventilation have led to significant mould growth on internal surfaces in this building.

8.2 HYGROTHERMAL MODELLING

The movement of water vapour in a building element and the problems it can sometimes cause is called hygrothermal risk. Designers and specifiers are required to take account of hygrothermal risk. To do this, various software packages are available. Simple modelling uses a tool called the Glaser method to establish the dew point in the walls and consequent condensation risk. More advanced modelling can use packages such as WUFI®, which gives more accurate results and is a better hygrothermal modelling tool for use on traditionally built structures. Here, the calculations are more complex and require a range of input values for the stone and mortar concerned. To provide these values, HES has conducted tests to establish the basic hygrothermal properties of selected materials, which can be used for calculations and are available in Technical Paper 37. For further considerations of hygrothermal modelling and building physics, see Technical Paper 15.

8.3 MOISTURE AND DECAY

The majority of decay mechanisms which affect traditional buildings are driven by moisture. Mould growth, for example, requires moisture to thrive. Insect pests which affect timber require high levels of moisture in order to live and breed. Masonry decay, such as efflorescence or spalling of brickwork, also requires the presence of moisture. This moisture can come from many sources. Much moisture concentration from defective or incorrectly maintained fabric is misdiagnosed as a hygrothermal problem; in many cases, it is simply water coming into the building. For more on this see the HES Inform Guide: Damp: Causes and Solutions and Short Guide 11: Climate Change Adaptation in Traditional Buildings.

In the context of this guide, it should be noted that moisture from both interstitial and surface condensation can lead to decay within the fabric of traditional buildings. For that reason, it is important that any efforts to improve the thermal performance of a traditional building take moisture and condensation into account.

9. AREAS FOR FABRIC INTERVENTION

After consideration of the various factors above, there is what might be described as a suite of measures for traditional buildings that have been extensively trialled and shown to give good results in terms of thermal performance, hygrothermal suitability and consequent EPC rating. These measures will be described in detail in the following sections, but Figure 14 gives a summary approach for a small cottage of a type common in Scotland. While a cottage is shown, the same basic approach could equally apply for a larger building.

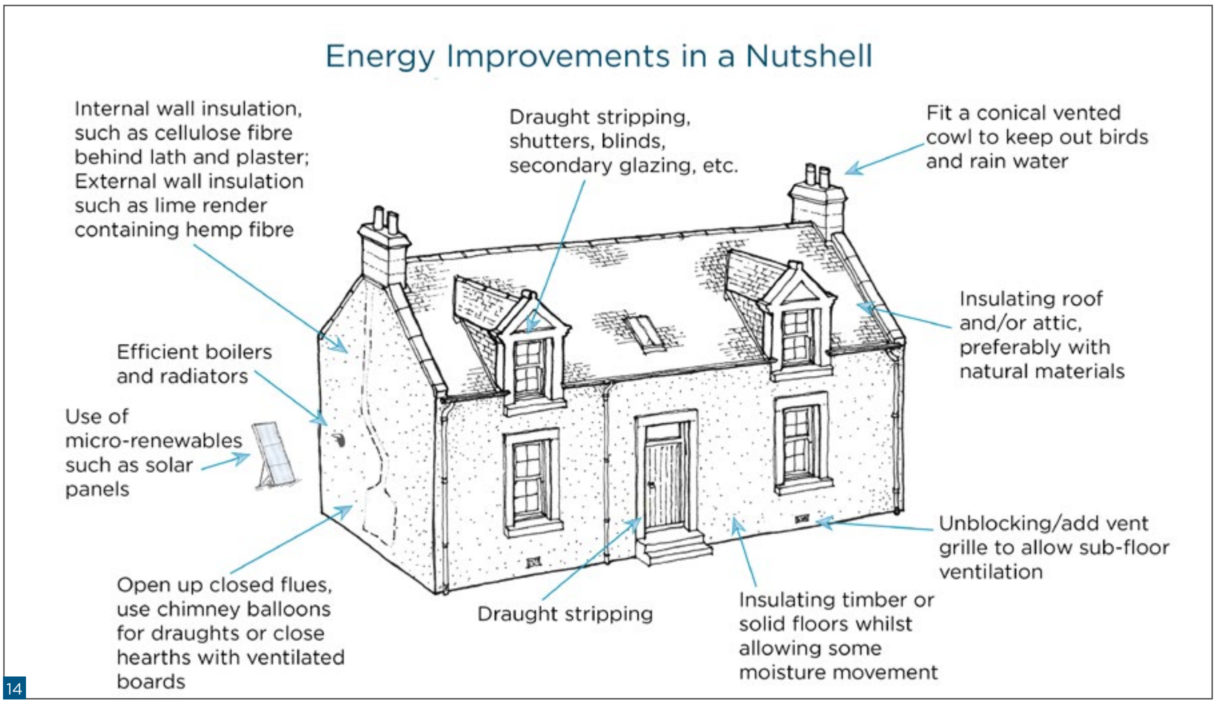

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Figure 14: Summary drawing of fabric upgrade measures for a traditional building. Image © John Gilbert and HES

Exactly what needs to be done will depend on the situation, but the measures are set out in priority order. A summary table is shown at the beginning of each section below to give an overview of the measures for each building element.

9.1 RETROFIT IN ROOF SPACES

Typically, around 25% of heat is lost through the roof of a building. Therefore, roof insulation is a common and effective means of reducing heat loss. Broadly, there are two approaches to roof insulation: insulating at ceiling level, which creates what is termed a cold roof space, or between the rafters, creating a warm roof space. These approaches, along with how to insulate less common roof types, are described in detail in this section.

Roof insulation	Pre-intervention U-values (W/m²K)	Post-intervention U-values (W/m²K)	% Improvement
Sheep's wool insulation, 280mm	1.4	0.2	86%
Hemp insulation, 250mm	1.5	0.2	87%
Polystyrene beads, blown into cavity behind coom	1.5	0.4	73%
Wood fibreboard, 50mm, to coom	1.6	0.8	50%
Wood fibreboard, 100mm, to ceiling	1.9	0.4	79%
Aerogel, 10mm, to dormers	1.7	1.2	29%
Wood fibre insulation, 200mm	1.3	0.2	85%
Sheep's wool insulation, 240mm	1.6	0.4	75%
Bonded polystyrene beads, blown into cavity behind coom	1.9	0.4	79%
Wood fibreboard insulation, 80mm, to dormers	0.45	0.37	18%
Aerogel, 11mm, applied to inner face of existing plaster finishes (average U-values)	0.49	0.32	35%
Wood fibreboard insulation, 100mm, (average U-values)	1.0	0.14	86%
Wood fibreboard insulation, laid over attic floor	4.0	1.1	73%

Table 1: Range of roof insulation types and performance improvements. (Source: HES Refurbishment Case Studies and Technical Paper 24.)

9.1.1 Loft insulation (cold roof)

When insulating a roof, it is important to assess what the fabric build-up is above the sarking. If there is a vapour barrier present (such as a bitumen under slate felt), consideration should be given to providing ventilation in the roof.

For loft insulation, there are recommended thicknesses of material, and for most open-fibre materials, such as sheep's wool, 280mm is recommended. How this is laid out depends on whether the attic space is to be used. If it will not be used, then the material can be laid between the joists and a second layer laid over the joists at right angles to this. This approach creates what is termed a cold roof. If a deck or flooring is required, then the additional height is achieved by adding an extra joist to carry the decking above (Figure 15); this is generally the approach taken by most insulation installers.

In HES case studies, a vapour permeable and hygroscopic material has consistently been used to ensure effective humidity buffering and moisture management. Materials used in this context include rolled materials, such as sheep's wool; board-based materials, such as hemp and wood fibreboard; and loose fill materials, such as cellulose. Generally it is easier to use materials supplied in flexible rolls, which may also result in a tighter fit between ceiling joists.

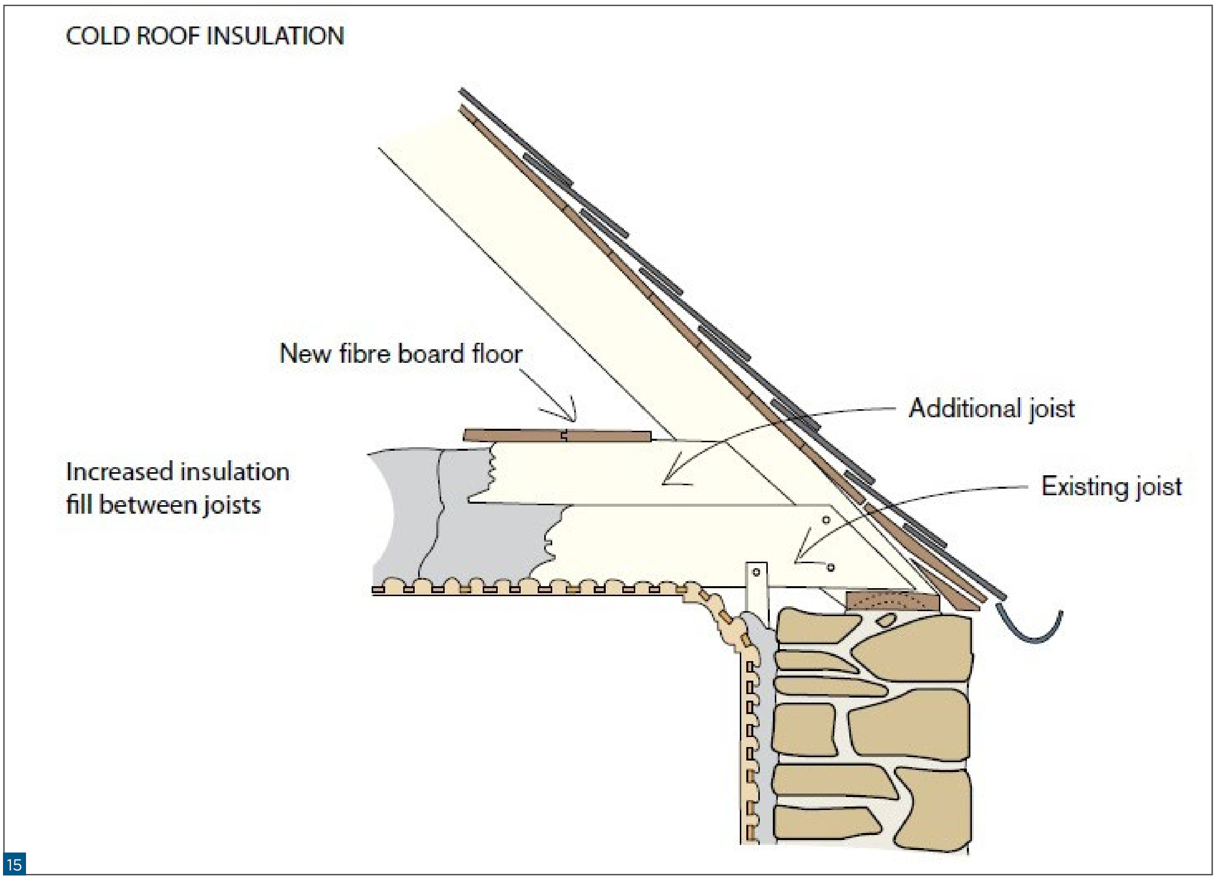

Figure 15: Technique for standard loft insulation with a new floor. Note the ventilation route left at eaves level, between the insulation material and the rafters.

Although every installation will yield different results, these case studies have shown strong improvements in thermal performance through loft insulation. In one project, sheep's wool insulation improved the U-value from 1.4 to 0.2 (Figure 16), and in a separate case study, wood fibre insulation between ceiling joists resulted in an improvement from 1.5 to 0.2 (Figure 17). These represent substantial improvements in the performance of a roof space. In another case study, wood fibreboard laid over an attic floor resulted in a U-value improvement from 4 to 1.1: again, a significant improvement in performance.

It should be noted here that the installation of any new roof insulation should overlap with any insulation in the external wall, so as to maintain the continuity of the insulation line around the perimeter of the building and avoid cold bridges. The access hatch to a loft space should also be insulated and draughtproofed to prevent warm, moist air rising in bulk into the roof space and condensing.

16

Figure 16: Sheep's wool insulation laid between rafters at Edinburgh Castle. Note the accommodation and fastening of wiring above the insulation.

17

Figure 17: Wood fibreboard laid between ceiling joists.

Consideration should also be given to electrical wiring in the roof space, as seen in Figure 17. The safest and neatest approach is to route electrical cables above the insulation material to allow easy inspection and access. In all cases, it is advised to consult a qualified electrician as part of any retrofit work to ensure safety.

To allow ventilation into the roof spaces, a 50mm gap should be left between the termination of the insulation and the start of the pitch of the roof close to the wall head. Additional ventilation may be required following the installation of loft insulation, especially if the roof has bituminous roofing felt under slates (Figure 18). This most commonly takes the form of slate vents placed at intervals along a pitched roof. If additional ventilation is required, it should have as minimal a visual impact as possible and can be achieved through vents at the eaves or on the ridge. Vents on the main roof pitch are also possible, with various types available to minimise visual impact.


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Figure 18: Low-profile roof vents on a slate roof following an upgrade to the roof space.

9.1.2 Insulating roof slopes (warm roof)

Roof spaces may be also be insulated by putting the insulation between the rafters; this results in a warm roof space. This might be useful if warmer attic space is required. If there are no existing linings in the roof space, the technique is simple, and insulation may be cut to the width of the rafters and held in place with timber battens fastened to the side of the rafters, as shown in Figure 19.

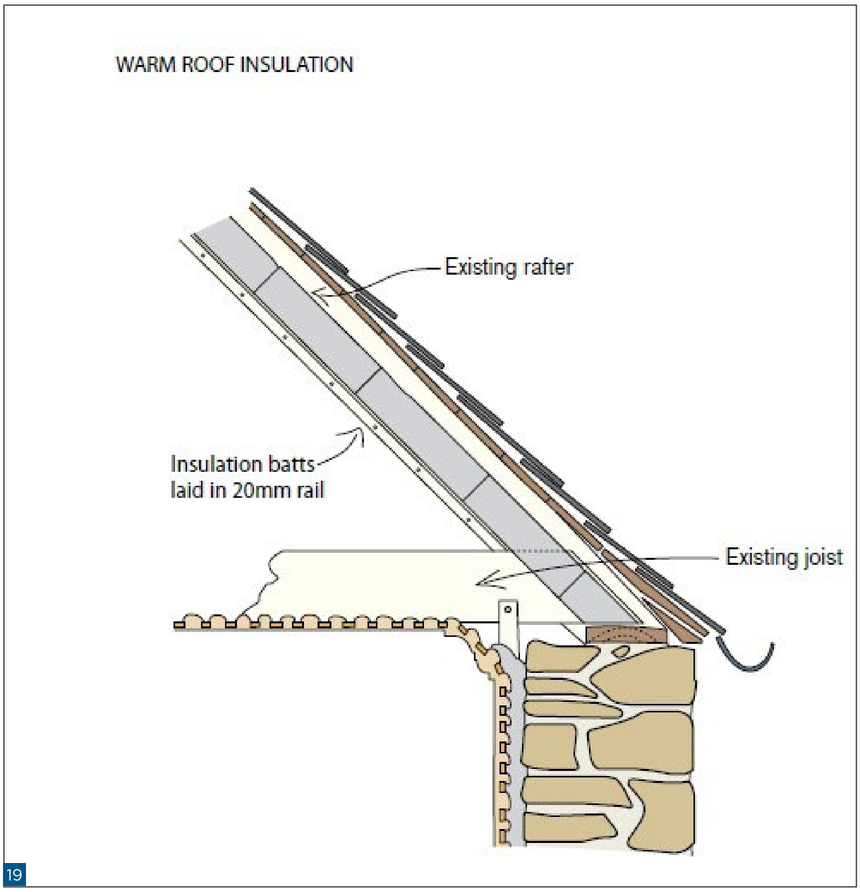

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Figure 19: Insulation of roof slopes installed between the rafters, giving a warm roof.

In order to best manage water vapour movement, a vapour permeable material should be used for insulation. For ease of working, a board-based material or semi-flexible material, such as hemp batts or wood fibreboard, might be most suitable (Figure 20).

Figure 20: A roof slope insulated with wood fibreboard between the rafters.

Any materials used should fit snugly between the rafters to avoid gaps and it is best that they are cut in a workshop or in the open air due to to avoid the risks of generating dust in the enclosed space. In Scotland, most rafters are of sufficient depth to give room for adequate insulation. However, if the rafters are not deep enough for the desired thickness of insulation, they may be deepened by attaching timber straps to the bottom edge. If some form of lining is required, the timber baton holding the insulation may be omitted and the insulation held in place by the plasterboard or other lining. Where there are original linings in the attic space, the guidance for coom ceilings in the section below should be followed.

An air gap of approx. 50mm is generally left between the insulation and the sarking boards to allow a degree of air movement. Traditionally, roofs often incorporated ventilation into their construction by the inclusion of a 'penny gap' between each sarking board. This allows air to circulate throughout the roof structure, ensuring dispersal of any water which may fall under the slates in extreme conditions or where a defect has occurred. The use of bitumen-based underfelt in the post-war period has contributed to less draughty attics, but such attics will need additional ventilation when insulation work is carried out. Some modern roofing membranes give a vapour control layer that allows the passage of vapour while minimising air leakage. If such materials are properly specified, roof vents are not required; however, care should be taken to fully assess the ventilation of a roof space that is being insulated.

Some roofs are open to the inside and might be lined. This is occasionally found in workshop space or church buildings. If the roof is being re-slated, an aerogel blanket laid on top of the sarking can also be an option. This gives a good thermal barrier, as well as cushioning the slates (Figure 21).


21

Figure 21: An aerogel insulation blanket laid on top of the sarking.

9.1.3 'Room in the roof' or coom ceilings

What are termed 'rooms in the roof' are a feature of many Scottish buildings. They are formed when a building has an upper storey where the ceiling is partially, or in some cases fully, part of a pitched roof. This ceiling is commonly referred to in Scotland as a 'coom ceiling'. Whilst not as easy to insulate as a more accessible loft, there are likely to be considerable benefits in making the effort to properly insulate these ceilings.

There are three areas to address in the room in roof. First, there is the short vertical wall which will often rise from the wallhead and which can be insulated in a similar way to a situation where internal wall insulation is installed. A gap should be left, however, to allow air flow from the eaves; therefore, using a board-based insulation framed out from the wall is likely to be the most suitable option.

Then there is the sloped area of coom ceiling and the short flat section, which is often found forming in effect a very shallow 'loft' type space close to the apex of the roof. Access to the space at the apex of the roof is necessary when insulating these areas. This is often found in the form of a small trapdoor. If there is no such access, it will have to be formed. The separation of the rafters should be measured, and sections of insulation material cut to that width. These short sections are taken into the space and slid down into the void between the coom ceiling lining and the sarking board.

As with rafter insulation, a 50mm air gap should be left between the underside of the sarking and the top of the insulation material. If access is difficult, it may be necessary to remove existing ceiling linings, insulate between rafters and the flat area at the apex, and then reinstate the former linings or fit new linings. Sometimes the insulation material can be eased down the coom by using a plastic sleeve or cover to prevent hanks on wood burrs and other small obstacles. The small ceiling is insulated in the normal way described in the sections on cold roofs above. An indicative diagram showing this is Figure 22.

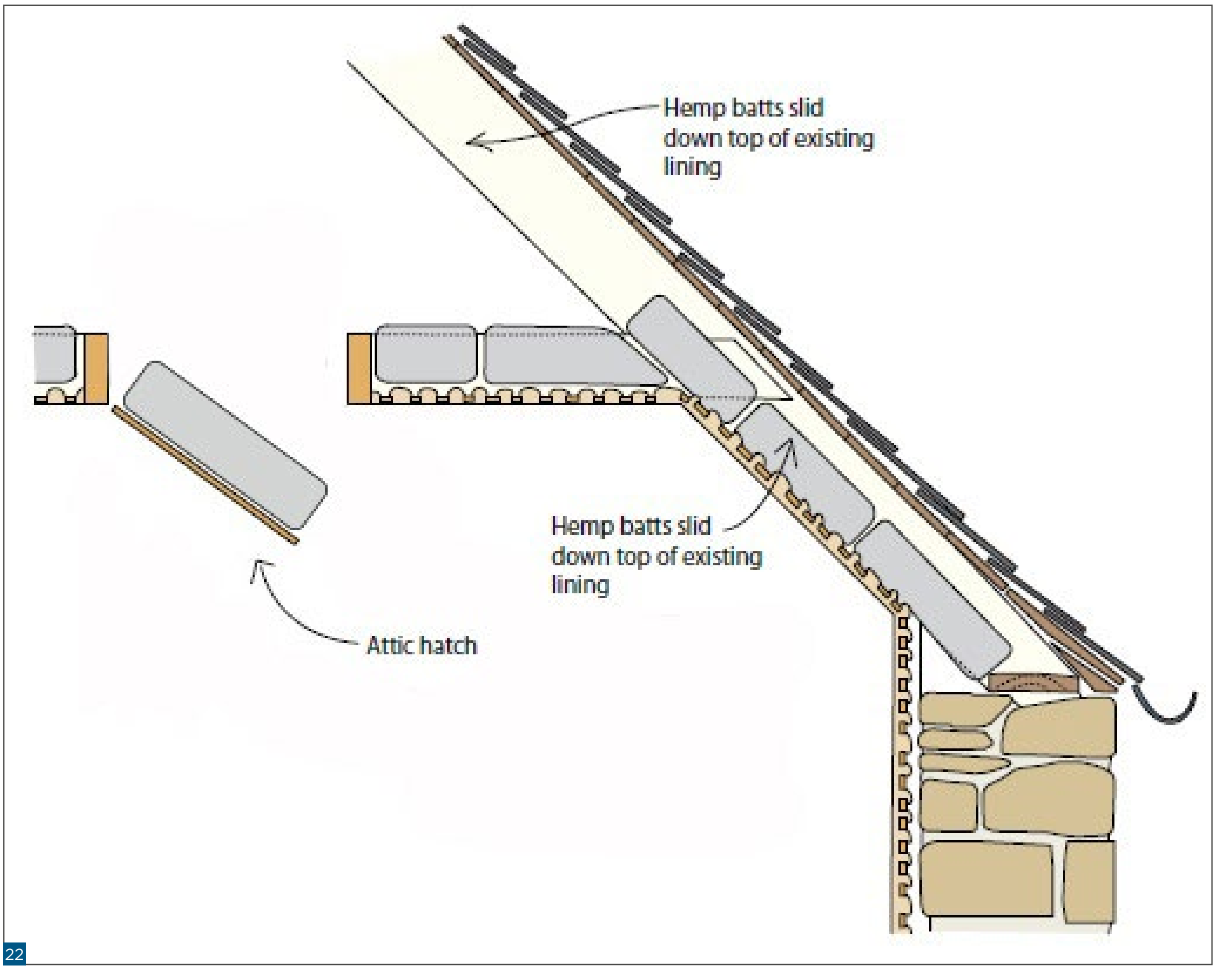

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Figure 22: Technique for insulating 'rooms in roofs' or coom ceilings.

HES case studies have achieved some significant improvements in 'room in the roof' and coom ceiling situations. In one building (Refurbishment Case Study 20), a U-value improvement from 1 to 0.13 was achieved in the attic coom, and in a second building (Refurbishment Case Study 6), an improvement in a room in the roof using 50mm of wood fibreboard inserted behind an existing timber ceiling lining saw an improved U-value of 0.8 achieved (Figure 23).


23

Figure 23: Wood fibreboard used behind an existing timber lining on a coom.

9.1.4 Dormer windows

A further feature of buildings with 'rooms in the roof' is dormer windows which project from the roof structure. These are particularly common when rooms are used as bedrooms. By their exposed nature, they can be a considerable source of heat loss. There are various options to retrofit dormer windows to improve thermal performance, as seen in Figure 24. The sides of the dormer, commonly called 'cheeks', will typically require a thin insulation board to be applied, as space is limited. One option would be to use an aerogel blanket insulation, which is available in either 5 or 10mm thicknesses. Wood fibreboard can also be used to improve the cheeks and ceiling of dormer windows in a similar way. The small area of the dormer ceiling should be insulated in the normal way and is often accessible from the roof space above. See Refurbishment Case Study 16.

Although every building will be different and will give different results, in one HES case study the U-value of a dormer cheek was improved from 1.7 to 1.2 by using aerogel insulation.

Figure 24: Insulation work to a dormer using wood fibreboard.

9.1.5 Insulating flat roofs

Insulating a flat roof presents a number of technical challenges. The methods and materials used should be carefully considered prior to any work taking place. Flat roofs generally have some degree of slope, usually around a 1 in 60 incline, which is a standard detail to prevent water pooling on the surface of the roof. Traditionally, flat roofs were covered in metal, most commonly lead, although zinc and copper are also sometimes used, with bituminous coverings becoming common on flat roofs from the mid-19th century onwards. When insulating flat roofs, in particular those covered in a metal material as seen in Figure 25, it is important to reduce the risk of condensation by maintaining clear ventilation through the provision of suitable vents to the outside. Otherwise there may be condensation on the underside of the roof covering, with consequent corrosion of the metal and decay in roof timbers.

When insulating flat roofs, the insulation is usually placed between the joists supporting the sarking boards, or ‘decking’, as it is often termed in flat roofs (Figure 26). This might require removal of all or part of a ceiling internally to allow the fitting of the insulation between joists. A rigid vapour permeable insulation material can then be installed between the joists close to the new ceiling linings, either reinstated lath and plaster or a modern alternative. The underside of a flat roof should be ventilated and a consistent, unobstructed pathway for air of at least 50mm in depth should be provided. This technique entails considerable disruption and loss of original material in the ceiling and should be considered carefully. Where ceiling heights allow, it may be possible to apply insulation directly to the existing ceiling, finished with a new lime plaster ceiling over the insulation; although an assessment of the structure of the existing ceiling will be required and additional ventilation will still be a consideration. An alternative method of installing the insulation between joists is to remove the roof covering to allow access from above. This is only likely to be practical when the roof covering is to be renewed.


25

Figure 25: Where a flat roof is covered in lead or other metal, care is required not to cause conditions on the underside that lead to corrosion following retrofit.


26

Figure 26: A typical underside of a flat roof.

9.2 INSULATING FLOORS

A cold floor can absorb heat and, in the case of suspended timber floors, can introduce cold air from below the floorboards, significantly affecting thermal comfort. The thermal performance of both suspended timber and solid floors can be improved as described below, although in the case of solid floors, this can involve considerable disruption. Suspended timber floors typically lie 300 to 500mm above the solum and are carried by timber joists, either in a clear span or sometimes supported by sleeper or dwarf walls. Effective insulation is best installed below a timber floor and, as with loft insulation, a vapour permeable material should be used to avoid accumulation of moisture or raised humidity in the void. Hemp and wood fibreboard insulation have been shown in HES case studies to be appropriate for the insulation of suspended timber floors.

Floor insulation	Pre-intervention U-values (W/m²K)	Post-intervention U-values (W/m²K)	% Improvement
Wood fibre insulation, 80mm	2.4	0.7	71%
Aerogel, 30mm, to existing solid floor	3.9	0.8	79%
Wood fibreboard insulation, 80mm	4.0	1.0	75%
Insulated lime concrete, 100mm, laid over underfloor heating pipes	4.0	0.5	87%

Table 2: Range of floor insulation types and performance improvements.
(Source: HES Refurbishment Case Studies and Technical Paper 24.)

9.2.1 Insulating suspended timber floors

The approach with floors is largely dictated by access and quality of the existing floor material. If the floor is accessible from below with a reasonable crawl space, a stiff or semi-rigid insulation material can be fixed directly between the joists with timber batons or a softer, more flexible material held in place by a net fixed between the joists. This allows the floor timbers and floorboards to remain undisturbed. However, even if there is a crawl space, consideration should be given to the working conditions and the health and safety of those doing work in confined spaces. Where such access is not possible, it will be necessary to lift the floorboards to install the insulation.

At this stage, it may be decided that disruption and potential damage means the work should not be carried out. This might be the case where there are timber floors with a complex layout or an additional covering on top, such as parquet. Most timber floors can be lifted and, if started from the right end, damage to boards can be minimised (due to the angle of the nailing) and they can then be set aside for relaying. Timber runners are then fastened to each side of the joists (Figure 27).

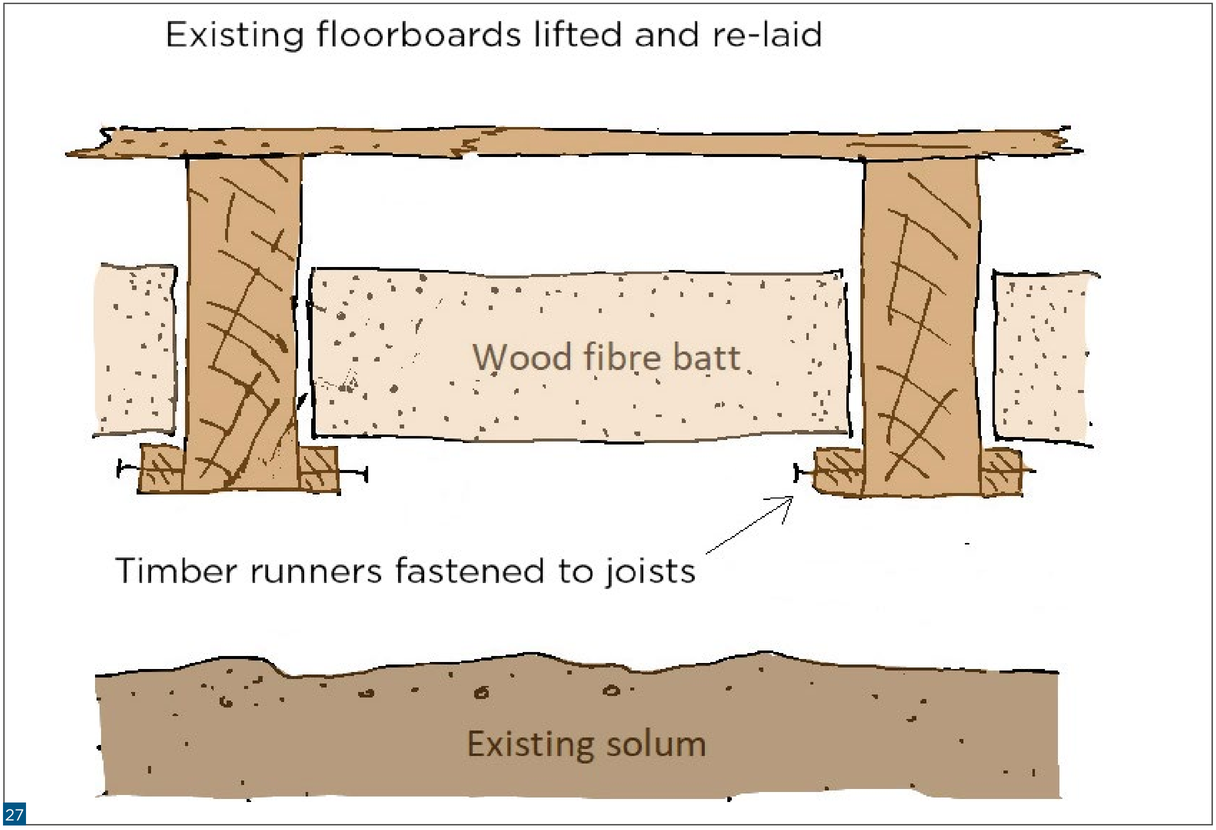


Figure 27: Indicative drawing showing the arrangements for a wood fibreboard on a suspended timber floor.

The board should be cut to ensure a snug push fit and the cutting is sometimes best done outside. With a snug fit, sufficient air control is achieved without the use of additional materials. In any event, absolute airtightness is not necessarily needed. The lifted boards are then refastened, as shown in Figure 28. Older flooring timber is generally of a better quality than new and a good finish can be achieved (Figure 29).

Figure 28: Relaying a timber floor once the insulation is in place.

Figure 29: A relaid floor can be finished to a high standard.

In HES Refurbishment Case Study 2, by using 80mm of wood fibreboard, the U-value of the floor improved from 2.4 to 0.7. During such work, it is prudent to check the integrity of the masonry and mortar around the joist ends as well as also the condition of the timber joist ends themselves. Any voids or areas of missing mortar should be pointed up to ensure structural integrity and reasonable airtightness. If floor joists are found to be suffering decay, the source of the moisture which is causing this should be rectified and the floor joists repaired prior to insulation work taking place.

In a further case study, it was found that the lifting of every sixth floorboard allowed sufficient access to fasten batons to the sides of the floor joists and the fitting of insulated board. This considerably reduced disruption and potential damage to floorboards. When insulating a suspended timber floor, electrical cables should be tidied up. They can also be put into conduits, to allow for easy rewiring at a later date and reduce the risk of rodent damage. All suspended timber floors require free movement of air through the solum void, and especially so if the floor has been insulated and the void is consequently colder. To allow this free air movement, the outside ground level should be below the ventilation grilles in the masonry. Similarly, any corrosion, accumulated paint or vegetation that might block the airflow should be removed prior to insulation work taking place.

9.2.2 Insulating solid floors

An old solid floor is often a source of cold and discomfort and many solid floors are made of uninsulated concrete which can cause dampness in traditional walls. The thermal upgrade of such a floor can, therefore, address thermal comfort and building condition. Some solid floors will be tiled or flagged, so intervention may not be possible. However, where a floor is required to be lifted for another reason or where original features have been lost and there is a modern material, insulation will improve the thermal performance. This can be achieved either through fixing an insulated board on top of the existing floor or by excavating and laying a new insulated lime concrete floor in its place. A thin but high-performing insulating board fixed on top of a concrete floor can greatly improve thermal performance (Figure 30).


30

Figure 30: Aerogel board being laid onto a concrete floor. Image © Changeworks

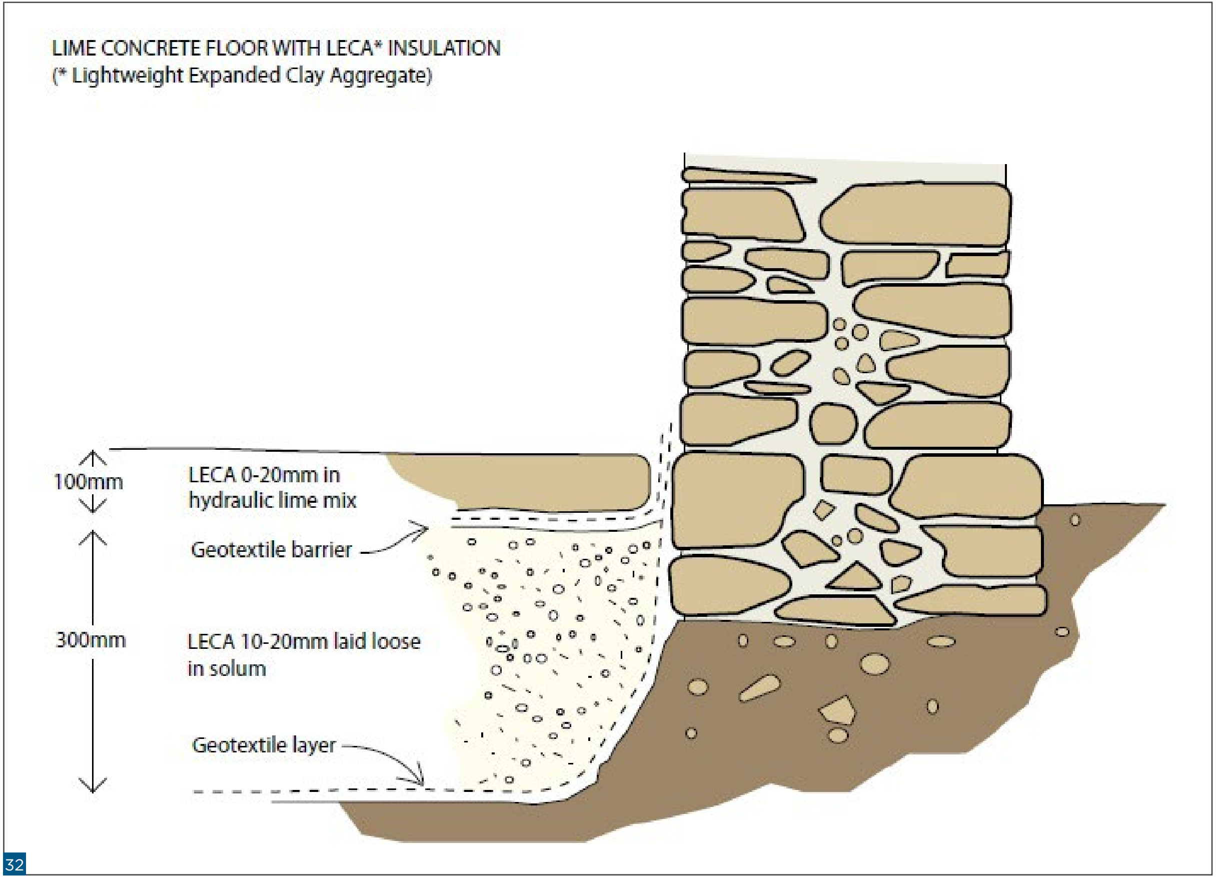
For example, in HES Refurbishment Case Study 6, the use of 30mm aerogel board gave an improvement in U-value from 3.9 to 0.8. Aerogel board can be supplied in various thicknesses and then cut to size and fixed with adhesive. The base of doors will usually require to be trimmed, resulting in some loss of fabric. Skirting boards should be removed and reinstated a little higher, so as to allow full coverage of the insulation, and a new floor covering will need to be laid over the insulated board.

Older concrete floors are often replaced with an insulated version of the same, using a phenolic foam to give a thermal barrier. However, whilst thermally effective, this is not vapour permeable and could, therefore, lead to water concentrating in the base of a traditional mass masonry wall. Replacing a concrete floor with an insulated lime concrete floor retains the ability to absorb and release moisture whilst improving both the thermal performance and the general health of the building. Lime concrete floors have proved to be a good base for underfloor heating systems, and there are a range of suppliers who give specifications for the concrete work and the heating coils that go in them. In one HES case study (Refurbishment Case Study 22), a ground source heat pump was connected to an underfloor heating coil bedded in an insulated lime concrete floor (Figure 31). In this case, a U-value improvement from 4.0 to 0.5 was achieved.

Lime concrete floors vary in detail depending on the supplier and the specification, but generally, the solum is excavated and the material is replaced with an insulating material such as lightweight expanded clay aggregate (LECA) pellets or foamed glass aggregate. This type of make-up is shown in Figure 32.

31

Figure 31: Coils for an underfloor heating system laid on top of a lime concrete floor. The heating is powered by a ground source heat pump. Image © Callum Innes



32

Figure 32: Outline detail for a lime concrete floor.

Once laid, lime concrete will need to cure and be protected from frost and impact damage, normally for at least two weeks. When the lime concrete has cured it can be polished to a finish, or a floor covering, such as flagstones bedded in lime mortar, can be laid. A lime concrete floor is a good base to put in a heating coil, often used with a heat pump, which can sit under the floor finish; flagstones can be a good finish for this type of surface (Figure 33).


33

Figure 33: A flagstone floor relaid on a lime concrete heated slab.

9.3 IMPROVING TRADITIONAL WINDOWS

Sash and case windows are extremely durable and, if maintained correctly, they can last in excess of 100 years, with many timber windows in Scotland in their second century of use. However, traditional glazing is commonly considered draughty or inefficient and, therefore held responsible for significant heat loss from buildings. Whilst much of the draught can, in fact, be convection downdrafts from air contact with the cooler glass, a single glazing pane is indeed not a good insulator, with a U-value of around 5.5.

From a conservation and sustainability perspective, the existing window fabric (timber frames) should be retained wherever possible; however, many improvements can be made to the thermal performance of a window without negatively affecting its fabric or appearance. HES has used a range of tests to assess the thermal benefits of specific interventions, which can be carried out to make traditional windows more thermally efficient. The results of these case studies are presented in detail in Technical Paper 1: Thermal Performance of Traditional Windows, and summarised in Table 3 below, which gives an overview of the range of improvement measures that can be carried out.

Improvement method	Reduction in heat loss	U-values (W/m²K)
Unimproved single glazing	-	5.5
Fitting and shutting lined curtains	14%	3.2
Closing shutters	51%	2.2
Modified shutters with insulation set into panels	60%	1.6
Modern roller blind	22%	3.0
Modern roller blind with low emissivity plastic film fixed to the window facing side of the blind	45%	2.2
Victorian pattern roller blind with plain fabric	28%	3.2
A 'thermal' honeycomb blind	36%	2.4
Victorian blind and closed shutters	58%	1.8
Victorian blind, shutters and curtains	62%	1.6
Secondary glazing system	63%	1.7
Secondary glazing and curtains	66%	1.3
Secondary glazing and insulated shutters	77%	1.0
Secondary glazing and shutters	75%	1.1
Double glazed pane fitted in the existing sash	79%	1.3
Secondary glazing, double glazed with aluminium frame to existing single glazed timber sash and case	85%	0.8
Secondary glazing, double glazed with timber frame to existing single glazed timber sash and case	88%	0.6
Secondary glazing, single glazed with timber frame to existing single glazed timber sash and case	71%	1.5
Aerogel, 10mm, blanket fitted to timber window shutters	82%	0.4
Polycarbonate secondary glazing held with magnetic strips	56%	2.4

Table 3: Results of U-value testing for improvement measures to sash and case windows.

9.3.1 Shutters, curtains and blinds

Traditional options for reducing heat loss through windows, such as blinds, curtains and shutters, can result in a significant reduction in heat loss with no impact on the existing window fabric. Shutters alone can reduce heat loss by 51%, with a HES trial achieving a U-value of 2.2. A combination of these options can reduce heat loss by as much as 62%, only 1% less than through the installation of secondary glazing. While this will result in reduced light levels when the shutters are closed, the lowest external air temperatures and the period of greatest occupancy is generally at night. Roller blinds, as shown in Figure 34, were commonly fitted to windows in the 19th century and in many buildings the original brass fittings are still present in the top corner of the sash case. These blinds allowed privacy during the day, reduced penetration of sunlight and also helped to retain heat. If original fittings remain, these can be reused with new fabric. Alternatively, new roller blind mechanisms can be installed with little damage to the existing window fabric in a range of modern materials with varying thermal properties.

Full-length, lined and well fitted curtains can control draughts and reduce heat loss by up to 14%. Curtains have no impact on existing window fabric, although care should be taken to ensure they do not obstruct radiators.


34

Figure 34: Traditional pattern roller blinds can help reduce heat loss through a window.

Commonly found in older buildings, timber shutters can reduce heat loss through windows by up to 51%. Due to cost, however, many buildings were not constructed with shutters and have imitation fielded panels made to look like shutters instead. Restoring shutters which have been painted closed is generally straightforward. The benefits are considerable, as thermal imaging can reveal (Figure 35).

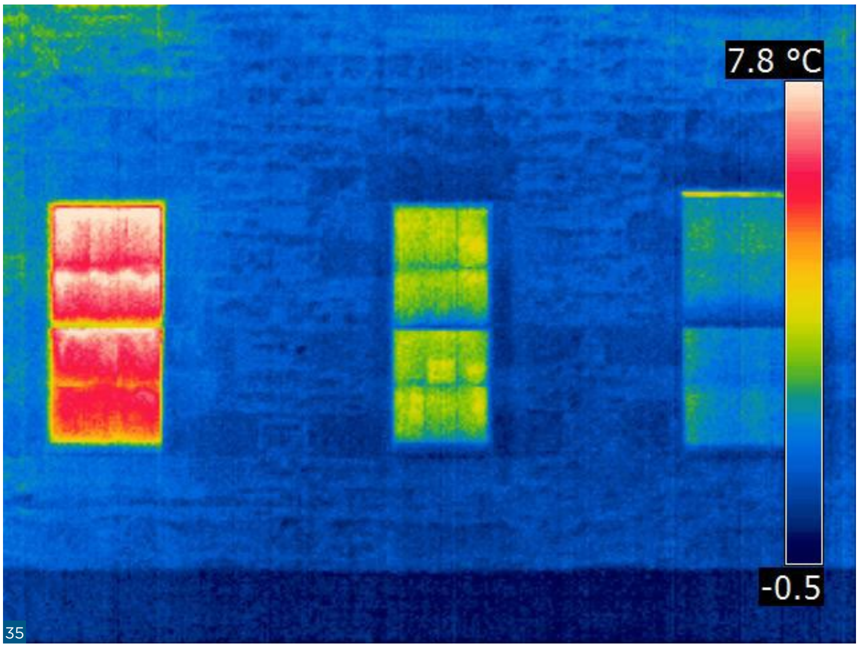


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Figure 35: the middle window has shutters, clearly showing a reduced heat loss in comparison to the window on the left.
© Changeworks

The thermal performance of shutters can be further improved by applying a thin layer of insulation, such as aerogel blanket, which in a HES case study resulted in a 60% reduction in heat loss. Such insulation can be fixed to the internal panels of the shutters and overlain with a thin layer of plywood and new timber beads before painting. Where shutters have been removed but the framing and housing remains, a new shutter can be made using traditional joinery techniques, such as mortice and tenon joints with fielded panels, or by quicker modern techniques. If there is no housing or shutter case, a shutter can be fixed directly to the sash case, as sometimes seen in basements and working areas of older buildings. If new shutters are being manufactured, they can be glazed, as seen in Figure 36, to allow them to be closed during daylight hours, in effect acting like secondary glazing, but with the flexibility of a shutter. Such a solution can be particularly beneficial in commercial properties which are occupied during daylight hours.

Figure 36: Glazed shutters in use.

9.3.2 Draughtproofing

A timber sash and case window in good condition will have modest air leakage, which measurement has shown to be equivalent to the air infiltration through a trickle vent, and as such should not need draughtproofing. However, where there is excess air ingress through wear and tear, draughtproofing of sashes can reduce air leakage by up to 80%, although this will not improve the U-value of the window itself. A range of products that can be used on the window joinery are available. They range from brush strips to foam cushions and a type of silicone sealant applied to the fixed part of a window. Such a seal is shown at Figure 37.

37

Figure 37: A newly fitted brush strip (white) on a casement window at Holyrood Park Lodge.

Draughtproofing will result in some loss of existing fabric in the preparation of the routing channel needed to hold it in place or the replacement of the parting beads. It is also possible to incorporate the draughtproofing into the baton rods which are commonly replaced several times in the life of a sash and case window. Ventilation may need to be reassessed following draughtproofing to avoid increased internal humidity and a potential build-up of condensation on cooler areas such as glass. In cases where draughtproofing is part of a wider refurbishment requiring a building warrant, the installation of trickle vents may be necessary and listed building consent may apply. For indicative details of trickle vents in sash and case windows (Figure 38) and other details, see the HES Short Guide 'Sash and Case Windows'.

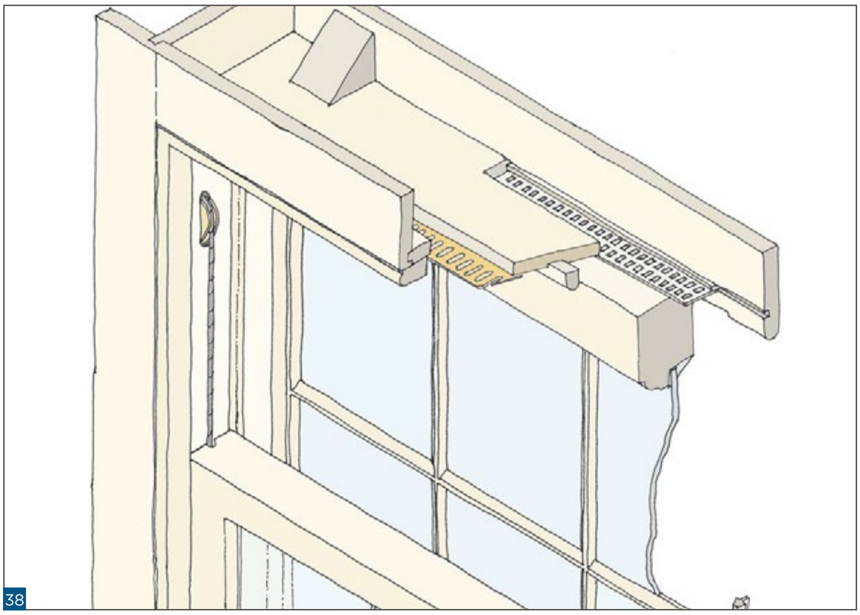

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Figure 38: Trickle vent fitted in the head of a sash and case window. Image © John Gilbert

9.3.3 Secondary glazing

Secondary glazing is essentially a second window installed internally next to the original window to reduce air leakage and conduction heat losses. It is one of the most effective methods for improving thermal performance, reducing heat loss by 63% to a U-value of 1.7 (single-pane secondary glazing). Used in conjunction with other methods such as blinds and shutters, a reduction in heat loss of over 75% can be achieved to a U-value of around 1.0.

Secondary glazing is available in a variety of styles and can be effective in improving U-values without the loss of existing fabric and with minimal effect on the external appearance of the window. It is normally a single pane of glass, but secondary double glazing can also be used. It is a good option in listed buildings where the existing windows are historic and may contain early glass. Most secondary glazing is made from standard profiles in aluminium, although they can be made in timber by a joiner, as shown at Figure 39.


39

Figure 39: Timber framed secondary glazing in a dormer window.

Frames for secondary glazing can be positioned at any point along the window reveal, but where shutters are present, secondary glazing needs to be mounted within the staff beads of the window to allow the shutters to operate; this is shown at Figure 40.

Some secondary glazing can be fixed as non-opening, although consideration will need to be given to ventilation and cleaning requirements in this case. Some proprietary secondary systems are made of a sheet of polycarbonate mounted on a magnetic strip. This mounting system allows for easy removal in summer and for cleaning, and is shown in Figure 41. Such a system should be able to achieve a U-value of around 2.4.

Figure 40: Secondary glazing mounted within the staff beads, allowing the use of shutters.

Figure 41: Polycarbonate secondary glazing mounted on a magnetic strip.

Externally mounted secondary glazing systems, as seen in Figure 42, are generally harder to fit to ensure a good junction with the existing frame and, as they can be visually more obtrusive, they are not normally suitable for listed buildings. However, they can have a number of benefits, including reducing weathering to existing windows or the cames of leaded lights, thereby reducing weather damage and maintenance costs. Such a system may be preferable in very exposed locations where the advantages of durability and protection outweigh aesthetic considerations. It is advisable to allow ventilation in the gap between the original window and secondary glazing to avoid decay or erosion of the original window fabric. The visual impact of external secondary glazing can be considerably reduced by matching the paint colour to that of the timber window behind.


42

Figure 42: External secondary glazing which gives weathering protection, as well as a degree of thermal improvement.

9.3.4 Improved glass

Where appropriate, glass in sash and case windows can be replaced with types of window glass that has better thermal efficiency than a single pane of glass. New panes of this type come in many forms and they can be retrofitted into the existing window frames. This minimises the impact on the character of the window, although it does involve the loss of original glazing. Therefore, such interventions may not be appropriate in certain situations (see Managing Change Guidance on Windows) and an assessment of the historic and cultural significance of the original glass is required before such work is undertaken. For example, the removal of historic crown glass should be discouraged, given the rarity of surviving examples and the significant visual value which crown glass adds to a building elevation. However, where little or no historic glass survives, this may be an option. Where timber frames have suffered decay, these components can be repaired with new timber sections before the new units are fitted.

Improved glass panes range from thin or narrow profile double glazing to more advanced vacuum pane technology; a judgement will have to be made on the most appropriate type of glass.

Laminated glass is two layers of glass with an insulating film between them. They are only slightly thicker than a standard pane and have 50% better performance and additional security benefits. Whilst a little heavier than a standard pane, they will require less modification to the sash to accommodate them than other thicker alternatives.

Narrow profile double glazed units, where the sightlines are reduced with a thinner edge strip, give better thermal performance than a single pane, especially when the unit is filled with various types of inert gas such as argon. However, they are thicker and heavier than a normal pane and will need the checks of the existing sash or rebates in the astragal which hold the glass to be made deeper to fit the new unit (approx. 6mm). The new panes, commonly 12mm thick, are then fixed into place using synthetic or natural putty. These should comply with all six parts of the British Standard. New sash cords and sometimes heavier sash weights are required to allow balanced opening. Figure 43 shows such units in a 19th-century window sash in Edinburgh (Refurbishment Case Study 8 has further details).

Figure 43: Narrow profile double glazed panes set into an existing window sash. Image © Gordon Barclay

More information on the performance of various types of double glazed units can be read in HES Technical Paper 9: Slim profile double glazing, and Technical Paper 20: Slim-profile double-glazing in listed buildings.

Vacuum panes are a recent development, where two pieces of glass are separated by a narrow gap from which the air has been removed. The sheets are kept apart by a matrix of small beads. Such units have good thermal performance from a U-value of 1.2, with more recent and less visible products of this type reaching a U-value of 0.7. They are nearly the same thickness as a single pane (6mm) and only weigh a little more than a standard sheet. This makes them technically suitable where minimum intervention on the sash is required (Figure 44). However, they are more costly than other options and there is a minimum size. Some observers comment on the beads that are visible close up.

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Figure 44: Vacuum panes were trialled at Archibald Place, Edinburgh, in 2009.

Standard dimension double glazed units can also be retrofitted into some larger sashes. This suits a ‘one over one’ glazing pattern. As above, the checks need to be made deeper and there is an increase in weight to consider (Figure 45).

45

Figure 45: A standard dimension double glazed unit fitted into an existing sash.

In some projects, there may be existing glass of historic value which needs to be retained. This glass can be modified with an additional new pane to create a double-glazed unit with the historic glass. This is an expensive process but retains the look of the original fenestration, as can be seen in Figure 46.

46

Figure 46: Original glass modified to a form a narrow profile double glazed unit.

9.3.5 New windows

Where the timber of the sash and the case is in poor condition and cannot be repaired, new windows can be manufactured to the traditional pattern, yet incorporating many of the improvements described above. These would include brush strips or other draught reduction measures, security features such as sash locks and the glazing technologies covered. In many properties, the original windows have long been replaced with a poor alternative which may have reached the end of its life. In this case, the original fenestration pattern can be reinstated. This is sometimes called a ‘conservation gain’ and will raise the amenity of the property and could add value. An example of a new sash and case window from a HES case study is shown in Figure 47.

Figure 47: A new sash and case window in a Category B-listed window in Stromness. Note the new working shutters.

Cost will be a factor with any new window, but with improved energy efficiency and manufacturing techniques, the owner will have made a sound choice from an architectural and energy point of view, with a product that can last for over 100 years.

Shutters have always been part of the window arrangements on many older buildings and should be considered part of the assembly. Their upgrading or reinstatement should be considered in any refurbishment work, as they will save more heat, provide better security and in some cases save money on curtains.

Sash and case windows are not the only glazing type in Scotland, although they are the most common. Similar principles of thermal upgrade and draught reduction, as detailed above, also apply to many other windows constructed of wood.

9.4 EXTERNAL DOORS

Many external doors are a defining feature of the elevation and, in smaller buildings, will be a big part of the presentation of the house. Older doors were well made with durable materials and they should, therefore, be retained and upgraded where possible. The heat loss from doors can be reduced by draughtproofing around the door frame and insulating the fabric of the door itself. These techniques are normally only used on external doors as there is little need to insulate internal doors, unless there are significant heat differentials between rooms. Whilst the thick timber door frames perform well thermally, the thinner panels are a source of heat loss.

9.4.1 Insulation to panels

The panels can be improved by adding a thin layer of high performing insulation, such as an aerogel-based product, onto the back of the existing panel. This may require the removal of the existing moulding to get a good fit and allow the covering. Such insulation is normally about 6mm thick and is glued in-situ and covered by a sheet of 5mm plywood. The edge of this covering is finished with a plain band (Figure 48) or a more decorative moulding if depth allows, as on the tenement door shown in Figure 49. In this case, an improvement in U-value from 3.9 to 0.8 was achieved. (See Refurbishment Case Study 1, as well as Refurbishment Case Study 6 and Refurbishment Case Study 8.) Even more complex door shapes can accommodate this improvement (Figure 50).

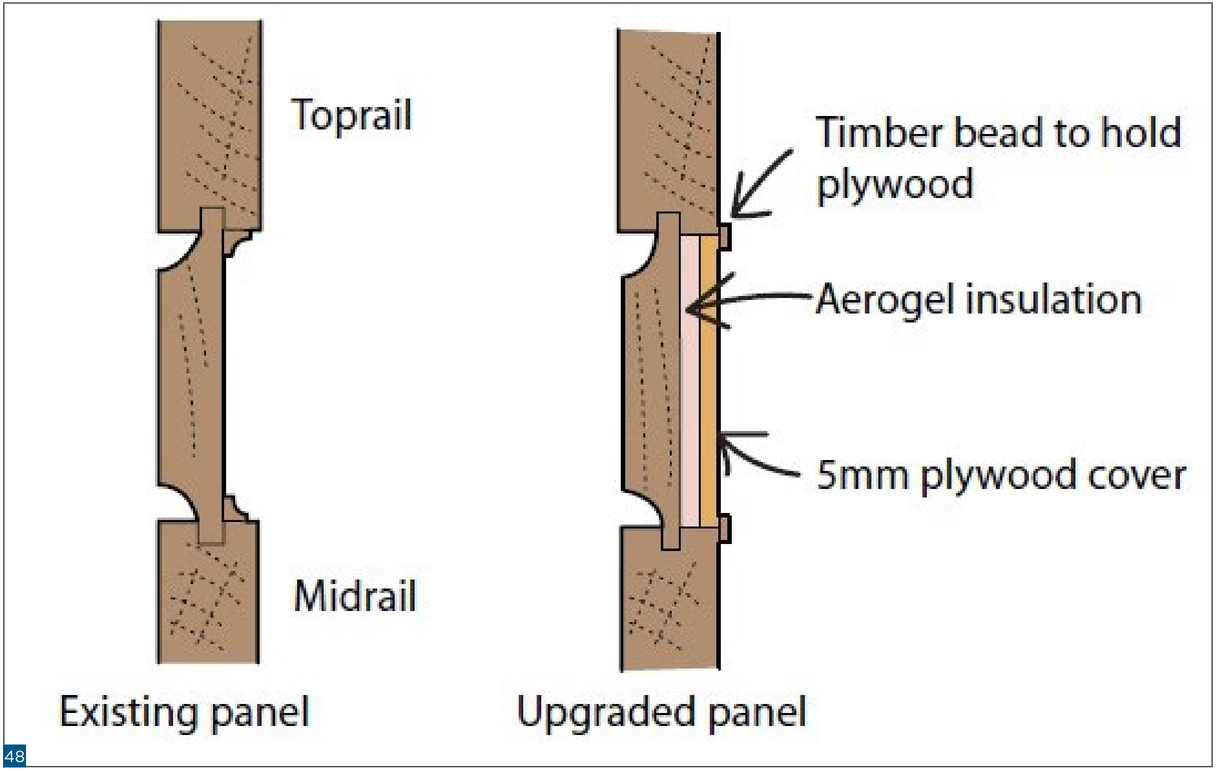

Figure 48: Detail of an aerogel-based insulation material fitted onto a standard panelled door.

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Figure 49: A door in a tenement with the insulation under the new plywood panels prior to painting.

Figure 50: On this door in a B-listed building, aerogel has been used in a similar way; the letterbox has also been closed up following a change of use.

Draughtproofing around the edge of a door can also help to reduce heat loss, as shown in Figure 51. Different techniques have various implications; some strips are very visible from the outside and might not be suitable. Where the door meets the check of a stone surround, a cushion-type strip adhered to the masonry will be best. Sometimes narrow timber sub frames are used to achieve a better seal to the door. Where the door meets a timber frame, the strips are normally set into the door, much as with the casement window in Section 9.3.2. If the door is a fire door, specialist advice may be needed.

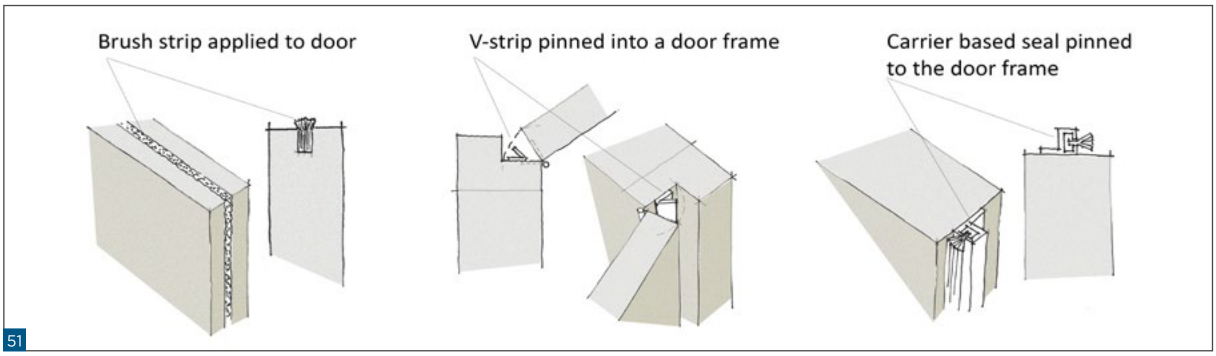

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Figure 51: Types of draught strip for doors.

9.5 SOLID WALL INSULATION

The predominant wall type for pre-1919 buildings in Scotland is what is generally called a ‘mass masonry wall’. Such walls are typically around 600mm in thickness and built of two skins of rubble, bonded with a lime or clay mortar, and a filled core. Internal finishes can be plastered on the hard or with a lath and plaster lining, as shown at Figure 52. Sometimes the external face is harled or, for later buildings, left as a rubble or other masonry face.

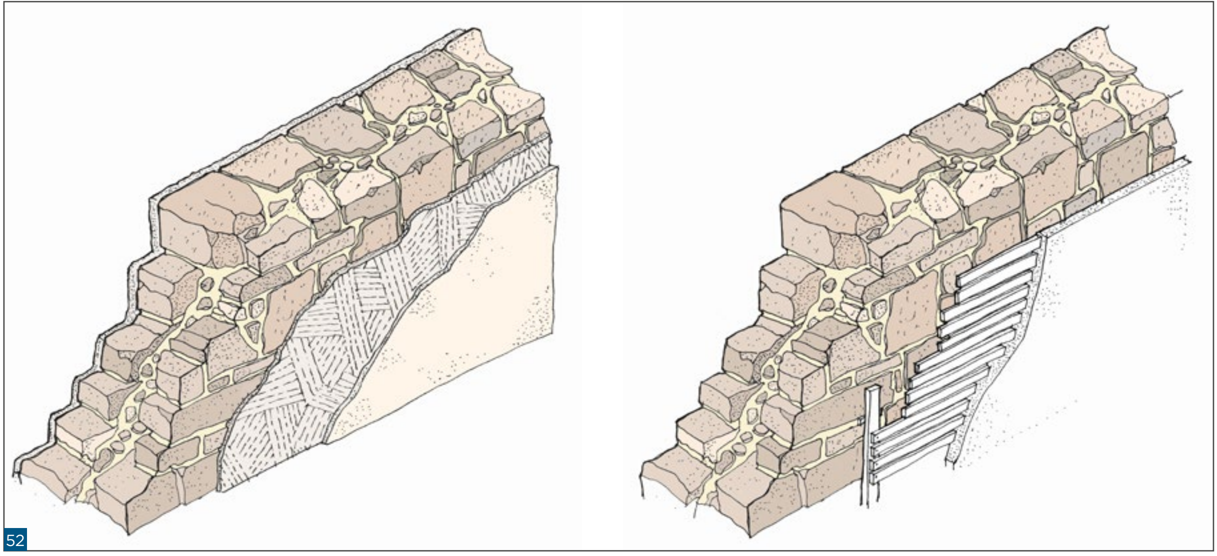

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Figure 52: General wall types found in Scotland: plaster on the hard (left) and lath and plaster (right). Image © John Gilbert

Recent HES research has shown that insulating mass masonry walls can considerably improve their thermal performance. This improvement can be achieved using a number of methods and materials. All the methods and materials trialled by HES have allowed moisture vapour movement to continue. Some of these methods align with good conservation practice, are relatively low cost and less disruptive to building occupants, whilst also allowing the retention of existing internal linings and finishes.

As discussed in Section 8 of this guide, traditional mass masonry walls allow moisture movement through building fabric. Traditional internal finishes made from hygroscopic materials also assist in buffering the humidity produced by domestic occupation (such as by breathing, showering, the use of washing machines, etc.). It is therefore necessary that any insulation, as well as any finishing material applied over the insulation, allows this movement of moisture vapour to continue. In considering a wall insulation of any type, the situation and exposure of the building to prevailing weather, especially wind-driven rain, is important. Walls with high exposure should not be retrofitted without full consideration of their integrity and performance. In such cases, resources may be better spent on external detailing improvements to better manage wind-driven rain.

9.5.1 Hygrothermal considerations

In all areas of retrofit, especially walls, there should be consideration of the nature and the mechanisms for the movement of heat and water vapour through the building fabric. When these processes take place in a structure, they are often referred to as ‘hygrothermal’. While more intuitive judgements based on experience are fine, some projects may require more formal validation. Designers often call this process ‘condensation risk analysis’. There are different approaches to this assessment, but essentially, once a refurbishment design for a building or building element is worked out, it is checked with software to assess the effects of the intervention on the building fabric from a moisture movement point of view. For simple interventions on most building components an assessment tool called he Glaser method is used; it will profile the moisture concentration or relative humidity across the wall and indicate any risk of condensation within the fabric or between building elements. This is called ‘interstitial condensation’. There are other systems for doing this assessment, and a common tool is WUFI®, where there are more inputs and an assessment made over an extended timeframe; this is called dynamic simulation. More can be read on this topic in HES Technical Paper 15: Assessing Risks in Insulation Retrofits using Hygrothermal Software Tools.

The case studies, from which much of the material for this guide has been taken, recorded the conditions in walls after the upgrade work, reassuring stakeholders that the measures are not damaging. Results from one property (Refurbishment Case Study 4) are shown at Table 5 below.

Insulation type	Average relative humidity of room (%)	Average relative humidity at interface between wall and insulation (%)	Average relative humidity 50 mm into the wall fabric (%)
Hemp board, 100mm	52.1	65.2	66.6
Wood fibreboard, 80mm	20.7	61.7	58.9
Blown cellulose, 50mm	21.9	14.8	14.3
Aerogel board, 50mm	45.9	64.4	63.3
Bonded polystyrene bead, 50mm	58.3	16.4	15.8

Table 4: Relative humidity readings recorded at the wall/insulation interface in five tenement flats. (Data from Historic Scotland Refurbishment Case Study 4.)

9.5.2 Approaches for internal insulation to walls

There are four approaches to the application of internal insulation to mass masonry walls. These are:

- insulation inserted behind existing wall linings
- insulation applied to existing wall linings
- insulation applied directly to masonry or plaster on the hard
- insulation held in place by timber framing.

The method used will depend on the extent and condition of original fabric, such as existing linings (e.g. lath and plaster), and the level of thermal improvement which is desired. Where lath and plaster survives, there will normally be a space or cavity between this and the masonry wall. Lath and plaster is an original feature and should be retained; it is as much a part of the fabric as the walls. When people say ‘going back to the masonry’, they are really describing very extensive downtakings. However, where original linings have been lost, more recent dry lining can be removed and replaced with insulation either directly to the masonry on the hard, or, where space allows, the wall can be framed with timber to hold insulation in place. Some materials, such as calcium silicate board and insulated lime plasters, are best applied directly to masonry, whilst other materials, such as wood fibreboard and hemp board, are held in place with framing.

Avoid thermal or cold bridges when insulating a wall. These are formed where different elements of the building structure are present which lose heat at a more rapid rate, for example, where thinner walls are present in a splayed window reveal, or where a ‘press’ cupboard is built into the fabric of a masonry wall. The presence of surfaces of lower temperature can lead to condensation and possible decay of materials. In practice, it is harder to fully avoid this when retrofitting insulation than in a new build situation, but steps should be taken to minimise the risk as far as possible and such areas should always be attended to.

As is reiterated, an appropriate vapour permeable material should be used to avoid creating a vapour barrier which could lead to increased levels of moisture and associated decay of masonry, mortar and timber within a wall. A material such as hemp or wood fibreboard, blown cellulose, or calcium silicate board or an insulated plaster is most likely to achieve this. Non-vapour-permeable products, such as phenolic foam, while thermally effective, may not be appropriate in traditionally constructed buildings as they could lead to moisture concentration and subsequent fabric decay; they should therefore be avoided.

A large number of properties were reviewed for condition, including the walls, in a wide study carried out in 2019. This found that all the wall interventions were performing well with no poor outcomes. Some measures had been in place for over ten years. For an overview of the projects where we insulated walls, see HES Technical Paper 24: Project Review. A summary of options for solid walls is shown at Table 6, showing the measure and the pre- and post-intervention improvement.

Wall insulation	Pre-intervention U-values (W/m²K)	Post-intervention U-values (W/m²K)	% Improvement
Polystyrene beads, 40mm, blown into cavity between internal plaster linings and external masonry walls	1.6	0.8	50%
Polystyrene beads, 45mm, blown into cavity between internal plaster linings and external masonry walls	1.4	0.7	50%
Polystyrene beads, 100mm, blown into cavity between internal plaster linings and external masonry walls	0.5	0.4	20%
Aerogel, 10mm, plastered on hard	-	0.8	-
Cellulose insulation, blown behind lath and plaster (average post intervention U-values)	1.3	0.7	46%
Aerogel, 10mm, behind plaster	1.4	1.0	29%

Calcium silicate board, 15mm, applied to inner face of external walls and plastered	1.5	0.7	53%
Polystyrene beads, blown into cavity between internal plaster linings and external masonry walls	1.5	0.5	67%
Aerogel, 10mm, applied to inner face of external wall and plastered	1.6	0.9	44%
Blown polystyrene beads, 50mm	1.1	0.32	71%
Blown cellulose, 100mm	1.1	0.29	74%
Hemp insulation, 100mm	1.1	0.22	80%
Wood fibreboard, 80mm	1.1	0.19	83%
Aerogel, 40mm	1.1	0.37	66%
Aerogel, 50mm	1.1	0.32	71%
Wood fibreboard, 100mm	2.1	1	52%
Calcium silicate board, 50mm, applied to inner face of external wall and plastered	2.1	0.4	81%
Aerogel, 10mm, applied to inner face of external wall and plastered	1.3	0.6	54%
Cellulose insulation, blown behind existing plaster linings (average U-values)	1.4	0.15	89%
Insulated lime plaster to inner face of external masonry, applied on the hard	1.8	1.1	35%
Polystyrene beads, blown behind lath and plaster	0.57	0.3	47%

Table 5: Improvements in U-value given by various internal wall insulation options used in Historic Environment Scotland case studies.

9.5.3 Insulating behind lath and plaster

Blown, injected or sprayed materials can be used to improve the performance of mass masonry walls which have a lath and plaster wall lining, in a similar way to the techniques used in cavity wall insulation. This allows the retention of existing wall linings and minimises disruption to historic material, as well as reducing cost and disruption to the occupants. These materials may also be used in situations where plasterboard wall linings are present. Using this method, there is, however, a significant reduction in the ventilation of the cavity between the lath and plaster and the masonry wall, and it is therefore essential that a vapour permeable material is used to allow movement of water vapour through the fabric. Appropriate materials used in HES case studies include blown cellulose and polystyrene beads. The suitability of these options must be assessed by the designer of the retrofit project. It should also be noted here that there is a need to consider the electrical wiring behind. This might need to be put into conduit to allow later alteration and as a safety measure.

When inserting or blowing material behind lath and plaster wall linings, it is important to ensure that the masonry can stay dry by retaining or improving water vapour permeability. The role of external maintenance is necessary in achieving this, including the proper functioning of rainwater goods such as gutters and downpipes. Modern external finishes such as cement render may compromise water vapour permeability. Where practicable, all steps should be taken to ensure the best level of permeability possible. In most domestic buildings this is likely to require the removal of textured wallpapers and vinyl paint finishes, revealing the plaster beneath. Prior to installing, the insulation gaps at the base of the wall should be closed off to prevent material falling into voids below. This is achieved by removal of the skirting boards and packing the lower part of the wall with a fibrous material such as wood wool or hemp fibre. Holes in the plaster are then made every metre or so to permit access for the material to be installed. The insulation material is then blown in from successively higher levels until the ceiling is reached. The outline methodology for this is shown in Figure 53.

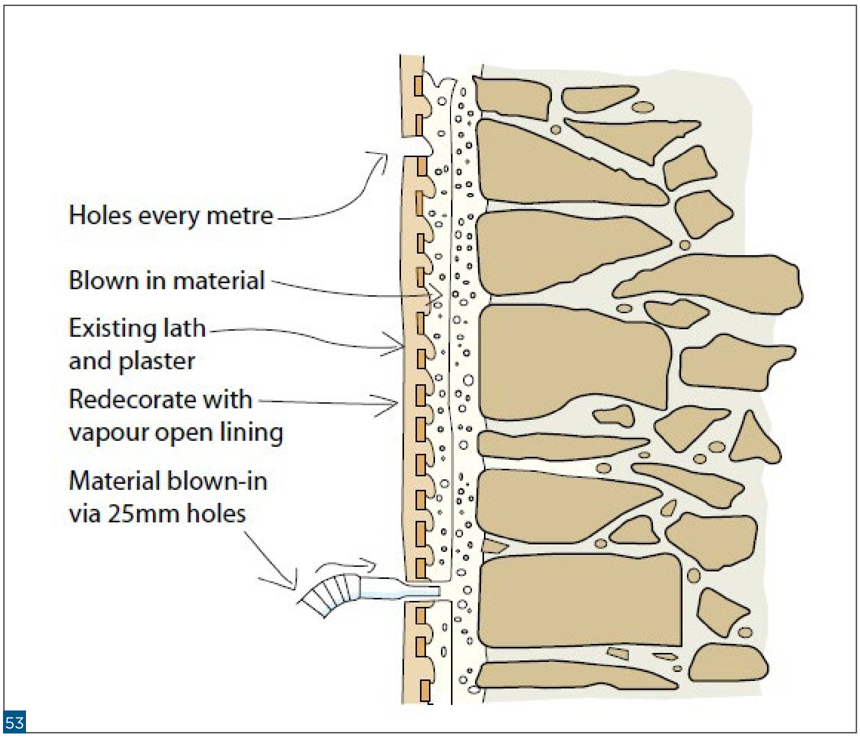

Figure 53: Diagram showing the blowing in of an insulation material.

A thermal imaging camera can be used to ensure the insulating material has filled all the voids. Any missed areas can then be refilled, and the holes patched prior to redecoration. For more details on this work see HES Refurbishment Case Study 2 (Figure 54).

Figure 54: Cellulose fibre being blown behind lath and plaster.

Lining paper applied with a water-based paste provides a good base for the application of traditional distemper, clay or mineral paint, or other permeable finish when redecorating after the work is addressed. Although the U-values achieved will vary considerably depending on which material is used and factors such as the depth of void which exists between the masonry and wall lining, HES case studies have shown the use of bonded polystyrene beads in this way resulted in a U-value improvement from 1.1 to 0.32; and by using blown cellulose, an improvement was achieved from 1.3 to 0.6 in one case study and 1.1 to 0.29 in another.

9.5.4 Insulation applied onto existing wall linings

Where concerns exist over intervention in the void behind lath and plaster, the addition of a thin layer of insulation onto the lath and plaster may be appropriate. HES have used aerogel-based products applied to the surface of lath and plaster to improve thermal performance. This allows the air gap behind the plaster to continue to function unchanged. It may be an appropriate approach where the wetting and drying cycle of a wall is of concern, such as in a very exposed location. With a total thickness of 25mm, aerogel insulation will not significantly affect room proportions, cornice details or other finishing elements.

Aerogel-based insulation comes as either a board or a blanket, supplied as a roll of material. The blanket can be supplied in 5 or 10mm thicknesses and has the advantage of being able to be used on curved substrates. It is fixed to the existing wall finish with an expanded steel mesh using thermally decoupled expansion fasteners, which are required to prevent thermal bridging. Two coats of plaster are then applied on the mesh and finished with a permeable paint finish. The total thickness of this measure is in the region of 25mm (see Figure 55 for the insulation layer before the plaster covering coat). Aerogel blanket has given a range of thermal improvements in HES case studies, including one improvement in U-value from 1.6 to 0.9 (see Refurbishment Case Study 1 and Refurbishment Case Study 3).

Aerogel is also available as a board, for application onto plaster or masonry in a single intervention. This reduces the number of work stages and gives more control over the finish.


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Figure 55: Aerogel blanket applied directly to masonry using thermally decoupled expansion fasteners (Refurbishment Case Study 3).

9.5.5 Materials applied directly to masonry without framing

Where a wall was originally plastered on the hard, there is an opportunity to insulate directly onto the existing plaster surface, minimising the impact on the room proportions and facings. HES has trialled the use of a calcium silicate board in this situation, although wood fibre-based products and other vapour permeable insulation materials can also be directly fastened to a mass masonry wall.
The calcium silicate board is available in a range of thicknesses to suit site conditions and the thermal improvement sought. Existing wallpaper and paint should be stripped from the masonry and a vapour permeable adhesive applied to the wall before the insulation is fitted in place (Figure 56). The board is finished with two coats of plaster and a permeable paint. In one HES case study, this method improved U-value from 2.1 to 1 (Refurbishment Case Study 3 and Refurbishment Case Study 6).


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Figure 56: Application of calcium silicate insulating boards.

9.5.6 Insulated plaster

A further method of internally insulating a mass masonry wall directly onto masonry is to apply an insulated lime plaster (Figures 57 and 58). Such an internal finish may be suitable in some situations, especially where the existing plaster is decayed or has been lost. It is also suitable where the walls are not entirely flat. This material is a relatively new product and normally consists of a lime binder, aggregate and the insulation material, which may be shredded hemp (called 'Hemp Shiv'), perlite or other materials of a natural origin. When using insulated lime plaster, the material is batched up and normally applied in two layers to achieve the desired thickness, before being given a smooth finish. Generally, the overall thickness is 60–80mm. Lime wash, distemper or clay paint may be used for final decoration. In one HES case study at Downie's Cottage, such an internal insulated lime plaster was applied in two coats to a thickness of around 60mm (Refurbishment Case Study 22).


57

Figure 57: First coat of insulated lime plaster being applied directly to the masonry of the Category A-listed Downie's Cottage, near Braemar. A second coat is applied in much the same way.

Internal lime plaster of this type has a vapour open finish and is therefore compatible with the breathable nature of traditional construction.

58

Figure 58: The finished room at Downie's Cottage showing the insulated lime plaster and the relaid stone flagstones. Image © Callum Innes

9.5.7 Insulation applied within framing

Where original lath and plaster wall linings have been removed or are badly damaged, there may be space following the removal to fix new timber strapping or framing to the masonry to hold a thicker board-based insulation material such as hemp or wood fibreboard. The use of timber framing to hold insulation is a well-established technique in construction and there is a wide choice of appropriate vapour permeable insulation materials available, both as rigid boards or more flexible batts, as seen in Figure 59. The depth of the framing is dictated by the thickness of the insulation products and this should be considered in relation to room features and available space. The material is placed within the framing and finished with either plasterboard or clay board. It is important that if plasterboard is being used, this should not have a foil back or other integrated vapour barrier (or VCL), as such a material will impede the movement of moisture through the assembly.

59

Figure 59: Hemp fibre insulation with clay board.

A further alternative uses vertical timber studs fixed to the wall, and cellulose in wet form is sprayed directly between the framing (Figure 60). Once dry, the cellulose is then planed flush to the strapping and finished with clay or plasterboard. The U-value improvement with these methods will vary depending on the thickness and type of material used.


60

Figure 60: Cellulose insulation being applied damp.

HES case studies found that 100mm of wood fibreboard improved the U-value of the wall from 2.1 to 0.19, as seen in Figure 61 (see Refurbishment Case Study 6); 100mm of hemp board improved the U-value from 1.1 to 0.22, and 50mm of aerogel board from 1.1 to 0.23 (for both, see Refurbishment Case Study 4). Cellulose insulation applied between framing gave a U-value of 0.15 (Refurbishment Case Study 16). These levels of improvement are more significant than the less invasive measures described in Section 9.5.3.


61

Figure 61: Wood fibreboard insulation applied within framing. A U-value of 0.19 was achieved in this example.

9.5.8 External wall insulation

In some situations, insulation can be applied to the external face of a masonry wall. Due to aesthetic considerations and difficulties in application, this approach is unlikely to be appropriate to many traditionally constructed buildings; for example, where there is high quality ashlar work or a visually attractive façade. There will also be issues with detailing external wall insulation on traditional buildings, such as at window and door reveals, in connection with gutters and downpipes, and in detailing at roof level. There is also a considerable visual impact with external wall insulation, as shown in Figure 62. Where a building has previously been rendered or harled, the application of an insulated replacement may be appropriate and practicable, essentially reinstating a historic finish with additional properties or features.

62

Figure 62: The visual impact of external insulation.

This may be especially beneficial where a previous impermeable cement-based render is failing and its removal may benefit the building fabric through improved moisture movement. In many cases in Scotland, the gable ends and rear elevations of buildings are architecturally less complex and may suit a thin form of external insulated render. Such an example can be seen in the failing historic render in Figure 63, which could be replaced with an insulated lime render. In many traditionally constructed buildings, a lime harl is the traditional wall finish. The changing climate in Scotland, with an increase in rainfall, will make better external protection of our buildings necessary, and a return to traditional finishes may be a part of this.

Figure 63: This gable end, which is in need of maintenance and showing the remains of a lime render, is well placed to receive an appropriate form of thin external insulation.

However, with the materials and techniques available at present, external insulation is likely to be expensive to install and may only be effective where relatively large areas are being treated in an area-based upgrade scheme. This might include the rear elevations and gables of tenements. It is important that any external wall insulation being used on a traditional mass masonry wall is moisture vapour permeable. (Lime-based materials of this type are in their infancy and have yet to be trialled by HES.) Boards and spray-applied materials that do not allow a degree of moisture movement through the structure would be of high risk on a traditional mass-walled building. It should also be noted that a building warrant is required for any application of insulation to an external wall.

For external insulation, a board and render system such as wood fibreboard may be appropriate if it allows the vapour permeability of a masonry wall to be maintained. In Figure 64, wood fibreboard of 100mm thickness has been applied to the walls and the roof of a pend beneath a tenement in Glasgow (see Refurbishment Case Study 4).

The boards are protected from direct moisture using special edge and drip detailing to keep driven rain away from the board. The board is finished with two coats of vapour permeable render to make it fully weatherproof. The thermal improvement in this case study saw a U-value reduction from 1.3 to 0.4. Generally the difficulties in detailing, such as the one described above and seen in Figure 64, make external wall insulation a complex option for improving the thermal performance of traditional buildings.


64

Figure 64: A wood fibreboard external render system applied to a pend in Glasgow.

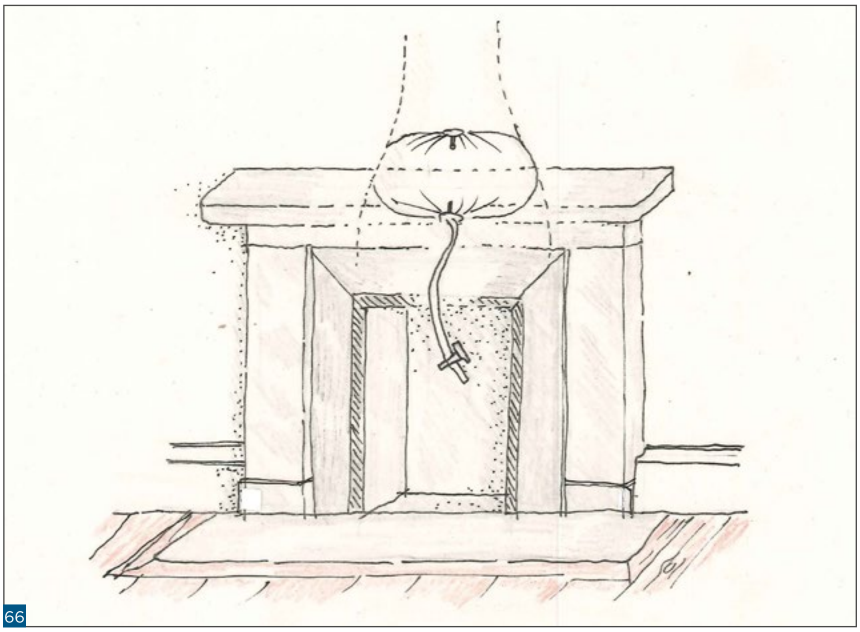
9.5.9 Chimneys and flues

Fireplaces, flues and chimneys are important in providing ventilation in traditional buildings. While they are part of the ventilation function described in Section 7, as they are a fabric measure as well, the details are considered here. Open flues generally provide a passive stack effect of moving air up through the flue and drawing it out of the building. Fresh air can come in through vents at ground level and move through the building. The action of moving air within the flues draws air through rooms and assists in removing any concentrations of moisture within masonry, especially at exposed gable ends. Closed flues which have been blocked up with no allowance for continued air flow are therefore prone to an accumulation of damp if airflow is restricted completely, and as such, the permanent closing up of hearths, flues or chimney stacks is not advisable.

If a fireplace is no longer used and there is a desire to close it off to reduce draughts, it is important that some form of air movement is retained. An inflated chimney balloon (Figure 65) can be used to minimise draughts in the winter period, fitted as shown in Figure 66, which can be removed in the summer when increased airflow and the associated cooling might be required.


65

Figure 65: A chimney balloon as used to temporarily close off chimney flues.



66

Figure 66: Location of a chimney balloon in the flue above the opening.

A fireplace can also be temporarily closed off with a hearth board fitted over the opening. Figure 67 shows such a board, made of plywood and covered with a decorative fabric.

67

Figure 67: A hearth board used to temporarily close off a fireplace.

All chimney heads, whether in use or not, can be fitted with a vented cowl to keep out rain and birds while remaining in use (Figure 68). (Chimneys are a vulnerable and often neglected part of a building; for guidance on their repair and adaptation see HES Short Guide 11: Climate Change Adaptation for Traditional Buildings).

Figure 68: A cowl with mesh keeps a chimney dry but ventilated and free of birds.

Chimneys may, in some cases, be reused for new heating appliances such as some modern enclosed grates, wood-burning stoves and biomass micro-renewable systems, although this will not be possible for those in urban areas.

Figure 69: A baffle plate was installed in this fireplace to improve the control of ventilation.

Even though most people cannot use hearths and flues for combustion, these will still have a continued role in the provision of ventilation and in passive cooling in buildings during the predicted hotter summers. Figure 69 shows a reinstated mantelpiece and reclaimed cast iron inset at Holyrood Park Lodge. This was fitted with an iron damper to allow controlled ventilation into the room.

10.MEETING STANDARDS

The motivation for retrofitting buildings is often a need to reach particular standards. These are generally either Scottish Building Standards (most applicable to traditional buildings where conversion work is taking place) or various government standards which stipulate achieving a given Energy Performance Certificate (EPC) band. This section discusses considerations that are relevant to retrofit of traditional buildings when meeting both building standards and EPC bands.

10.1 THE SCOTTISH BUILDING STANDARDS

The Building (Scotland) Act 2003 is the legislation that provides the Scottish Government's legally enforceable building regulations and associated building standards, designed to provide buildings that are safe, efficient and sustainable. They cover areas such as fire safety, structural integrity, energy performance, accessibility and noise transmission. Although largely framed with 'new build' in mind, building standards also apply to most new construction work on existing buildings, including work on traditional buildings. The most relevant building standards to this guide are those covering Energy (6.2), Condensation (3.15) and Ventilation (3.14). However, there are many other standards that may apply to new construction work, and further details can be found here: Building Standards (www.gov.scot).

10.2 THE ENERGY STANDARD

Standard 6.2 of the energy section of the building standards states that 'every building must be designed and constructed in such a way that an insulation envelope is provided which reduces heat loss'. The building standards are supported by guidance that indicates one way in which the standard may be met. This guidance identifies U-values that should be achieved where work is carried out in relation to conversion of traditional buildings, and these are summarised in Table 6 below. It can be seen from column 5 of this table that HES case studies have demonstrated a number of measures which can meet the requirements of this standard, whilst still preserving the ability of the building fabric to dissipate moisture.

The building regulations, however, recognise there may be challenges in meeting some building standards where an existing building is being converted. For standard 6.2, the regulations confirm that 'where a building is being converted, this shall meet the requirements of the standard so far as is reasonably practicable and in no case be worse than before the conversion'. Reasonably practicable is defined in Scottish Building Standards as 'having regard to all the circumstances including the expense involved in carrying out the work'. This would include concerns over moisture, ventilation and impact on historic fabric.

Accordingly, regulation 12 of the building regulations sets out which building standards must be met in full and those that may be met as far as is reasonably practicable during such conversions. This preamble is important to note in the case of converting traditional buildings. It does not mean that the standards do not apply to conversions of buildings, traditional or otherwise, but simply that proposals may take an evidenced approach to demonstrate the extent to which heat loss can, in practice, be reduced when any work is taking place. Where measures are not technically feasible (for example, if improvement measures require the use of vapour impermeable materials), then the proposed method of meeting the standard ‘as far as is reasonably practicable’ should be discussed with the relevant local authority building standards service.

10.3 APPROACH FOR TRADITIONAL BUILDINGS

In clause 6.2.8 of the Scottish Building Standards, the conversion of historic, listed or traditional buildings is discussed in detail. It should be emphasised that this clause relates to all buildings of traditional construction and not just those which are listed or of perceived heritage value. The application is generally considered in the light that pre-1919 buildings are traditionally built, and their different construction principles are considered and acknowledged. This section of the building standards notes that ‘whilst achieving the U-values recommended previously should be the aim of any work, a flexible approach to improvement should be taken based on investigation of traditional construction, form and character of the building in question and the applicability of improvement methods to that construction’. This is, again, an important clause, as the performance of the building as well as its aesthetic appearance and character are specifically to be considered. In the context of this guide, that will often mean the use of insulation which promotes moisture movement. Indeed, building standards guidance specifically states that ‘the manner in which proposed improvements may affect moisture movement or the permeability of existing construction will also require assessment to address the risk of adverse consequences’. It is important to note that this guidance also states that a ‘do nothing’ approach should not be considered, but any intervention must consider the performance of the building and its heritage character.

10.4 CONDENSATION

Standard 3.15 on condensation requires that buildings ‘must be designed and constructed in such a way that there will not be a threat to the building or the health of the occupants as a result of moisture caused by surface or interstitial condensation’. This is often interpreted as implying that work to improve or convert traditionally constructed buildings must incorporate vapour barriers or materials which are impermeable to moisture in order to reduce the risk of condensation. However, this is not the case, as the intention of the standard is to prevent potential damage to a building or the health of the occupants from the effects of surface or interstitial condensation, rather than preventing either from occurring.

Standard 3.15 does not therefore require the use of a particular method to eliminate the risk of condensation causing damage or presenting a risk to health. Confusion often arises due to the quotation in the building standards of British Standard BS 5250. This standard has been updated recently, and is now titled BS 5250, 2021. It is important to use the revised standard, which contains specific information relating to traditional buildings and how they work. Critically, it includes reference to the vapour permeability of traditional building fabric and to the fact that vapour impermeable materials are often not the most appropriate for traditional buildings. The requirements of building standard 3.15 relating to condensation can be met using various strategies which do not restrict the movement of moisture through building fabric – including ventilation, the use of hygroscopic materials to buffer humidity, and the maintenance of building fabric, which is permeable to moisture and promotes its dissipation. For the purposes of this discussion, the measures set out in this guide are part of the approach which BS 5250, 2021 advises and which can be used by a designer to establish and validate or demonstrate the measure applied for in a building warrant application.

10.5 INSULATING FLAT ROOFS

It is noted in the building standards guidance that the creation of a 'cold' flat roof should be avoided due to the risk of interstitial condensation forming on the cold underside of a flat roof deck; the effect of which on both the roof structure and insulation can be severe. This is important to note when dealing with the insulation of flat roofs in traditional buildings. As the removal of flat roof coverings, especially those of lead or copper, can be a difficult and expensive task to execute, it may be that for some traditional buildings the insulation of flat roofs is impractical. The building standards guidance further notes that metal roof finishes should have a ventilated air space on the cold side of the insulation, in addition to a high-performance vapour control layer near the inner surface of the insulation. The detail noted earlier in this guide, whereby soffit ventilation is provided to the cold side of a lead-covered flat roof, is likely to be sufficient to meet this standard.

10.6 AIRTIGHTNESS

There is no guidance on airtightness levels that should be met where existing buildings are being altered/converted. In one HES case study, airtightness of 10.7 $m^3/h/m^2$ @ 50 Pa has been achieved following interventions from a previous figure of 16.9 $m^3/h/m^2$ @ 50 Pa (Figure 9). The overall air leakage in a second HES case study was an average of 11.25 $m^3/h/m^2$; an improvement of 26% from the pre-intervention figure of average 15.29 $m^3/h/m^2$. During the testing, it was clear that there was still air leaking from the windows and the assessors judged that further window draughtproofing would give a still better figure.

10.7 BUILDING WARRANTS

The building warrant process is one of the ways that the Scottish Building Standards are applied. You will generally need a building warrant to build, convert, alter, extend or demolish a building under the Building (Scotland) Act 2003. However, there are some types of buildings that are generally exempt from the building regulations (schedule 1 to regulation 3). Certain changes in occupation of a building also attract building regulations – these are defined as 'conversions' (schedule 2 to regulation 4). There is also a range of work, including some repair work, that does not need a building warrant, provided the work meets the building standards (schedule 3 to regulation 5). Further information on these issues can be found in Section 0 of the Building Standards Technical Handbooks.

The building standards system is operated by local authorities who are appointed to the role of 'verifier' to receive and approve applications for building warrants and to accept or reject completion certificates where work described in a building warrant is complete. If you are uncertain whether a building warrant is needed or not, it is advisable to check with the building standards team at your local authority. Note that a building warrant is required for any application of insulation to the outer surface of an external wall.

When applying for a building warrant, sufficient information should be submitted to enable the verifier to check that the proposed building work meets the building regulations. This normally consists of suitable plans accompanied with a full specification and enlarged details, as considered appropriate for each project. A building warrant will only be issued when the verifier is satisfied that proposals comply with building regulations.

Further details of the application for building warrant process can be found in chapter 3 of the Building Standards Procedural Handbook.

On completion of the construction work, the owner or their appointed agent must submit a completion certificate to the local authority, which confirms the work meets the building regulations and is in accordance with the building warrant. A completion certificate for a completed new building or a conversion must be accepted by the relevant local authority before the building can be occupied.

10.8 APPROVED CERTIFIER OF DESIGN

To assist with this process, depending on the size and complexity of your project, you may wish to consider appointing an Approved Certifier of Design. Approved Certifiers of Design are members of a scheme provider appointed by the Scottish Government to certify that their design work meets the building regulations. Such an appointment has the benefits of saving time with the building warrant application process and offers a discounted building warrant application fee. At present, the structural and energy sections of the building standards can be certified by an approved certifier.

10.9 CERTIFIER OF CONSTRUCTION

In addition, aspects of construction can be certified by an Approved Certifier of Construction. The type of work that can currently be certified by a Certifier of Construction is electrical, plumbing, heating and drainage work. Using a Certifier of Construction also attracts a discount on the building warrant fee.

10.10 MAXIMUM U-VALUES TABLE

To assist users of this guide in selecting measures, Table 6 shows details of the various individual and collective U-values required under the building regulations, as well as the qualifications noted above.

Type of element	Area-weighted average U-value (W/m^2K) for all elements of the same type			HES Case Study result achieved
	(a) Maximum U-values for conversion of heated buildings	**b) Maximum U-values for conversion of unheated buildings**	**(c) Individual element U-Value (W/m^2K)**	
Wall (Solid)	0.3	0.22	0.70	0.15 80mm cellulose (RCS 16) 0.19 80mm WFB (RCS 6) 0.22 100mm hemp (RCS 4) 0.29 100mm cellulose (RCS 4) 0.3 50mm bonded bead (RCS 35) 0.32 50mm bonded bead (RCS 4) 0.32 50mm aerogel board (RCS 4)
Floor	0.25	0.18	0.70	0.7 80mm WFB (RCS 2) 0.5 100mm lime concrete (RCS 22)
Pitched roof (insulation between ceiling ties or collars)	0.25	0.15	0.35	0.2 280mm sheep's wool (RCS 2) 0.2 250mm hemp board (RCS 3)
Flat or pitched roof (insulation between rafters or roof with integral insulation)	-	0.18	0.35	0.14 100mm WFB (RCS 20)
Windows, doors, roof lights	1.6	1.6	3.3	0.6 double secondary glazing (RCS 1) 1.5 Single secondary glazing (RCS 1) 0.4 aerogel blanket to shutter (RCS 1) 2.4 polycarbonate secondary glazing (RCS 2) 1.9-2.9 slim profile glazing (Technical Paper 20) 0.8 10mm aerogel blanket to door (RCS 10)

Table 6: Maximum U-values applicable to the conversion of historic, listed or traditional buildings from the Scottish Government's Building Standards Technical Handbook (Domestic) with reference to Historic Environment Scotland Case Studies' and Technical Papers' results.

11. GETTING THE WORK DONE

Having selected the appropriate measures, it is necessary to identify the correct contractors and tradespeople to undertake the work. It may be worth employing someone with experience in traditional and older structures, as they may be more knowledgeable about how older buildings behave.

11.1 DESIGN AND SPECIFICATION

In a whole house retrofit, due to the complexity of the work, it is advisable to employ a professional designer with experience of this type of project. This formal construction term means the employment of a chartered architect, chartered surveyor or design and built contractor, who specifies and combines the work into a construction project.

11.2 CONTRACTORS

Much insulation work done in Scotland is product-based, which means that often only a small number of easily available materials are considered for use regardless of the building type. These may not be suitable for older structures, as described in the guide, in which case a contractor with a wider range of skills will be necessary. Often, the skills needed are mostly joinery, and therefore a joinery contractor with specialist sub-contractors is a good way to proceed.

11.3 RECORDS AND BUILDING INFORMATION

During the construction work, it is very likely that the Construction (Design and Management) regulations (CDM regulations) will apply. These require the building owner and contractor to manage the project to meet CDM standards. They also oblige the client/owner to compile an inventory of the products and materials that have been used in the refurbishment. This makes it possible to identify and record any hazardous materials that might affect later maintenance, and also allows later users to check what is there by referring to the Health & Safety File. Information on energy improvements should also be held here, including products used, operating manuals for equipment and suchlike. This information will be needed by the energy assessor when the EPC is done at the end of the project. It is the job of the owner to prove that the measures are in place and there is evidence for them being there. Construction photographs of insulation in dormer windows, for example, will be useful here.

12. THE ENERGY PERFORMANCE CERTIFICATE

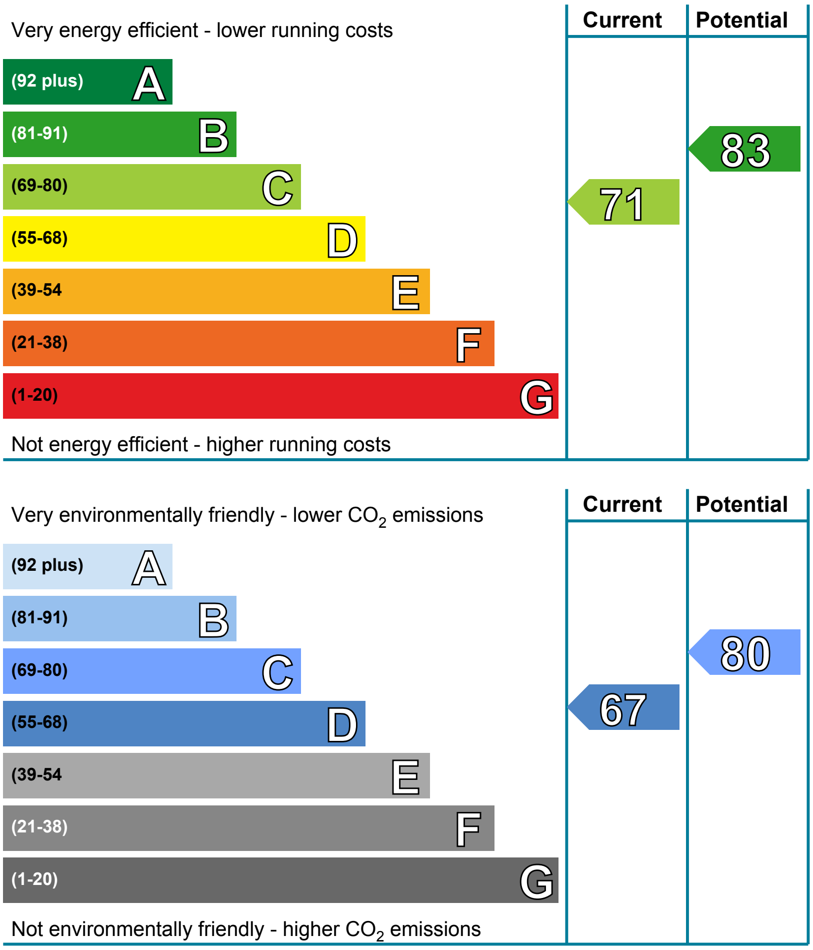
In most refurbishment projects, an important outcome for the owner will be an improvement in the Energy Performance Certificate (EPC) rating. This might be required to rent, lease or sell a home or building. Energy efficiency targets in Scotland will be met through use of the EPC process, so getting the EPC done properly is an important part of any retrofit project. The EPC band achieved will depend on the measures but also on the amount and accuracy of data included in the assessment process. This can be influenced by the experience of the assessor and the time spent on the survey, both of which can be affected by the way the work is priced. Key points are considered here, and readers are invited to look into the additional details needed to achieve a good EPC result. The example of the Holyrood Park Lodge case study is worth describing in detail, as it shows how great the difference can be depending on the approach taken.

Key points with the EPC assessment: the Assessor can only input what they see on the day of the survey. If measures cannot be seen, then the owner must show evidence for them. This might consist of photographs and data sheets, and possibly invoices for paid work. The type of fuel used as primary heating will make the greatest difference. A property which is off the gas grid will have a lower EPC than a similar property with mains gas. Insulation is measured in increments of 100mm, so don’t choose 75mm insulation unless you have to, as you will only be assessed for 50mm. Appendix Q of the Standard Assessment Procedure (SAP) Conventions Table shows what other measures can be assessed with additional input. In an older building, many measures or factors will be available here.

12.1 HOLYROOD PARK LODGE EPC

In this project, the building received a pre-intervention EPC of Band F with a SAP rating of 35. This poor rating is much as you would expect from an unimproved solid-walled traditional detached property. When it was reassessed following fabric improvements and using existing RdSAP conventions, a SAP rating of 71, the lower part of EPC Band C, was recorded. This is a good score for a 19th-century building (see Refurbishment Case Study 37). With further work, considering the addition of a renewable heating source, the EPC predicted that a score of 83, a Band B, could be achieved.

What was crucial in this process was the use of an experienced assessor who was given sufficient time to properly assess the building and used the ‘extended data’ entry options, as seen in Figure 70.



70

Figure 70: Post-intervention EPC from the Holyrood Park Lodge case study, where the pre-intervention EPC was band F.

Specifically, this consisted of measuring of all the components of the room-in-the-roof, including the ‘flat ceiling’ above, the vertical walls, the sloping ceilings of the cooms and the gable walls. Details of the boiler, the heating controls, hot water provision, secondary heating and lighting were also included. The details of the double glazing were entered, as well as chimney details. Detailed information on the insulation and other interventions was also provided to the assessor, as this had been compiled during refurbishment work. Where the same building was assessed using a simplified non-invasive survey with no product information supplied, the assessment gave a SAP Score of 48, an EPC Band E, representing a reduction of 15 points from the more detailed assessment.

The evidence from this case study clearly shows the importance of a detailed survey and analysis conducted by an assessor who understands the complexities of traditional buildings. This gives traditionally constructed buildings the best chance of being accurately assessed in the EPC process.

In early 2024, a new version of RdSAP is coming into use which will introduce important changes to how traditional buildings are assessed. These will include the need to measure windows and an improved methodology for measuring rooms in roof. The U-value assumptions for traditional stone walls in Scotland have been revised, and shutters are now counted towards the thermal performance of the building. There are also changes around recording thicknesses of insulation. It is important these are fully taken into account with any EPC assessment when the new RdSAP is brought into use. Historic Environment Scotland is planning to issue guidance on this, which will be referenced when complete.

12.2 THE FUEL SOURCE AND THE EPC

While it has been shown that the Lodge was able to achieve a good EPC rating after extensive fabric measures, it must be acknowledged that the biggest factor in the EPC assessment is the fuel source used in the primary heating. At the moment, mains gas gives favourable weight to those on the gas grid. Electric heating, portable gas and biomass do not fare so well and rural properties are often at a disadvantage, regardless of the extent of renovation or the care taken in the preparation of the EPC. For this reason, we have also modelled the Lodge in an off-the-gas-grid scenario using different heating and fuel systems; this work is also expected to be published in the future.

13.CONCLUSION

Traditionally constructed buildings are capable of being upgraded to give a much improved level of thermal performance. This can be achieved by interventions which are sympathetic to the building's appearance, character and performance, and in many cases, without resorting to the wholesale loss of original building fabric – therefore also supporting a circular economy – or the use of incompatible materials. These principles have been clearly demonstrated in the HES case studies programme.

Through careful consideration and application of the information on methods and materials described in this guide, the thermal performance of traditionally constructed buildings can be significantly improved. This will help to ensure that an important element of the nation's building stock has a viable future and can play its part in creating a sustainable and low-carbon Scotland (Figure 71).

Figure 71: A range of buildings which have been retrofitted as part of Historic Environment Scotland's technical research work. Several are listed and they have all had significant work carried out. Here, they are shown in their post-retrofit state.

14. CONTACTS AND FURTHER READING

14.1 CONTACTS

Historic Environment Scotland
Longmore House, Salisbury Place, Edinburgh, EH9 1SH
W: www.historicenvironment.scot

Conservation (technical advice)
T: 0131 668 8951
E: technicalresearch@hes.scot

Heritage Management (planning/listed building matters)
T: 0131 668 8981
E: hmenquiries@hes.scot

The Energy Saving Trust
W: www.energysavingtrust.org.uk

Home Energy Scotland
W: www.homeenergyscotland.org

The Pebble Trust
W: www.thepebbletrust.org

Under One Roof
W: underoneroof.scot

Society for the Protection of Ancient Buildings (SPAB)
W: www.spab.org.uk

Sustainable Traditional Buildings Alliance (STBA)
W: www.stbauk.org

14.2 FURTHER READING

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English Heritage Saving Energy guidance:
https://historicengland.org.uk/advice/technical-advice/energy-efficiency-and-historic-buildings/

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Historic Environment Scotland Technical Papers

- Technical Paper 1 - Thermal Performance of Traditional Windows
- Technical Paper 2 - In-Situ U-Value Measurements in Traditional Buildings
- Technical Paper 6 - Indoor Air Quality and Energy Efficiency in Traditional Buildings
- Technical Paper 7 - Embodied Carbon in Natural Building Stone in Scotland
- Technical Paper 9 - Slim-Profile Double Glazing
- Technical Paper 10 - U-Values and Traditional Buildings
- Technical Paper 12 - Indoor Environmental Quality in Refurbishment

Historic Scotland Refurbishment Case Studies

- Refurbishment Case Study 1. Windows and wall upgrades to five tenements, South Side, Edinburgh.
- Refurbishment Case Study 2. Wall, floor, roof space and glazing upgrades, Well O’ Wearie Cottage, Edinburgh.
- Refurbishment Case Study 3. Wall and roof space upgrades, Wee Causeway Cottage, Culross, Fife.
- Refurbishment Case Study 4. Wall upgrades to six tenement flats, Sword Street, Glasgow.
- Refurbishment Case Study 5. Roof space and glazing upgrades, Tenement, The Pleasance, Edinburgh.
- Refurbishment Case Study 6. Wall, floor, door, roof space and glazing upgrades, Kildonan Cottage, South Uist.
- Refurbishment Case Study 7. Wall, floor, roof space and glazing upgrade, Scotstarvit Tower Cottage, Fife.
- Refurbishment Case Study 8. Wall, floor, roof space and glazing upgrades, Garden Bothy Cottage, Cumnock, Ayrshire.
- Refurbishment Case Study 9. Roof space upgrade, Leighton Library, Dunblane.
- Refurbishment Case Study 10. Wall upgrade, Tenement, Govan, Glasgow.
- Refurbishment Case Study 11. Wall, door and glazing upgrades to two tenements, Rothesay, Isle of Bute.
- Refurbishment Case Study 12. Roof space and glazing upgrades, Terraced House, Newtongrange, Midlothian.
- Refurbishment Case Study 13. Wall and window upgrades, Whitevale Street, Glasgow.
- Refurbishment Case Study 16. Thermal improvements to fabric of a 1800s granite farmhouse, Kirkton of Coull, Aberdeenshire.
- Refurbishment Case Study 19. Trial church heating: radiant panels and air source heat pump, Kilmelford Church.
- Refurbishment Case Study 20. Wall and roof upgrades, 1930s house, Perth, Perthshire.
- Refurbishment Case Study 21. Re-instatement of micro-hydroelectic plant, Blair Castle, Perthshire
- Refurbishment Case Study 22. Repairs, wall and floor upgrades to a highland cottage, Downie’s Cottage, Braemar.
- Refurbishment Case Study 27. Ventilation and insulation upgrades, Holm Farm Cottage, Grantown-on-Spey.
- Refurbishment Case Study 35. Wall upgrades in 19th-century flats, Lauriston Terrace, Edinburgh.
- Refurbishment Case Study 37. Wall, roof, floor and glazing upgrades in 19th-century building, Holyrood Park Lodge, Edinburgh.

Historic Environment Scotland Guides

- Short Guide: Micro-Renewables in the Historic Environment
- Short Guide: Maintaining Your Home
- Short Guide: Climate Change Adaptation for Traditional Buildings
- Short Guide: Sash and Case Windows
- INFORM: Maintaining Sash and Case Windows
- INFORM: Maintaining Traditional Plain Glass and Glazing
- INFORM: Ventilation in Traditional Houses
- INFORM: Domestic Chimneys & Flues
- INFORM: Improving Energy Efficiency in Traditional Buildings
- INFORM: Timber Window Shutters
- INFORM: Mould Growth
- INFORM: Tenement Maintenance
- INFORM: Condensation

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15.GLOSSARY

For more information on Scottish building terms, see the *Dictionary of Scottish Building* by Glen Pride (Rutland Press, 1996).

Aerogel	A synthetic porous material derived from a gel, in which the liquid component of the gel has been replaced with a gas, resulting in a material with very low density and thermal conductivity.
Architrave	The moulding framing a door or window.
Astragal	A bar that separates and supports the individual panes of glass in a window.
Batt	Semi-rigid insulation board.
Calcium silicate board	A rigid, micro-porous mineral board. Its high capillary action assists in humidity regulation. The nature of the material means that mould cannot form on its surface.
Cames	Strips of lead that hold the glass in place in a leaded light.
Cellulose insulation	Formed of cellulose fibre commonly derived from recycled newspapers. It can be blown into cavities, laid as loose fill or applied directly to a wall through damp spraying.
Chimneystack	The part of a chimney that rises above the roof of the building, often containing a number of flues.
Cold bridge	Sections of building fabric which have considerably lower thermal resistance than neighbouring areas when, for instance, an element directly connecting the interior to the exterior surface of a building, or where an area is insufficiently well insulated.
Cold roof	The method of applying insulation above a ceiling in a loft space so that everything above the insulation is colder than that below.
Condensation	The formation of liquid water on a surface from a gas or vapour state due to the air temperature falling below its dew point.
Coom ceiling	A Scottish term for a sloping ceiling, the upper side of which forms part of the roof of the building.
Cornice	A decorative horizontal moulding that runs along the junction of an internal wall and the ceiling.
Dew point	The temperature at which the water vapour in a volume of humid air at a constant barometric pressure will condense into liquid water.
Draughtproofing	The process of reducing air leakage in the frames of windows, doors or loft hatches.
Dry lining	A wall lining commonly formed of plasterboard on timber studs, which does not need to be plastered.
Dwang	A Scottish term for a transverse piece of wood inserted between joists or posts in order to stiffen them.
Eaves	The lower edges of a roof that usually project over a side wall in order to carry rainwater away from the fabric.
Geotextile	A moisture vapour permeable artificial fabric.

Harling	A Scottish term for the application of an exterior render of roughcast comprised of lime and aggregate.
Hemp board	A rigid board-based insulation formed of fibres from hemp plants. Hemp/wool insulation is a semi-rigid insulation formed of a mixture of hemp and wool fibres.
Hydrophobic	Incapable of absorbing moisture.
Hygroscopic	Capable of absorbing and releasing moisture.
Jamb	The vertical side posts used in the framing of a doorway or window. The outer part of the jamb, which is visible, is called the reveal.
Joist	A beam supporting the floor or roof, which is normally made of timber.
Lath and plaster	The building process used for lining internal walls from the 18th century up until the mid-20th century. Vertical timber battens are fixed to the masonry; thin timber laths are then horizontally mounted. Three coats of lime plaster complete this lining. The gap behind the laths and plaster is normally 25 to 30mm.
Leaded light	A window formed of a lattice of small panes and held within strips of lead known as cames.
LED lighting	Light-emitting diodes emit visible light when electricity is passed through them. They are a form of energy-efficient lighting.
Lime concrete	A concrete formed of aggregate with lime rather than cement as the binder.
Mansard roof	A roof that has two slopes on each side, the lower slope being longer and steeper than the other and often incorporating dormer windows to allow the roof space to be inhabited.
Mass masonry	Masonry formed of material such as stone, brick or earth without a cavity separating the inner and outer parts of the wall.
Mineral paint	A moisture vapour permeable paint finish.
Mineral wool insulation	A type of thermal insulation made from an inorganic fibrous substance that is produced by steam blasting and cooling molten glass, slag or rock.
Phenolic foam	A synthetic polymer made from thermosetting foam plastic and used in thermal insulation.
Plaster ‘on the hard’	The application of lime plaster directly onto the surface of masonry walls without any laths.
Rafter	A sloping timber extending from the wall plate to the ridge of a roof.
Relative humidity	The amount of water vapour existing within a mixture of air and water vapour, expressed as a percentage.
Reveal	The part of the jamb between the frame and the outside wall, which is ‘revealed’ in the sense that as it is not covered by the frame.
Ridge	A horizontal line caused by the junction of two sloping roof surfaces.
Sarking	A continuous layer of timber boards onto which slates or tiles are laid.
Secondary glazing	A second window installed internally next to the original window.
Sheep’s wool insulation	A flexible insulation formed of wool with a small percentage of polyester binder.
Skew	Scottish term for the coping stones that run along the top of a sloping gable.

Skirting	A finishing board that covers the joint between the wall and the floor of a room.
Solum	The vacant area underneath a suspended timber floor.
Staff beads (window)	A moulded or beaded angle of wood or metal set into the corner of plaster walls to protect the external angles of the two intersecting surfaces.
Suspended timber floor	A floor suspended above ground level, usually consisting of timber joists spanning the ground floor, supported by sleeper walls. This allows air ventilation and prevents dry or wet rot occurring on the timber.
Sustainability	The long-term responsible management of resource use, encompassing environmental, economic and social dimensions to allow for the endurance of said resources.
Thermostat	A device that senses temperature and is used to maintain a constant temperature.
Trickle vent	A small opening in a window or building component to allow for ventilation, where natural ventilation should occur but may be impinged.
U-value	The measurement of the rate of heat loss through a building component; the lower the U-value, the less heat is lost through that building element. U-value is expressed in W/m^2K.
Warm roof	Insulation is usually placed on or adjacent to the roof rafters, so that everything below the insulation is as warm as the rooms in the house.
Window case	The framework of a window that holds the sash in place. Often referred to as a ‘sash case’.
Water vapour permeability	The ability of a material to allow water vapour to pass through it.
Window sash	The timber frame around the glass in a window. The term is used almost exclusively to refer to windows where the glazed panels are opened by sliding vertically or horizontally, hence the term ‘sash and case window’.
Wood fibreboard	Rigid insulating board, available in various forms and made from a wood-based material.

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