Department for
Communities

An Roinn
Pobal

Depairtment fur
Commonities

www.communities-ni.gov.uk

Historic
Environment
Division

Guidance for the Thermal Upgrade of Traditional Buildings

December 2023

As the Construction Industry Training Board for Northern Ireland, CITB NI welcomes and endorses this guidance on improving the energy efficiency of traditional buildings. This guidance creates a solid grounding for undertaking appropriate works to older and listed buildings, increasing knowledge and awareness of opportunities and challenges to ensure that Northern Ireland's historic environment retains its character and significance, whilst increasing occupant comfort and improving energy efficiency. Northern Ireland has an increasing number of pre-1919 buildings requiring repair and maintenance, and as we continue to move towards net zero targets, the retrofit of older buildings will form a significant part of regional construction output. Therefore, this guidance is not only important to the heritage sector, but also to the wider construction sector.

CITB
CONSTRUCTION INDUSTRY
TRAINING BOARD NI

Contents

Introduction

Reducing our energy use has become an urgent global issue, as our finite resources are used up and the same uncontrolled use of those resources has caused harm to our environment. The world's global dependence on energy has been increasing at an alarming rate. According to the International Energy Agency (IEA), from 1973 to 2019, world-wide energy consumption increased by 115%[1]. The building sector has contributed to a large portion of this increase.

Our traditional[2] buildings represent an opportunity for us to 'do the right thing', both in terms of reducing our carbon output and reducing fuel poverty, in tandem with conserving valuable heritage. Through understanding these buildings and applying the right approach, we can benefit from their embodied energy, better their performance and sustain them for the future.

This document aims to:

- describe the physical qualities of a traditional building,
- encourage understanding of the built fabric,
- advise on relevant legislation,
- provide practical measures which can be taken to improve efficiencies and comfort without damage or harm to occupants, fabric, building character and architectural heritage and
- consider the various types of complementary energy systems (e.g. micro-renewables).

The document is intended to help inform a broad audience including owners or stakeholders, building professionals, expert tradespeople and installers involved in the retrofit of traditional buildings.

The technical drawings included in this guidance document are diagrammatic only and are used to illustrate general principles. They are not intended to be used as drawings for purposes of construction nor statutory compliance. Older buildings need to be evaluated individually to assess the most suitable form of construction based on a wide variety of possible variables. Historic Environment Division (HED) does not accept liability for loss or damage arising from the use of this information.

Clay Gate Lodge Mount Stewart Co. Down

Our companion document to this guidance is Retrofit of traditional buildings - what to consider when planning for the future

---

[1] https://www.iea.org/reports/key-world-energy-statistics-2021/final-consumption (increase from 194ExaJoules in 1973 to 418EJ 2019)

[2] Traditional refers to construction methods and for the purposes of the guidance, the term historic will also be used as most historic buildings in Northern Ireland are of traditional construction

1 Why do we need to address the energy efficiency and performance of traditional buildings?

There is clear evidence that climate change is happening. The shift in our climate has caused a number of variations as greenhouse gasses (GHG) have trapped heat near the earth's surface and our oceans have absorbed vast amounts of heat energy.

In Northern Ireland our climate will become wetter and warmer, which will impact heritage buildings. For example:

- structural damage to heritage assets
- the collapse of unstable masonry elements
- the decay of building fabric caused by increased saturation
- microbiological growth in interiors and

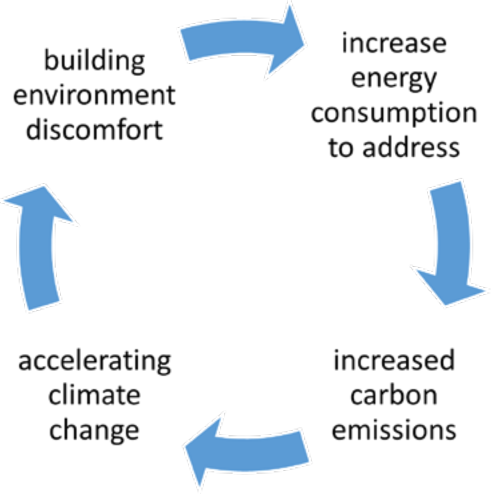
Inappropriate energy efficiency or adaptation strategies or techniques can pose a further risk to traditional buildings, but appropriate thermal upgrade of traditional buildings responds to the impacts of climate change in two main ways.

1. Reducing carbon footprint - Improving the insulating properties of buildings reduces the requirement for fuel energy (and thus carbon) expenditure to control internal temperatures (both heating and cooling) in buildings. This contributes to the now statutory requirement to reduce the carbon footprint of buildings, mitigating against future climate change impacts by reducing a building's operational carbon needs.

2. Protecting buildings by adapting to change - Because of the changing temperatures and extreme weather events which are already happening, historic buildings need to adapt. More extreme changes in temperature as well as increased storms occurrence and higher predicted rainfall requires improvement of the external envelope, to improve comfort for their occupants.

Energy consumption and Climate change

> “Buildings account for 40 % of total energy consumption in the (European) Union. The sector is expanding, which is bound to increase its energy consumption. Therefore, reduction of energy consumption and the use of energy from renewable sources in the buildings sector constitute important measures needed to reduce the Union’s energy dependency and greenhouse gas emissions.” [3]



The cycle of increasing energy consumption by buildings to address climate change impact

Background on Climate Change Action

The 1992 United Nations Framework Convention on Climate Change (UNFCCC) is the primary framework for international climate change cooperation. The more recent 2015 Paris Agreement is the historic legally binding agreement which set in place a durable and dynamic framework requiring all Parties to take climate action, an agreement to pursue efforts to keep warming below 1.5°C and to support to those countries with insufficient resources to do likewise.

Addressing Climate Change Globally

The International Energy Agency (IEA) report global energy-related CO2 emissions grew by 0.9% or 321 Mt in 2022, reaching a new high of over 36.8 Gt. This included a post pandemic spring back and above following a 5% shrink in 2020 as a result of the pandemic.

It sets out key activities (buildings and energy) to achieve net zero by 2025[4]:

- no new sales of fossil fuel boilers by 2025
- 50% of existing buildings retrofitted to zero-carbon-ready levels by 2040
- 50% of heating demand met by heat pumps and
- nearly 90% of electricity from renewables by 2050 (nearly 50% from low emissions sources by 2025)

Addressing Climate Change in the UK

The **Climate Change Act 2008** introduced the UK’s first legally binding target for 2050 to reduce greenhouse gas emissions by at least 80% compared to 1990 levels. On 27 June 2019 the UK government **amended the Climate Change Act** and set a legally binding target to achieve net zero greenhouse gas emissions (100% lower than the 1990 baseline) from across the UK economy by 2050. Improving energy efficiency is central to meeting the United Kingdom’s long-term goal of cutting greenhouse gas (GHG) emissions.

---

[3] European Union DIRECTIVE 2010/31/EU 2010

[4] https://www.iea.org/reports/world-energy-outlook-2022/an-updated-roadmap-to-net-zero-emissions-by-2050

Addressing Climate Change in Northern Ireland

The Climate Change Act (Northern Ireland 2022) sets a target of net zero greenhouse gas emissions by 2050. It aims to reduce greenhouse gas emissions through adaptation and mitigation measures, develop a low carbon inclusive skilled workforce and a strong circular economy, and a clean environment- cleaner air and water, more sustainable land use and improved habitat and greater bio-diversity.

View of harbour and terrace backs from Donaghadee Motte

Climate Change and Heritage Buildings

An ICOMOS (International Council on Monuments and Sites) Working Group on Climate Change and Heritage[5] was established in 2016.

Part of the work of the working group is co-ordinating the drafting of a new ICOMOS Charter on Climate Change and Heritage. (A charter is ICOMOS's most formal type of international doctrinal document, addressing heritage and conservation as a discipline.)

In 2017 the ICOMOS General Assembly meeting in Delhi, welcomed the adoption of the Paris Agreement and to align with it, requested the development of climate change policies and engagement.[6]

UNESCO has also prepared a Draft Policy Document on Climate Action for World Heritage (2021), which is an update of the 2007 policy document on The Impacts Of Climate Change On World Heritage Properties.

---

[5] ICOMOS Working Group on Climate Change and Heritage concept note

[6] https://www.icomos.org/en/focus/climate-change/60669-icomos-work-on-climate-change

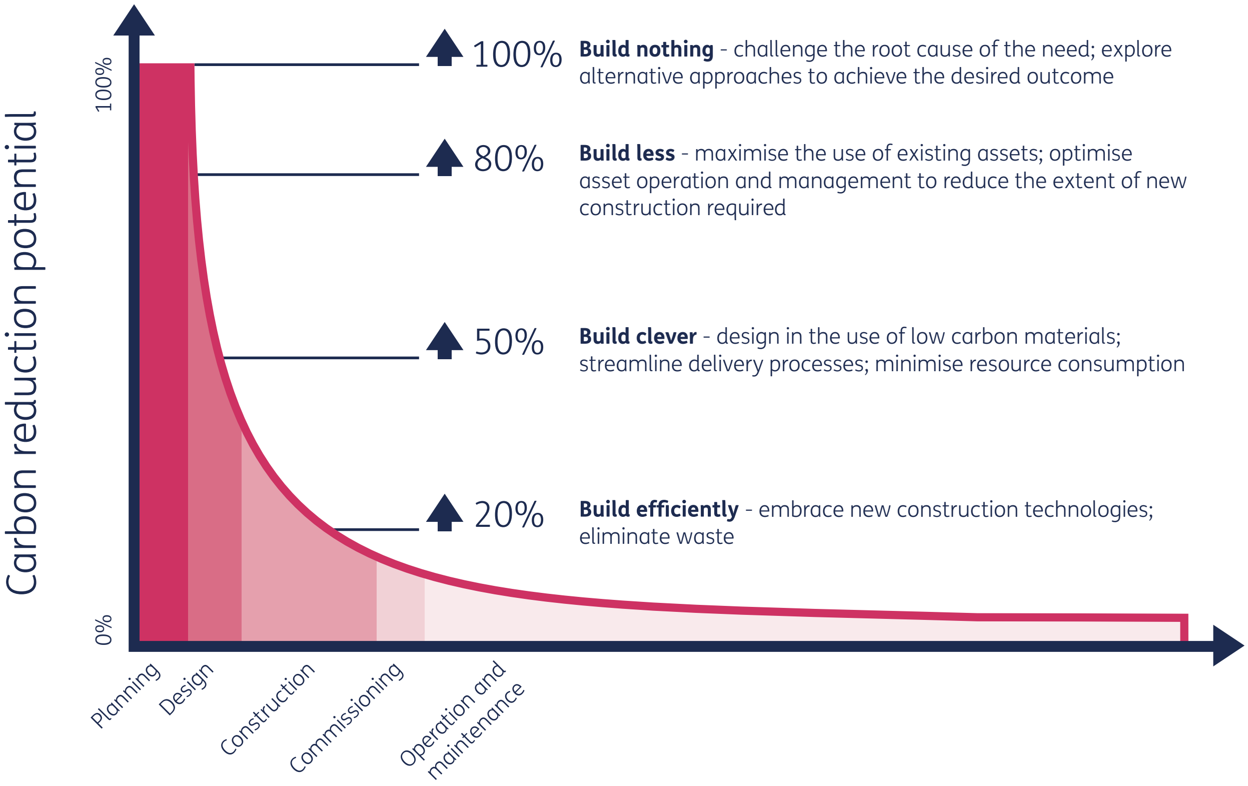
The Case for Retrofit

> **“The greenest building is the one that already exists”**
>
> Carl Elefante, former president of the American Institute of Architects.

Embodied carbon (the total energy used to bring a building into being) is now recognised in the context of a ‘net zero carbon’ building, where upfront carbon is minimised to the greatest extent possible and all remaining carbon reduced or, as a last resort, offset to achieve net zero across the life cycle.

Being able to reduce embodied carbon is dependent upon the stage of a build project. Typically, those that will have the most effect will relate to early decisions during the strategic planning stage because embodied energy is the ‘the energy that is required to extract, process, manufacture, transport and install building materials and is (then) deemed to be embodied in the finished building’.[7]

This is where existing buildings have a head start and an important role to play, because no further carbon expenditure is needed to bring them into being, and their retention and upkeep can preclude the requirement to build new and expend further energy. As energy efficiency standards improve, retrofit makes more sense – the energy which will be used in a new build will almost always outweigh that to retrofit an existing building.[8]



Tackle carbon early (below) ‘More opportunities for carbon reductions exist earlier in the construction process’[9]

---

[7] IRON (buildingsofireland.ie)

[8] ditto

[9] Tackle carbon early. Source: HM Treasury (2013) and Green Construction Board (2013), reproduced under the terms of the Open Government Licence (Crown Copyright 2013)

Net Zero

The term ‘net zero’ is commonly used and generally means that buildings are highly energy-efficient with the operational energy use provided by renewable energy (preferably on-site but also off-site production), to achieve net zero carbon emissions annually in operation.

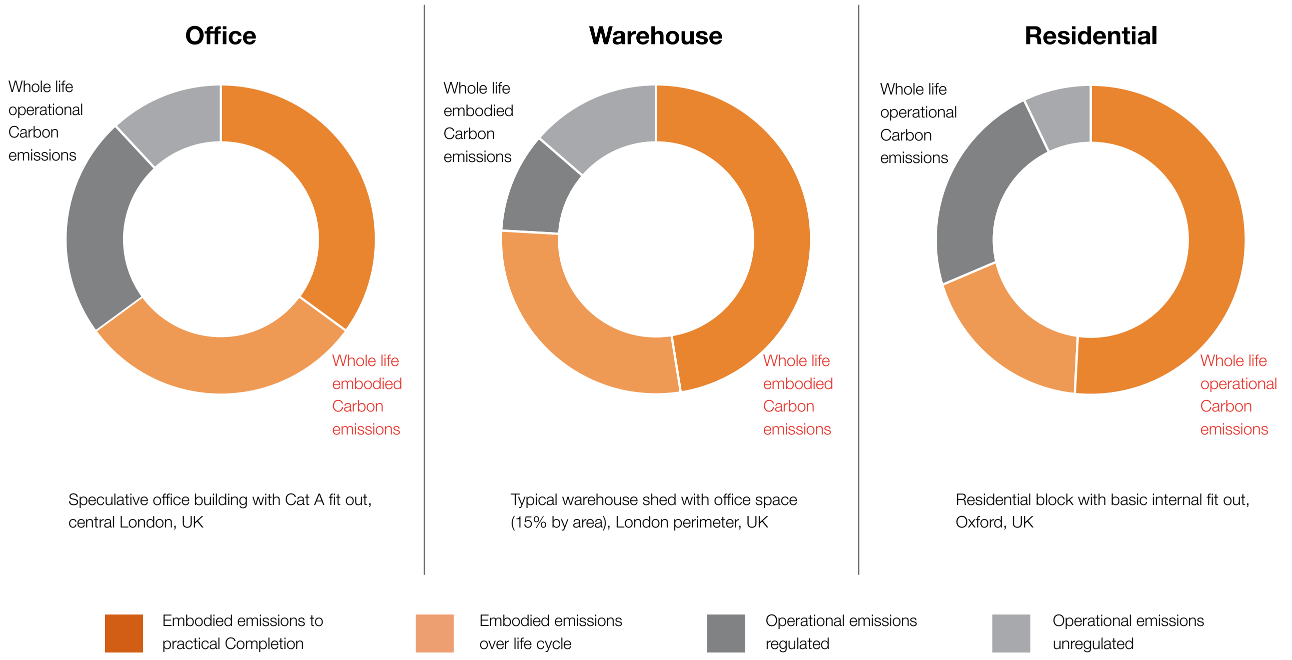
An Industry Response

In December 2019, the Royal Institute of British Architects launched its Sustainable Outcomes Guide. The guide details metrics, targets and goals for eight sustainable outcomes and correspond to the key UN Sustainable Development Goals (SDGs)[10].

Clear illustration is provided for the need for buildings to be considered for their whole life carbon rather than their operational energy alone.

Other industry sources[11] quote the fact that 2/3 of 200,000 tonnes annual waste is construction waste, that the construction industry contributes approximately 10% of annual carbon emissions and also makes a call for a cut to VAT on refurbishment from 20% to 5 or 0% to encourage retrofitting.[12]

Given the overarching global emergency and legislation and emerging legislation, there are likely to be standards which will soon be mandatory to go toward achieving targets and goals for reducing carbon expenditure. These can be met without compromising historic buildings and this



Speculative office building with Cat A fit out, central London, UK

Typical warehouse shed with office space (15% by area), London perimeter, UK

Residential block with basic internal fit out, Oxford, UK

Pie charts illustrating indicative relationships between operational and embodied carbon emissions for three building typologies © Diagrams: Sturgis Carbon Profiling/ RICS included in RIBA Sustainable Outcomes Guide 2019

---

[10] https://www.architecture.com/knowledge-and-resources/resources-landing-page/sustainable-outcomes-guide

[11] https://www.architectsjournal.co.uk/news/introducing-retrofirst-a-new-aj-campaign-championing-reuse-in-the-built-environment

[12] At publication date, VAT in Northern Ireland is a reduced rate of 5% on energy saving measures made to residential buildings. See guidance at Gov.uk

guide sets out to describe how these might be sensitively proposed and implemented.

Research on pre 1919 buildings

Suitable and sensitive energy saving measures in historic buildings can result in significant carbon reductions. Studies by Historic England have shown that the pace of retrofitting is key to making maximum environmental gains i.e., increasing energy efficiency on a number of buildings quickly will save proportionally more carbon than tackling them over a longer period of time[13].

1.4 Carbon saves - 4 scenarios

- Scenario I: There is no refurbishment or demolition of pre-1919 residential building.
- Scenario II: 50% is refurbished in a 10 years period, starting in 2021.
- Scenario III: 15% is refurbished in a 10 years period, starting in 2021.
- Scenario IV: 25% is refurbished in a 25 years period, starting in 2019.

Retrofitting 15% of traditional buildings over a 10-year period (Scenario III), would reduce carbon emissions by 11.9 million tCO2 and save £2.4 billion in the cost of reducing carbon emissions to achieve the UK's environmental targets. In comparison, retrofitting 25% of historic buildings over a 25-year period (Scenario IV) would result in £2.5 billion of savings.
The costs of offsetting carbon saved at Scenario IV marginal (£0.1bn) despite a significantly larger proportion of buildings retrofitted, suggesting that retrofitting historic buildings at a quick pace is paramount and confirming the need to urgently reduce operational carbon in existing buildings (Historic England, 2020).

Table 1: Comparing carbon saved in different scenarios[14], against a baseline (Scenario1)

Scenarios	Carbon saved (tCoze20) against scenario I (millions)	In 10 years-old Conifer tree (millions)	In real monetary values in 2019 prices (billions)	In UK's GDP (2019)
I	0	0	£0	0%
II	39.6	9.4	£3.4	0.11%
III	11.9	2.8	£2.4	0.08%
IV	15.5	3.7	£2.5	0.08%

Source: Based on estimates using the Carrig Conservation International Report (2020),[15] Council tax: Stock of properties (2019), the UK Office for National Statistics (2019) and the International Fund (2019)

---

[13] Valuing carbon in pre-1919 residential buildings (historicengland.org.uk)

[14] Scenarios include both the operational and embodied carbon emissions of residential historic buildings.

[15] **https://historicengland.org.uk/content/docs/research/understanding-carbon-in-historic-environment/**

2 What is a traditional building?

Many of our listed buildings are termed 'traditional', by which we mean they were erected pre 1919 and are of solid wall, vapour permeable construction. These often have a pitched roof with a slate or other traditional or natural covering. Some 16% of Northern Ireland's buildings are pre-1919 construction. (10% of Republic of Ireland's buildings are of the same period).

Their construction methods mean that their fabric behaves differently to a modern cavity built or framed building. This document looks at how we approach introducing energy efficiency measures to reduce their energy consumption and make them more comfortable to live in without compromising their special character, which in the case of listed buildings is protected by legislation[16].

The previous chapter explains why retaining existing buildings is important in terms of locking in embodied carbon. This is not exclusive to protected traditional buildings; many unprotected traditional buildings also have a lot to offer us and their retention can equally contribute to addressing climate change.

Bellaghy Castle, limewashed rubblestone walls

---

[16] The Planning Act 2011 (NI)

3 Principles of traditional fabric behaviour

Walls

The walls of most historic buildings in Northern Ireland are solid in nature. These range from mud walls in our thatch and vernacular buildings (these are mostly grouped south of Lough Neagh) to stone to brick, with variations and combinations in between, depending on the period and on the building's status.

Various traditional walls: clockwise from top left – fine ashlar stone, rusticated limestone, rendered mud wall, coursed limestone, polychromatic brick, random coursed greywacke.

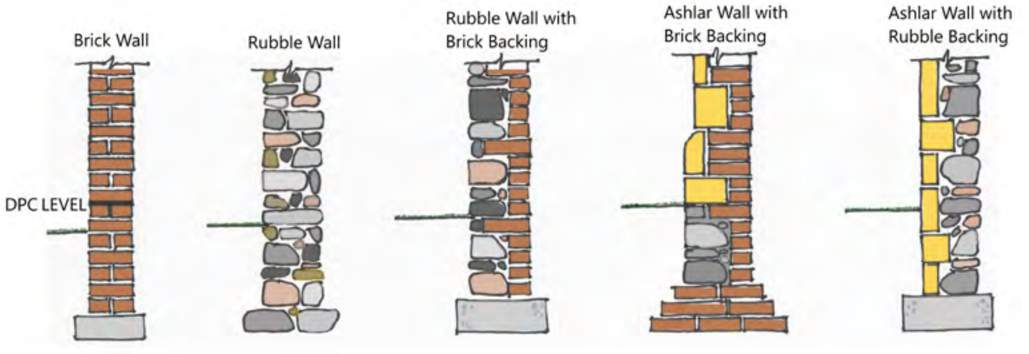


Diagram of solid wall types ©2009 University of the West of England, Bristol

However they were formed or constructed, their commonality is that the materials used (mud, stone, clay brick, timber, lime) are almost all hygroscopic[17], that is, they can absorb moisture from the air, but crucially, they can also readily release it when environmental humidity allows. They will therefore act as a buffering medium between the external and internal environments, absorbing and releasing climatic and inhabitant generated moistures without barrier. The heat generated by the inhabitants and other heat sources serves to keep this process active and ensures the cycle of vapour passing through the wall is maintained and the wall remains in good physical health. The absence of this exchange occurring is one of the reasons why an empty traditional property can deteriorate more quickly than a vacant modern building.

We describe the fabric of the wall as being 'breathable '[18] or vapour permeable. These terms describe a materials ability to allow water vapour to pass through it and is technically measured as the m/mu-value or μ value. This diffusion resistance factor indicates how much higher the materials resistance to displace water vapour is when compared with a layer of air of the same thickness and temperature. Materials with a diffusion factor up to 10 are considered to have a very high vapour permeability.

Comparison of μ-values

	Water vapour diffusion Resistance
Rock wool	1.0-1.3
EPS	20-70
XPS	80-150
Sheeps's Wool	1.0-3.0
Gypsum plaster	10.20
Lime render	7.15
Masonry Paint	300+
Polyurethane insulation with foil	2000
Cement render	15-25

It is key this quality is maintained for the health of both the building and inhabitants when thermal upgrading is proposed. Most of these traditionally constructed walls did not have a damp proof course and depended on good maintenance, ventilation and habitation to keep them reasonably dry, although slate courses were sometimes used, and later, mastic asphalt.

---

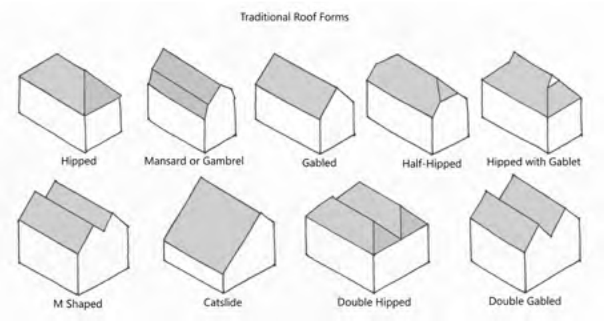
[17] Granite and slate are not hygroscopic materials

[18] Caution is advised around the use of the term 'breathable' especially when seeking solutions for traditional walls in additive products

Roofs

Traditional buildings are most commonly protected by a pitched roof. This may be simple single pitches or complex forms with valleys and leaded sections bridging parts of a deep plan. It may be thatch or tin or slate/stone shingles. All of these materials require a structure for support, which traditionally has been timber, ranging from the interesting bog oak and rare cruck frames of our thatch buildings to the truss and cut timber structures of the largest of stately homes, country houses, and former mill buildings.

Valley to slate roof, double pile arrangement



Pitched roof types

Complex roof with glass, lead and slated elements

Slate roof with lead 'catslide' and modern corrugated roof abutting

New double pile roof at Carrickfergus Castle

As with the wall element, these roofs allow a building to breathe through the materials themselves or through gaps in their abutment or arrangement (slate). The thatched roofs behave most similarly to the traditional wall, the heat and moisture of the inhabitants is buffered by the layer of turf over the timbers (called the scraw) and deep layers of straw, rye or flax over that.

The slated roof is traditionally laid on battens or sarking. Sarking is a timber boarded base and was traditionally laid over structure, often with an intentional gap, called a ‘penny gap’, to allow ventilation of the roof space. This is a Scottish detail but some crossover inevitably occurred and it is found for example in Donaghadee which was heavily influenced by trade with Scotland. The sarking detail is also suited to exposed locations.

More commonly, the slated roof onto battens was often parged with a lime slurry to reduce draughts but as lime is hygroscopic this similarly allows for the passage of moisture. This is also called lime torching. The introduction of roofing felt was rare before the 20th Century and introduced a layer which was not vapour permeable to the build up.

Almost without exception (and excluding the insulating qualities of thatch and minor effect of sarking and lime parge/torch), the traditional roof was uninsulated. The introduction of insulation to roofs is a measure that can greatly increase a buildings thermal efficiency without impacting its character unduly but should be carefully thought out and implemented to ensure the intervention will not have a detrimental effect on the fabric.

Parging/torching to underside of slate

Sarking board under protective layer during build

Thatched roof

Sarking board

Derry / Londonderry roofscape

Windows

Windows play a vital role in the overall character and appearance of traditional buildings, both internally and externally. They are important to our appreciation of a building as the inhabitant or as the wider public who experience the building in its setting.

Traditionally windows were largely single glazed, timber, often sliding sash though more latterly casement. Likewise, later (20th century) windows were sometimes steel, but remained single glazed. Historic glass is of particular interest, especially given the small amount remaining following a turbulent modern history and its impact, particularly in our town centres. It was thinner than modern glass, with imperfections and sometimes colour from impurities which gave it character[19]. Because it was thinner it meant more slender bars were adequate to support it in the frame.

Georgian sliding sash in painted brick surround

Historic windows are particularly at risk as an element of the building frequently targeted by thermal upgrade schemes. This may be because of their perceived contribution to heat loss, and because as an element of work, they are considered easier to replace or address than the walls or floor.

Metal window with pivot turn opener

Their timbers are often of superior quality, having been produced from slow grown timbers, therefore denser and with greater durability. It is important for the character of a building that their essential form and characteristics are retained and maintained though there are sympathetic measures which can be taken to reduce heat loss through traditional windows.

---

[19] Inform Guide: Maintaining Traditional Plain Glass and Glazing | HES (historicenvironment.scot)

Multi pane casement windows

20th century steel windows

Bay window with door slim profile timber

3 panes over 2 sliding sash timber

Fixed 16 pane light

20th century, Critall doors

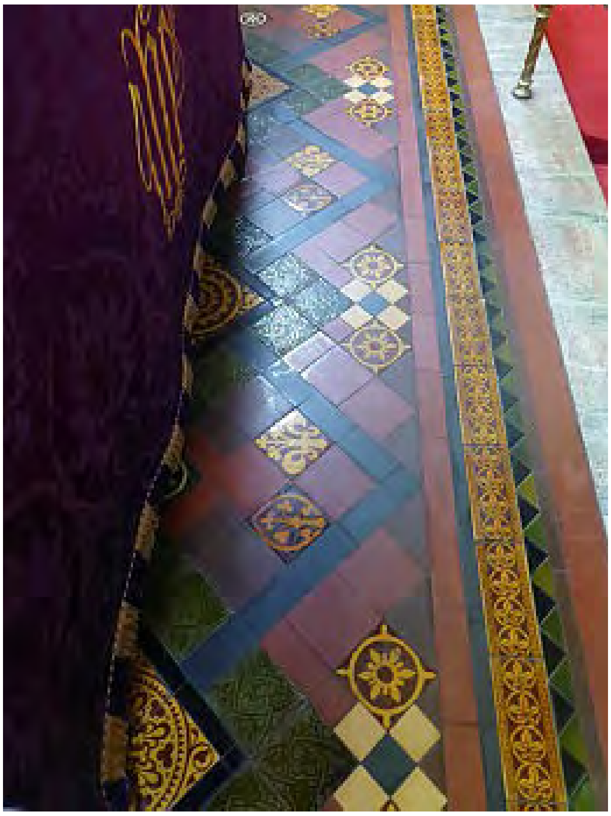
Floors

Traditional buildings (as with modern buildings) have both solid and suspended ground floor constructions. Solid ground floors most simply might consist of a compacted earth floor, or with the addition of stone or tiles. There is usually no separating membrane as a barrier to the damp of the earth, something which will sometimes cause alarm to those inexperienced in working with traditional buildings.

Where these applied floors are still in place and are of interest and significance, it may be difficult to upgrade thermally without damage to friable or otherwise delicate finishes.

Suspended floors consisted of timber structure and boards which likewise would be uninsulated and sometimes, as in a church where there might be solid and suspended areas, unventilated. Suspended floors may provide a greater opportunity for upgrading thermally, where their subfloor level can be accessed, insulated and the superstructure (floorboards) then replaced, without loss or impact on historic fabric.

As with the roof and walls, this element should remain vapour permeable and/or ventilated. Sealing off an historic floor with modern materials e.g. concrete, can force trapped moisture into its surrounding walls to escape; measures can be taken to ensure this risk is avoided or minimised.



Victorian tiling to church, image Alastair Coey Architects for HED

Repaired and salvage flooring, image Alastair Coey Architects for HED

Worn floor boards

Stone flagging to church aisle

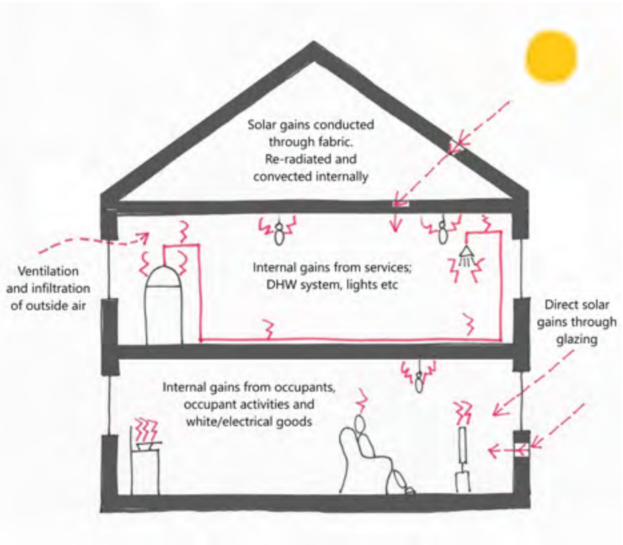
Geometric pattern stone floor

Pitch pine parquet

4 Comfort and expectations

Occupant behaviour & comfort

Our modern lives are busy, and our time spent at home and in workplaces is intermittent for large portions of our lives. In general, the very young and the elderly will proportionally spend a greater amount of their time at home, although changes brought about by the Covid-19 pandemic may exert a long-term influence on our daily movements.



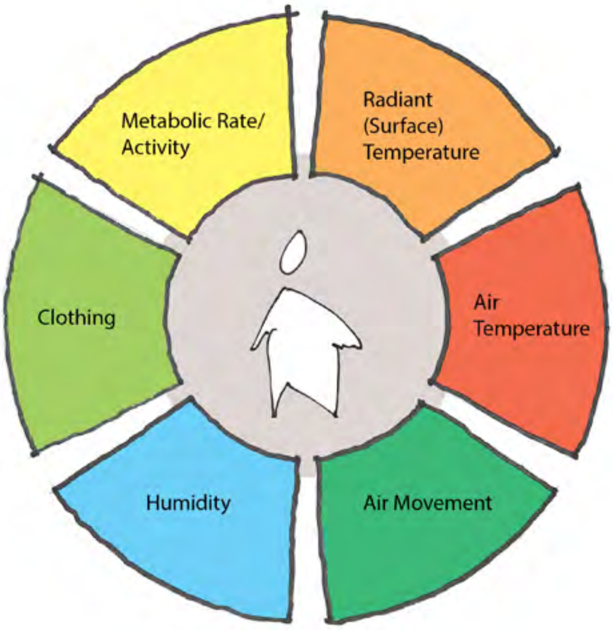
Source: BRE Guidance document Overheating in Dwellings

The levels of comfort and technical services we expect have a significant effect on the energy a building consumes; the greater the number of heat generating appliances and lighting that are operating in a building, the less the demand on the heating system to provide comfort, although modern appliances are much more efficient in terms of energy usage and will produce negligible heat. The number of people using a building will also influence the heating demand. While this may be relevant in a busy workplace or communal building, its effect is minimal within a dwelling.

4.1 Heat gains

Northern Ireland has a temperate climate with modest extremes of minimum and maximum temperatures, when considered on a daily, seasonal and annual basis.

A comfortable internal temperature is accepted as being in the range of 18-21°, dependent on room use, but there are behaviours and interventions which will reduce heating demand from the whole space approach that is accepted in a modern building. Thermal comfort is defined as the ‘condition of mind that expresses satisfaction with the thermal environment and is assessed by subjective evaluation’ (ANSI/ASHRAE 2020).[20]



Thermal comfort factors

BS EN ISO 7730:2005 sets out the factors which influence thermal comfort, four of which are environmental and two are directly occupant controlled.

---

[20] https://www.sciencedirect.com/science/article/pii/S0360132309000559 , CIBSE TM 68 - Technical Memorandum 68: Monitoring Indoor Environmental Quality

Local (thermal) discomfort can be caused by unwanted local cooling or heating of the body. The most common local discomfort factors are:

1. draught (defined as a local cooling of the body caused by air movement),
2. vertical air temperature difference (between head and feet),
3. too cold or too warm floors, and
4. radiant temperature asymmetry (cold or warm surfaces eg. cold wall or windows),

With these factors in mind, and to fully appreciate what we need to feel comfortable, we need to understand the behaviour of traditional building fabric.

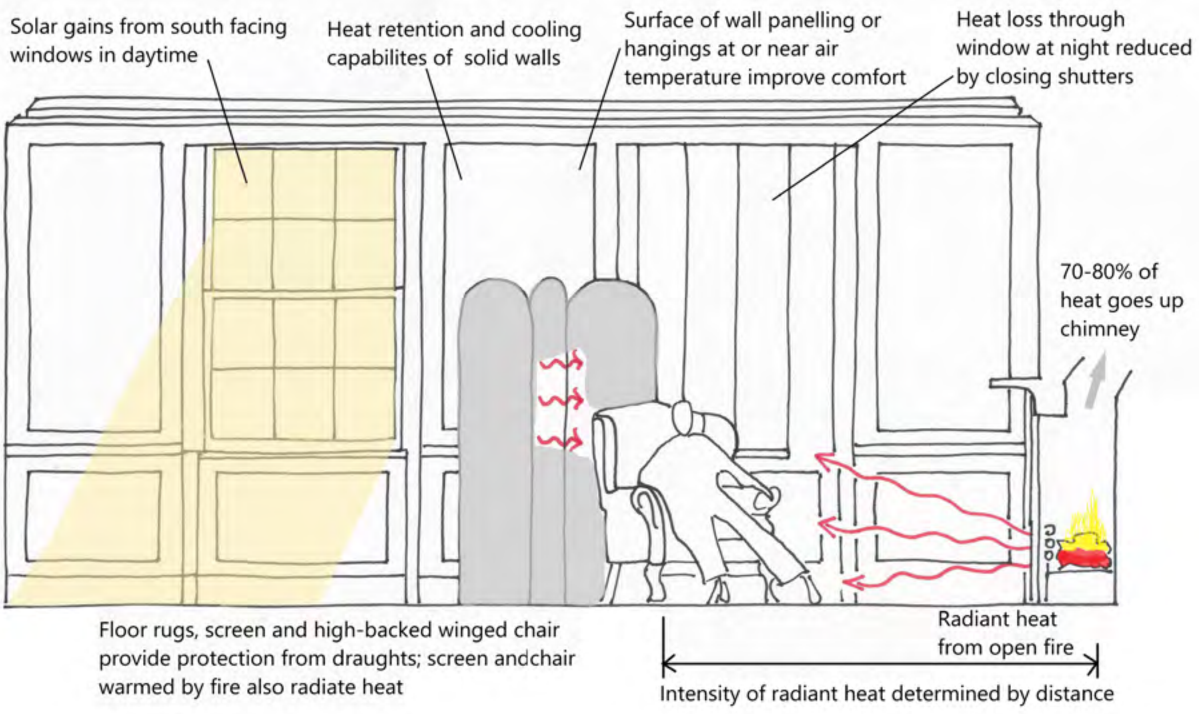
A solid masonry wall is a good thermal sink, but if there is insufficient heating energy in a building it cannot warm up. This happens when a building is intermittently occupied and/or heated. A traditional building consequently behaves very differently to a modern building which is designed to heat up quickly when heat is delivered, as the structure is lighter (less mass). Hence, a cold masonry structure will conduct or 'radiate' cold and make the inhabitant uncomfortable (see 4 above). Being aware of this and making simple changes in occupant behaviour can counteract this. Some measures that will increase comfort include:

a. Dressing to suit
b. Using local radiant heat sources
c. Preventing draughts and localising thick floor covering
d. Employing freestanding screens and wall hangings against external walls
e. Using furniture which protects from draughts

Fabric hangings and screens were used historically for decoration but also to mitigate against cold radiant surfaces. Likewise, furniture created spaces within spaces – high sided chairs and curtained beds.

Privacy and containment provided by curtain, Glencolmcille Folk Village

Historic interior, decorative screen and throws to furniture, the Argory, National Trust



Traditional forms of heating and thermal comfort[21]

This is termed an 'adaptive comfort' approach, 'the adaptive approach notices that people use numerous strategies to achieve thermal comfort. They are not inert recipients of the environment, but interact with it to optimise their conditions'[22].

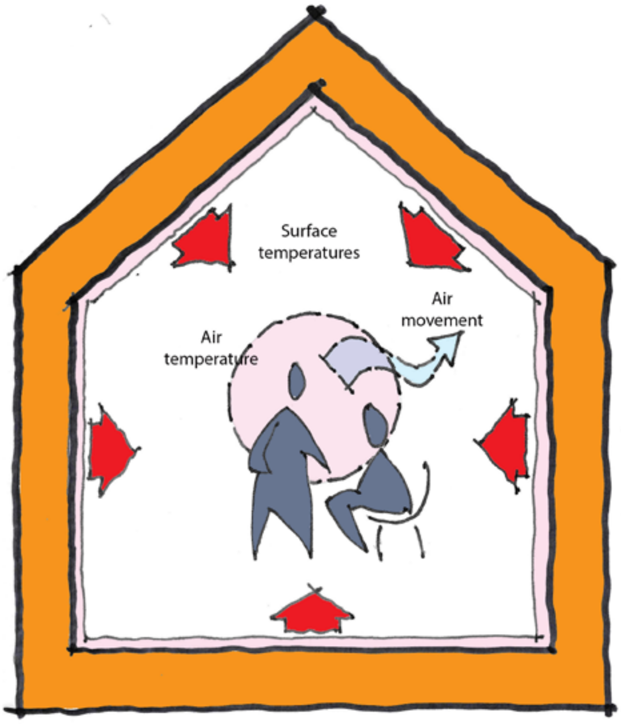
There are 3 components which make up the adaptive approach - physiologically adaptive, psychologically adaptive, and behaviourally adaptive. Our physiology allows reaction in our bodies to reduce heat loss for example, our psychology means that over time we might adapt to have a reduced sensitivity, and finally that we behave in line with our environment, wearing more layers if it is cold for example.

The diagram below illustrates why simple measures to alter the local environment can be used to increase comfort. Operative temperature is the term given to the experienced temperature which can be improved by managing draughts (curtains, enclosure) and blocking radiant cold (or warm) surfaces (screens, fabric wall hangings).

---

[21] https://historicengland.org.uk/images-books/publications/eehb-how-to-improve-energy-efficiency/heag094-how-to-improve-energy-efficiency/

[22] M.A. Humphreys
Thermal comfort temperatures and the habits of hobbits
Nicol, Humphreys, Sykes, Roaf (Eds.), Standards for thermal comfort, E & FN Spon, London (1995)



Applicable where typical interior air speeds of 0.1 m/s or less:

Operative Temperature or the temperature experienced by the inhabiatnat is:

Approximately
0.5 Air Temperature + 0.5 Average Surface Temperature

eg.
0.5 x 24 degree C + 0.5x19 degree C = 21.5 deg. C

Operative temperature

For illustration, an ill maintained sliding sash window is an obvious source of discomfort as it will allow draughts; while this can be welcome ventilation or at worst not troublesome in summer when air is warmer, in the winter cold moving air will immediately cause discomfort.

Air moving at 0.1 – 0.15m/s is found to be uncomfortable and felt as a draught in a cold climate in the winter. In the Summer (in a cold climate) the velocity which might be felt as a draught increases to 0.3m/s and above.

Where windows are single glazed, there will be a transfer or conduction of cold outdoor temperatures to the interior.

Air speeds of 1m/sec will bring a cooling effect of 2.6^{o}C so it is important to address these as repairs or upgrades alongside considering the use of shutters or curtains as buffering measures.

We will address measures to improve thermal efficiency of windows in Section 8.

Building Condition

When considering a thermal upgrade and measures to increase the energy efficiency of a building, a primary concern is the current condition of the building. **The first measure should always be appropriate repair.**

The following should be addressed before embarking on or considering any further interventions:

Is the building dry?

If you can identify water ingress or damp areas, use the following checklist to pinpoint potential and easy to rectify problems. A wall can be over a third less energy efficient if damp, so it is important to make sure the fabric is kept dry.

Is the roof sound and weathertight?

Look at lead flashings at chimneys, abutments, valleys, as well as the condition of slates. Check for split, slipped or missing lead, missing, slipped or cracked slates, cracked cement or mortar fillets at parapet skews, cracked flaunching (cement capping for run off) at chimneys, damaged/deteriorated rooflights

Are the rainwater goods adequate and functional?

There should be adequate downspouts for the roof areas which can be checked by calculation[23]. Climate change to a wetter environment means there may be additional downpipes, or a larger size required, though you may need listed building consent to enact such a change if the building is protected. Check they are all free running and have not become blocked with fallen leaves, which could cause an overflow of gutters into the top of walls. Gutters and downpipes should have a regular maintenance check, for splits and corrosion which will cause the misdirection of water into the built fabric.

Missing downpipe which has caused damage and staining to the brickwork, and wall saturation

Are the gullies free running?

Like the guttering and downpipes, if the gullies become blocked so that water cannot drain, or cannot drain quickly, this will misdirect rainwater to the foot of the building where the wall can draw it up through capillary action, causing damp.

Cast iron downpipe discharging into gully and keeping the base of the wall dry

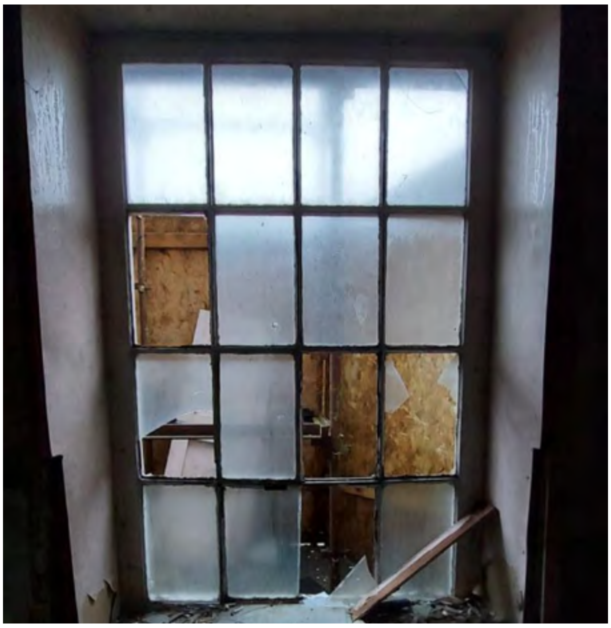
---

[23] Building Regulations (Northern Ireland) 2012 Drainage Part N (buildingcontrol-ni.com)

Is the ground to the perimeter of the building free from soil or detritus build up?

Over time, a building can have its external level raised unknowingly, through the gradually build-up of organic matter, sometimes windblown, sometimes through occupant activity. The level outside should be below the interior floor level so that moisture cannot be drawn into the wall by capillary action, and cause dampness. Take action to clear any built-up matter. If hard exterior surfaces (e.g. tarmacadam) have been installed at a higher level, consider reducing them to allow free air circulation at the wall base. (This may require listed building consent and care taken not to undermine shallow historic foundations) . Install a french or gravel drain to the building perimeter to allow water to percolate away from building.

Extreme case of water not draining from building perimeter; in this case due to a broken culvert, water is able to soak into the wall



Broken window (above) & same window repaired (right)

Are the windows draught free?

Windows can be overhauled by specialist companies to minimise draughts but consider replacing small sections of missing putty and fitting discreet brush strips and parting beads to reduce draughts.

Are spaces sufficiently ventilated?

Conversely, it is important that adequate ventilation is provided to ensure air is not moisture laden (high relative humidity), causing condensation on cooler walls and surfaces. This is especially the case in rooms where there is a lot of heat and moisture generated – bathrooms and kitchens – and ventilation, natural and mechanical should be managed to minimise moisture and humidity.

A building condition survey carried out by a conservation professional is recommended to inform project planning – different levels of survey will be required for different projects.[24]

---

[24] https://historicengland.org.uk/images-books/publications/conservation-basics-conservation/basics-marketing-spreads/

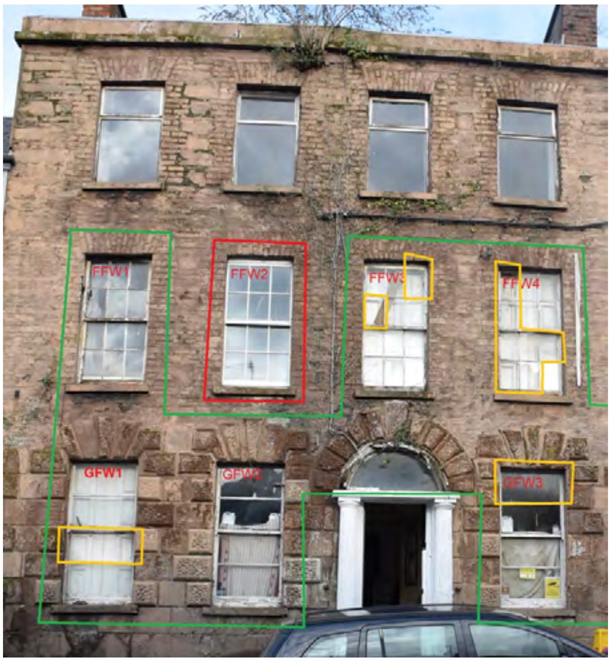
Workmanship & materials

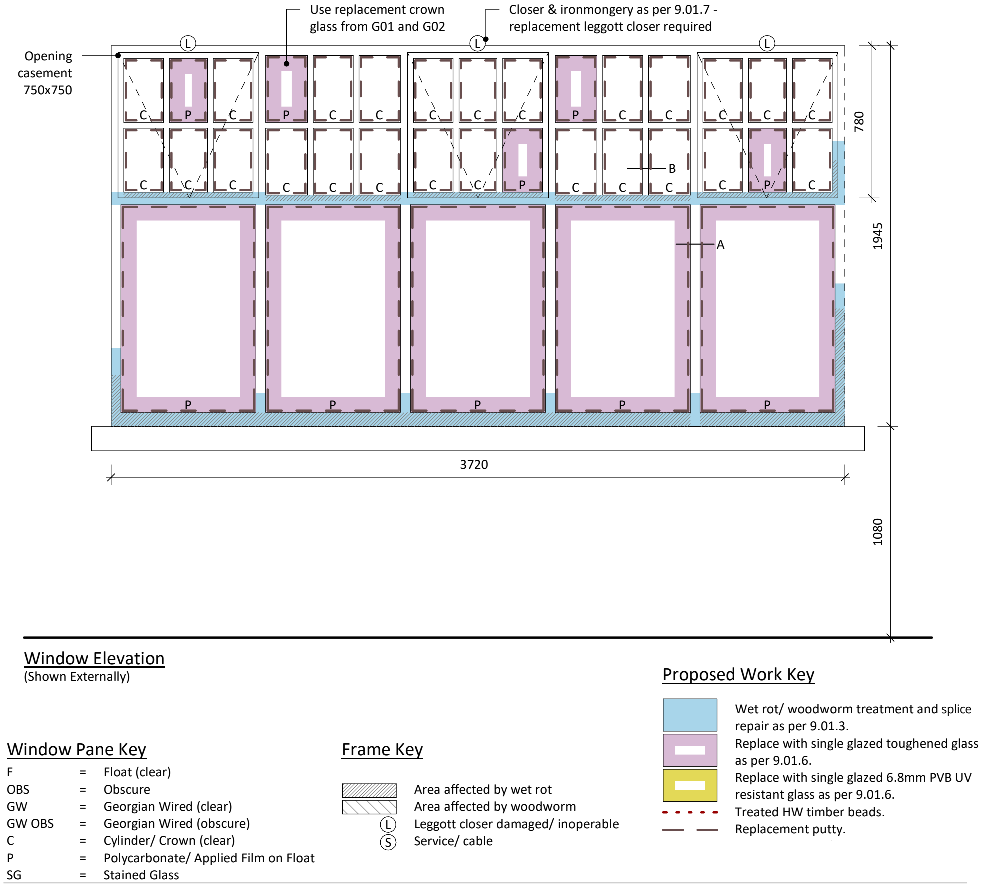
People with traditional skills can be more difficult to find than those used to working with modern materials and methods.

Working with an historic building is a specialism, from the consultants to the contractors and sub-contractors employed on site. It is important to find the right person who can deal with the building sympathetically and just as importantly, who will understand they may have to do new things to make the building work.

With the basics of care and maintenance for a traditional building, the right approach and method will have a bearing on how sustainable the work and therefore your building is. The cheapest quote may not be the best person for the job and in the long term could cost you more money by approaching the task incorrectly and causing harm.

The table below shows the importance of using traditionally skilled people in works to an historic building. The longevity of work can be up to 10 times as durable, illustrating the worth of appropriate workmanship and skills. w





Building condition survey image and window survey with work plan (Courtesy C60 Architects)

Type of repair	Good standard repair longevity (years)	Poor standard repair longevity
Brick replacement	100+	<30
Protective lime wash coating	<20	<10
Repointing mortar joints	60-120	5-15
Stone insert/indent repairs	60-120	10-20

Comparative longevity in years for good and poor standard of repairs. Good standard of repair is one which is undertaken in the correct, traditional material and executed by a skilled tradesperson. (Source: English Heritage Conservation Basics, 2013)

Simple energy saving measures

The following non-invasive measures can be implemented to reduce energy usage without any impact on historic fabric.

- Restrict fully heating rooms in daily use; run heating minimally to unused rooms to guard against mould growth, but ensure adequate ventilation
- Turn down thermostats by 1° which can reduce fuel bills by 5-10%
- Use energy efficient lighting and task lighting
- Close curtains and shutters at nightfall
- Use chimney balloon when not using fireplaces
- Use external postbox rather than puncture door or insert insulation within opening
- Fill gaps in floorboards with jute or marine twine
- Draught strip external doors
- zone heating*

*this is a mechanical intervention to consider when project planning

5 Technical & legislative

DfC is committed to supporting people, building communities, and shaping places. Part of this aim is recognising the value of historic buildings and encouraging energy efficiency improvements in a way which will not harm the buildings special interests.

This is why it is important that we understand traditional (solid wall), historic buildings and apply the relevant legislation correctly.

This section outlines the relevant legislation to be considered when restoring, renovating or retrofitting a listed building[25]:

- Building Regulations
- Planning Legislation

Their application will be most successful when considered holistically i.e., energy efficiency considered in tandem with heritage significance. A conservation accredited adviser will have the best understanding of this and be able to advise you.

We begin with the background for the building regulations.

What are building regulations?

"Building Regulations set requirements and standards for building that can reasonably be attained, having regard for the health, safety, welfare and convenience of people in or around buildings and others affected by buildings or building matters. They also further the conservation of fuel and power, and make provisions for access to buildings."[26]

There is currently no general requirement for existing and unaltered buildings to upgrade their performance (including thermal performance) but certain changes can trigger the need to comply, such as extending, renovating or changing use. The circumstances and degrees of the compliance required can vary when a property is protected by a designation or when they are of architectural or historic merit. This is because applying the same standards to these buildings can be difficult without affecting character or appearance but also because they may impact built fabric detrimentally by altering their ability to 'breathe'.

Example of adding to an historic building to make it accessible

Primary & Secondary Legislation

The Building Regulations (Northern Ireland) Order 1979 is the primary statutory instrument regulating Building Regulations in Northern Ireland. While it has been amended over the years, the 1979 Order (as amended) remains in force. This legislation set the basis for the current Building Regulations (2012) which is the secondary (or subsidiary) level legislation; this Order places a number of obligations in relation to heritage buildings:

---

[25] The Building Regulations also refer to buildings of historic or architectural merit requiring special consideration, usually these will also of solid wall construction due to their age. This chapter refers to application of the regulations to this group; any adapted consideration by building control is at their discretion.

[26] https://www.finance-ni.gov.uk/articles/building-regulations-northern-ireland

Article 3 – Building Regulations

Article 3 of the Building Regulations (Northern Ireland) Order 1979 sets out the matters for which the Department [Department of Finance and Personnel - DFP] may make regulations. These are listed in Schedule 1 in the Order and align with the Technical Booklets published by the DFP.

Article 3A – Protected Buildings

Article 3A of the Building Regulations (Northern Ireland) Order 1979 requires district councils, "in the carrying out of any of their functions under Building Regulations to have regard to the desirability of preserving the character of protected buildings".

Protected Buildings are defined in the Order as "listed buildings" and "buildings situated in conservation areas" in accordance with Planning (Northern Ireland) Act 2011.

Article 10(1) – Enforcement of Building Regulations

Every district council is obliged to enforce Building Regulations in its district, under the Building Regulations (Northern Ireland) Order 1979.

This includes Article 3A of the Order, which means Councils are committed to this objective.

The secondary (or subsidiary) level legislation (Building Regulations) sets out the actual requirements. The current Building Regulations (Northern Ireland) 2012, set 'reasonable' requirements to ensure the health, safety, and welfare of people in and around buildings.

These functional regulations relate to fire protection and escape, drainage, acoustics and conservation of fuel and power. The regulations set out these requirements with qualifying terms, such as 'reasonable provision', 'adequate', and 'as far as reasonably practicable'. A single solution may not therefore be suitable for all situations and each case should be considered on its own merits.

Portaferry (Conservation Area)

This becomes particularly pertinent when dealing with traditional buildings rather than new builds and extensions, where fabric behaviour is quite different, in many ways, from behaviour and capabilities in a fire, to thermal behaviour as we are considering in this document.

Guidance (Technical Booklets)

Technical Booklets are prepared by the Department of Finance and Personnel (DFP) to provide practical guidance on the technical requirements of the Building Regulations (Northern Ireland) 2012 (the Building Regulations).

Since 2012, when the published technical documents moved from providing 'deemed to satisfy' solutions, to becoming guidance, councils coming to a decision on the adequacy of any proposal, must take into account any other relevant considerations, such as protected buildings and in this case a lesser but reasonable standard of functionality may be accepted.

District Councils have a legal duty to take account of the desirability to preserve the character of protected buildings; all technical booklet introductions, under subhead 'Protected Buildings' set out that:

"District councils have a duty to take account of the desirability to preserve the character of protected buildings when carrying out their functions under Building Regulations. Therefore, where work is to be carried out to a protected building to comply with Part F or any other Part of the Building Regulations, special consideration may be given to the extent of such work for compliance where it would unacceptably alter the character or appearance of the building. Protected buildings are defined in Article 3A (2) of the Building Regulations (Northern Ireland) Order 1979 (as amended)."

However, it is also important to note that regulations cannot be dispensed with and that the approach and treatment is required to be tailored or bespoke to the protected and/or traditional building.

The section below sets out guidance on the technical requirements of the Building Regulations (Northern Ireland) 2012 (the Building Regulations), Conservation of Fuel & Power (F1& F2) only, as this is the most relevant section in relation to energy efficiency.

In practice, one section of the regulations should not and must not be considered in isolation; for example, Part K, Ventilation is closely allied with matters of fuel conservation through thermal upgrade and requires equally careful consideration, as neglecting ventilation when retrofitting can be harmful to building and inhabitants. This guide is not intended to replace appropriate professional expertise but is intended to illustrate how the regulations provide for variances of protected and traditionally constructed buildings.

The relationship between law and guidance

In 2014, amendments to the Building Regulations strengthened recognition that protected and historic buildings required different treatment.

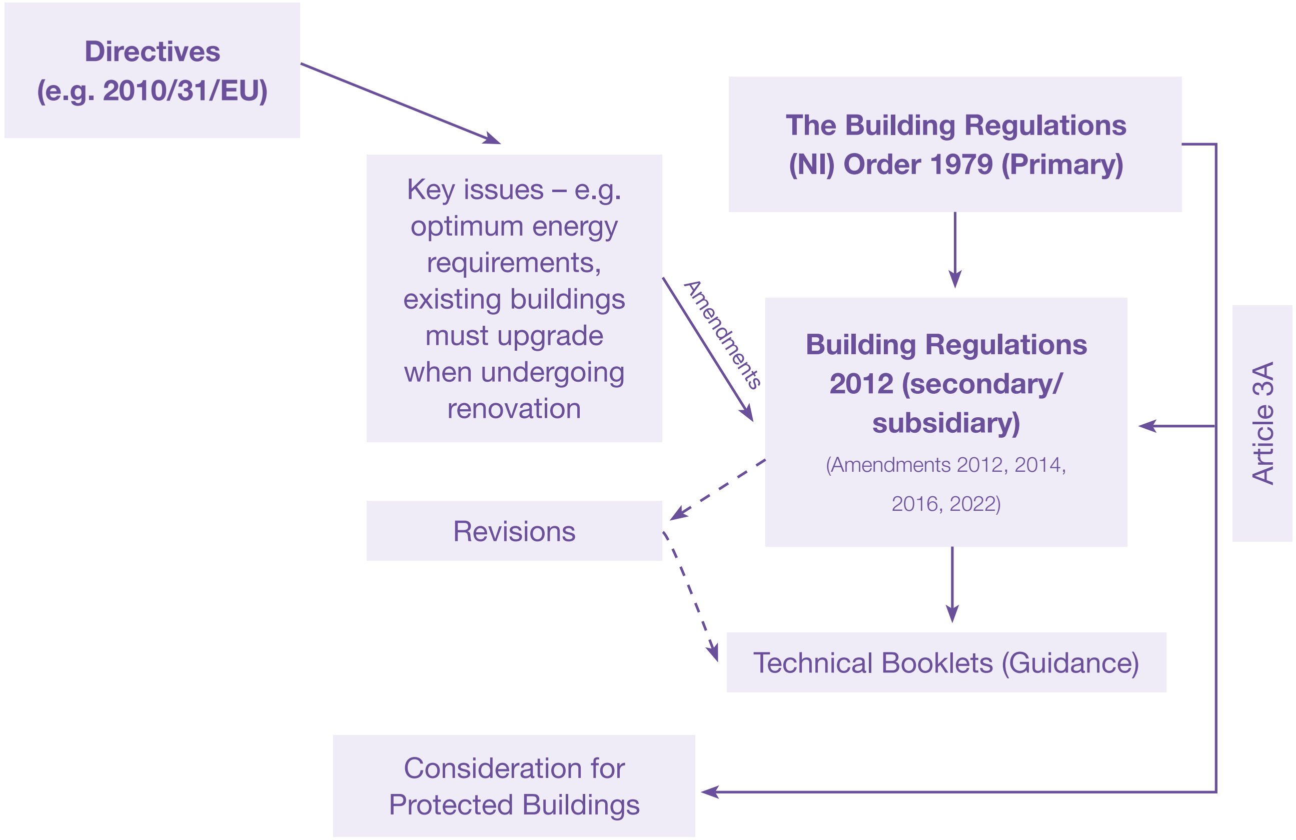


Table showing relationship of EU directive 2010/31/EU[27] (UK legislation), Primary and secondary NI legislation, and Guidance

The 2014 amendments to the building regulations and technical documents covered legislation and guidance for 3 areas, in response to the (recast) European Energy Performance of Buildings Directive (Directive 2010/31/EU[28]):

a) consideration of high efficiency alternative systems (Article 8);

b) buildings exempted from certain energy efficiency requirements (Article 4 (2)(a));

c) recognition of the term “major renovation”. (Article 2(10)(b))

The nearly zero energy building (NZEB) requirement (new buildings) (Article 9(1) of 2010/31/EU) was implemented 1 Jan. 2019 for new public buildings, and all new buildings from 31 December 2020.

---

[27] Amended by EUR-Lex - 32018L0844 - EN - EUR-Lex (europa.eu) - DIRECTIVE (EU) 2018/844

[28] EU legislation which applied directly or indirectly to the UK before 11.00 p.m. on 31 December 2020 has been retained in UK law as a form of domestic legislation known as ‘retained EU legislation’. This is set out in sections 2 and 3 of the European Union (Withdrawal) Act 2018 (c. 16), drafted with the specific purpose of ensuring that existing EU environmental directives will continue to apply in UK law.

Amendments with respect to protected buildings and buildings of historic or architectural merit

This led to amendment of the subsidiary level legislation - building regulations[29] - in 2014 (from 2012) and included the following:

(2) The energy efficiency requirements shall not apply to—

(a) protected buildings, where compliance with the energy efficiency requirements would unacceptably alter their character or appearance;[30]

It is considered that the italicised part of this regulation is important, as it implies that improving the energy efficiency performance of a building should be undertaken when appropriate but with an understanding and respect for the special characteristics of the protected building, and not that there is a wholesale veto on making improvements to the thermal performance.

In turn, an amendment to the technical guidance documents was also issued in 2014 to align with secondary legislation (Building Regulations) with respect to Conservation of Fuel and Power. (F1 (Dwellings) and F2 (Buildings other than dwellings)) These amendments were embedded in June 2022 revised Technical Booklets F1 & F2.

These also call for tightened minimum fabric standards and further reduced carbon emission rates, to all new buildings. These uplifts are in line with Phase 1 of the N.I. Executive's Energy Strategy 'Path to Net Zero Energy' document released in December 2021 and work continues to implement phased uplifts to align with other UK countries.

Considerations regarding protected buildings and buildings of historic or architectural merit are set out under two headings:

1. **Maintaining character and/or appearance**
2. **vapour permeability ('breathability')**

Previously (to 2014) these had been set out less specifically for buildings of historic or architectural merit, rather than naming protected buildings.

Regulation 38 describes the 'energy efficiency requirements'. Energy Efficiency requirements are defined in the guidance as requirements set out in Part F of the Building Regulations, concerning Conservation Measures, Target carbon dioxide emission rate, Consequential improvements, Renovation of thermal elements, Consideration of high-efficiency alternative systems, Nearly zero-energy requirements for new buildings & Provision of information.[31 & 32]

Often quoted from the technical guides is the requirement when renovating to upgrade a whole element or building to a given and improved u value (i.e., 3.59, Table 3.3 of F1); however, the technical guides are clear on considerations for protected buildings and buildings of merit. (See also Major Renovation – below)

Excerpts from Guidance

F1 (2022)

3.3 Protected Buildings
Building work to an existing dwelling is exempt from the energy efficiency requirements (i.e., regulations 39, 40, 41, 43, 43A, 43B and 47 of the Building

---

[29] The Building (Amendment) Regulations (Northern Ireland) 2014 https://www.legislation.gov.uk/nisr/2014/44/regulation/6/made

[30] The Building (Amendment) Regulations (Northern Ireland) 2014 **No. 44** Building Regulations, substitute Regulation 38(2)(a)

[31] https://www.legislation.gov.uk/nisr/2012/192/contents/made

[32] https://www.legislation.gov.uk/nisr/2014/44/contents/made

Regulations) if the dwelling is a protected building and where compliance with the energy efficiency requirements would unacceptably alter its character or appearance.

The case for a protected building to be exempt from the energy efficiency requirements of the building regulations must be supported by evidence

e.g. by restrictions imposed by the Planning Service, advice from the Department for Communities Historic Environment Division, or advice from a qualified conservation specialist, etc.

3.58 When undertaking the renovation of thermal elements, special considerations apply to protected buildings, buildings of historic or architectural merit and to buildings of traditional construction that need to "breathe"

Belfast Gasworks Meter House

Unprotected buildings are also considered:

3.4 Special considerations may apply where the building to which the work is to be carried out is not a protected building but has historic or architectural merit and compliance with the energy efficiency requirements of part F would unacceptably alter the character or appearance of the building."

3.5 When undertaking work to or in connection with a building of historic or architectural merit, the aim should be to follow the guidance in this Technical Booklet to the extent that it is practicable. Particular issues in relation to work to buildings that warrant sympathetic treatment and where specialist advice from conservation experts would be beneficial include –

a) restoring the historic character of a building that has been subject to inappropriate alteration (e.g. replacement windows, doors and rooflights);

b) rebuilding a building (e.g. following a fire or filling in a gap site in an historic terrace); and

c) making provisions for the fabric of historic buildings to "breathe" to control moisture and long term decay problems.

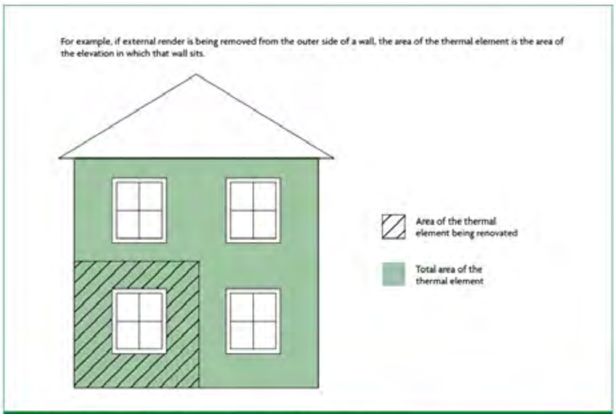
Booklet F2 (buildings other than dwellings) provides similar guidance.

Renovation of elements

Major Renovation or replacement (of thermal elements)

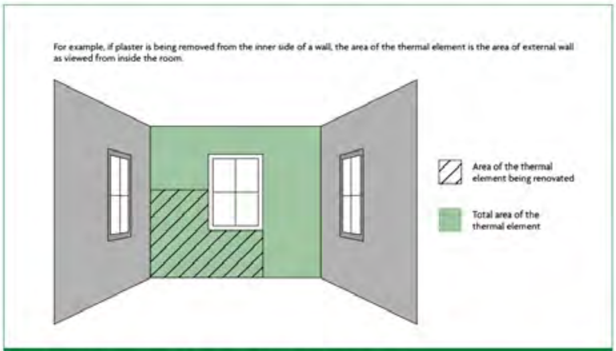
Major renovation is defined as ‘the renovation of a building where more than 25% of the surface area of the building envelope undergoes renovation.’ This includes the area of all the external surfaces combined where the renovation relates to the whole building, external walls, floor, roof, windows, doors, roof windows and rooflights.

The second instance where upgrade of thermal elements will be required is when greater than 50% of the surface of the individual thermal element is being renovated.



For example, if external render is being removed from the outer side of a wall, the area of the thermal element is the area of the elevation in which that wall sits.

Diagram 11.1 Renovation of a thermal element from the outside



For example, if plaster is being removed from the inner side of a wall, the area of the thermal element is the area of external wall as viewed from inside the room.

Diagram 11.2 Renovation of a thermal element from the inside

Excerpt from England Approved Document L 2021 (Crown Copyright)

The necessity to fully comply with requirements of the regulations is precluded by a building being protected.

Likewise, where replacement is proposed this will apply, but in any case, note the requirement to comply with Regulation 39(a)(i)[33] is caveated ‘in so far that it is technically, functionally and economically feasible.’ (Regulation 40).

Such a scheme of renovation or replacement would be subject to control through a Listed Building Consent (see below) where a building is protected but note that this does not apply where localised or like for like repairs are undertaken.

Extending a traditional building

Much as compensations can be made elsewhere for traditional building fabric that cannot be thermally improved to new build standard when renovating, the same is true when a solid wall building is extended, for example, through the addition of micro renewable energy sources.

Known as ‘off-setting’, a new extension can be designed to meet or ideally exceed standards to balance out the energy efficiency and carbon emission rates of the whole building.

Regulations will expect any extension to meet a standard of performance either through the thermal efficiency of the individual or collective fabric elements, or by demonstrating that the whole extended building carbon emissions are not greater than a notional building of similar size and shape (using the Standard Assessment Procedure – known as SAP).

---

[33] http://www.buildingcontrol-ni.com//assets/pdf/building-regulations-ni-2012.pdf

Caledon Wool Store with contemporary extension

Measurement

For new buildings, the measurement of a buildings efficiency is measured by the Government's Standard Assessment Procedure (SAP) for Energy Rating of Dwellings; and in relation to a building other than a dwelling—by the Simplified Building Energy Model (SBEM); or a Dynamic Simulation Model (DSM).

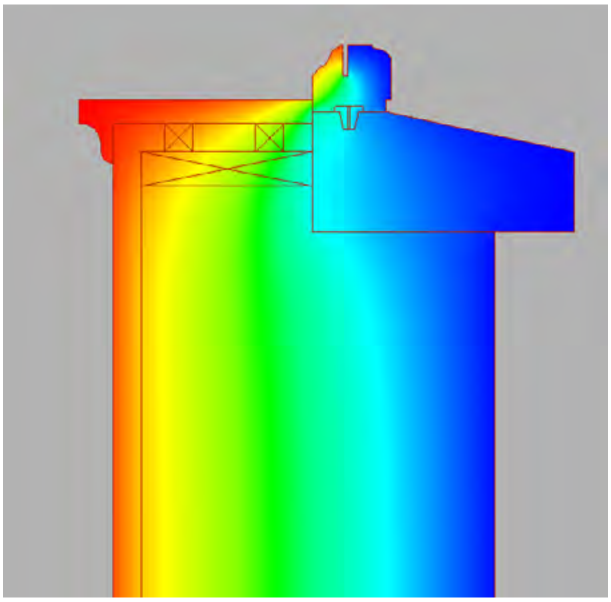
However, for existing buildings, a simplified version of SAP called Reduced Data SAP (RdSAP) is used to assess the energy performance. An RdSAP assessment will use a set of assumptions about the building based on conventions and requirements at the time the building was constructed. Solid wall U-values are provided.[34]

Protected buildings may not be able to fulfil new build fabric standards of thermal efficiency, but the assessment procedures allow for the input of other measures, such as e.g. renewable energies, highly efficient boilers, to improve scoring.

More detailed analysis can be undertaken using WUFI (Wärme Und Feuchte Instationär - translation - heat and moisture transiency) which uses hygrothermal modelling (heat and moisture transport through fabric).

WUFI is commonly used as a means of assessing the risk of moisture problems in traditional buildings, particularly if the proposal is to retrofit a building to improve thermal performance by applying internal insulation. Accurate results can be difficult to achieve due to the unknowns around the technical characteristics of traditional materials. Unlike SAP, results also depend on the input of data for the local climate and internal environment.

EPCs (Energy Performance Certificates) are required for all buildings which are constructed, marketed for rent or sale, under the Energy Performance of Buildings Directive, and are based on this calculation methodology (RdSAP, SAP, SBEM, DSM). However, there is ongoing research which would indicate these are not a suitable means to measure the performance of a traditionally constructed building.



A simple condensation check on an internally insulated wall - window junction, using a simulator to determine the Psi or linear thermal bridging heat loss (Courtesy C60 Architects)

---

[34] https://www.bre.co.uk/filelibrary/SAP/2012/RdSAP-9.93/RdSAP_2012_9.93.pdf Table 8 NI (Nov. 2017, update expected Spring 2024)

On site, there are 'hands on' energy audit methods of assessing how a building may perform. Survey methods of assessing a buildings performance:

Air-tightness can be measured by positioning a large fan into an otherwise sealed opening and forcing air through it into, or from the building. This allows the pressurised or depressurised building (to 50 pascals difference with the external atmosphere) to reveal its rate of air leakage by calculation. This is called air pressurisation or air tightness testing. Using a smoke machine with a pressurised building allows an observer to see where the air is being drawn out and hence where the building is ‘leaky’.

Infrared thermography uses a special infrared camera to show varying surface temperatures of the building fabric. This can be used to detect where heat flow is highest from a heated building in the winter months and where the cold bridges are. This will allow the heat loss areas to be more accurately diagnosed and addressed but caution is advised, the imagery is a point in time and other factors are in play.[35]

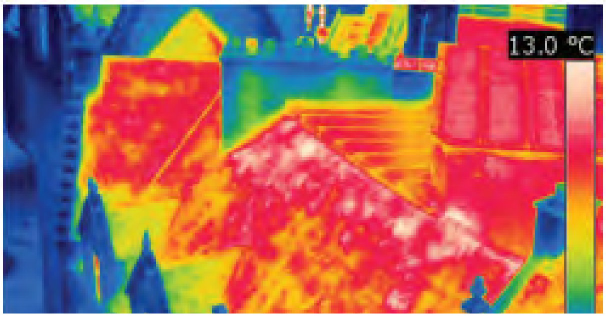


Image from Historic Environment Scotland's Short Guide Thermal Imaging in the Historic Environment © Historic Environment Scotland

The remainder of this document provides practical and technical advice on how to approach thermal upgrade of traditional fabric. The broad approach[36] should be focused as below with respect to the building regulations:

- Assess current energy loss through fabric
- Take account of historic significance and sensitivity to change
- Propose fabric upgrade to maintain heritage significance
- Sustain a use suitable to the building for the foreseeable future

Requirements for permission including listed building consent

When a building is listed, protection encompasses the complete interior and exterior of the building and can also extend to fixtures and free-standing objects within its curtilage[37]. A listed building consent (LBC) application[38] is required under legislation (Planning Act (NI) 2011) when alterations to a listed building are proposed which “would affect its character as a building of special architectural or historic interest” Owners or custodians should always seek the view of a qualified conservation professional to ascertain this, or if in doubt can contact the relevant local planning authority or HED directly to discuss in principle.

Some examples of how and why various thermal upgrades will require control and assessment of the intervention are provided below:

---

[35] https://www.historicenvironment.scot/archives-and-research/publications/publication/?publicationId=088dab34-1194-43e6-af5e-a62801090992

[36] See HED Guidance: HED - Applying the Conservation Principles (communities-ni.gov.uk)

[37] See guidance https://www.communities-ni.gov.uk/publications/criteria-scheduling-historic-monuments-and-listing-buildings-special-architectural-or-historic

[38] See Guidance on making changes to Listed Buildings: Making a better application for listed building consent | Department for Communities (communities-ni.gov.uk)

- Insulation to roof: may require insertion of increased ventilation which can alter the character of the roof, may require changes to eaves/roof level which need to be managed/designed to suit if possible
- Upgrade to windows: double glazing is only permitted in certain circumstances and will be assessed on a case-by-case basis, double glazing can dramatically change authenticity of historic windows through reflection of glass, depth of frame, inauthentic fixing methods. Secondary glazing needs to respect existing features, for example shutters, window reveal detail, joinery craft. Loss of historic fabric (glass, timbers) is of prime importance and is not acceptable where sound.
- Drylining walls: aside from the impact to the building physics which must be assessed, drylining may be wholly inappropriate due to building detailing for example, historic cornicing, historic wall coverings or treatments
- Insulating floors: inserting insulation to below floor voids may not be possible due to loss which would be incurred, for example, fragile finishes such as historic tiling.

The guiding test when considering thermal upgrade changes is to ensure the significance of the building is maintained without causing long-term damage to the historic fabric.

An asset's significance will benefit and be better understood where the greatest proportion of historic fabric is retained. Interventions therefore need to be carefully balanced – there may be areas where compensating gains can be made, and areas where intervention is simply not possible due to impact on historic fabric and significance.

For this reason, before changes are proposed, a 'Statement of Significance' should be prepared. This will determine the contribution of the affected historic fabric to the buildings significance with particular consideration of:

a) External features
b) Spaces and layouts
c) Internal features
d) Historic features
e) Technological interest

Examining building records

The sensitivity of the historic fabric varies from building to building and even within a particular building so it is essential that a consistent approach is taken to assessing the impact of proposed interventions in line with planning policy[39] and best conservation practice. Change must be managed to sustain the asset's values and significance.[40]

---

[39] The Strategic Planning Policy Statement NI 2015,(SPPS) and retained policy under transitional arrangements of the SPPS, Planning Policy Statement 6 Planning, Archaeology and the Built Heritage, which will cease to have effect in a district, when a council adopts its Local Development Plan, Plan Strategy. Refer to Historic Environment Division's 'Conservation Principles: Guidance for the sustainable

[40] Refer to Historic Environment Division's 'Conservation Principles: Guidance for the sustainable management of the historic environment in Northern Ireland

The guiding criterion for material/fabric conservation is paramount when considering interventions and supports the conservation philosophy of international charters and treaties, and regional conservation policies and standards[41]. All proposals should clearly demonstrate how these have been addressed within any application.

I. Maximum retention of historic fabric – keeping as much original sound fabric as possible
II. Minimum intervention – undertaking only the minimum physical work to the fabric to achieve an outcome
III. Reversibility – interventions can be installed and removed without loss of historic fabric. Additive measures are always preferable in this respect.
IV. Clarity – intervention should be distinguishable (though it is accepted that thermal additions should be inobtrusive; this term relates better to repairs of structure or extensions for example)
V. Sustainability – a natural slate roof can outlast a man-made slate 3-fold (150 yrs. vs 50 yrs.) therefore using the right materials is key. Likewise, the term can apply to ensuring a sustainable future for the building; the interventions will keep the building in active use without compromising fabric. (For example, by use of traditional or tested[42] compatible vapour permeable materials instead of inappropriate dry lining or modern cements)

When interventions are being proposed e.g., paint on sealants, HED urges caution of manufacturers and specialists' claims for new products and recommends the suitability of such products should always be explored by your qualified conservation consultant.

For more advice on the preparation of an LBC application in general see 'Guidance on making changes to Listed Buildings: **Making a better application for listed building consent'**

If a building is not listed, listed building consent will not be required, but some changes to a building, particularly in a Conservation Area, will require planning permission and/or be subject to Conservation Area controls or consent process. Contact your local council for advice.

Our history is marked in the fabric of Northern Ireland's buildings and places. The most significant are listed, marking and celebrating their special architectural and historic interest and protecting them for future generations.

Guidance on making changes to Listed Buildings: Making a better application for listed building consent

Historic Environment Division

DfC Department for Communities

HISTORIC ENVIRONMENT FUND

DfC Historic Environment Division Guidance on making changes to Listed Buildings

---

[41] See Sources of advice & Other reading

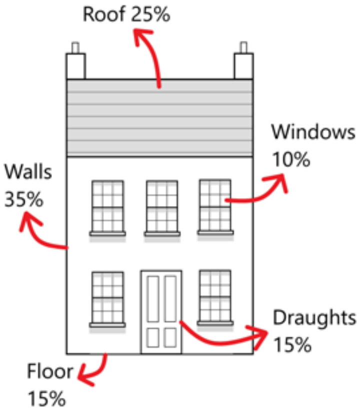
[42] The Burra Charter explains that 'The use of modern materials and techniques must be supported by firm scientific evidence or by a body of experience' in relation to Article 4.2 'In some circumstances modern techniques and materials which offer substantial conservation benefits may be appropriate.'

6 Heat Energy behaviour and Building health

This section sets out the routes and manner of heat loss and moisture movement from and within a building, and some of the terminology commonly used to describe it.

Where is my building losing heat?

The amount of heat being lost through any element will obviously vary from building to building, dependent on many factors, but the approximate proportions illustrated in the figure below are a good indicator.



Typical heat loss proportions

Heat loss from a building occurs in 3 ways:

Transfer/conduction – heat travels through materials from warmer side to cooler side

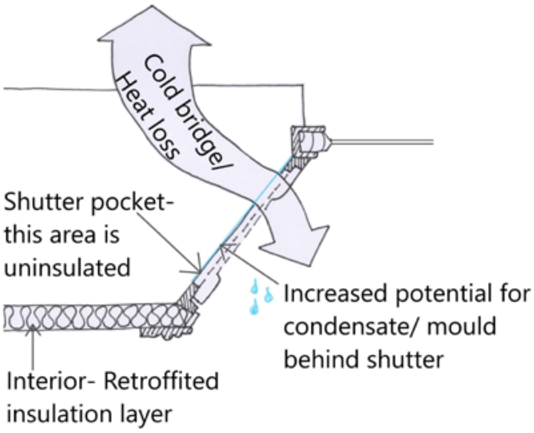
Air movement/convection – warm air is exchanged with fresh/cooler air intentionally (managed ventilation) or through gaps and openings (draughts or unintentional ventilation)

Radiation – heat radiates from building surfaces to the atmosphere

Thermal bridging

Thermal bridging or cold bridging occurs when the transfer of heat is at a faster rate at 'bridges' than where there are no 'bridges' in the structure. An example of a bridge might be where a steel support for a balcony crosses from the cold side (outside) to the warm side (inside) of a wall. Because steel is more conductive of heat (and cold) energy this will create a cold spot on the interior face where there is an increased susceptibility to mould growth and condensation.[43] This is pertinent to a discussion about thermal upgrades because a wall lining which has to avoid certain historic fixtures and features will leave areas even more susceptible to bridging and its impacts. It may therefore, be inappropriate to specify such a lining in such situations.

Another good example of this is at the panelled reveals of an historic window opening; stopping a modern lining short of these sets up a large differential in temperature across a wall because of thermal bridging.



Cold bridge at reveal where wall is insulated internally

---

[43] Mould stage precedes/occurs before condensation. Mould will occur above 80% relative humidity (RH), 100% RH required for condensation to form.


Shutters to reveals

Where reveals have an existing lining/plaster/lath depths a reasonable balance can be reached by using the depth to install a vapour permeable and hygroscopic layer of insulation(cellulose, sheep's wool) which will be less unforgiving than a modern lining because it is technically compatible with the historic structure. Where there are shutters folding into a void (as below), they may take up the whole of the void depth making this approach unfeasible.

Thermal bridges can often be designed out through the careful addition of insulation and the application of thermal modelling analysis (such as WUFI - See Measurement section Pxx) to a proposal can determine if the risk has been eradicated.

U values

All building materials have a lambda (λ) value[44] which indicates thermal conductivity, or 'k-value' of a material, or simply how well it conducts heat. It indicates the quantity of heat (W - watts), which is conducted through an area of 1 m^2 wall, in a thickness of 1 m, when the difference in temperature between the opposite surfaces of this wall equals 1 K (or 1 ºC). Therefore, its value is expressed in W/mK. The λ or K values of all the materials which make up an element are required in their various thicknesses/depths to allow calculation of the 'U value' of an element. This u value indicates the rate at which heat is transferred across a building element and is expressed in w/m^2K. A low u value is better than a higher u value as it indicates a slower rate of heat loss. As previously set out, a damp component will have greater conductivity than a dry one [45], and can significantly affect u values.

A wall can be over a third less energy efficient if damp

---

[44] https://www.engineeringtoolbox.com/thermal-conductivity-d_429.html

[45] BS7913:2013 (5.3.1)

Material	LAMBDA (W/MK)
Aluminium	200
Steel	60
Concrete	1.4
Brick	0.8
Wood	0.13
Wood Fibre	0.045
Expanded Polstyrene	0.036
Mineral Wool	0.035
Phenolic Foam	0.022
Aerogel Board	0.013

Lambda (λ) values of some common building materials

Calculating u values

U value is measured in w/m^{2}K (Watts per metre squared Kelvin)

First, calculate the R value or resistivity of the materials at the thickness or depth within the element (e.g. wall)

$R = l/ \lambda$

where l is the thickness and lambda is the conductivity

So e.g. the R value for 100mm wood fibre would be:

$0.1/0.045 = 2.2$ m^2.K/W

When all of the resistivity of the materials making up the element are calculated the U value is simply the reciprocal of the sum of these. The external (Ro) and internal surfaces (Ri) have a fixed resistivity which is included in this calculation:

$U = 1/ (Ro+ R1+ R2 + R3 +\ldots. Ri)$

A traditional solid wall conducts (loses) heat better than a modern cavity wall in general, i.e. It has a higher u value. However, recent research has proven that the traditional wall performs somewhat better than desk-based calculations or simulations would indicate:

SPAB[46] research showed that a thick granite wall had a calculated u value of 2.56 W/m^{2}k but an actual performance of 1.75 W/m^{2}K, a value which shows performance was better than expected by 46%.

Likewise, an ashlar limestone wall showed a performance 95% better than expected (0.97 W/m^{2}K versus calculated value of 1.9 W/m^{2}K). In fact, this research showed that calculation underestimates in-situ U-value performance in 79% of cases.

This is attributed to the unknown make up of solid walls, a lack of homogeneity (such as is found in a new build), non-specific conductivity values for varying traditional materials and the omission of the thermal mass consideration (see below) in a standard u value calculation.

Thermal mass

When we refer to thermal mass of a structure, we are commenting on its ability to absorb, retain and release heat slowly over time. A structure with a low thermal mass, such as a timber frame building does not perform this process well. Most traditional buildings, especially those from the 19th century, have a high thermal mass and their ability as an energy store is much greater [47]. Features of a traditional wall of mass are:

a) Good thermal store
b) Slow reaction times
c) Temperature moderator
d) Moisture moderator (if vapour permeable)

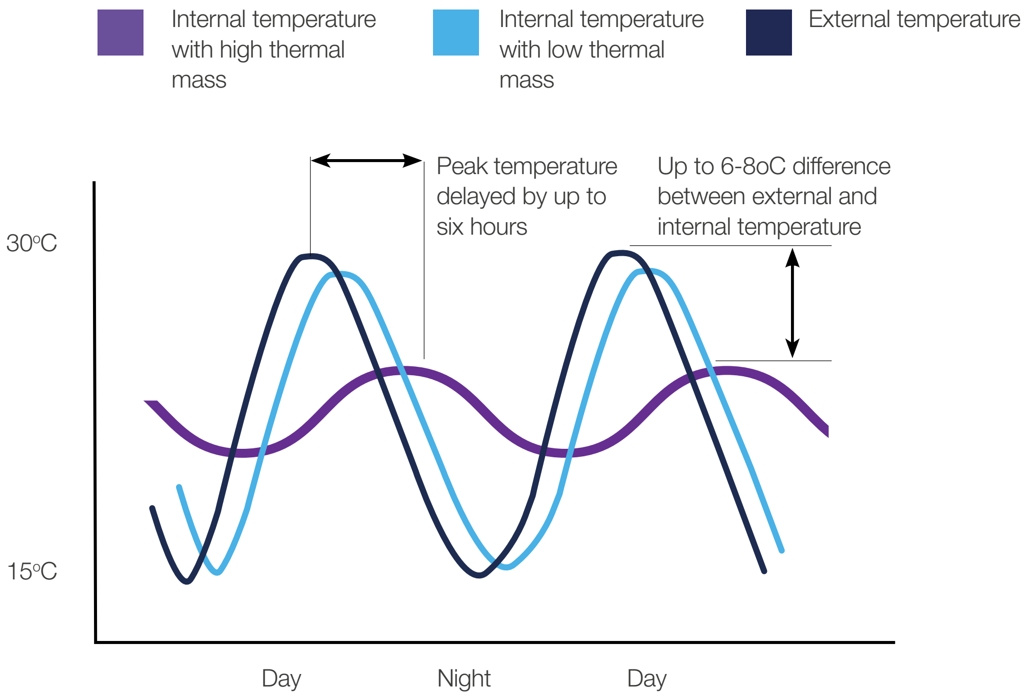
The qualities can be exploited when they are better understood. For example, dependent on orientation, a building with high thermal mass can benefit from passive solar gain during the day to be released slowly later in the day when the temperature cools – this is called a thermal lag as the mass serves to moderate or dampen the temperature extremes.

The lightweight wall and the mass masonry wall may theoretically have the same u value but the ability to retain and release heat is an advantage not figured into the calculation described in the previous section.

---

[46] Society for the Protection of Ancient Buildings

[47] A state of good repair and appropriate use of materials is fundamental to good performance



Effect of thermal mass to equalise temperature fluctuations

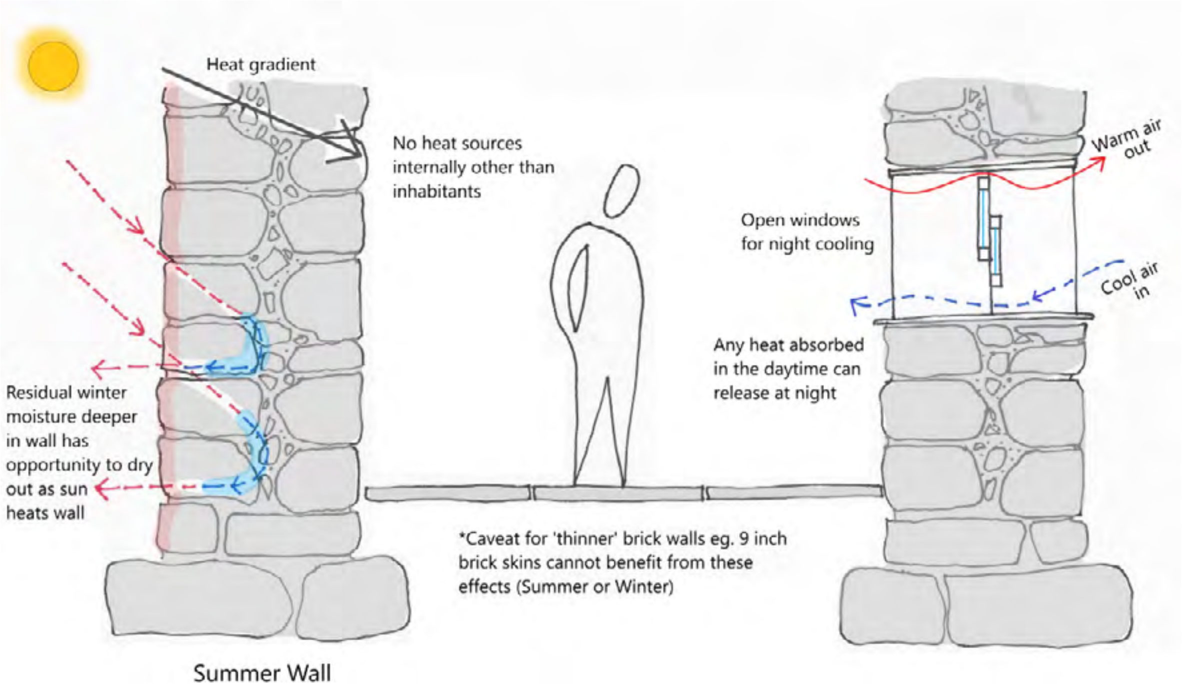
Overheating in traditional buildings

Due to our northerly latitude, in Northern Ireland, when we discuss insulating buildings, we are generally trying to reduce the energy we use to heat them and increase comfort in the colder months, and this guidance is in line with that. However, research[48] has shown that with increasing temperatures and well-sealed and insulated buildings, overheating has occurred as far north as Inverness, so any complacency about overheating may be misplaced.

As the above section describes, the thermal mass of traditional buildings is a good interior temperature regulator. Furthermore, wood fibre and hemp which can be used to insulate internally have a density which means they act as a heat store alongside the masonry, allowing a phase shift of heat release from the peak of the day to the cooler night (8-10 hrs). As with keeping a building warm, using insulation which isolates the wall and prevents access to its thermal mass is counterproductive as it negates its potential benefits in buffering higher temperatures.

To deal with periods of overheating, in night-time hours, windows left open purge the building of its heat using passive methods of cross ventilation and creating stack cooling passages through taller buildings. Being able to ventilate, preferably naturally, is important both for general building health and for overheating periods.

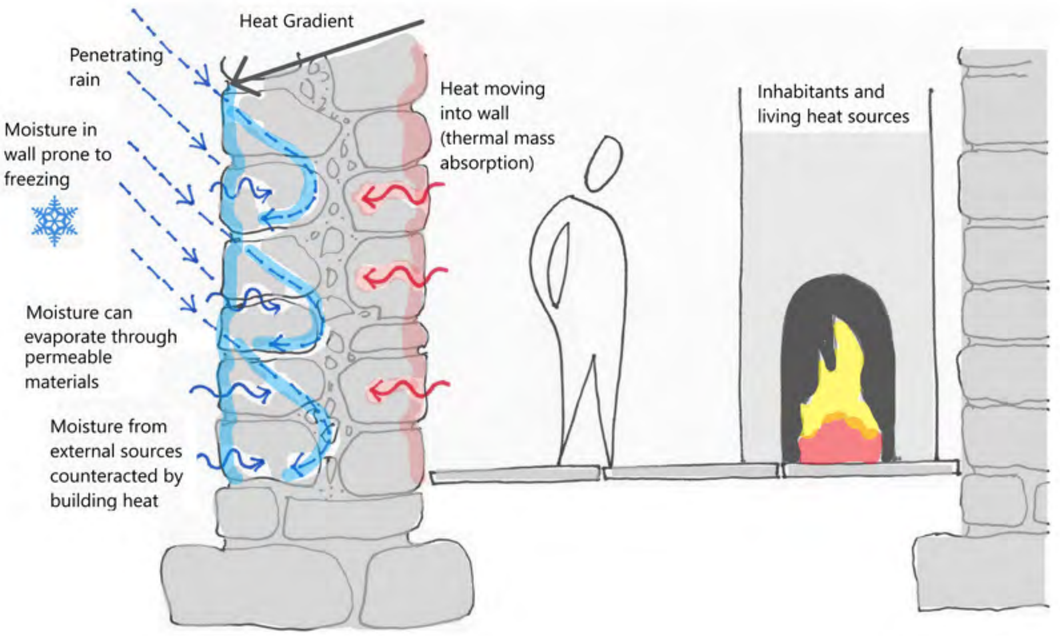
Traditional buildings are also often well placed to deal with hot temperatures and solar gain as their glazed openings are usually a smaller proportion of the building envelope.



Behaviour of solid wall buildings in Summer

---

[48] Lomas, K.J. and Porrit, S. (2016) 'Overheating in buildings: lessons from research', Building Research and Information, 45(1-2), pp. 1-18.



Behaviour of solid wall buildings in Winter

Moisture, Ventilation & Internal Air Quality

Ventilation, humidity and moisture are interlinked when we discuss internal air quality.

A traditional building will generally require a higher rate of ventilation to control humidity (and prevent damp and mould) than a modern building. To achieve acceptable comfort levels, a relative humidity level between 45 to 55 percent is considered comfortable for most people. Some moisture is not a problem in itself, provided it is not the result of a building malfunction and it is balanced by adequate ventilation and evaporation over time.

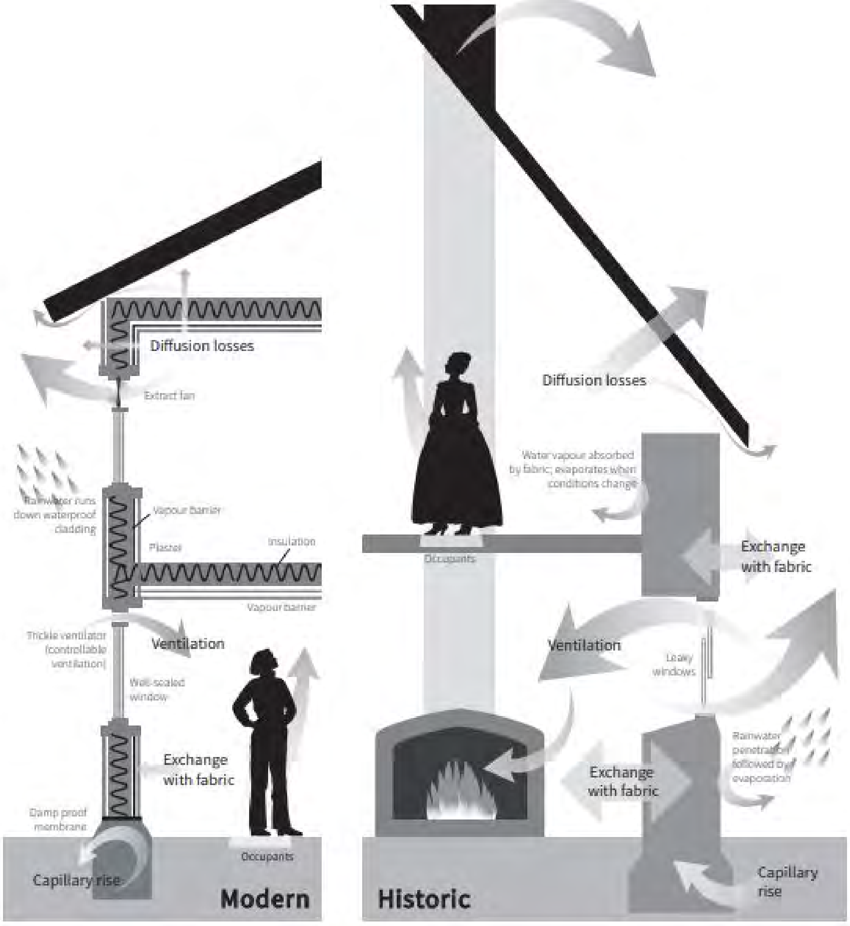
Just as a damp wall is more inefficient at keeping a building warm, a humid internal atmosphere will be more uncomfortable and feel more 'clammy' as it cools than a drier internal atmosphere - there is a theory that the moisture conducts cold to our skin.

A poor air change rate and stale air will not only threaten internal finishes through encouraging **mould** growth, but the presence of these moulds can affect wellbeing and increase the potential for illness of the occupants – especially the vulnerable, asthmatic and allergy prone. It can contribute to the so called 'sick building syndrome', where contaminants from equipment and pollution are not changed out of the air quickly enough and are absorbed instead by the occupant. A daily 'purge' of a buildings atmosphere by opening windows for 10 minutes or so is advised to counteract this effect.

Where damp air lingers and there is no opportunity to circulate, moulds can form; for example, areas will be more prone to mould where furniture against walls prevents good air and heat circulation in a room. Corners of a room are also prone to mould if air circulation is inadequate and is also due in part to the large external cold surface area (of an external corner) making the smaller internal corner area a 'concentrated' cold bridge. Moisture in our buildings has become increasingly problematic as fuel costs have risen and less heat is being delivered to spaces. Lime plaster is hostile to the formation of mould because of its high pH which acts as a fungicide; alkaline materials are less prone to mould - conditions for mould growth include nutrient availability, temperature, pH and moisture.

Traditionally, buildings were vapour permeable and moisture migrating through the walls and accumulating in the building was dispersed through operational chimneys by stack effect[49] as well as by incidental ventilation through door and window gaps. Closing up of flues and application of dense modern renders and plasters, and modern drylining can seal a traditional building so much that air becomes trapped or is slow to refresh.

This can lead to a requirement for additional vents to walls or roofs which may impact the character of a building and require consent. Hence, vapour permeable materials are so important as a first principle when considering thermal upgrade interventions to traditional buildings. In conjunction with this, we generate greater amounts of moisture in our homes than happened historically so that, even with the correct, compatible materials, it is critical that ventilation must be considered in tandem.



Typical differences in movement of moisture and air in modern and traditional construction[50] © Historic England

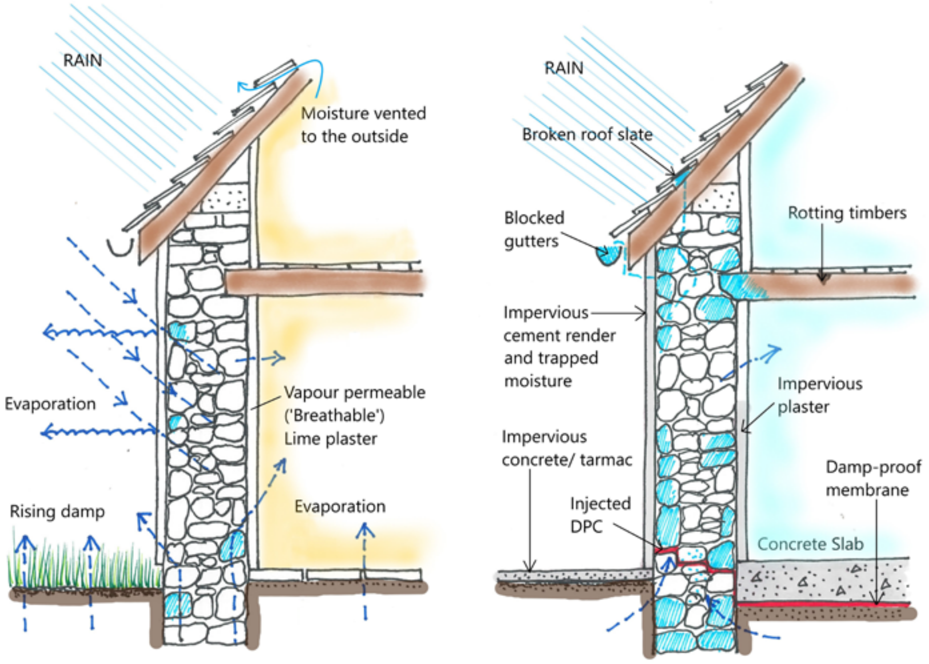
Prolonged damp conditions can also contribute to problems with timber health, for example, roof timbers or embedded historic timbers in the walls, leaving them vulnerable to fungal decay and/or insect attack.

---

[49] The stack effect is the forced expulsion of air through chimneys or openings at height, brought about by a difference in air pressure between inside and outside (warmer air to cooler atmosphere), also through suction (venturi effect) of air crossing a chimney opening, pulling internal air up and out of the building.

[50] https://historicengland.org.uk/images-books/publications/eehb-how-to-improve-energy-efficiency/heag094-how-to-improve-energy-efficiency/

The diagram below shows how well meant improvements can create problems.



Traditional 'Breathable' Solid Wall

Results of Applying Modern Impervious Materials

Well meant 'improvements' [51]

A further consideration when improving the airtightness alongside ventilation is the issue of **radon**[52]. The Building Regulations, Part C, 25(3) & 26 (2) defines, and provides for prevention or limitation of radon entering a building. The Action Levels described are concentrations above 200 Bq/m3 for dwellings. There are also degrees of action required depending on risk, the higher risk areas (as mapped) showing a higher probability of the levels exceeding the Action Level, whereby not only will a membrane be required but additional measures such as a sump to depressurise the subfloor and so reduce the amount of gas which is forced up into the building.

Increasing the airtightness may result in higher levels of gas which will require better controlled ventilation to address. This can be by sensor (triggered by radon concentration) or by positive input ventilation and should be designed by a mechanical and electrical engineer. Northern Ireland Environment Agency can be contacted for advice concerning radon.

Principles to address radon concentration increase are therefore:

- Prevent or limit ingress,
- depressurise subfloor
- Manage by ventilation/dilution
- Pressurisation of building spaces

---

[51] https://www.wtbf.co.uk/old-building-information.php

[52] Radon in Northern Ireland: Indicative Atlas https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/453712/PHE-CRCE-017__maps_without_place_names_.pdf

Moisture in buildings

There are four sources of moisture which can affect a traditional building:

1 Rain/atmospheric moisture

Rain will penetrate the outer reaches of the traditional wall and then evaporate back out in dryer periods, aided by heat from the interior of the building

2 Rising damp

Damp at the foot of the traditional wall is often referred to as rising damp and is the drawing up of ground moisture by capillary action through the wall. In an occupied building this is mostly held in balance by evaporation.

3 User generated moisture

This is the moisture generated by occupants through breathing, activity, washing and cooking. Overburdening of the internal air can lead to condensation and/or mould growth on cold surfaces especially prevalent where inappropriate materials or make ups have been employed.

4 Broken or malfunctioning services

Damaged or leaking pipework, internally or externally, can cause damp penetration and is easily resolved when pinpointed as the cause.

Behaviour of moisture in fabric

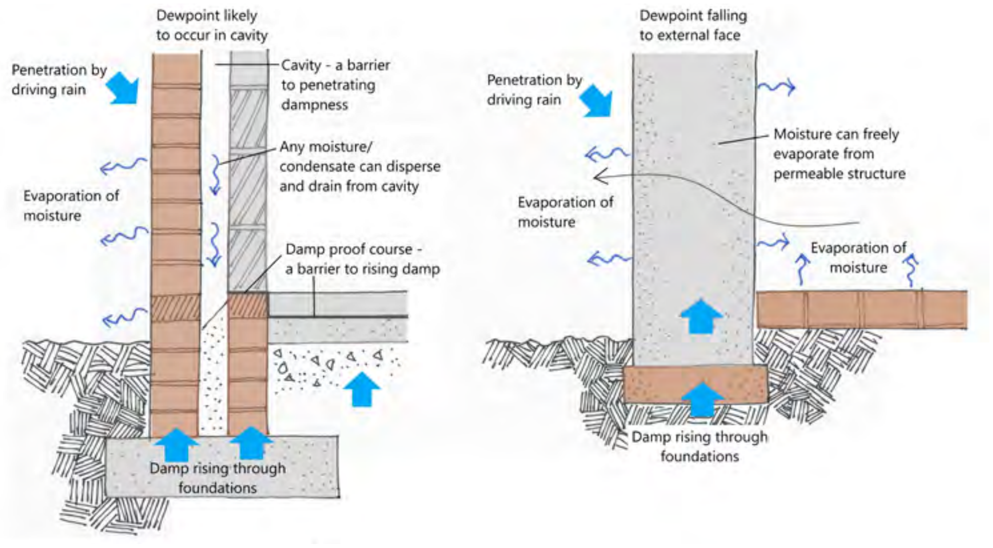
Moisture is held in the pores of built fabric, and vapour permeability describes the dynamic movement of moisture in and out of pores. Larger pores allow easy movement, moisture drawn up by capillary action into very small pores can be more difficult to dry out.

There are often two movements of moisture occurring in a traditional wall at any one time:

Liquid moisture (penetrating rain) is trying to move from a higher relative humidity outside to a lower relative humidity inside, and the position of moisture in the wall moves constantly in response to internal and external conditions. Evaporation occurs at the surfaces and the core may remain wetter. This has both daily and seasonal fluctuations.

Meanwhile moisture vapour will be attempting to disperse or diffuse through pores in the structure, and this is driven by vapour pressure. Where the fabric is healthy and these processes can occur unimpeded, the balance will generally be held at a tolerable level.

The diagram below shows management of moisture in a modern versus a traditional (solid) wall.

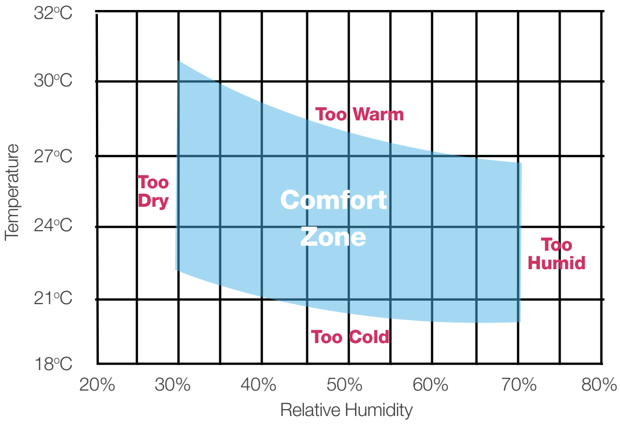


The importance of permeability in traditional buildings

Traditional materials are, broadly speaking, permeable, with the exception of granite and slate. Brick, stone, traditional mortars, plasters and renders, unglazed finishes, earth, mud, turf/scraw, early concrete (Roman) and timber can all be described by this term.

The relative ease of moisture movement through traditional buildings with compatible fabrics is the reason embedded timbers in masonry can survive so well after many years without a membrane separating them from the surrounding masonry. This is dependent on good and appropriate maintenance.

Moisture and therefore air quality is managed by maintaining the permeable fabric which ensures water vapour is buffered (high vapour content taken up by permeable fabric, released at lower pressures).



Thermal Environmental Conditions for Human Occupancy, specifies conditions in which 80% or more of the occupants would be expected to find the environment thermally acceptable

Permeability allows a surface to absorb a certain amount of rainwater and to evaporate it again. A soft historic brick wall with a lime-based mortar is a relatively soft surface which will perform this function holistically, a basalt wall with lime joints will rely heavily on its joints to allow moisture release in dryer periods. This is why the sealing of an historic surface to become impervious, or the repointing in cement will put stress on the wall materials, any water penetrating through cracks or decayed areas (which are inevitable) will be unable to freely evaporate causing damp, cold walls. On seeking egress, moisture will damage the surface (e.g.spalling bricks) when it builds to create pressure and finds the path of least resistance on a surface which has lost its homogeneity.

Mortar washout at the base of a wall

Having a certain level of absorbency also has the effect of reducing rapid run-off so retaining a surfaces permeability is important to avoid the damage this can cause; when run-off is localised to a portion of the wall surface because other parts have been made impervious by inappropriate ‘sealing’ treatments for example, rapid erosion can result.

There are other situations in the traditional building where interrupting permeability by the addition of impermeable linings or barriers may impact the fabric.

For example, when timber structure is embedded in walls, interrupting the balance which allows moisture to dissipate can cause issues (such as allowing timbers to become saturated).

As a rule of thumb, it is preferable to increase permeability progressively from the interior of a traditional building to its exterior. An exception to this rule may be if a building is exceptionally and frequently exposed to driving rain for example.

A further example of alteration of the moisture management might be the introduction of tanking at a lower or basement level which can force water to adjacent portions of a building and requires careful management of any risk.

Modern damp proof courses are rarely effective as they are difficult to install successfully across a deep masonry wall, particularly stone. An injected damp proof course has a short shelf life and is likewise incompatible with a traditional mass wall make up as it relies on a uniform and level bedding. An electro-osmotic damp proof course is more sympathetic and works by using electric charge to counter capillary action through fabric. Best management of moisture is through good maintenance as set out in the Building Section above.

7 Building Elements

The technical drawings included in this guidance document are diagrammatic only and are used to illustrate general principles. They are not intended to be used as drawings for purposes of construction. Older buildings need to be evaluated individually to assess the most suitable form of construction based on a wide variety of possible variables. Historic Environment Division does not accept liability for loss or damage arising from the use of this information.

Roofs

As section 3, historic roofs fall mainly under two descriptions in Northern Ireland; pitched or flat (or very low pitched) roofs. Roofs are a distinctive part of the building and often collectively of an area as they display locally available materials, whether actually local or because of an established trade route. Their forms and detailing are also telling of the environment in which they are sited.

Tullycavey slate roof

Due to the structural limitations of timber, pitched roofs, especially those to large buildings may have a composite form of pitches, valleys and leadwork between, which can also make the thermal upgrade complex. For different reasons, the thermal upgrade of flat roofs can be similarly difficult.

A thatched roof falls into another category of pitched roof in that its material is inherently insulating and thermal upgrade is inextricably linked with its being maintained in good repair. A maintained thatched roof has an assumed[53] u value of 0.35W/m^{2}K, though the u value of a thatched roof with scraw layer has been reported to be as low as 0.19W/m^{2}K.

Types of roofs

Pitched roofs

Historic pitched roofs (other than thatch or TUT – thatch under tin) are usually sheathed in an outer layer of slate or stone. Slate is a split and cut stone (slate is a metamorphosised sedimentary rock), and coverings may have a slim profile (thickness) or heavier and thicker, such as the Co. Down Tullycavey stone shingle.

Roofs stepping downhill in Armagh

Alternatively, pitched roofs are covered with metal such as lead, zinc or copper. This was more common on buildings of status, such as churches or municipal buildings and was often to cover more complex or fluid roof forms such as cupolas, church apse or chapel roofs against the main structure. Later, in the 20th century, manufactured fibre boards were used, most commonly on non-domestic buildings, and consisted of cementitious boards, sometimes

---

[53] RdSAP 9.93 (bre.co.uk) – this is not fully comparable with an Irish thatched roof which includes 'scraw' or turvess, and so may have a lower u value.

with asbestos content, such as the corrugated fibre sheets found on outbuildings.

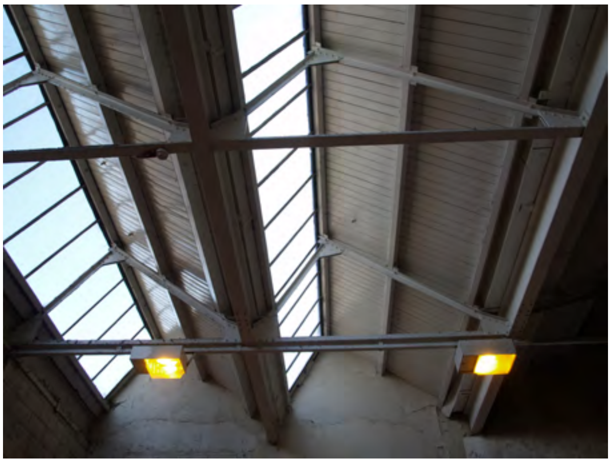
Flat roofs

Historically, flat or shallow pitched roofs were often covered by metal – lead or zinc, and more occasionally, copper. These were applied seamed, batten rolled or stepped, dependent on their being along fall or across fall (more common to valleys). In the second half of the 19th Century, mastic asphalt became an option for flat roofs, later in the 20th Century benefitting from polymer additives which increased its lifespan. Also later in the 20th century, untreated/uncoated aluminium seamed roofs were popular.

Structure

A timber roof superstructure was the most common roof structure historically, with steel later enabling larger spans in industrial and manufacturing buildings in the early 20th century. Steel had gradually replaced cast iron and wrought iron as a construction material from the mid to late 19th century. (Cast iron was good in compression but not in tension and so less suitable for roof members. Wrought iron performed equally well in tension and compression but was more expensive to produce than steel).

Both pitched roofs and flat roofs had timber structures, larger pitched roofs may have had a truss enabling larger spans with a timber secondary structure between the primary truss structure. Flat roofs mainly consist of a timber joisted deck which may or may not have a ceiling attached to its underside, dependent on building type.



Steel structured roof

Issues & risks

The proportion of heat lost through roofs is commonly cited as approximately 25% of all fabric heat loss. Roofs can present the least disruptive area to increase insulation of a building, especially pitched roofs, and where situation permits, the standard of insulation can be over and above statutory requirements. This can help to balance out other areas of a protected building where gains might be more difficult and invasive, for example, windows and walls. Be aware however that historic structures are usually structurally undersized (by modern standards) and any additional loading should be assessed. The addition of insulation to an historic building is not without risk, and should be addressed on a case-by-case basis:

Risk of loss of historic fabric and detail (internal)

Especially where the roof deck or make up includes a closely fixed ceiling, e.g., a flat roof or canted ceiling (following roof slope), the retrofitting of insulation may require the removal or disruption to an historic ceiling to insert insulation. An assessment should be undertaken to determine risk of cold bridging or cold spots and if the retrofit would cause irreversible damage of historic fabric. The same applies to detail, for example, a run plaster cornice. if the material is of significance, another solution should be pursued and/or the risk assessed of remaining uninsulated and seeking gains elsewhere.

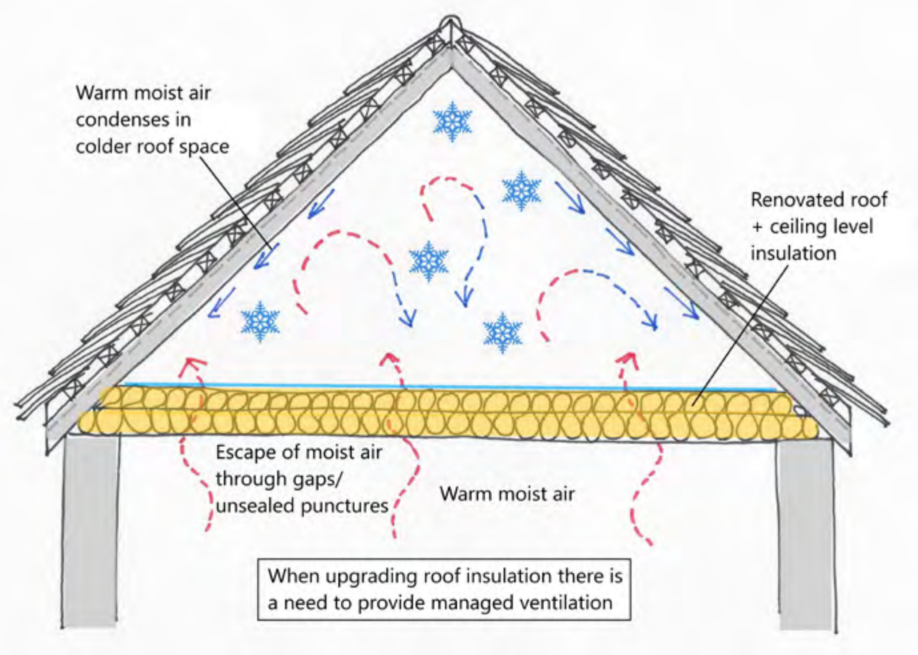
Risk of change to historic detail or modern intervention (external)

The addition of roof insulation may necessitate a change of roof line or detail. In particular, the addition of insulation at rafter level or above to create a 'warm' roof space may require the outer roof level to be raised. This has repercussions for the roof detail, it may raise the eaves unacceptably, raise the ridge, create undesirable abutment heights to other parts of the building or other roofs, all of which may affect the character of the building. Insulation to the roof void may also trigger a requirement for increased ventilation to the void and the insertion of new vents to gables and/or roof slopes (see below). If required, these must be discreetly placed, and be as minimal as is required to disperse moisture.

Note: any changes proposed to the roof of a protected building will require Listed Building Consent

Change of dew point/condensation

The dew point occurs where warm moist air meets the point in the structure where the temperature drop causes the air to deposit its moisture. It is the trigger for condensation. In an uninsulated roof, the warm moister air circulates up through any voids and within historic roofs there is usually plentiful unintended ventilation which allows the moisture to be safely dispersed. The roof timbers are also hygroscopic and will buffer any moisture, allowing it to be carried and dispersed at a drier period. The addition of insulation at ceiling level and renovation closes gaps and makes the roof space less draughty. This will mean the roof void is much colder with less air movement, and whilst this is good for energy consumption, it can present a risk as moisture condenses in the voids. Increased ventilation may be required to disperse the moisture and the unintended consequence of dampness which may affect the timbers.



Dewpoint diagram illustrating venting requirement. Cold roof space following insulation at ceiling level. There has been a temperature drop in the roof space, moisture can condense due to lower temperature but lack of ventilation can cause moisture to accumulate on timbers and encourage decay.

Historic roofs sometimes have ‘parging’ to the underside of the slate which has a small insulant effect but is also vapour permeable. If the roof space becomes overly moist, this can cause the parging to degrade, and may cause the loss of the functional historic detail to the building.

Condensation within a structure can degrade detail and can cause its decay and eventual loss.

Monitoring fabric

The introduction of insulation can hide the roof structure, for example, insulating below rafters, or laying quilt insulation over ceiling joists, prevents them being visible for fabric monitoring purposes. The use of hygroscopic material to insulate is encouraged in an historic building as it will act with the timber and other historic materials to buffer moisture.

The alternative is to stop moisture moving to the cold side by the introduction of vapour barriers with impermeable insulation. However, gaps in insulation and barriers, can leave routes to structure where damaging condensation can occur. Vapour barriers above historic ceilings can also prevent dispersal of moisture and cause delicate lath and plaster ceilings to become laden with moisture and potentially cause their degradation. High levels of moisture should be managed for these reasons.

Roof zone Thermal Bridges

The introduction of insulation can result in the occurrence of thermal bridges as no installation will result in a perfect constant layer of thermal material.

Some examples of where cold bridging may occur are as follows:

- Gaps in insulation
- Internal wall carried into cold roof void to roofline/underside of roof
- Parapet wall through cold or warm roof void/chimneys
- Thermally unbroken rooflight to warm roof
- Dormer windows (uninsulated or less insulated)
- Historic structure such as purlins/trusses
- Extract fans from habitable spaces through cold voids to roof vents
- Fixings through a ceiling to structure above insulation level
- Plumbing pipework and tanks (insulate above)
- Damp or wet, or compressed insulation
- Rafters (e.g., canted portion attic ceiling)

Blocking Ventilation routes

The installation of insulation can inadvertently block ventilation routes to voids which have kept historic roof timbers in balance over time. This can happen when insulation blocks off eaves air routes, e.g., laying quilt insulation over ceilings and extending into eaves or blocking air routes by extending rafter line insulation into eaves. This can leave cold spaces without ventilation and encourage condensation on roof structure where it can lead to decay.

Disturbance of hazardous substances

Working in lofts, can lead to exposure to hazardous materials, usually from the late 19th and earlier part of the 20th centuries. Special precautions must be taken to avoid exposure to fibres of asbestos, fibrous vermiculite and fibreglass as these can cause irritation and be hazardous to health. Do not try to repair or remove any asbestos materials yourself if you have not had any training for non-licensed asbestos work. You can seek advice from an environmental health officer at your local authority/council (see the Directgov website) Refer to HSE asbestos guides at: **https://www.hse.gov.uk/asbestos/**

Consider:

Heritage Significance

Existing construction, condition of roof covering and structure

Existing ventilation/weatherproofing of roof

Maintenance & appropriate removals

- Rectifying broken slates, split lead
- removal of existing ineffective insulation

Reversible & non-destructive interventions to upgrade

Impact on Heritage significance

Impact on fabric behaviour/environmental conditions

Impact on space

Future outcomes

- the balance of cost and effectiveness against disruption

Insulating materials

Insulation works by being resistant to the movement of energy in the form of heat, and so keeping heat where it is needed. Insulation has a low u value (see section 6) that is, the number of heat units (watts) being transmitted through a medium for every degree difference in temperature between the inside and outside of that medium, per square metre is low. Material to insulate falls into two manufactured types, vapour permeable and vapour impermeable. Below are examples of both:

Vapour permeable: wood fibre board, cellulose (paper), sheep's wool batts, hemp fibre boards, mineral wool (note, mineral wool is not hygroscopic). Hemp is a carbon negative material – the industrial production of hemp captures 15-20 tonnes of carbon per hectare during annual growth.

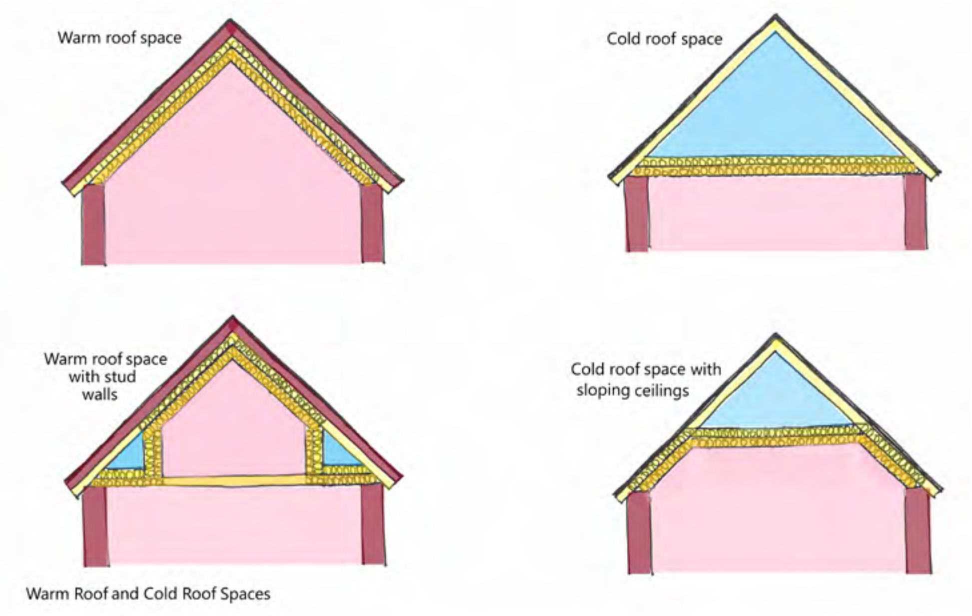
Vapour impermeable: foil insulation sheeting, including foil faced boards, Polyisocyanurate, Polyurethane, polystyrene boards, spray applied foam

In recent years there has been good progress made with 'greener' insulants. As well as their green credentials, these insulants also are largely vapour permeable and capable of buffering moisture. This makes them more compatible with historic fabric.

Financial return on insulating a roof with ceiling level (loft) insulation is around 3 years[54] for a typical semi-detached building.

---

[54] Based on Energy Saving Trust data for an oil fuel heated semi-detached dwelling. See Roof and loft insulation guide - Energy Saving Trust



Cold roof space and warm roof space diagram; this should not be confused with warm and cold 'deck' construction, terms used at the flat roof section

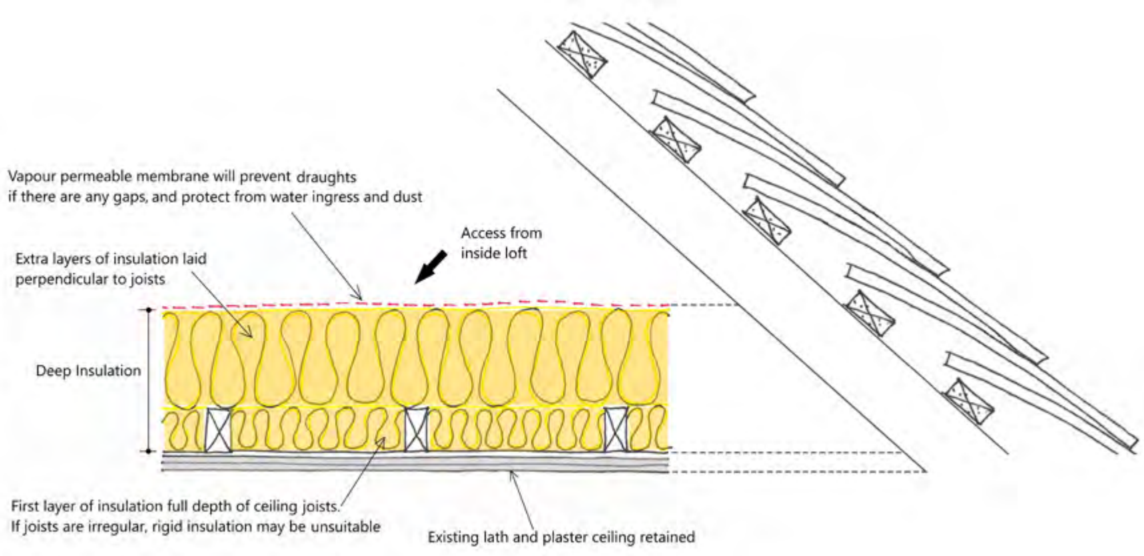
Option positions for insulating pitched roofs

On the flat (ceiling level) with an unfinished roof space

Inserting insulation horizontally above the ceiling is widely considered the easiest way to improve thermal efficiency. The insulation can be squeezed between ceiling rafters and care must be taken to avoid missing areas which can create cold spots, invite mould, and allow disproportionate escape of heat.

Soft batts of sheep’s wool, wood fibre or other mouldable hygroscopic material works better with the irregularities of an historic roof and historic timbers. The depth should be constant to avoid localised variations. Any openings for services in the ceiling must be well sealed to prevent warm moist air moving freely into the roof space. Insulate the plumbing pipework and water tanks as these will be at greater risk as the roof space is now colder. Conversely, electrical services should not be buried in insulation which may cause it to overheat. Maintain eaves ventilation and consider additional ventilation if required. Some historic roofs will have unintentional ventilation due to e.g., penny gapped sarking but caution should be taken to ensure roof space is neither under nor over ventilated. Structure should be monitored to ensure the change of roof space atmosphere (moisture, temperature) does not compromise fabric. It is generally easily reversible and renewable if necessary.

This method creates a cold roof space.

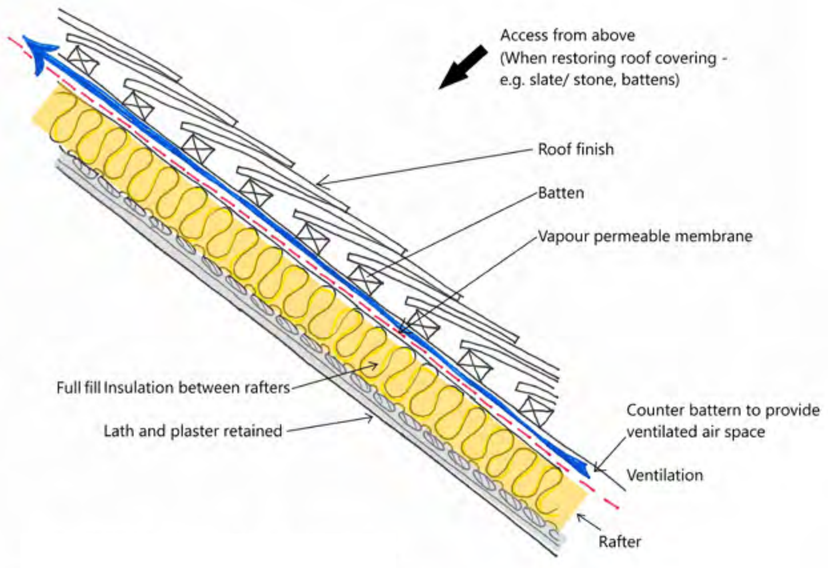


Insulating between and over ceiling joists in an unfinished roof space - cold roof space

Insulating between rafters

A pitched roof may be **insulated between rafters;** as with the ceiling level insulation. Using breathable, malleable materials works better with historic timbers and roofs. The main drawback with this method is that historic timbers are usually quite shallow, allowing for minimal depth insulation. Above the inserted insulation, an air gap of 50-60mm should be retained to allow passage of air from eaves to ridge or plenum with an exit (e.g., gable vents). If roof work introduces a new membrane, this should be a vapour intelligent layer so that any moist air can dissipate easily.

If this can be accommodated in rafter depth, it has the advantage of not altering roof lines. Rafters become a bridge between cold and warm but as timber, they can usually buffer any moisture forming (their thermal conductivity factor is low in comparison with other materials). This method creates a warm roof space.



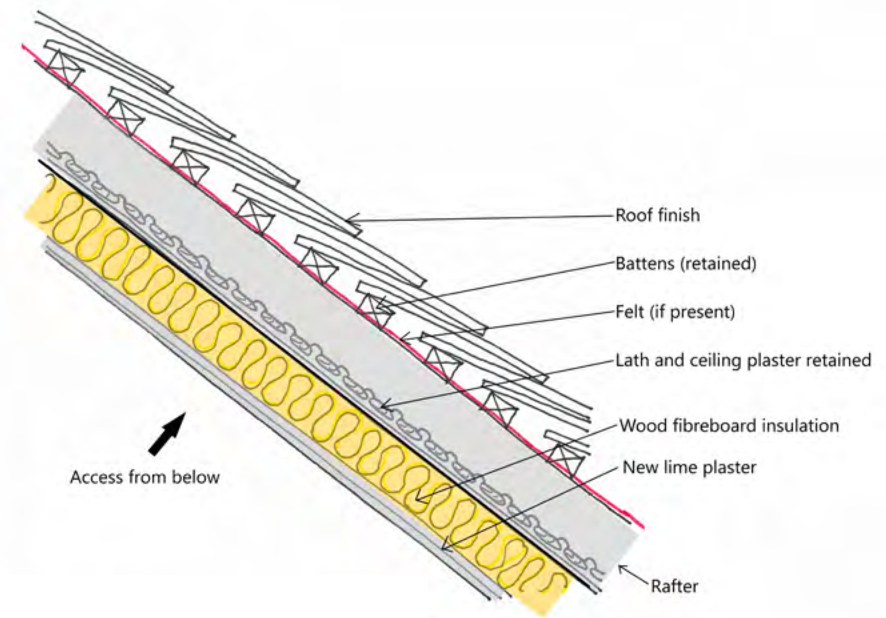
Insulation between the rafters only

Insulating below rafters

This method may allow a greater depth of insulation to be provided and therefore increase thermal efficiency. The drawback is that the rafters will be hidden from view completely, so monitoring becomes difficult without removal.

The insulation should be installed perpendicular to the rafters, but intervention will be needed in the form of additional battens to underside of rafters to secure the insulation.

This creates a warm roof space.

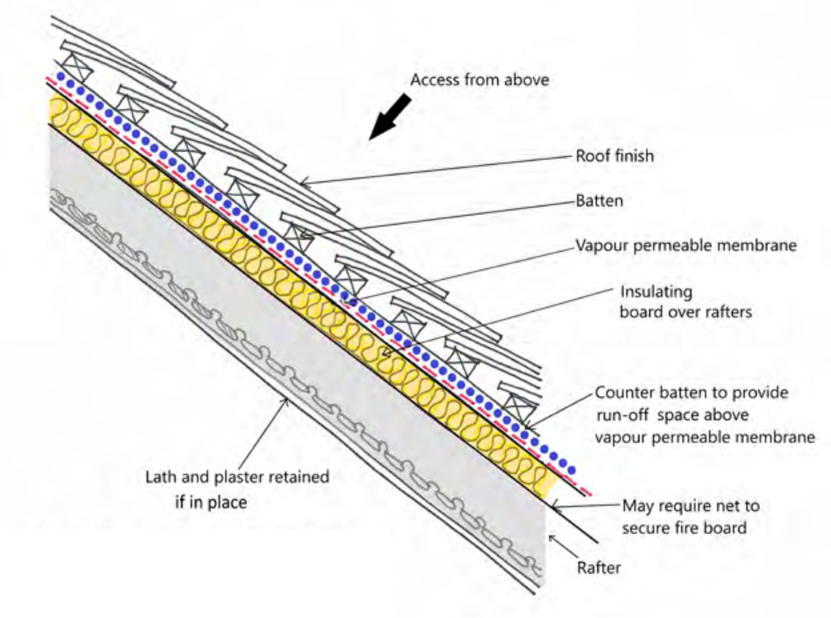


Insulation below the rafters and ceiling (lath and plaster ceiling retained)

Insulation above rafters

Insulation **above rafters** creates a true warm roof and warm deck structure, in that all structure is contained and protected from the outside temperature. However, in a retrofit situation, it can alter roof profile and detail which may not be acceptable to the aesthetic of the historic building. It is also invasive, in that it requires the full removal of a roof before replacement to new build up, and for this reason is best restricted to roofs where extensive work has become unavoidable for the benefit of the building for other reasons and only if it does not alter unacceptably. Historic roofs often derive character from their undulating and uneven profile and this intervention would remove that quality. Additional build up will consist of the insulant, battens to length of rafters to fix, and counter battens (this may be required to allow for run-off behind slate battens). Modern super-efficient insulants such as aerogel may be useful in this scenario due to their slimness, but may be cost prohibitive.

This creates a warm roof space.

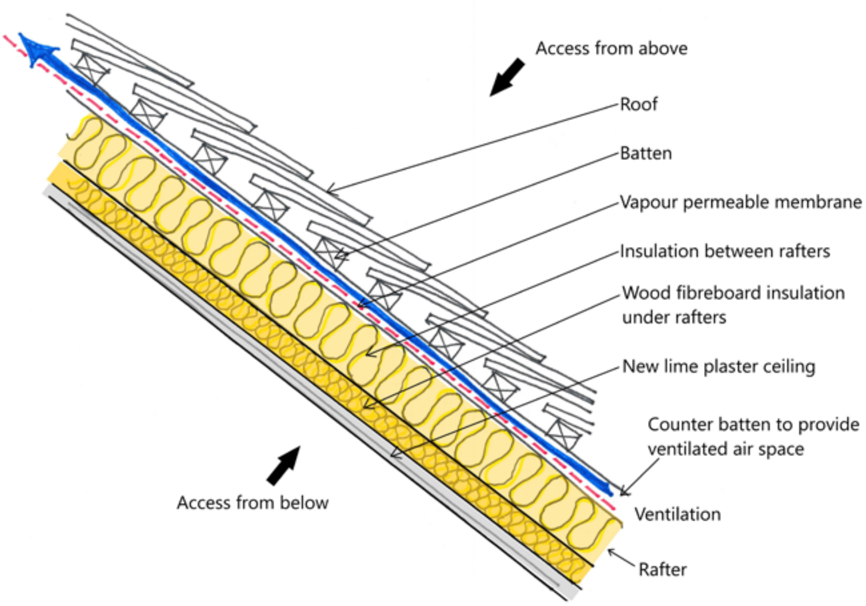


Insulation above rafters only, roof finish dismantled, counter battened space to allow for any run-off

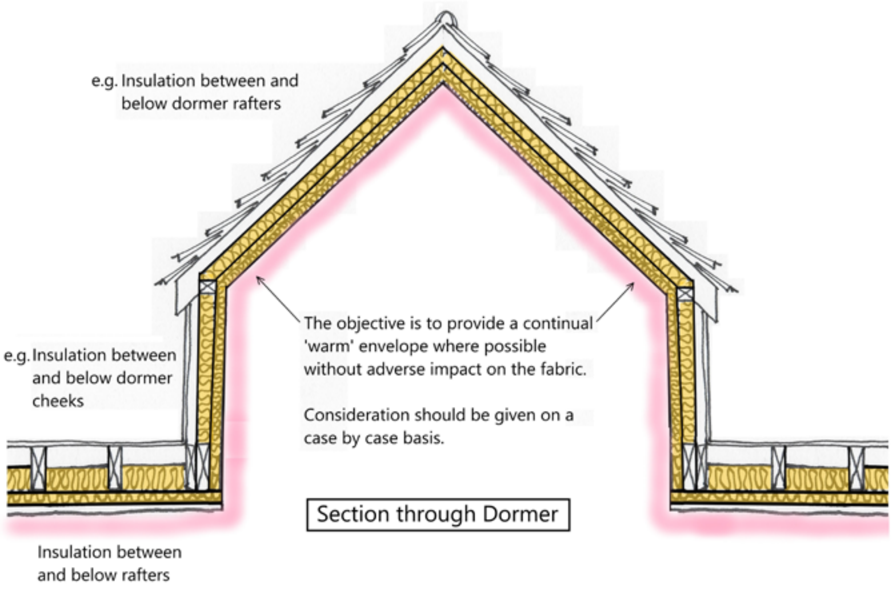
Combination of methods

The methods described at rafter level to insulate can be combined e.g. **insulating between and below rafters** to increase depth of insulation.

All the risks mentioned should be considered when proposing insulation and this should be undertaken on a case-by-case basis.



Insulation between and below the rafters

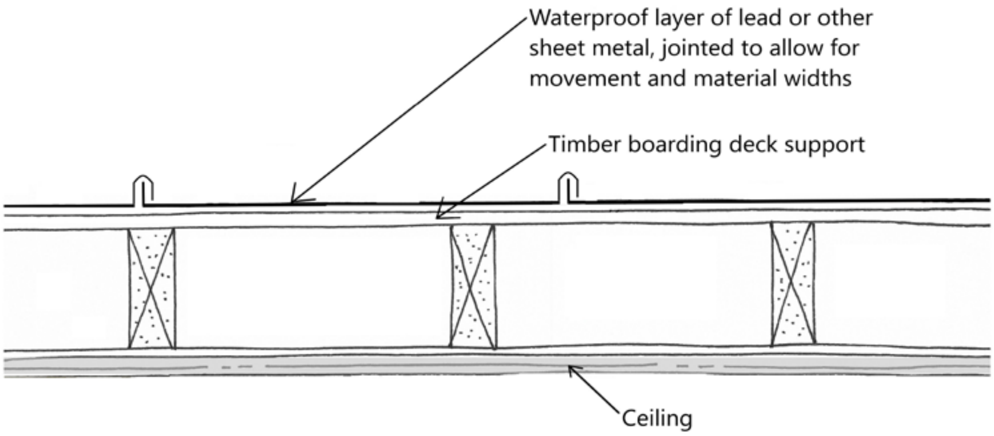


Strategy for insulating a roof dormer

Dormers present particular problems as they need to be insulated to their flanks or cheeks as well as their roofs for the insulation to be as continuous as possible to minimise cold spots

The ultimate aim when insulating is to create an unbroken envelope of insulation. The success (or weak areas) can be gauged by drawing a continuous line through a section view of the building to represent the proposal to retrofit.

Option positions for insulating flat roofs



Standard Flat Roof Build Up

- Historic structure is usually timber
- Timber boarding deck support
- Waterproof layer in lead or other sheet metal

The image above shows a standard flat roof build up. The historic structure is usually timber, the deck support is formed by timber boarding and the waterproof layer is lead or another sheet metal which is jointed to allow for movement and material widths.

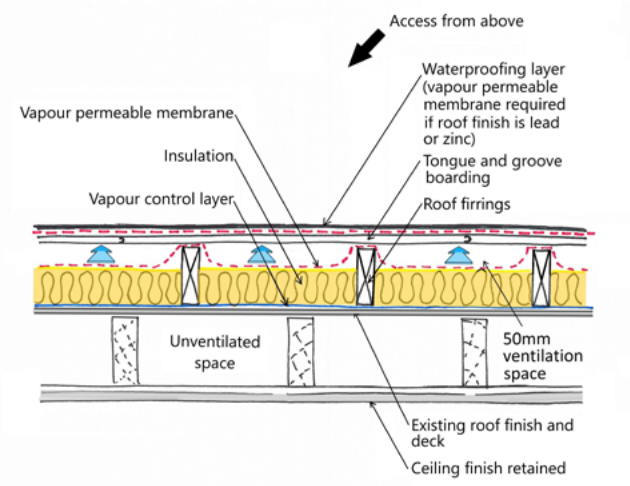
Risks with flat roof insulation arise with lowering the temperature of the roofing (lead) which can lead to corrosive condensate (pure water) on the underside, and difficulties with ventilating voids (removing resultant moisture). Difficulties can also arise with acids in new plywood and new oak decking (high in tannic acid) in contact with metals, as the acid can corrode the metal roofing.

Insulating above structure (warm roof deck)

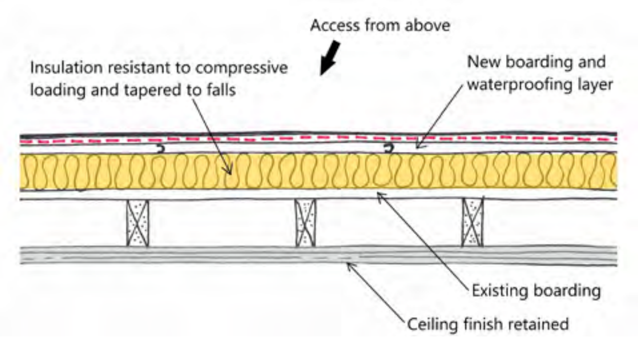
A warm flat roof deck is formed when insulation is added above the structure and below the waterproof covering. This will usually require the removal of the existing roofing and the raising of the finished level of the roof and this approach will not always be feasible due to the impact it may have on adjoining structures or features. Additionally, it requires the disturbance of an historic covering, and may be appropriate if it were due for renewal only. The underside of the roofing will become colder and prone to condensate forming if the insulation is not airtight (which it is unlikely to be). A vapour barrier below insulation can be used which prevents moisture travel, but this can be difficult to make truly airtight due to fixings through it. The use of a vapour permeable membrane is preferred above insulant along with buffering insulation (wood fibre for example). An intelligent membrane will let moisture disperse as temperature and atmosphere allow. Ventilation below the roofing finish is essential if the roof is a lead or zinc finish[55], and this will require careful eaves and/or abutment detailing[56] which will not impact the character of the building particularly if it is protected by listing.

Insulating from above may be a more appropriate option if for example the ceiling fabric is of particular historic or architectural significance within the building.

The diagrams below illustrate two approaches to insulating to create such a roof.



Ventilated warm roof (insulation above existing roof finish)
- Access from above
- Exisiting waterproof layer retained
- New roof deck added above an existing deck with a venrilated area above the new insulation layer
- This adds considerably to the depth of the roof which pay pose detailing problems with other parts of the adjoining construction



Unventilated warm deck system Not suitable for lead or zinc roof coverings
- Access from above
- New waterproof layer, existing ceiling retained underneath
- Not suitable for lead or zinc proof - as there is no ventilation between the insultation and the underside of the roof covering therfore finishies such as asphalt, stainless steel and copper preferable

---

[55] Underside Condensation and Corrosion of Lead Sheet Roofs (buildingconservation.com)

[56] Guide-to-Rolled-Lead.pdf (usercontent.one)

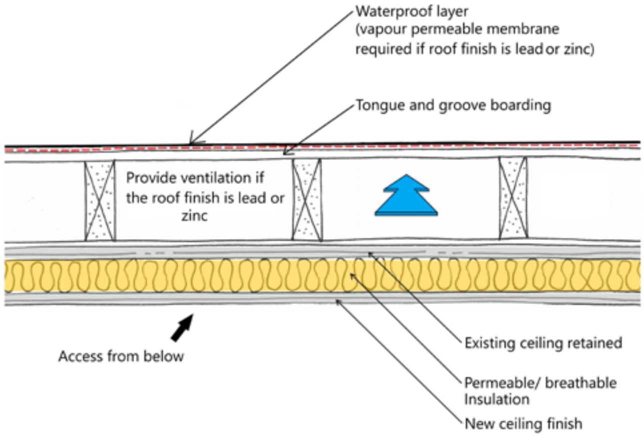
Below or within deck (cold roof deck)

A cold roof deck is formed when the insulation is applied below or to lower portion of the structure, and thus the structure (or part thereof) and deck remain in the cold part of the roof.

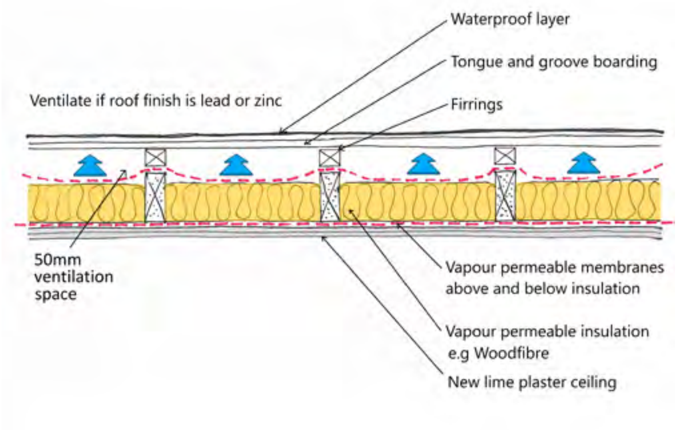
Placing insulation between joists or below joists may be appropriate when the roof covering cannot be disturbed due to its significance or physical obstacles preventing it, and/or is not due for renewal. Where a ceiling exists which is not of particular significance, and where room height permits, insulation may be added to the underside of the existing ceiling.

Where there is no ceiling, or it is not required to be kept, opening up from the underside to insert insulation between joists is possible. If vapour permeable membrane and buffering insulation is used, the space above, which should be a minimum of 50mm can remain unventilated, but only if the roof covering is not lead or zinc. Lead or zinc coverings must be ventilated due to susceptibility to condensate which can corrode the metal.

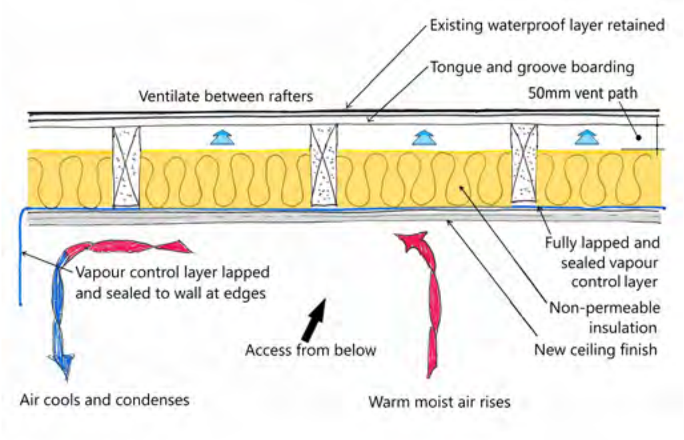
The diagrams to the right illustrate, top, insulation below ceiling, middle, insulation between joists with permeable insulation and bottom, insulation between joists with impermeable insulation.



Ventilated cold deck using vapour permeable insulation



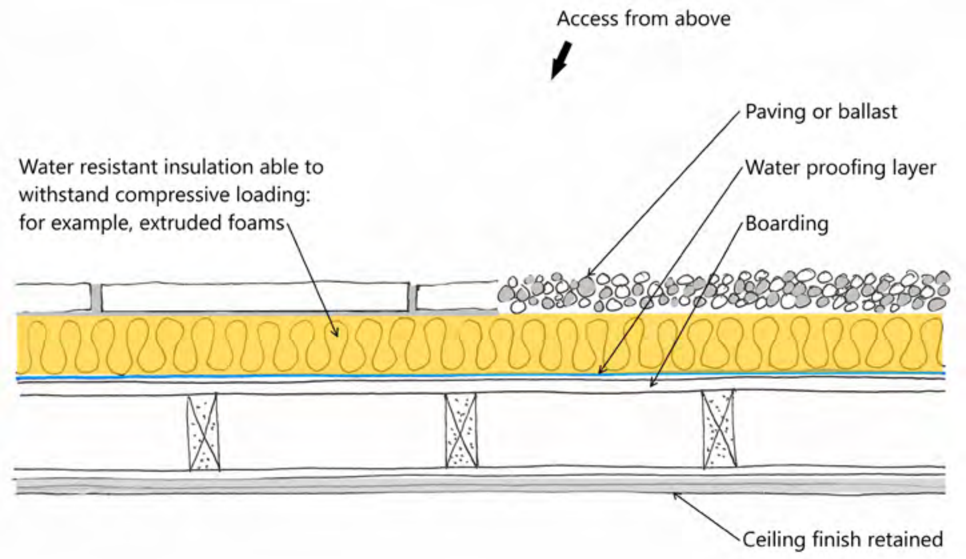
Insulation added below roof structure



Ventilated cold deck using non permeable insulation

On top of roof waterproof layer (inverted roof)

An inverted roof is appropriate over a bituminous or vinyl roof, where space permits above the deck and where it is unlikely to impinge on character. It should not be used over a metal roof because of tendency for joints to move and capillary action to draw water in. An inverted roof places insulation and weight on top to keep in place through gravity – may be ballast such as pebbles or turf, or paving slabs. The structure will need to be proven as capable of carrying the extra load. This system keeps the roof intact, does not require it to be disturbed if it is sound, and reduces the temperature wear and tear on the membrane. Ventilation is not required and the whole of the structure is in the warm zone.



Inverted roof diagram

Summary

- Keep roofs in good repair and keep rainwater goods and coverings sound to take water away quickly
- Consider heritage significance
- Avoid spray on or non-reversible insulating treatments
- Locate insulation for minimum impact to appearance/fabric, detail impact of raising roof lines, additional ventilation requirements
- Avoid recessed light fittings in ceilings
- Avoid uneven treatments which encourages cold spots
- Unventilated voids (to flat roofs) may benefit from vapour barrier membranes
- Prepare a detailed proposal which takes account of the heritage significance.

Walls

Principles, materials, and methods

An earlier section 3 (Principles of Traditional fabric behaviour) has described the general composition of a traditional wall which makes up most of our pre 1919 buildings, and at 'Where is my building losing heat?' the average % heat loss of the various elements has been quantified. The walls of a building lose the greatest proportion of energy in terms of heat loss. They are also an element of a traditional historic building that carries a lot of risk when the solution to improve thermal efficiency is not well considered, both for the fabric (decrease in permeability, effects on features and character) and for occupant health (air quality).

Adding insulation to solid walls either internally or externally has two-fold risk;

1. It may aesthetically alter the character of the historic building, and this will especially be a primary consideration where the building is protected by listing, or in a designated area such as a Conservation Area (external insulation). An intervention to add insulation will require listed building consent where the building is listed.
2. Adding wall insulation may affect how the fabric behaves.

The principle of permeability has been explored earlier and is fundamental to the consideration of insulating solid walls. Historic fabric can be fragile and altering the building physics can impinge directly on finishes and composition to the detriment of the wall and the special interest of the building.

The early cavity wall originated to stop driving rain and moisture crossing the structure and in the UK these were more common in coastal areas. They separated inner and outer leaves but had tying bricks at intervals and the cavity was often very slim (50mm or less). The rat trap bond is an example of this type of wall. This type of wall began appearing in the late 19th and early 20th century and by the 1970's the cavity had become more like what we see today and was more widely insulated. Work to upgrade cavity walls performance by insulating between leaves[57] is not within the scope of this guidance[58] but also carries risks such as cold bridging at missing portions (due to blind filling through punctures) and moisture crossing a narrow cavity via the newly installed insulation.

Issues & risks

Inserting or applying insulation to solid walls

Heritage & aesthetic Impacts

The proposal should be carefully considered to ensure that the significance of the building is not impacted; the features should remain unaffected, the character unimpeded by any changes which could alter reading of the building. Any intervention to a protected building should consider this in the first instance.

Room proportions, especially in smaller buildings, can be altered by reduction in size through additional layers to the room internally.

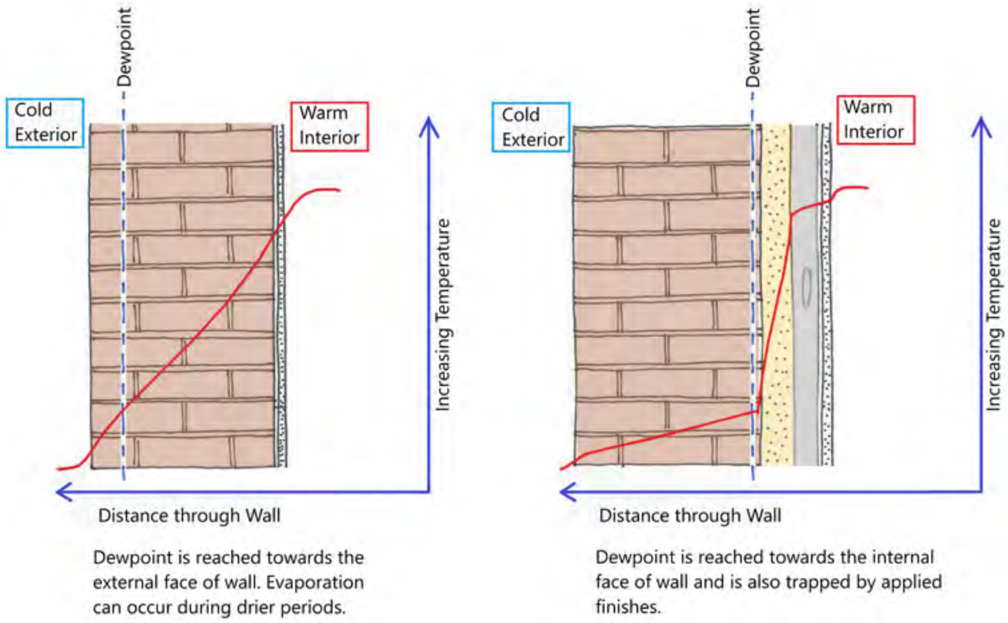
Temperature profile and damp

The proposal should be examined through calculation to determine the new temperature profile and where dew point (condensation) is likely to fall. While this is difficult to be certain

---

[57] Post_Installation_Performance_of_Cavity_Wall__External_Wall_Insulation.pdf (cewales.org.uk)

[58] How to install cavity wall insulation - Energy Saving Trust



Dewpoint/ temperature profile through wall*, uninsulated (left) and with insulated lining (right)

about with an historic solid wall due to its non-homogenous nature, it is still a useful tool. A dew point towards the inside of the building may indicate the structure has been insulated by too large a margin, forcing a radical change (reduction) in heat moving through it which could be damaging and introduce moisture to an area which cannot dry out.

Damp issues can manifest because of:

- the lowered temperature of the wall (in the case of internal insulation),
- reduced drying of the fabric,
- increased fabric moisture whether through rain ingress or interstitial condensation or ground damp to wall bases. A wet wall is up to 30-40% less efficient thermally.

The increased moisture in the wall can migrate to hygroscopic salts in the wall. Salts can damage the fabric of the wall when they recrystallize by expansion and cause the masonry to become friable; for example soft brick may be reduced to powder by salt action.

Increased moisture within the wall can cause:

- Timber decay e.g., Embedded joist ends
- Decay of masonry fabric through increased freezing and thawing
- Staining because of movement of historic wall deposits (e.g. salts & combustion deposits), mould, or
- Corrosion of embedded metals.

The thermal storage of heat energy which is provided by the mass masonry wall (including that absorbed through direct solar gain from south facing windows) will no longer contribute to the internal temperature when a wall is lined with insulation.

Impermeable insulation risks

Insulating inappropriately will interrupt the vapour permeability of a solid wall.

The wall will no longer buffer the moisture content of the air where a non-permeable system is used, and extra mechanical moisture control fittings may be required to compensate.

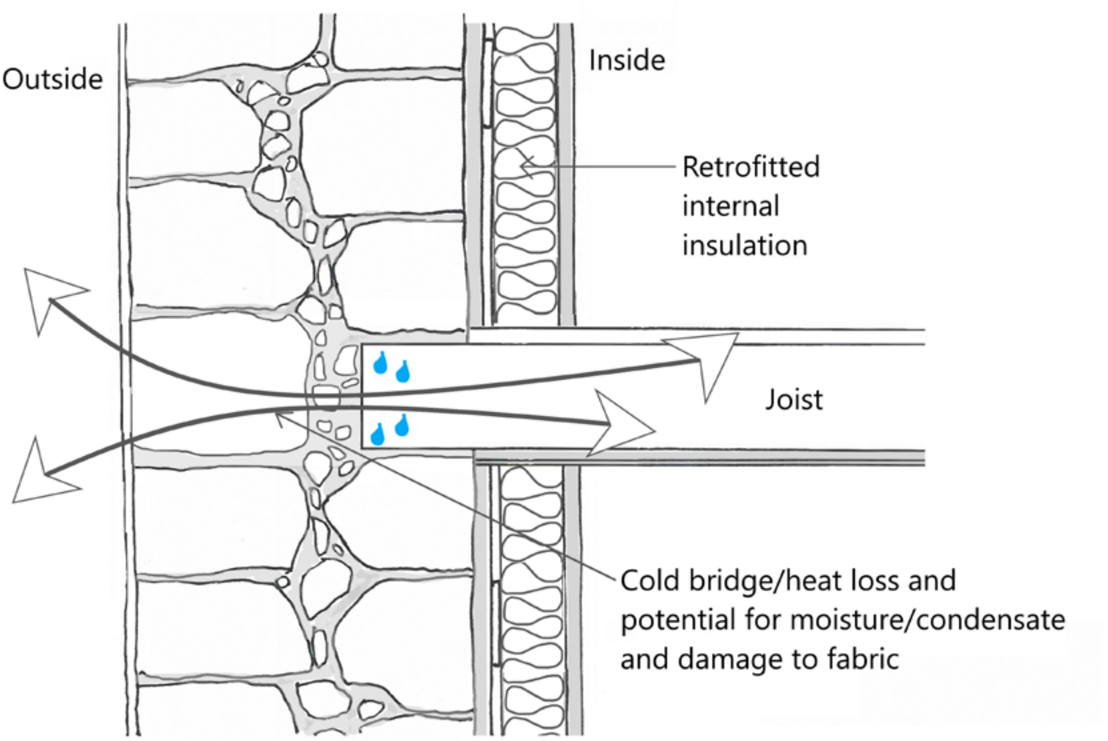
These can have a physical impact on appearance and character depending on where and how they route through and terminate from a building.

Thermal bridges

Thermal bridges may be the result of differential temperatures where routes across the new thermal layer are breached or bridged through poor installation or unavoidable fixtures or details. These points will disproportionately attract condensation because the large area of the wall is not sharing the task.

Reveals of windows for example, are an area which is difficult to insulate to the same degree as the main wall, and in addition often has important architectural detailing to consider. Mould is unsightly, unhealthy, and continual moisture can be the trigger for decay. It needs a compatible surface[59], mould spores and moisture to form. Condensation forms at 100% relative humidity (RH) but risk of mould which forms at 80% RH is therefore higher and will occur more readily and before the air is completely saturated. Both result when there are cold surfaces, moisture, and lack of ventilation.

Another junction which needs careful attention when insulating internally is the upper floor to wall, where the floor void structure to wall becomes a cold bridge if the void is not opened up and the insulation carried through.



Junction of floor joist with insulated wall (uninsulated at junction)

---

[59] Lime is alkaline and should generally discourage mould

Outcomes

Monitoring of the traditional historic wall is usually not possible when an insulating layer has been applied to a building. The best conservation led approach will always ensure that any system being considered is wholly reversible, and by that definition, should be additive without destruction.

Thermal gains may be small when all factors are taken into consideration, but it is possible to improve the thermal performance of a solid wall through careful design.

As a rule of thumb, the permeability of layers to an insulated solid wall should increase from inside towards the outside, i.e., the vapour resistance should decrease, and the external face should be less resistant to vapour than the inside so that drying occurs to the outside.

Financial returns on insulating a solid wall may be 20-30 years[60] or more depending on your building.

Consider:

Heritage Significance

Existing wall construction & condition of walls

Maintenance & appropriate removals

- carrying out good, appropriate maintenance (repointing in lime, repairing external render)
- removal of inappropriate material (cement renders, vinyl paints)

Reversible & non-destructive intervention to upgrade

Behaviour of the solid wall fabric

Impact of proposals on Heritage significance

- the significance of the building and the impact on significance of upgrading thermally

Impact of proposals on wall fabric behaviour & energy calculations

- technical issues of insulating a solid wall

Impact on space

Future outcomes

- the balance of cost and effectiveness against disruption

---

[60] Figures based on Energy Saving Trust data for an oil fuel heated semi-detached dwelling. See Advice on insulating your solid walls - Energy Saving Trust

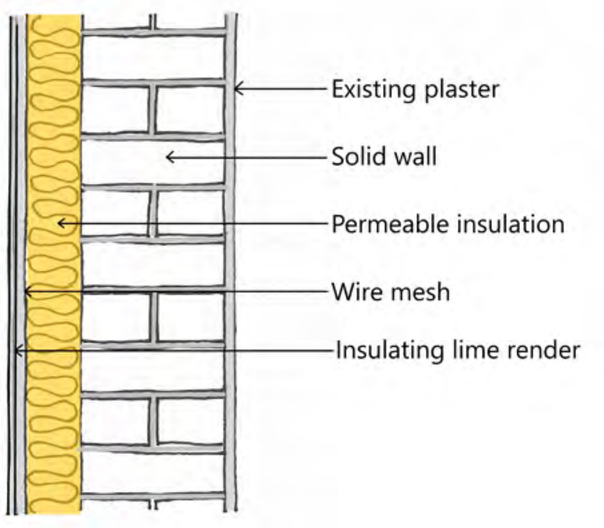
Removed window lining (left) and masonry reveals (right) - a difficult area to address when improving the thermal performance of the building

A number of fixtures and fittings to be considered if retrofitting: historic lath,built in cabinetry, window linings, shutters all present challenges for insulating internally and the level of removal or dismantling may not be feasible.

Insulating Methods and materials

Insulating solid walls fall into two main categories, internal wall insulation and external wall insulation, or IWI and EWI for short.

External wall insulation



Solid Wall - External insulation. This shows a permeable solution with an insulation such as hemp-lime or wood-firbre batts fixed to the masonry and finished with a permeable lime render.

Technically, a well-executed external wall insulation is more effective and healthier for a building than internal wall insulation. Consider it as an overcoat, it keeps the fabric dry and warm and thereby removes or minimises risks of condensation within the wall or at least moves it to the outer layer. The internal environment benefits from retaining the effects of the thermal mass as it is not buffered by another layer internally. However, externally insulating a building successfully requires a myriad of additional measures to be carried out, which means that external insulation is rarely appropriate for a protected building and has an impact on the external appearance of most buildings. This is due to the consequential effects on the detail of the building, alongside the disguise of the original wall material and finish. Applying a layer of insulation will normally require (dependent on depth) the following:

- Changes to eaves detail
- Extension to roof over greater wall depth
- Relocation and extension of building services (e.g., waste plumbing

It can impact on the detail of:

- Eaves
- Window setting (depth)
- Loss of detail around windows and other openings
- Loss of other decorative detail
- Building plinths
- Covering up brickwork
- Proportion of features e.g., bays, dormers

There are however modern systems which will provide a modest increase in thermal performance, and which work in tandem with traditional materials such as a hemp-lime render.

A listed building consent application is required and would be considered on the individual merits of the proposal, but it would be advisable to discuss with Historic Environment Division in the first instance if your building is listed.

Typical U-values (W/m²K)

Insulation material	Thickness of insulation		
	100mm	150mm	200mm
Mineral wool slab	0.31	0.22	0.17
Expanded polystyrene (EPS) slab	0.33	0.23	0.18
Polyurethane (PUR) slab	0.22	u/a	u/a
Phenolic foam slab	0.22	0.14	0.11
Foamglas slab	0.34	u/a	u/a
Cork	u/a	u/a	u/a

*Based on a notional 215mm thick solid brick wall (existing U-value: 2.2 W/m²K), insulation and render

Internal Wall insulation

This is a more widely proposed solution for the thermal upgrade of solid historic walls. There are two prime approaches to this:

1. the internal insulation and new wall layer creates an airtight and vapour impermeable[61] envelope and prevents moisture from the internal environment passing into the historic wall or
2. the thermal lining is designed to be vapour permeable and allows a flux of moisture to pass through both the new thermal layer and the historic structure

The second of these options is preferable for traditionally constructed buildings though there are still a number of other factors to consider in designing such as lining including position and form of lining, dew points, depths of achievable lining, and finishes to complement the intervention.

The first option is difficult to carry out successfully as it is unforgiving – to be successful, it relies on creating an un-punctured bubble which in reality is impractical to achieve due to necessary penetrations, fixings and openings.

In either scenario, bridging across the thermal lining is a risk in that it can create isolated areas for condensation to form, encouraging mould and condensation.

Materials

Insulating materials come in a variety of forms and types but can be described within 3 general categories:

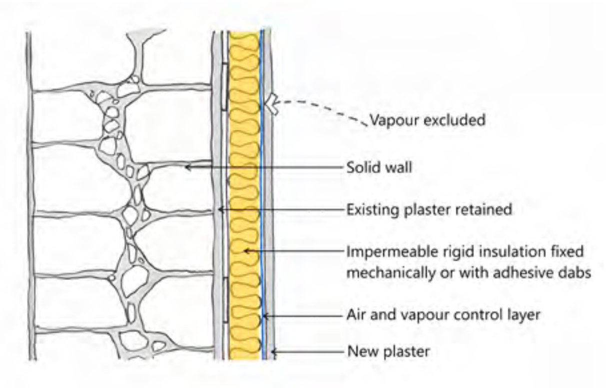
Modern impermeable insulation boards

Modern rigid boards – closed cell and extruded plastic insulation. These are often also foil faced so have an additional reflective quality (for heat) but which also acts as a vapour and airtightness control when taped. They can also be bonded to plasterboard to give a composite board. They are less suitable for insulating a traditional wall. They can be fixed onto a framing system or into a timber frame, onto dabs, or mechanically fixed into wall. To prevent damp forming between the insulation and the wall, a cavity can be ventilated. In practise this is destructive to a protected structure i.e.. Insertion of regular venting to the external face

---

[61] Airtightness and vapour permeability are not the same. (Intelligent vapour open membranes allow the movement of water vapour dependent on relative humidity of neighbouring air)

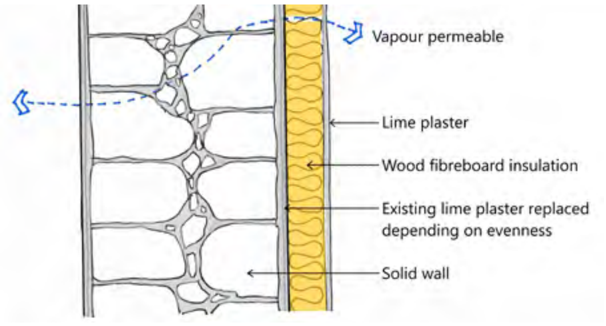
reduces the effectiveness of the intervention considerably as the lining becomes akin to a screen rather than part of the wall, with colder air circulating behind it (creating a thermal bypass).



Solid wall: Rigid non-permeable insulation

Modern vapour permeable insulation boards

A variety of natural materials are hygroscopic and work in a complementary fashion with the wall – cork, wood fibre boards or batts, and aerogel. All can be fixed mechanically to a wall and finished with a lime plaster. Aerogel in particular is very slim and has an extremely good thermal conductivity value 0.015W/mK[62], however because of its cost, it is likely to only be used in premium projects or on small areas, for example, window reveals. Vapour permeable insulation will not need a vapour barrier because it will function in sympathy with the solid wall, though attention should be paid to avoid thermally isolating the masonry (causing it to be cold and the dewpoint of the wall to fall to the internal side)



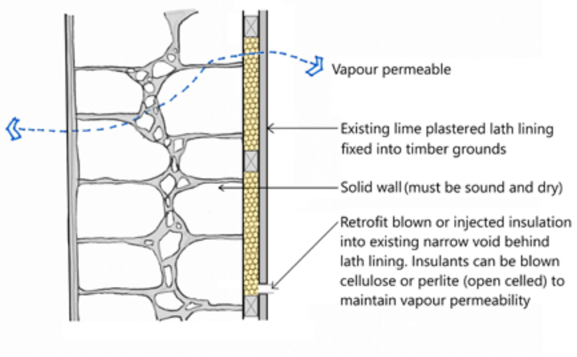
Internal solid wall insulation (with no vapour control layer)

Applied insulating render

Lime render can be obtained which has a hemp or cork element in a premix. This is applied traditionally externally or using a plaster mix for internal walls to increase the thermal performance of the solid wall. Manufacturers claim a modest improvement in the performance of a solid brick wall, citing the decrease in u-value from an uncoated 1.71w/m^{2}k for a 215mm brick wall up to 1.00W/m^{2}k for the same wall coated with 50mm of hemp-lime render[63]. Render or plasters should be lime based and vapour permeable to behave in sympathy with a traditional wall. Any cementitious renders or plasters will need to be removed in advance to allow performance as intended.

Blown or injected insulation

Where traditional walls have a lime plastered lath lining fixed into timber grounds, this can present an opportunity to retrofit a small amount of insulation into the narrow void. At most this is likely to be around 50-75mm. The wall must be sound and dry. Suitable materials are open celled insulants such as blown cellulose or perlite which will allow the wall to continue to be vapour permeable. A micro bore camera is used to check fill is without gaps, having installed from base to top in layers and at intervals.



Internal solid wall injected insulation (with no vapour control layer)

---

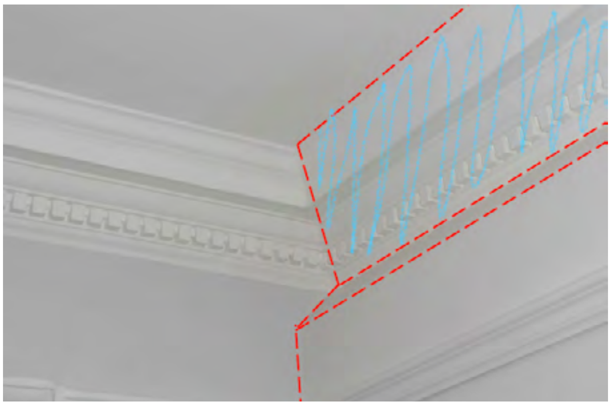
[62] As a comparison, wood fibre board's thermal conductivity is approximately 0.04 W/mK, so 2-3 times better at conducting heat or a poorer insulator than aerogel

[63] greenspec: Housing Retrofit: Insulation: Insulated Render

Other materials in the wall

Having designed the appropriate solution to insulate the wall, it is important to ensure that the wall is not compromised otherwise by the addition of unbreathable acrylic render, cement pointing, plastic paints (inside or out) or vinyl wallpapers.

When considering any possible solution to insulate a wall, it is imperative that the wall must be in sound condition and have any pre-existing damp problems remedied prior to upgrade. See Building Condition at Section 4.



Internal insulation to external wall; intact cornice remains in place but creates a cold bridge where insulation steps back to respect it (blue). Potential risk for mould and condensation

Wood fibre insulation on site

Summary

- Keep walls in good repair and ensure rainwater goods and below ground gullies and storm drainage are taking water away from fabric
- Consider thermal mass benefits
- Detail the indirect effects of internal or external insulation on the building
- Avoid sealing historic walls with plastics and vinyls
- Avoid use of closed cell insulants and barrier membranes
- Prepare a detailed proposal which takes account of the heritage significance. Retain detail and features; work to maximise benefits without harm
- Avoid uneven treatments which encourages cold spots

Windows

Of all the elements of a traditional building, traditional or historic windows[64] are widely understood to behave inefficiently in thermal terms. While they will lose only typically 10% of a traditional building's heat (they are mostly proportionally small compared with areas of masonry), it can be an especially tangible heat loss for an owner or user because air movement around them can be felt, and condensation is evident in cold weather.

Windows are a weak point of a structure thermally, performing poorly in several ways:

- 'Good' transmittance/conduction of heat through single glazing (thermal bridge) – high u value
- Leakage or draughts through gaps
- Radiation of heat in waves through the window

Issues & Risks

Historic timbers are normally of superior density and should be retained when possible. It is important to repair by scarfing or splicing e.g., bottom rails, which have suffered decay, rather than replacing a whole window, but obviously windows should be in their best repaired condition for optimum function thermally.

Historic Georgian window and glass

Historic glass is increasingly rare and should be retained where it exists. Period cylinder or crown glass is much superior visually due to its imperfections. It is not completely flat, as a modern float glass is, and provides much of the visual interest to historic windows. The difficulty arises when period glass is held in a frame which needs a lot of refurbishment to make it functional once more. Hard putties can mean separating and salvaging the valuable glass is difficult and time consuming, but always worthwhile. Historic glass occasionally has etched detail put there by past inhabitants which makes it more significant to the buildings story.

---

[64] See HED Guidance Windows: a guidance booklet on openings. See also **HED Toolkit** for further technical guidance

The design of the window is also significant, from how it is jointed, its profile and section size, to its mechanism, its horns, or lack thereof, its size and glazing pattern. All have a lot to tell us about the age of the building and/or the age of the window.

The condition of the window should be examined:

- Is all the glass in place and without cracks or broken sections?
- Is the putty sound and without gaps or missing strips? Disrepair will encourage draughts
- Is the frame in good decorative order?
- Is the frame sound? Missing or decayed timber will admit draughts, likewise corroded metal
- Is the mechanism in working order? Pulleys, ropes weights, dry sash box, sound fixed casement hinges, stays
- Is the window working in alignment? Sliding sash especially can move laterally between loosened staff beads and parting beads. This makes the meeting less snug and more draughty
- Are all the bead rails present?
- Are there shutters and are they operable?
- Is the masonry to frame or subframe joint closed to stop air entering around the frame?

Repairs to window, timber cill, parting bead, putty and outer trim

Review the materials:

- Are windows metal (cast iron or steel), or timber?
- Is glazing historic glass or modern replacement?
- How is the glazing fixed?
- What is the opening mechanism?
- Are there different materials and types of windows in different parts of the building?

Before considering changes to windows, owners should first undertake maintenance that is required, using materials matching the original. Changing elements to different materials, techniques and methods will require listed building consent where a building is protected by listing.

The following interventions are non-invasive but will provide a reduction in heat loss:

- Using heavy lined curtains
- Using existing timber shutters
- Magnetic fixed or clipped to frame transparent sheeting for winter use

See comparative research findings by Historic Environment Scotland at page 81 and 83 below.

Consider:

Heritage Significance

Existing window condition

Existing window specification

Maintenance & repair

Upgrade & Non-invasive measures, Additive & reversible measures

Existing U values

Impact of proposal options on Heritage significance

Invasive measures – acceptable and unacceptable

Future outcomes

Minor, additive or reversible Interventions

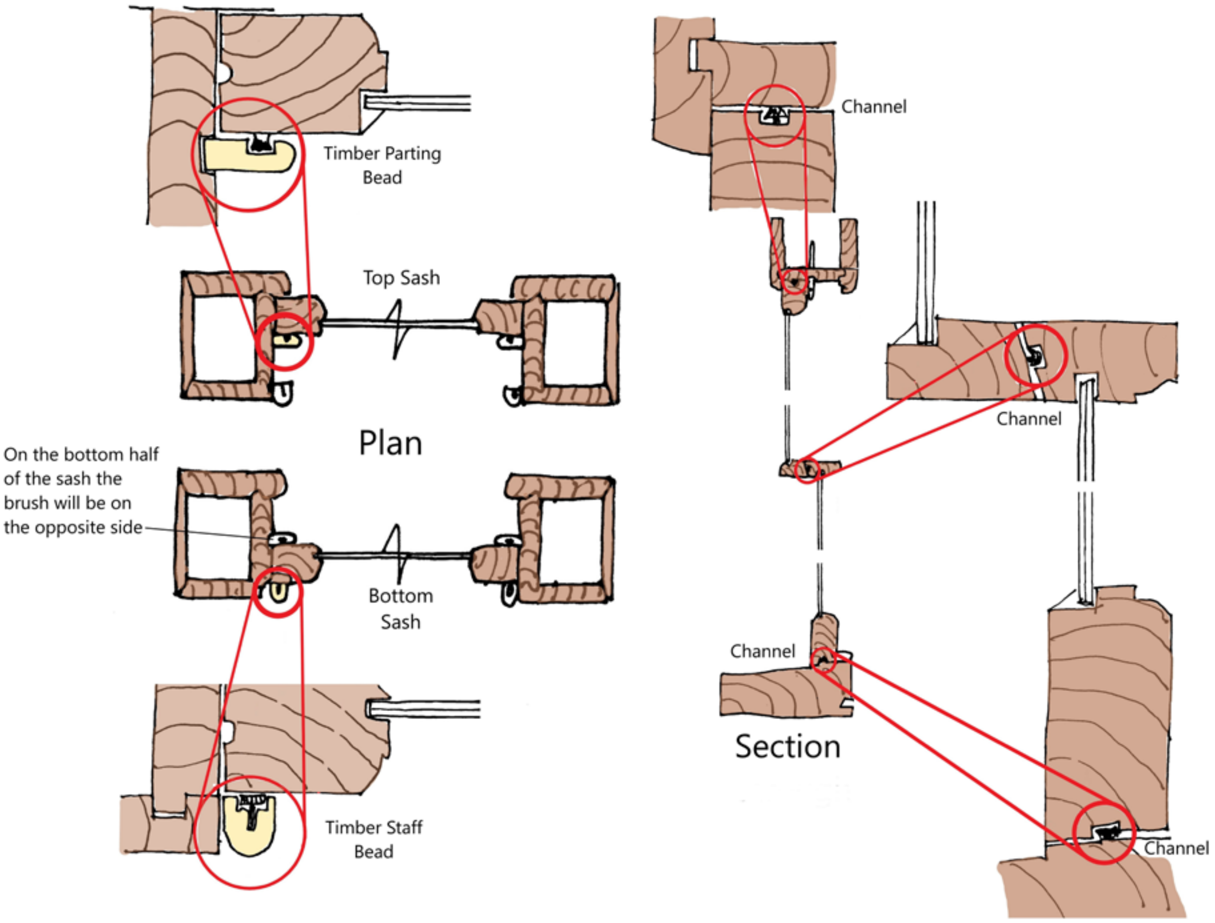
Draught stripping

Once maintenance and repair and the above non-invasive measures have been considered, draught stripping should be considered. Consent may be required for this work.

Soft brush or nylon strips can be applied to the staff beads, and a proprietary parting bead strip to reduce draughts. If a more extensive overhaul is proposed, the whole window can be removed and these fixed into shallow routered channels by a joiner at the same time[65]. They should be applied on the side of the sub-frame case and at meeting stiles, base, and headrails. A reduction or eradication in the air movement around a window will increase comfort though it will not decrease the U value of the window. Draught stripping can make a sash window easier to slide up and down. Draught stripping will not remove convection down currents of air as this is circulating air cooled by cold glass moving back into the room.

---

[65] Where interventions are made to windows in a listed building, the proposal should be discussed with Historic Environment Division who will advise prior to any work being undertaken.



Opportunites for Draught Proofing Windows

Insulating shutters

Existing shutters can be upgraded by a skilled joiner to incorporate an insulant such as a slim aerogel board sandwiched within the panel.

New shutters/glass shutters

Where shutters are missing, they might be replaced with new shutters. As traditional shutters are used mostly at night or low daylight times, a glass shutter might be a good option, which can let light in but provide an increase in thermal performance.

Glass shutters

Secondary glazing

Secondary glazing can be custom made to fit to the historic window and is installed inside the window. They should be designed to align with main glazing pattern where they are not a single fixed pane. They may be timber, aluminium, or other more attractive metals such as bronze; the decision will be led by the situation, e.g., a simple vernacular building might best suited to a side hung timber casement secondary windows, a bronze or other dark alloy would lend itself well as secondary glazing to a leaded window set into stone mullions. Each situation should be considered on its own merits. Some windows will not lend themselves to a secondary system for example if there is detailed joinery panelling around the window, or a protruding historic stay might protrude too far from the window.

Protruding historic stay

Secondary glazing is extremely effective acoustically, as it sets off or largely isolates from the window. It can be as effective thermally as double glazing depending on other window treatments used alongside it. It is a good conservation led approach as it allows the original fabric to be fully retained, and it is also reversible, although some people dislike the intrusion of the extra layer from the interior. Its obvious benefit is that when in use, views and light are still uninterrupted, so it is not a night-time only solution as timber shutters are.

Less common is external secondary glazing, but this might be considered in exposed locations or where leaded, camed or stained glass lights are found. It is quite obtrusive to a building's character however, as it changes the appearance not only of the building but in long and context views. Storm glazing which is demountable seasonally and is not sealed to the reveals can usually be effective in protecting delicate glazing fabric and reduce infiltration of air through the window. It is often used with fragile stained glass church windows.

Invasive measures

The next level of intervention which will increase the thermal performance of the window is change to the window glazing, which may affect its character.

Consent is required if the building is protected by legislation (listed).

The following changes are **not** conservation led solutions:

- Replacement of timber or metal windows with uPVC[66]
- Removal of historic glass
- Removal of an appropriate sliding sash to be replaced by facsimile versions e.g. top hung casement
- Removal of an appropriate historic window to be replaced by a modern window without good justification

Modern technology has improved the available options to upgrading the u-value of glazing in an unobtrusive way. Where historic glass is lost, and windows and/or glass is to be replaced, timber frames can be routered slightly deeper (where profile allows) to receive a slim profile double glazed unit. These can be obtained in depths down to 9mm where they have a cavity, although newer vacuum technology has reduced the depth of a unit to 6-7mm, where microscopic dots hold panes apart from each other. These vacuum units have been shown to be very effective thermally, with manufacturers reporting u values as low as 0.8 W/m^{2}K (for glass only). Some vacuum units have a visible vacuum sealing point on each pane, which alongside the micro dots may be visually unacceptable in many instances.

Proposals which use new technologies should be approached with caution noting the Burra Charter explanatory note ' The use of modern materials and techniques must be supported by firm scientific evidence or by a body of experience'[67]

---

[66] uPVC has a high embodied energy, that is, the total energy used to manufacture is large in comparison with other materials. Historic timber frames have a low embodied energy.

[67] Article 4.2 Traditional techniques and materials are preferred for the conservation of significant fabric. In some circumstances modern techniques and materials which offer substantial conservation benefits may be appropriate.

Research carried out for Historic Environment Scotland[68] reports that a Georgian (multi paned) window performs better with secondary glazing than with gas filled slim profile double glazing, and a Victorian window (simple one pane over one pane arrangement) has roughly equal performance. The multiple glazing bars in a Georgian window are individual thermal bridges so these will reduce the effectiveness of the small individual panes when considered as a whole.

Slim double glazing also has limitations when proposed for large windows as slim glass panes held only slightly apart will flex when they are oversized for their slenderness. On very fine frames, double glazed units can also be too heavy for a window frame, and this can preclude their use.

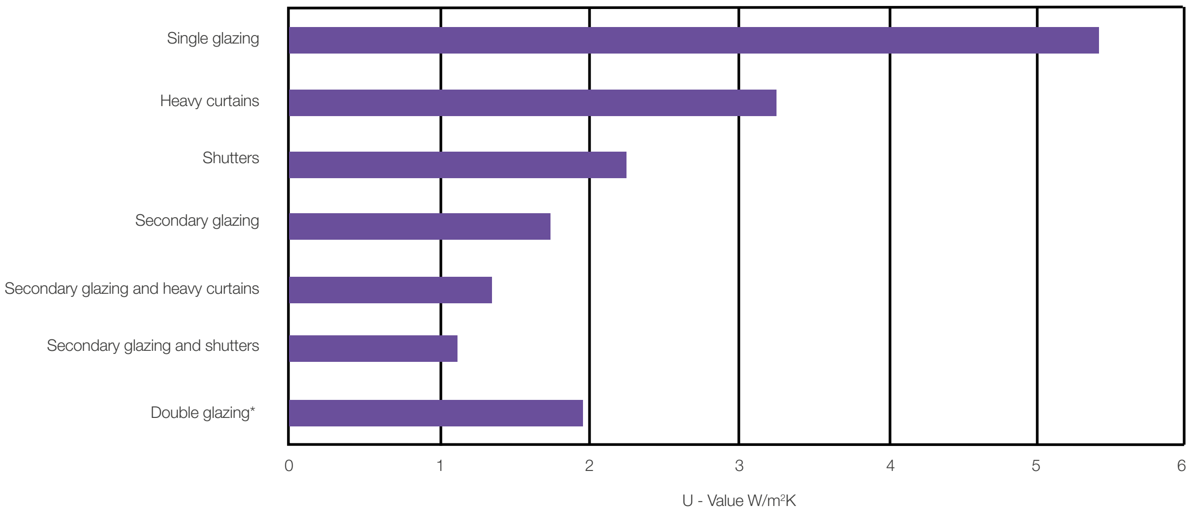


Diagram of comparative u-values for various window treatments, research by Dr Paul Baker (2008) illustrating that appropriate additive measures can out perform double glazed windows. Figures are for centre of pane. See also table below.
*Slim profile double glazing

---

[68] Data from Historic Scotland Technical Paper 01 -Thermal Performance of Traditional Windows Double glazing*

Changing single glazing to double glazing has impacts other than physical impacts on the frame. A single glazed window gives a black appearance, and introducing double glazing of any kind, with or without coatings, increases the reflectivity of the window. This may be unacceptable and should be assessed on a case-by-case basis. Double glazing also decreases the G-value of a window, that is, the light and heat transmitted through it by the sun, and thus thermal gain is also reduced. Approximately 85% of the solar energy to the single glazed window will transmit as heat energy, while it will be approximately 70% for a standard double-glazed window.

The fixing of the new unit into the frame should also be as authentic as possible. A ‘putty line’ timber fixing bead (triangular profile) might be substituted for putty by manufacturer or joinery workshop. Its acceptability (or otherwise) will be assessed as part of a listed building consent application by HED where a building is listed.

Where there is a visible cavity between the glass panes of the slim profile double glazed unit itself, this should be coloured to match the window, most commonly white, as this allows the spacer bar to ‘disappear’ more discreetly into the frame. Aluminium spacer bars should be avoided, aside from increased visibility, aluminium is an excellent conductor of heat and thus undesirable in a window make up.

Aside from authenticity, there are practical reasons for maintaining single glazing with putty fixing over the installation of slimline double glazing:

- The double glazed sealed unit and putty may not be compatible
- Double glazed unit is more prone to expand and contract and putty is too rigid to accommodate/liable to cracking
- The putty and double glazing unit need separating by tape and clips needed to hold in place.
- The manufacturer may not guarantee the work (for one or more of the above reasons)
- The cost and the resulting thermal efficiencies gained are unlikely to repay the investment made

Summary

- Historic glass should always be retained
- Maintain and repair windows for best performance and longevity
- Consider heritage significance of the window/s
- Consider embodied energy
- Consider low impact and reversible measures as a first option
- Consider the range of double glazing available and talk to HED if the building is listed
- Prepare a detailed proposal which takes account of the heritage significance
- uPVC windows are not an appropriate energy efficiency measure to apply to a historic building

U values for window treatments

The following data from Historic Environment Scotland's Fabric Improvements document[69] sets out the percentage thermal improvements provided by the various upgrade and/or intervention measures to a standard Victorian ‘one over one’ timber sliding sash

Improvement method	Reduction in heat loss	U-value 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
Modified 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

---

[69] Historic Environment Scotland – Short Guide, Fabric Improvements for Energy Efficiency in Traditional Buildings

Floors

There are two main types of floor structure found in historic buildings:

- Suspended – timber, concrete, jack arch floor, brick vaults (e.g. over basement)
- Solid – stone or tile finishes over compacted earth, or compacted earth alone to historic vernacular buildings

An original historic floor will be of traditional construction/materials with ‘permeable fabric that both absorbs and readily allows the evaporation of moisture’. (Building Regulations England Part L description) This encompasses compacted earth floors to intricately tiled floors to boarded hardwood floors. It is important to remember that there is no ‘one size fits all solution’ for historic buildings. Traditional buildings will lose approximately 15% of their total heat loss through the floors.

Consider:

Heritage Significance
Existing floor condition, construction & behaviour
Non-invasive measures, additive & reversible measures
Opportunity or need?
Services
U values – quantify potential gain
How to best approach
Invasive measures – acceptable and unacceptable
Unintended consequences - eg. timber moisture, condensation
Impact on Heritage significance
Materials
Future outcomes - consider the balance of cost and effectiveness against disruption

Suspended floors

Boarded suspended floors with a sub floor void were introduced in the 18th century. Before they had a sub floor void (unimpeded air space), they consisted of floorboards over joists laying in direct contact with the earth. These floors could be susceptible to decay for obvious reasons especially in a damp environment. Later, in the late 19th and early 20th century, a concrete capping (sometimes called an ‘oversite’) was often introduced as a measure to deter vermin and prevent vegetation growth. Airbricks or cast-iron vents allowed for air flow underneath these joisted and boarded floors, which maintained the health and longevity of the timbers. Historic floors carry a great deal of character in their patina and settled and often uneven levels. Their material, techniques and technology of fixing, jointing and laying are significant of their time and place.

Thermally insulating a floor is usually proposed for a ground floor but may also apply where there is an uninhabited and unheated basement, or where a first floor (or above) is located over an entry or carriageway. In the case of a floor over a basement, these floors can be barrel vaulted in brick or stone, or a jack arch structure, in which case the structure cannot be opened up to insert insulation, other than from above. Otherwise, the option will be to undercoat the arches or barrels to the detriment of visual appearance.

Brick barrel vault supported floor above,

Issues & Risks

A suspended floor may be a convenient structure to insulate, given its assembly of loose parts. However, there are several issues and risks to consider:

Structure: Some historic floors may act structurally, that is, the floorboards make a plate that braces the floor and the surrounding structure. Take advice from a conservation accredited structural engineer if you are unsure, but this may only mean that the entire floor cannot be removed wholesale at one time, and any deconstruction must take place in increments.

Damage: Boards may be 'secret' fixed through their tongue (tongue and groove boards), these can be difficult to remove without damaging. Older drier boards may also tend to split when historic fixings are removed and prising them up is attempted. Wide boards are difficult to source and replace with modern timbers.

Character: Lifting historic boards can break up wear and settle patterns which lend so much character and patina to a floor. Where it is deemed necessary and permitted by consent, any lifting of such floors should be preceded by the numbering of boards and the identification through a detailed drawing of where these are laid so that they can be replaced in the same pattern.

Floor with parging to underside of boards, discovered on opening up

Ventilation: Inserting insulation into suspended floors can interrupt a previous path of air movement. This may be particularly true when closed cell insulant is used and moisture cannot dissipate. Boards have sometimes maintained their soundness because ventilated (or unventilated) sub floors have also unintended air infiltration around gaps between boards, and introduction of vents should be considered to compensate. Sub floor vents should always be maintained and where a building has been extended, for example, clear routes through the sub floor must likewise be extended.

Health & Safety: Consider access if floors must be accessed from below because of a significant floor finish, for example. Sub floor space from underside of structure to solum (subfloor) can be as little as 300-500mm and so extremely restricted, but also consider harmful materials which could be encountered. Some of these, such as asbestos in existing services, should only be dealt with by specialist contractors.

Services: Electrics and water pipes may be located in subfloors. If these are to be repositioned or relocated, electrics must be kept cool by placing below insulation or by upgrading and carrying through conduit to avoid a fire risk. Conversely, water pipes will need to be lagged where the space they cross becomes colder, to avoid frost and consequential damage risk.

Change: Historic timbers are drier than modern timbers (where ventilated & healthy). Interventions such as under floor heating may cause this drying to increase and reduce moisture content in timber, leading to cupping or movement of boards.

Characterful floors, and low impact, low cost and reversible measures to increase thermal performance

Materials: It is advisable to use hygroscopic insulants which act in sympathy with the historic structure. This means avoiding the use of non-hygroscopic materials (e.g. polyurethane) and taping and sealants which often accompany modern materials (See materials section, page 90).

Where a building is in good repair, and rain and waste water are well managed around it, risks from damp through floor should be minimal.

A simple measure which will reduce radiant heat loss through suspended floors and reduce draughts is the addition of rugs or fitted carpet. The historic floor will remain intact beneath; however, use natural and permeable materials, wool, felt, sisal etc which will allow vapour to move through and deter sweating, which can result when impermeable foam underlays and/or plastic membranes are used.

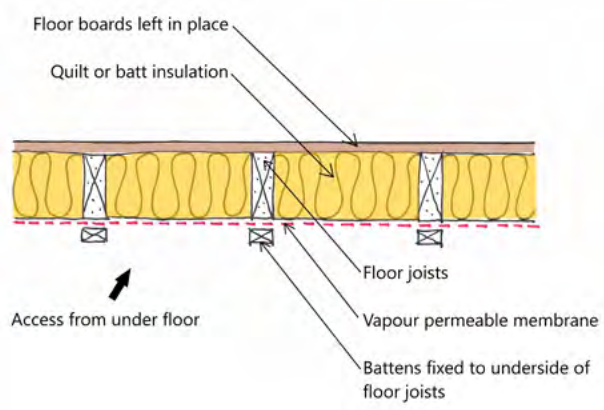
Filling wide floorboard gaps with a compressive strip can also reduce draughts. A proprietary product may be used or a sisal or marine twine of appropriate width can be inserted. This also has the advantage of allowing the floorboards to expand and contract with the seasons. Where there are particularly wide gaps or occasional or irregular gaps, using timber slivers will reduce air infiltration.

Insulating from below

Insulating from below has the advantage of not disturbing the historic floor surface. There will not be an opportunity to install a vapour permeable membrane just below the boards as these will remain in place, but this can be added below the joists instead.

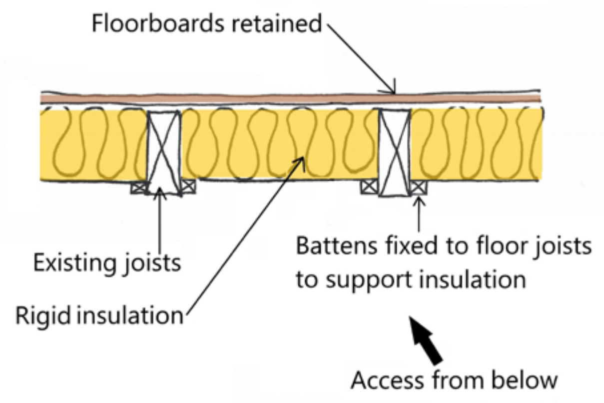
Semi flexible wood fibre boards or batts can be compressed slightly into the joist-to-joist spaces but should not be over compressed as this will squeeze out all the air which provides their thermal performance. If using a rigid modern insulation, this will be more difficult to achieve, as it would need to be cut to suit between the usually irregular historic joists, and there is more opportunity for gaps.

A net or vapour permeable membrane can be stapled to joist undersides to keep the batts in place, and additional battens can be fixed to the underside of joists as a secondary measure. Any risk of condensation on the cold side end of the joist should be dealt with by the air movement to the subfloor.



Fixing insulation between joists from accessible subfloor supporting on membrane or net

Rigid insulation will be better supported by side fixed runners or battens to sides of joists as it does not have the same ability to flex with the structure and is more prone to dropping out of the inter joist space.



Fixing insulation between joists from accessible subfloor supporting on runner battens

Insulating from above

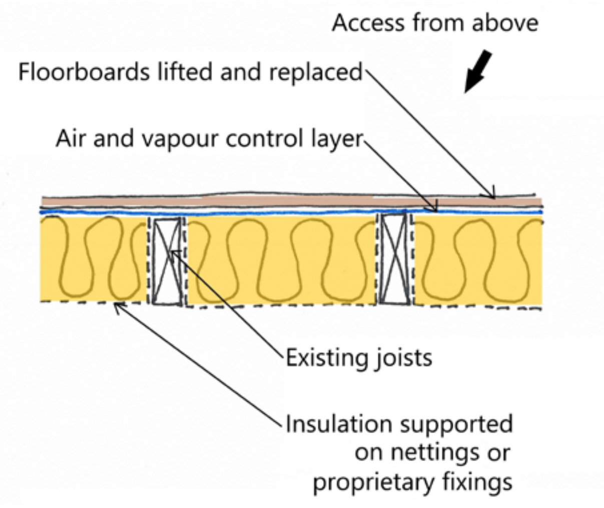
Insulating from above is a more invasive option, given that it will usually require all or most of the boards to be removed, although Historic Scotland have successfully insulated a floor from above by removing only every sixth board to gain access[70], and this should be considered if it means less disturbance of a sound historic floor.

If boards are being removed over the whole floor, it is an opportunity to install a permeable vapour membrane over the joists; an intelligent membrane will allow moisture to move in flux with the environmental humidity and will reduce rapid air movement.

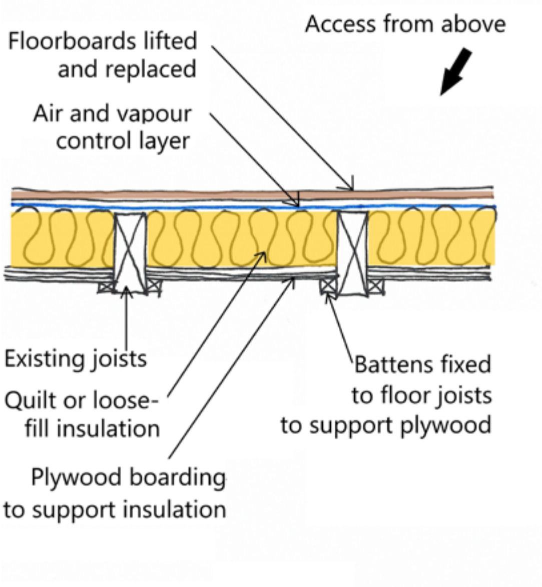
The resulting insulation is similar to the method when undertaking from below; compressible batts can be pushed in to fit snugly and rigid batts should be cut to suit or loose fill cellulose can be used which will settle against all of the irregularities in the structure, non-rigid insulation such as quilt or sheep’s wool can be dropped in once a suitable ‘holder’ has been made. This might be a netting, secured around the joists (A) or a ply base dropped in before the insulation (B):

---

[70] Refurbishment Case Study 2 | The Engine Shed | An Seada Einnsein (Page 10) Wells O’ Wearie, Edinburgh – Thermal upgrades to walls, roof, floors and glazing



A. Fixing insulation from above the floor supported by netting



B. Fixing insulation from above floor with ply support

Where a floor is not of significance and it is considered appropriate upon a heritage assessment that it can be covered over to achieve and enhance thermal performance, a slim breathable board may be considered but will raise the floor level, as a sandwich or floating floor will need to be created. This will need to be considered alongside repositioning skirting, shortening doors, and dealing with the floor level issue at junctions with stairs.

When opening up or accessing floors, it is prudent to take the opportunity to review condition thoroughly and carry out any joist repairs that are necessary. Additional to decay to subfloor timbers e.g., joist bearing ends, often inappropriate notching for services has previously taken place. Notching should not take place to the top of historic timbers (or any structural timber) as this is the portion that is in compression and notching will weaken strength (likewise bottom notches will impact tension in member). Consider repairing through timber wedged insertions which will reinstate compressive strength to the top of the joist for example. If notching or drilling is required and alternative routes cannot be found, tight control should be applied.

Image shows principle of repair to structure, this repair to truss footings

Materials

As with previously described elements, introducing new materials[71] and elements to an historic structure needs to be carefully considered. It is important that materials introduced are established, proven and compatible.

For this reason, modern impervious materials such as closed cell insulants, which are often foil faced should be avoided as they are not hygroscopic nor vapour open. Even where they

---

[71] ICOMOS CHARTER- PRINCIPLES FOR THE ANALYSIS, CONSERVATION AND STRUCTURAL RESTORATION OF ARCHITECTURAL HERITAGE (2003) 3.10 The characteristics of materials used in restoration work (in particular new materials) and their compatibility with existing materials should be fully established. This must include long-term impacts, so that undesirable side-effects are avoided. See also footnote 60 above

might be vapour open, for example, mineral wool, they might not be hygroscopic, therefore they do not buffer the moisture but get wet and stay wet, taking time to dry, which when placed next to historic timbers will encourage decay.

However, the risk of using non-permeable insulation to the floor is less than in other areas such as wall lining.

In contrast, sheep's wool, hemp fibre, wood fibre, cellulose, all buffer moisture as the adjacent original materials. A note of caution however, this is assuming a functioning, dry, vapour permeable environment – a hygroscopic insulant cannot compensate for an environment that is permanently wet or damp because of disrepair or malfunctioning element such as a broken downpipe. Hence repairs to structure, repointing, rainwater goods and so on, should all take place before installation of insulation.

U Value

The U value and comfort factor of a draughty boarded floor can be improved by insulating it.

Current building control requirement calls for a U value of 0.18W/m^{2}K to a ground floor in a modern building (0.15W/m^{2}K where there is underfloor heating) as a minimum acceptable standard. It will often depend on accessibility and suitability of intervention to an historic floor especially where the building is protected by listing, as to how much a floors thermal performance can be improved. Shallow joists can impede the addition of a good depth of insulation but can still make a significant difference.

The u value does not consider the draughtiness, and comfort can be improved by blocking draughts, which helps in the perception of the room temperature, and in comfort

For example, a 100mm addition of wood fibre board within the depths of floor joist with a vapour open membrane layer can increase the performance of a previously uninsulated suspended floor from 0.75W/m^{2}K to 0.32W/m^{2}K, reducing the heat transmittance through the floor by over 50%.

Solid floors

Historic solid ground floors, pre 20th century, commonly consisted of compacted earth of the local ground made up and levelled to receive a wearing, usable finish. Or they may have consisted of a rubble subfloor with sand or clay levelled over as a bed for tiles or other wearing finish, or a combination of both. These floors usually pre-date suspended floors.

Another means of providing a floor (16th-19th c) was the use of lime or gypsum laid straight onto rammed earth; this was often dyed with natural dyes such as brick dust or ash[72]. This was usually limited to passages rather than rooms. The Victorians laid stone flags onto beds of ashes.

Although it was used earlier, the late 19th and early 20th centuries were when reinforcement was introduced and the use of concrete [73] became more widespread, particularly after the 2nd World War, with wider availability of Portland cement. The first codes and regulations for the design of reinforced concrete structures were published in the UK in the 1920s and 1930s.

In the 1950's a UK restriction on timber imports meant solid, independent, concrete ground floors on a hardcore bed became more common (ground bearing), often with

---

[72] Historic England Insulating Solid Floors Guidance

[73] Concrete is defined as a composite material composed of fine and coarse aggregate bonded together with a binder or fluid cemen that hardens over time. Historically the binder would have been lime but with the availability of and superior hardening strength of Portland between wars, this became the more commonly used binder for construction.

a bituminous coating for damp proofing and sealing, sometimes also a bedding for thermoplastic or vinyl asbestos tiles or wooden block flooring.[74]

Although the make-up changed slightly and included a damp proof membrane after this, up until the 1990's, floors could be uninsulated under building regulations.

Because a floor shape can be efficient in terms of thermal performance – low perimeter to area ratio, large, simple rectangle – or inefficient – high perimeter to floor area ratio, complex and long perimeter for the area, this has a large bearing on how important or effective insulating a solid floor will be and should be taken into account early on in analysis of heritage impact, cost and payback.

A mix of suspended and solid floor is sometimes found, for example, in churches, where aisles may be solid and pew areas suspended, or in service areas of a building, where the floor levels might step down to a rear pantry and scullery area, though these earlier solid floors, if original, will seldom be Portland cement-based concrete.

In contrast to a lime or earth based solid floor, a dense concrete floor prevents free movement of moisture through a structure, which is at odds with traditional construction where moisture moves through the elements of a building in flux with the environmental conditions.

Insulating a solid floor is a disruptive and often irreversible action to historic fabric, so should only be considered where circumstance has prompted it, i.e., where there is a problem which requires the floor to be disturbed.

Insulating a solid floor by laying on a breathable board may be an option, as with a suspended floor, and similar issues should be considered.

Significance

If the floor is tiled or flags and these are well bedded and no problems are evident, advice would be to leave this undisturbed. Lifting historic tiles, flags, stone, or brick is a difficult task, as not only are they bedded and worn over a long use (which will be difficult to reset), but they may be friable and delicate and lifting them may cause them to break apart. Where they are worn to an unusable or unsafe state, dependent on their condition, it is sometimes possible to lift and relay upside down for another long cycle of wear.

Where they have previously been replaced with a modern finish or modern e.g., concrete subfloor, lifting to insulate can be more acceptable.

Structure

Historic walls may have shallow foundations or footings. In fact, they are often without what we would now consider a foundation, they may rest on a linear arrangement of flattish stones or slightly wider brick footings, or nothing other than firm subsoil (solid ground). (It was not until late 19th century that bye-laws required buildings to be built off foundations.[75]) Historic footings are a more flexible structure and ripples can often be seen in elevations, which while they look uncomfortable to the modern surveyor, do not always indicate any damaging modern movement. Excavating solid historic floors to insert new poured slabs and insulation can therefore be damaging, so care should be taken to determine what will or will not be acceptable to avoid undermining adjacent

---

[74] https://fet.uwe.ac.uk/conweb/house_ages/elements/section3.htm

[75] Public Health (Ireland) Act, 1878 came into place after the 1875 Public Health Act (England and Wales) and introduced a comprehensive code of sanitary law in Ireland, including for drainage, ventilation, streets, fire safety.

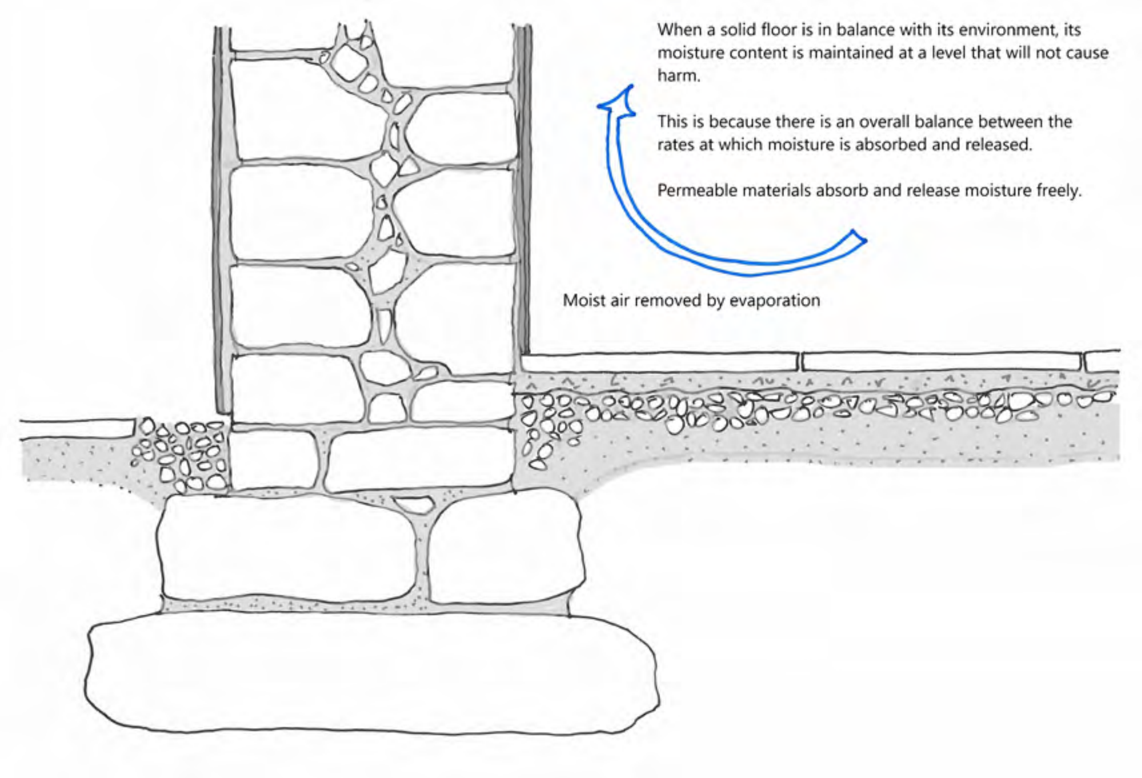
structural walls. Consult with a conservation accredited structural engineer for advice.

An additional concern with work to sub floors, is the use of equipment which can cause damage through the vibrations while operating.

Such work is only likely to affect larger scale projects, for example much of Belfast is built on Belfast sleech, a mixture of soft clay, silt, peat and mud and that up to the end of the 19th century the entire centre of the city was supported on a forest of timber piles, most of which are still performing their original function.

Damp

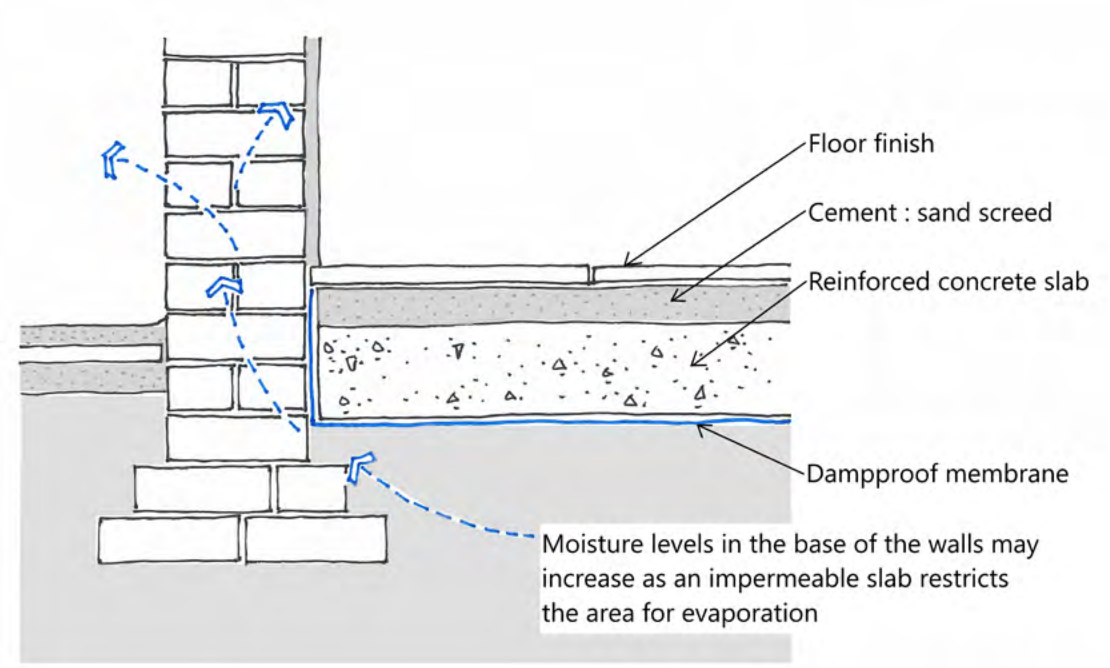
A solid ground floor of historic make up – earth/lime/stone – acts in harmony with its surrounds, and the whole of the floor plate can absorb and evaporate moisture without detriment to the materials.



Uninsulated historic ground floor in equilibrium with its environment

Damp can occur where moisture is drawn up from subfloor through earth but where everything is in equilibrium and there are no new circumstances (see Salts, below), a vapour permeable, hygroscopic structure manages the moisture. Interfering with this equilibrium can easily divert moisture into adjacent construction as moisture seeks a release.

Well intentioned replacements of suspended floors with concrete can result in damp issues to the perimeter.



Impermeable and uninsulated concrete slab with damp proof membrane replacing suspended timber floor

Salts

An historic floor may have a concentration of salts in its make-up. Salts may become evident when there is an increase in moisture in the floor and the moisture migrates to the hygroscopic salts. There will be two broad situations where this occurs:

1. When there is an increased moisture in the local environment (to the floor). This may be because of micro factors such as a burst pipe or defective downpipe or gully leading water to lie near or under the floor, or it could be a wider environmental factor such as a rising water table due to climate change (heavier rainfall) or other local changes to waterways for example.
2. Where the previously balanced absorption and evaporation of building environment moisture is interrupted by introduction of a vapour impermeable element over a large area and the increased moisture is not managed.

Salts cycling within an historic floor finish can cause the breakdown of the finish over time as expansion of crystals damages the structure.

Condensation

Condensation can occur on the surface of a cold floor where the air is warm and moist (in the spring or summer), and the floor is colder. In the winter, the interior building temperature and the warmer floor surface means that the condensation point is pushed deeper into the floor and becomes interstitial to the structure. An impermeable floor covering, e.g., uPVC vinyl, will trap moisture from evaporating and can cause a build-up of salts as well. Ill-advised concrete repairs can likewise exacerbate condensation in the floor.

It is worth noting however, that the earth will retain a relatively constant 10°C through the seasons.

Thermal mass

A solid floor provides a large thermal mass which can store and release heat. Much like the diagram at Section 6, Thermal Mass, the floor will moderate temperature. Underfoot, it can feel radiantly cold a lot of the time however, except when it has been directly heated by the sun where there are large south facing windows. Breathable floor coverings, such as coir, or wool can provide a buffer to any cold felt underfoot.

Recording and relaying

If it is acceptable to lift an historic floor because of an inherent problem which cannot be otherwise resolved, the floor should be recorded in place, mapped, and marked before lifting and setting aside in a suitable atmosphere. Even if a floor appears modern, the work should be undertaken incrementally as there may be significant items or make-ups to record below the upper layer.

Underfloor heating

A good ambient temperature can be obtained with the intervention to a solid floor of a low-pressure underfloor heating system, which will make use of the floor mass. This should only be considered where removing the existing floor is acceptable and/or consented in the case of a protected building. It will need to be augmented with insulation to prevent further downward loss of heat and this has an impact in terms of depth as described at 'Structure' above which need to be exhaustively considered. The average building will lose approximately 15% of its heat through the floor, this proportion being one of the smaller losses, it is advisable to concentrate efforts elsewhere due to the destructive nature of installing a new floor.

Insulating

Impermeable materials

In areas of radon concentration, an impermeable floor may be required by building control[76] although there are other routes which can be explored such as radon sumps and alarms to alert to unsafe levels, but otherwise, if installing a new insulated floor to an historic building, best practise is that it should be a vapour permeable element (see next section). Building control may consider radon alarms or sumps to be an appropriate alternative where a floor is not being disturbed.

Where a new concrete floor is being provided with insulation, a modern rigid insulant will be required, simply because it will be needed to bear the concrete slab and/or the concrete screed.

---

[76] Radon in Northern Ireland: Indicative Atlas https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/453712/PHE-CRCE-017__maps_without_place_names_.pdf

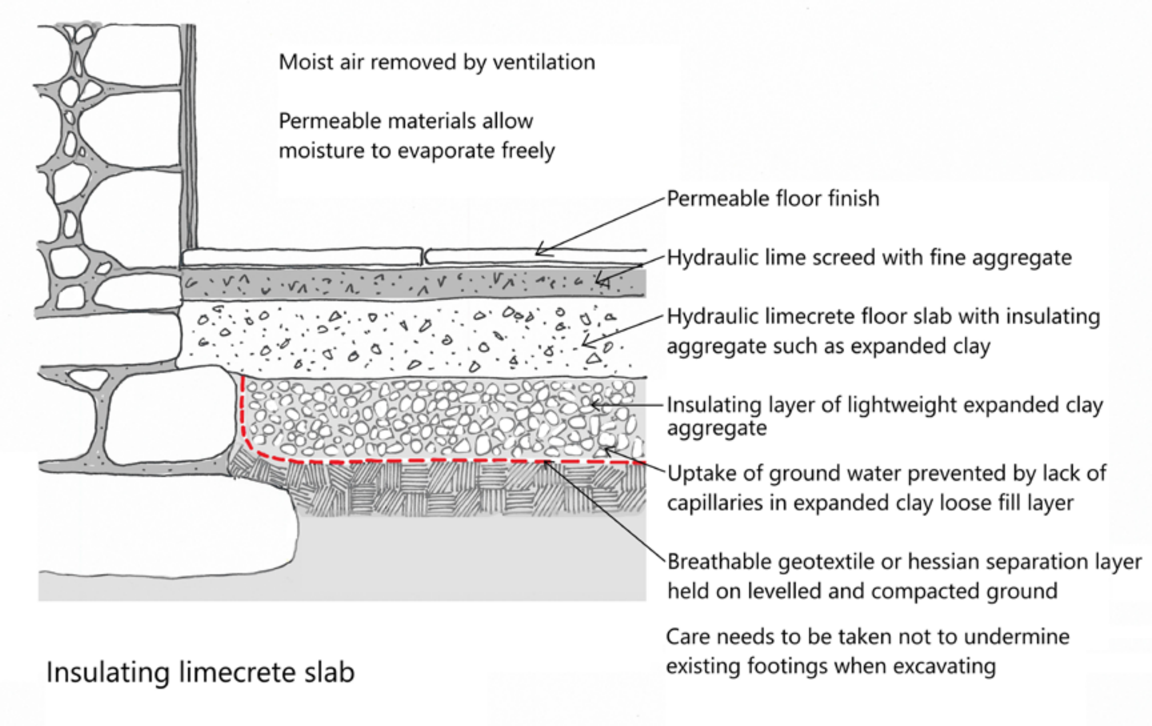
Providing a vapour open floor

Lime concrete can be used to provide a new vapour permeable floor. It has a long curing time but can be boarded to allow work to continue around it.

There are two ways of insulating a floor using a lime concrete:

The lime slurry can be mixed with lightweight expanded clay pearls, or it can be used over a layer of expanded clay (the two are separated by geotextile). The use of the large clay aggregate over a second geotextile layer prevents the uptake of moisture through the subsoil by capillary action as the spaces between the particles are large enough to discourage this. The image to the right shows recycled foamglass, which can bbe used under a lime slab in place of clay pearls. (©The Limecrete Company)

Alternatively, a combination of the two methods can be used (where the slurry or screed contains expanded clay pearls and there is also a layer of insulating large clay aggregate). Note that as the compressive strength is less than that of a concrete floor, the lime slab may have to be deeper, so ensure excavation will not undermine foundations.



Make up of a limecrete slab, replacement solid floor

It is important that a non-synthetic material is used for floor covering having installed a vapour permeable floor.

U values

Technical Booklets F1 & F2 call for new floors to be insulated to achieve a U-value of 0.18 W/ m^2K and renovated elements to achieve 0.25W/ m^2K "in so far that it is technically, functionally and economically feasible". In many cases, existing un-insulated floor U-values are already relatively good when compared with wall and roof U-values; refer to Section 5 regarding statutory consents for guidelines on application of the regulations to protected buildings.

As an example of what can be achieved with a retrofitted floor, a 220mm layer of lightweight expanded clay aggregate loose fill can achieve a U-value of 0.45W/ m^2K on its own. The size and shape of the floor (perimeter/area ratio) will affect the overall U-value performance, and therefore the depth of insulation required. Individual calculations will need to be prepared for each situation.

Summary

Avoid disturbance of a sound, dry floor

Avoid disturbing the floor if it has significant finishes which are fragile

Take account of how boards are fixed – top nailing, secret fixed?

Poor condition - evidence of damp/new movement or bounce in floor – may present opportunity if localised repairs will not suffice

Assess accessibility from above and/or below

Ensure ventilation pathways are adequate and open (no tree roots, earth build up) and remain so after upgrade

Take account of existing and new services and how they will be accommodated with upgrade/electrics cool, plumbing insulated

Ensure dry subfloor (suspended)

Deal with localised issues with water/damp before upgrade to prevent moving problem, for example, into wall base

Draughts

Simply defined, draughts are unintended and undesirable ventilation. In terms of energy conservation and comfort, they are extremely unwelcome but conversely can serve to keep the fabric of a building healthy. It is important that the draughts are eradicated but that suitable levels of ventilation are retained. (The subject of ventilation is extensive and inextricably linked with building physics including air quality.)

Draughts around windows and doors are the most often experienced and the easiest to address. The window section has described where measures to address these should be placed on a sliding sash, as an especially common historic window type.

Draughts from fireplaces are prevalent when the fireplace is unused but provide a good if unwelcome air exchange to the room. Chimney balloons can provide a reversible solution to this problem and are designed to have a trailing tail as a reminder to remove before lighting a fire.

Solutions to 'up-draughts' from ‘gappy’ floorboards have been described in the previous chapter and dealing with these will greatly increase comfort at floor level.

Down draughts from perforations to an upper floor ceiling (below a cold roof space) can be addressed by localised sealing, but efforts should be made to address the insulation of the roof and unintended air movement.

Services

Regardless of how energy efficient the building fabric becomes, for any building to have a function, it will need energy, for services, heat and light.

In the UK commitment under the Paris Agreement to reach net zero carbon emissions by 2050, this means collectively negating the carbon produced by reducing emissions from energy production and finding ways to absorb it.

Lighting

More than 25% of the electricity in an average house can be used up by lighting. Replacing older bulbs with LED (light emitting diodes) is the most efficient option. (Sale of halogen bulbs has been banned by UK Government since September 2021 and fluorescents are soon to follow. Some exemptions exist.)

Non-domestic buildings may opt for lighting delivered via Ethernet cabling. This is not cheaper in delivering lighting, but the cabling is smaller and uses less embodied energy when scaled up in a large building, and also allows greater control.

Smart Controls

When undertaking a renovation, where the building systems are involved, there may be opportunity to upgrade methods of control.

Heating, ventilation, and air conditioning (HVAC) systems react to temperature and air quality requirements; heat sensors can trigger heating or ventilation to turn on and off, efficiently maintaining a more constant temperature by not allowing overheating or over ventilation. They can deal with a single room or a whole building but particularly a larger system is unlikely to be a feasible solution for a domestic building, especially an historic one.

Demand Control Ventilation (DCV) similarly reacts to moisture triggers and can be a standalone system, suitable for domestic properties.

The more comprehensive of these intelligent systems is the (Mechanical Ventilation Heat Recovery) MVHR, which requires a building to be airtight to be efficient. This is not generally considered in traditional buildings because they are perceived as 'leaky', it requires a lot of work with historic components to make this feasible (draught proofing windows, sealing gaps in historic joinery) but more difficult is the impact the ductwork might have on the fabric and the aesthetic of a building. Lime plaster is 'breathable' and if it is in optimum repair, a lime plastered surface can be both airtight and vapour permeable, ie., one does not preclude the other.

There are now Wi-Fi systems on the market that work with remote sensors to trigger heat to come on and off as required, keeping energy demands to a minimum. These can be simple or more complex, for example operating different zones in the building, turning heat on when activity is detected and gauging hot water requirement by tank temperature.

Maintain and Upgrade

For the services that already exist in a building there are small measures that can reduce energy usage and prolong life:

Pipework to wet heating systems

Hot water pipework outside of the envelope should be insulated to ensure efficient delivery of heat where it is required. Cold pipework should have fully taped insulation to prevent warmer air condensing and potentially causing damage to fabric, and to prevent freezing (and bursting) pipes in colder weather.

Wet system radiator

Vent in floor, heat source unknown

Aerators or flow restrictors can reduce water use rates both hot and cold.

Existing & traditional Heat Sources

The open fire is an inefficient heat source; it does have the advantage of heating building masonry (thermal mass) surrounding it but is estimated to operate at only 30% efficiency as most of the heat energy is lost through the chimney. By contrast, a modern boiler can be 95% efficient – that is, 95% of the fuel is converted to heat. In order to control air leakage through an unused chimney, the use of a reversible insert (as previously described) can reduce heat escaping and cold downward draughts.

Traditional fireplace with cooking crook and pot, Mellon Homestead Ulster American Folk Park

Alternatively, the fireplace may be adaptable to house a wood burning stove. A good quality stove can operate at 80% efficiency.
It is considered that the stove can be operated to be carbon neutral if the correct fuel is used because of the carbon absorption by the timber during its growth. Logs should be neither kiln dried nor too wet as the former is energy intensive and the latter option releases harmful chemicals into the atmosphere and can damage your stove and chimney; tar deposits from sap can also cause chimney fires in the worst-case scenario. Wood should be seasoned and have 20% moisture content or less, which can easily be checked with a moisture meter. Defra (UK) have produced a helpful guide.[77]

Stoves can be linked to the radiator loop if they are equipped with a back boiler and can also heat hot water by exchanging some of this heat to the hot water tank. To meet this higher demand however, a greater amount of fuel will be needed by the stove.

Direct combustion heating sources in a room (open fire, stove) require a combustion air supply. This can be provided by a vent to the room. More efficient is the provision of this air directly to the appliance and some stoves have this option, where air is delivered straight to the enclosed grate via a pipe from outside.

Stoves are not suitable for use in thatched properties due to the high velocity of very hot embers they can potentially emit, which are a high risk to a thatched roof.

---

[77] Open fires wood burning stoves - guide-A4-update-12Oct (defra.gov.uk). New laws have come into force in the UK (England, Scotland, Wales) which mean new Ecodesign stoves must adhere to strict criteria around emissions and efficiency. In England sale of certain fuels have been disallowed (wet wood, bituminous coal) to restrict emissions to an agreed level. The emission limits relate to particulate matter (PM), organic gaseous compounds (OGC), carbon monoxide (CO) and nitrogen oxides (NOx).

Carbon Dioxide Emissions by fuel type

Fuel Type	Emissions (gCO_2/kWh) (NCV)[68]
Diesel (e.g. for generators)	263.9
Petrol (e.g. for generators)	251.9
Electricity (2019)	324.5*
Peat Briquettes	377
Sod Peat	375
Coal / Anthracite	361
Natural Gas	203
Wood Logs (Seasoned)	25
Kerosene	272
Bottled LPG (Propane or Butane)	232

* https://www.daera-ni.gov.uk/publications/northern-ireland-carbon-intensity-indicators-2021
** May be carbon neutral, dependent on source
All other figures, source: **https://www.seai.ie/data-and-insights/seai-statistics/conversion-factors/**

Low carbon options

Traditionally, heat has been provided by the burning of fossil fuels, alongside wood. The previous section described why wood is the best of these fuels because of its potential carbon neutral status when properly sourced and used. Natural gas has the lowest emissions of the fossil fuels; however, it is planned that by decarbonising the electricity grid further, that electricity can become a green fuel. In 2019, greenhouse gas emissions from electricity generation were down 12% on 2018 levels and 71% lower than 1990 levels[78]; UK government commitment is to decarbonise the electricity system by 2035.

Low carbon options are one step better, as they extract energy from the elements , earth, air, water, sun, wind and thus provide better options for decarbonisation.

Solar energy can be captured by photovoltaic panels (PV) and flat panel or/evacuated tube solar thermal collectors, the former providing electricity and the latter heating water (it can also be used for home heating, but this is less common). The technologies are distinctly different, photovoltaics convert light into electricity using semiconducting materials, by chemical and physical means, and solar thermal is a relatively simple transfer of the sun's heat to a closed loop containing solar thermal fluid.

Photovoltaic panels require a large area on the roof and can be harder to locate on or in the setting of a protected building. Solar thermal requires a much smaller installation and so easier to site. If you live in a Conservation Area, or in or near a listed building, permission is required and you must consider if the installation would cause irreversible change to historic fabric and if they can be located to avoid impacting character and setting.

A typical solar panel (PV) takes around 6 years to pay back its energy cost but only 1.6 years to payback its carbon cost (carbon cost of manufacture). A typical solar panel will save over 900kg of CO_2 per year.

---

[78] https://www.gov.uk/government/news/plans-unveiled-to-decarbonise-uk-power-system-by-2035

Photo voltaics in discreet location on inner courtyard roof

Heat pumps work the same way as a refrigerator in reverse, by taking heat from the air, ground or body of water, and compressing it to provide heat to a thermal transfer fluid which is then circulated in a closed loop through underfloor heating. Heat pumps can also be used for hot water (with a back-up because of temperatures periodically needed to prevent bacteria growth), and for radiators. Because of the lower running temperature, more or a larger radiator surface will be required.

Heat pump at Caledon Wool Store

The pumps have an electricity demand so are only wholly decarbonised if the electricity is generated by PV installation for example. However, heat pumps are more efficient than other heating systems because the amount of heat they produce is more than the amount of electricity they use. The amount of heat produced for every unit of electricity used is known as the Coefficient of Performance (CoP). So, if a heat pump has a CoP of 3.0, then it will give out three units of heat for every unit of electricity consumed. An example is provided below:

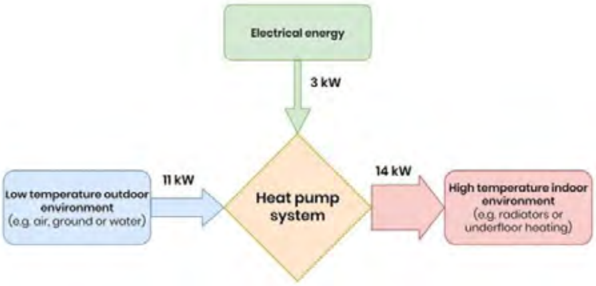
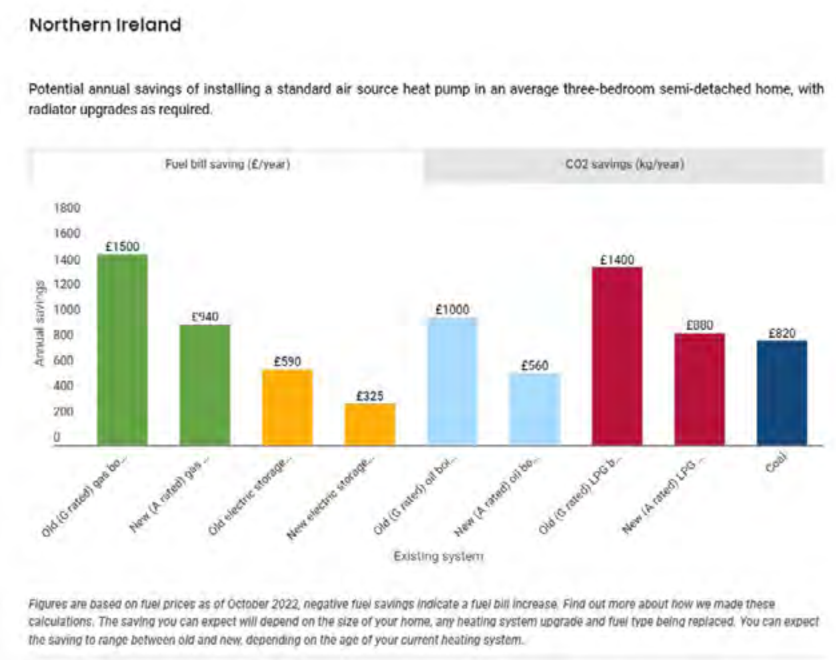


Diagram of heat pump coefficient, source: Energy Saving Trust October 2021

Large heat pumps may require a 3-phase connection, which will become more common if buildings have multiple electric vehicle charging, PV panels and heat pumps. This is because a single-phase supply limits how many items can draw on the power at any one time.

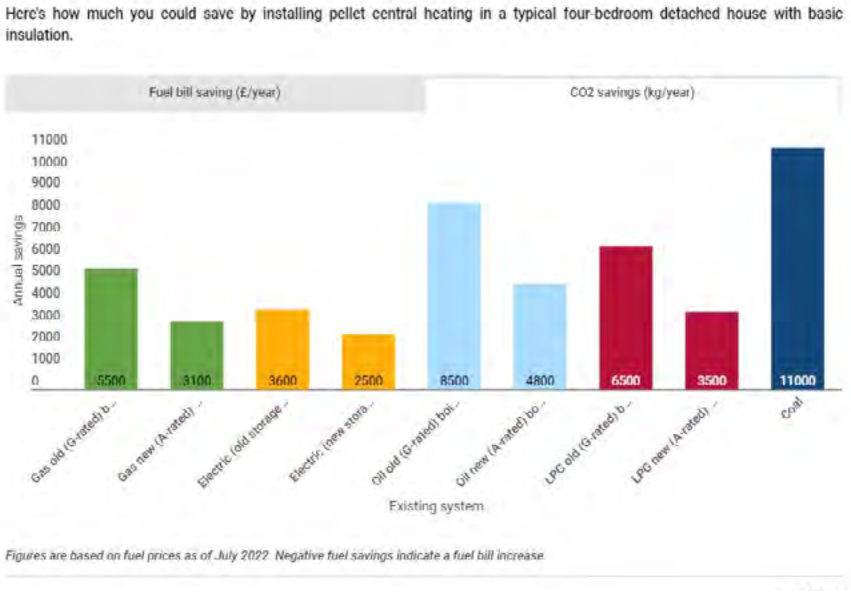
Heat pumps can be efficient but only where the thermal envelope of the building is of a reasonable thermal standard. To illustrate, the 2022 UK Government Boiler Upgrade Scheme required EPC recommendations for fabric upgrade, e.g., loft insulation, to be enacted[79] in order to be eligible for the scheme to upgrade from fossil fuel boiler to low carbon technologies. The heat load should be calculated to size the system. This is a calculation involving the buildings transmission losses and ventilation losses.


Northern Ireland

Potential annual savings of installing a standard air source heat pump in an average three-bedroom semi-detached home, with radiator upgrades as required.

Figures are based on fuel prices as of October 2022, negative fuel savings indicate a fuel bill increase. Find out more about how we made these calculations. The saving you can expect will depend on the size of your home, any heating system upgrade and fuel type being replaced. You can expect the saving to range between old and new, depending on the age of your current heating system.

Heat pump carbon savings


Here's how much you could save by installing pellet central heating in a typical four-bedroom detached house with basic insulation.

Figures are based on fuel prices as of July 2022. Negative fuel savings indicate a fuel bill increase.

Biomass (wood pellets) carbon saving

---

[79] There are exceptions for certain types of structure including listed buildings

Wind turbines can be visually intrusive when they are of a scale which will provide worthwhile payback. They work best when they can be sited away from buildings and views, as they create noise and shade. The wind power turns the blades which then drives a turbine to generate electricity.

Domestic sizes can be freestanding (generating 6kW) in an exposed location or building mounted (generating 2kW). Their cost can be prohibitive; a free-standing turbine can cost upwards of £30,000[80] but optimally can generate up to 9,000kWh per year. The average domestic Northern Ireland electrical energy consumption in 2020 was 3,682kWh.

Other heat sources include boilers fuelled by **biomass** and **biogas.**

Biomass comes from a biological raw material such as wood, crop residues, animal waste, converted to fuel by various processes. Some stoves can also burn wood pellets and run a heating system (as above). Carbon emissions are lower than those for coal or gas. There are some carbon emissions caused by the cultivation, manufacture, and transportation of the fuel, but if the fuel is sourced locally, these are much lower than the emissions from fossil fuels. Savings range from 2500Kg (new storage heaters) to 11000Kg(coal) CO_2 per year (figures correct at July 2022[81]). However, the storage volume needed for biomass can be a deterrent Biogas can be used in an existing wet system which has been adapted. The gas is a biproduct of bio waste such as agricultural or animal waste which ferments or digests inside a closed system – an anaerobic digester. A gas akin to natural gas which can be burned in a boiler, or which can fuel vehicles is produced after a further process. This is called biomethane. Combined heat and power systems (CHP) can use the biproduct gas before it passes through the second part of the process, to provide both heat and electric. In effect, this is a ‘mini’ power plant and is extremely beneficial where there is an industry or activity with a large amount of suitable waste.

Our companion document **Retrofit of Traditional Buildings** provides guidance on heritage considerations to be taken into account when proposing renewable energy installations.

---

[80] https://energysavingtrust.org.uk/advice/wind-turbines/

[81] https://energysavingtrust.org.uk/advice/biomass/

8 Glossary

Airtight	containment preventing the movement of air through the building envelope.
Authenticity	Those characteristics that most truthfully reflect and embody the cultural heritage values of a place
Breathable	See vapour permeable
Buffering	ability to take up peaks and troughs of heat, water/moisture
Capillary (action)	action of moisture being drawn up into tiny gaps due to surface tension of liquids
Dewpoint	Dewpoint is the temperature to which a given parcel of humid air must be cooled, at constant barometric pressure, for water vapour to condense into water. The condensed water is called dew. The dewpoint is a saturation temperature
Draught	unwanted local cooling caused by air movement
Embodied energy carbon/energy/ emissions	is the energy that was used in the work to make a product. Embodied energy is an accounting methodology which aims to find the sum total of the energy necessary for an entire product lifecycle. This lifecycle includes raw material extraction, transport, manufacture, assembly, installation, disassembly, deconstruction and/or decomposition.
Fabric	The material substance of which places are formed, including geology, archaeological deposits, structures and buildings, and flora
Hygroscopic	ability to absorb and allow passage or exchange of moisture vapour with surrounding environment
Intelligent membrane	a selective barrier; airtight but humidity-variable diffusion resistant - allowing vapour movement depending on the relative humidity/pressure profile through the membrane
Inert gas	a non-reactive gas. The cost of the gas and the cost of purifying the gas are usually a consideration when deciding to use it. Examples for inert gases are nitrogen, argon, krypton, or xenon. The latter three gases are used as infill gases for the cavities of double-glazed units.
Joist	structural timber, level floor or ceiling element

Operational carbon/ energy/emissions	The carbon emitted by a building during its use, management and operation.
Parge/parging	the application of lime mortar to walls or to the underside of roof slates or tiles or to other elements (also called torching). Used historically to draughtproof.
Pugging	traditional infill between joists, often lime or ash, to deaden sound, also called ‘deadening’
Rafter	structural timber angled pitch roof element
Relative humidity	the amount of water in air as a percentage of the maximum that could be held at the same temperature
Scraw	earthen turfs laid over scantlings (secondary timber structure) in thatch roof into which water shedding straw or reed etc is pinned
Significance	“Conservation means all the processes of looking after a place so as to retain its cultural significance.” Burra Charter. Significance means “aesthetic, historic, scientific and social value to past, present and future generations”
Solar gain	the increase in temperature that is caused by solar radiation
Thermal bridging	point or area within the structure where a differential temperature with its surrounds leads to a bridge for accelerated heat transfer
Thermal mass	usually masonry or dense mass which has ability to absorb, retain and release heat
Traditional building	constructed using traditional methods with permeable fabric that both absorbs and readily allows the evaporation of moisture
U-value	(or thermal transmittance co-efficient) is a measure of how much heat will pass through one square metre of a structure when the temperature on either side of the structure differs by 1 degree Celsius. The lower the U-value, the better is the thermal performance of a structure. The U-value is expressed in W/m^2K.
Vapour permeable	term applied to fabric which allows water vapour or gaseous moisture to pass through. Referred to colloquially as ‘breathable’
Vapour Barrier	prevents the movement of moisture, a plastic barrier

9 Sources of advice & further reading

There is wide availability of material to read on the subject, those listed below have been accessed during compilation of the guidance, others are noted within the text.

General

Historic Environment Toolkit | Department for Communities (communities-ni.gov.uk)

Listed Buildings - Repair and Maintenance | Department for Communities (communities-ni.gov.uk)

Technical Notes | Department for Communities (communities-ni.gov.uk)

Energy Efficiency in Traditional Buildings - Government of Ireland 2010

Retrofitting of Traditional Buildings - IHBC Toolbox (ihbconline.co.uk)

Retrofit and Energy Efficiency in Historic Buildings | Historic England

Energy Efficiency in Traditional and Historic Buildings | The Engine Shed | Part of HES

Guide to Energy Retrofit of Traditional Buildings | Hist Env Scotland (historicenvironment.scot)

How to improve Energy Efficiency in Historic Buildings in Wales (gov.wales)

Energy Saving Trust

Research

Historic Scotland Technical Paper 9 (2010) **Slim-profile double glazing Thermal performance and embodied energy**

Historic Scotland Technical Paper 9 (2010) **Slim-profile double glazing Thermal performance and embodied energy**

P.H. Baker and S. Rhee-Duverne (2021), **Sensitivity analysis of WUFI simulations of a traditional brick building (historicengland.org.uk)**

Simon Nicol, Justine Piddington and Helen Garrett, **The cost of poor housing in Ireland 2016 (bregroup.com)**

BRE (2016), **Solid wall heat losses and the potential for energy saving**

Society for the Protection of Ancient Buildings (2011-2019), **SPAB Advice: Findings** & **summary SPAB Completes Over Ten Years of Research into the Energy Efficiency of Old Buildings: A Precis**

Soki Rhee-Duverne (2019) **Simulation Models and Energy Efficiency in Historic Buildings | Historic England (usefulness of simulated against actual measures) –**

Soki Rhee-Duverne and Dr. Paul Baker (2015), **A Retrofit of a Victorian House in New Bolsover: A Whole House Thermal Performance Assessment (historicengland.org.uk)**

Brenda Dorpalen (2020), **Valuing carbon in pre-1919 residential buildings (historicengland.org.uk)**

STBA (2020), **Performance and Energy Efficiency of Traditional Buildings: Gap Analysis Update 2020 (historicengland.org.uk)**

Case Studies

Overheating and Historic Buildings | Historic England

Refurbishment Case Studies | The Engine Shed | Part of Historic Environment Scotland

Technology & technical

Richard Hobday (2022) **Technical Paper 36: Architecture and Health in Traditional Buildings (historicenvironment.scot)**

Scott Allan Orr (2021),**Technical Paper 35: Moisture Measurement in the Historic Environment**

Building Regulations and energy efficiency of buildings | Department of Finance (finance-ni.gov.uk)

2014 **PRACTICAL BUILDING CONSERVATION: ROOFING (historicengland.org.uk)**

Alliance for Sustainable Building Products 2018, **ASBP-Briefing-Paper-An-Introduction-to-Breathability**

Joseph Little, Calina Ferraro & Beñat Arregi (2015) Historic Environment Scotland **Assessing risks in insulation retrofits using hygrothermal software tools**

Tom Woolley (2022), Natural Building Techniques A Guide to Ecological Methods and Materials

Conservation professional registers

Find an Architect - Royal Society of Ulster Architects (rsua.org.uk)

RIBA - www.architecture.com Working-with-an-architect Conservation Register

RICS Find a Surveyor - Building Conservation Accreditation Scheme (ricsfirms.com)

Conservation-accreditation-register-for-engineers - CARE (ice.org.uk)

Guidance & Best Practice

BS 7913:2013 Guide to the conservation of historic buildings

BS 8631:2021 Adaptation to climate change. Using adaptation pathways for decision making. Guide

BS 5250:2021 Management of moisture in buildings — Code of practice

BS EN 16883:2017 Conservation of cultural heritage. Guidelines for improving the energy performance of historic buildings

Conservation Professional Practice Principles (Institute of Historic Buildings Conservation, 2017) **Conservation Professional Practice Principles - September 2017 (ihbc.org.uk)**

STBA Responsible Retrofit Guidance Wheel **Responsible Retrofit Guidance Tool(responsible-retrofit.org)**

RICS, Historic England and Property Care Association, joint position statement (2022), **Investigation of moisture and its effect on traditional buildings (rics.org)**

PAS 2035/2030 | BSI (bsigroup.com)

RICS Whole Life Carbon Assessment for the Built Environment Whole life carbon assessment (WLCA)

International Conventions

Convention for the Protection of the Architectural Heritage of Europe **(Granada Convention),** 1985.

European Convention on the Protection of the Archaeological Heritage **(Valletta Convention),** 1992.

International Charters

The International Charter for the Conservation and Restoration of Monuments and Sites (**Venice Charter),** 1964.

ICOMOS Declaration on the Conservation of the Setting of Heritage Structures, Sites and Areas. **(Xi'an Declaration),** 2005.

New Zealand ICOMOS Charter for the Conservation of Places of Cultural Heritage Value. 2010.

The Australia ICOMOS Charter for Places of Cultural Significance **(Burra Charter)**, 2013.

All images are copyright Historic Environment Division unless otherwise noted. Copyright for the illustrations listed below belongs to Historic England:
P59 (bottom), 60, 61 (top & bottom) © Historic England January 2016, P58, 59 (top), 63 (bottom right and left), 64, 65, 71, 73 (top), 73 (bot. left), 87 (top right), 88, 91, 92, 94, © Historic England April 2016, P24, 48 © Historic England June 2018
Illustration P45 © The Concrete Centre 2005
The following images are reproduced by kind permission of the National Trust: P5, P13 (top left and middle left), P19 (middle left), P21 (bottom left), P23 (bottom) and P53 (left).
Where we have identified any third-party copyright information you will need to obtain permission from the copyright-holders concerned.

Department for Communities | An Roinn Pobal | Depairtment fur Commonities
www.communities-ni.gov.uk

Helping communities to enjoy and realise the value of our historic environment

Any enquiries regarding this document should be sent to us at:

Historic Environment Division
Ground Floor
9 Lanyon Place
Belfast
BT1 3LP

Tel: (028) 9081 9226
Email: historicenvironmententenquiries@communities-ni.gov.uk
Web: www.communities-ni.gov.uk/topics/historic-environment

Front Cover Image:
Grade A listed building, Brownlow House Lurgan

9 781911 705628